Bushings

Power Transformers Lesson #3
The purpose of a bushing in electrical equipment is to provide a means of passing an electrical conductor through a grounded object without causing a short circuit or an electrical ground.
• Types of bushings for electrical equipment.
  – Bulk bushings
  – Condenser bushings
  – Gas filled bushings
Bulk Bushing

- An insulated tube for the conductor to pass through.
- For high voltage applications it is usually porcelain and may have skirts to increase the flash over distance.
- Can be oil filled or dry.
- Has no active components
An insulated tube for the conductor to pass through.
For high voltage applications can be porcelain or polymer.
Most often found on HV gas circuit breakers.
On circuit breakers is part of the breaker not a separate piece of equipment.
Has no active components

GAS FILLED BUSHING
Condenser Bushings

• For high voltage applications it is usually porcelain and may have skirts to increase the flash over distance.

• Newer style bushings may be polymer housings

• Has active components in the capacitive winding.

• The majority of transformer bushings in service today.
Oil Filled 115 kV Condenser Bushing
• Bushings
  – Fixed-Conductor
  – Draw-Lead Type
Figure 3.2 Large Bushing Packing

Figure 3.3 Small Bushing Packing
Lapp Apparatus Bushings
POC (Paper-Oil-Capacitor)

Lapp capacitor bushings for transformer and oil circuit breaker applications are a proven design based on a capacitor core with aluminum foil and high dielectric paper impregnated with dried, degassed oil. Lapp POC bushings meet all ANSI/IEEE standards for outdoor apparatus bushings, where these standards apply for voltage classes 25 kV through 600 kV. When a transformer application results in overload above ANSI/IEEE standards, a bushing having a higher current rating is recommended. Lapp bushings are designed to carry the short term overloads specified by ANSI/IEEE transformer standards. Lapp POC bushings for other applications (e.g., oil-to-oil, oil-to-gas, outdoor-to-indoor air, etc.) are available for various voltage classes and current ratings.

Design Features

1. Gaskets
   Nitrile rubber, cork gaskets are designed to provide even loading and oil tight seals with extended life.

2. High Compression Coil Springs
   Multiple heavy-duty coil springs provide uniform, active compressive loading on gaskets to compensate for temperature variations and to assure oil tight joints and reliable mechanical strength.

3. Clear-View Oil Reservoir (Medium and High Voltage Bushings)
   The tinted glass oil reservoir filters damaging ultraviolet rays, preventing oil deterioration. The oil level and condition is clearly visible from any angle.

4. Magnetic Oil Gauge (Extra High Voltage Bushings)
   The oil level is indicated by the pointer on the gauge.

5. Porcelain Housing
   The outdoor porcelain housing has sturdy sheds to provide required leakage and strike distance and has ground surfaces on top and bottom ends for oil-tight gasket seals.

6. Name Plate Data
   The name plate affixed to the mounting flange identifies the bushing by catalog number, serial number and year of manufacture with electrical ratings and factory measurement data.

7. Power Factor Test Tap (Medium Voltage Bushings)
   25 kV through 69 kV bushings have a power factor test taps. The test tap is connected to the ground layer of the capacitor core. An aluminum cap covers the insulated test tap assembly and grounds the tap to the flange when energized.

8. Voltage Tap or Capacitance Tap (High and Extra High Voltage Bushings)
   Bushings rated at 115 kV and above have a permanent internal ground. In addition, an insulated tap is connected to a floating capacitor layer. This tap, designated a capacitance tap or a voltage tap, is grounded except when used as a voltage source with a potential device. The voltage tap also serves as a means of measuring power factor and capacitance of the bushing core. The tap is ANSI standard type A, normally grounded.

9. Mounting Flange, Ground Sleeve Assembly
   The mounting flange and ground sleeve assembly is made of aluminum and provides nonmagnetic, corrosion-resistant, high-strength service.

10. Paper-Foil Capacitor Core
    Conductive layers of aluminum foil with high dielectric paper are wound around the conductor and into the bushing core to produce uniformly valued capacitors in series. This capacitance grading distributes the voltage and the electrical field uniformly throughout the core. The core is vacuum-dried and impregnated with dried, degassed oil.

11. Lower Porcelain Joint
    A collar maintains alignment between the ground sleeve and the porcelain, preventing porcelain-to-metal contact. Nitrile rubber o-rings in nitrile rubber cork gaskets provide sealing under controllable loads.

12. Lower Porcelain Assembly
    The lower porcelain has ground gasket surfaces on each end to facilitate alignment and maintain an oil-tight assembly.

13. Bottom Cap Assembly
    A confined nitrile rubber cork gasket provides a leak-proof seal between the porcelain and the cap. The end cap aligns the porcelain with the conductor.

14. Dried, Degassed Oil
    The internal space in the bushing between its exterior components and the core is filled with dried, degassed insulating oil.
**Bushing Repair and Diagnostics**

**Typical Repairs**

**General Electric**

- **550 kV - Recore**
  - *Problem:* High Power Factor due to ink migration.

- **25 kV, 12,000 A - Recore**
  - *Problem:* High Power Factor due to ink migration.

**Ink Migration**

Conductive ink moves from conductive layer (A) to insulating layer (B) within bushing core.

**138 kV - Reconductor & Recore**

- *Problem:* High heat due to multi-section conductor.
Lapp Generator Step-up (GSU) Transformer Bushings

POC (Paper-Oil-Capacitor) – 25 kV

Lapp POC bushings for use in Generator Step-Up (GSU).
Transformers are currently available at a voltage of 25 kV with current ratings of 10,000, 12,000 and 14,000 amperes. Extension of this product line up to 22,000 amperes is being engineered.

Lapp POC-GSU bushings have a minimum oil level and current transformer pocket of 21 inches. These bushings, at this time, can only be mounted vertically. Bushings for horizontal mounting are being engineered.

Chocolate glaze on the porcelain is standard. Munsell No. 70 grey glaze is indicated by adding a -70 suffix to the basic catalog number.
Bushing Repair and Diagnostics

A specially designated Bushing Repair Group, with its own facilities and years or experience, will keep turnaround times to a minimum.
And returned bushings are repaired and rebuilt to the same high quality standards that Lapp has for new bushings.
With our new program, savings up to 55% of the cost of a new bushing can be realized!

CAPABILITIES
Typical bushing repairs:
- Regasketing
- Core Replacement
- Stud Replacement
- Porcelain Repair
(if other manufacturers’ bushing)

Removal of porcelain and flange assembly from conductor.

PROCEDURE
1. A certificate showing PCB content of the oil in each bushing by manufacturer, catalog number, and serial numbers sent to Lapp.
2. Lapp return authorization number is assigned to each bushing by manufacturer’s name, catalog number, and serial number. Return authorization number needs to be noted on the bushing crate. Also, a non-PCB sticker or marking needs to be applied to the bushing crate.
Contact your local Lapp agent or the factory. Note: Customer is responsible for freight both ways.

Removal of spring loading pressure on 14,000 amp, 25 kV bushing.

5. Following repair of a bushing:
- ANSI/IEEE standard routine production tests and/or measurements will be made on the bushing as follows:
  - Leak check by internal pressurization
  - 1-minute dry withstand voltage
  - Power factor
  - Capacitance
  - Partial discharge
  - 24-hour external oil leak check

EXCEPTIONS
Other manufacturers’ bushings not considered for repair at Lapp:
- Compound filled bushings
- Bushings with varnished paper cores (i.e., no lower porcelain)
- Bushings with oil having PCB content greater than 50 ppm

Massive current carrying conductor with porcelain and flange assembly now ready for repair.
Figure 1-13: Design Details of a Typical Condenser Bushing, 115kV and Above
Figure 1-14: Design Details of a Typical Condenser Bushings, 69 kV And Below
Conductive ink moves from conductive layer (A) to insulating layer (B) within bushing core.
Test Tap Construction

GROUNDING SPRING

GASKET

TEST TAP COVER

MOUNTING FLANGE

3 (a)
Bushing Draw Lead Connection

Figure 3 - 15 Draw Lead and Retaining Pin.

Figure 3 - 16 Final Connector Cap.
Step 4 Once the draw lead has been retrieved, tie a strong non-abrasive nor metallic cord to the lead introducing the other end of the cord up through the bushing from bottom to the draw lead cap.

Step 5 Simultaneously; lower the bushing into the transformer while extracting/pulling the draw lead up through the bushing. After the bushing has come to rest on the cover/turret, verify that there are no kinks in the cable below the bushing and that sufficient strike distance exists between the cable and surrounding tank wall, core clamps, etc.

Step 6 Once the threaded top and the retaining pinholes are aligned, install the retaining pin and contact nut (if applicable). When draw lead is secured, remove the draw lead cord (refer to Figure 3-11).

Step 7 Verify that the top terminal threads (internal and external) and cap gasket is not damaged. Clean with dielectric solvent and install the bushing cap (refer to Figure 3-12).

Step 8 Finally tighten and torque all the bolts a cross pattern according with the Appendix Section.

![Image of bushing components with labels: Draw Lead, Retaining Pin, Draw Lead Cap, and Gasket.]

**CAUTION**

Bushing flanges are made of metal casting. Do not exceed the Specific Component Torque Values Table (Appendix), or permanent damage will occur.
GE Type U Facts:

There are several different design issues that have contributed to GE failures – the herringbone ink design, top terminal tightness, and the flex seal. Each will be described separately.

**Herringbone Ink I** – The condenser design with ink lined and plain kraft paper layers allowed a gap at the ends of the active ink layers in the condenser core (the paper with the ink is narrower). A heavily loaded transformer will generate heat, subjecting the bushing to a higher immersion-oil temperature, and consequently increasing the internal temperature in the bushing. The heated bushing oil expands and intensifies the pressure in the confined gas space. This causes an increased quantity of gas to become dissolved in the oil. Cyclic reduction in the transformer load and/or reduction of the ambient temperature allows cooling of the bushing oil. As the oil cools, it contracts, reducing the pressure of its gas blanket. If the pressure reduction occurs rapidly enough, the gas-saturated oil will develop a tendency to evolve bubbles of gas. This evolution will first occur in the highest electrical stress regions of the bushings, normally between the lined paper and the plain paper layers of the condenser core. A critical combination of gas bubbles and dielectric stress causes partial discharges to occur within the insulation system. The long-term effect of the discharges is an increase in the dielectric losses in the insulation system,
resulting in an increased power factor. Partial discharge occurs more frequently at the bottom of the condenser, where the bubbles get trapped. The discharge will make holes which can eventually cause shorted layers.
Herringbone Ink II (migrating ink) – Although GE designed and specified the herringbone ink process, they did not manufacture the paper, nor did they apply the Rescon conductive ink. The paper/ink process was completed by outside contractors. Reports as early as 1979 show that portions of the Rescon ink herringbone pattern had transferred from the printed-paper layers to the plain draft paper layers. Investigations have revealed that where Rescon-printed paper made contact with the overlapping plain paper, evidence of corona action or evidence of slight burning was found. The result is an increase in power factor.

Herringbone Ink III – During the cutting of lined and plain kraft paper, in the condenser winding process, ink/particulates were generated, further complicating the rising power factor phenomenon. Analysis of failed bushings indicates that sludge found at the bottom of the bushing is usually this ink/paper particulate or breakdown by-products and not migrating ink. By 1985 GE had made many internal quality improvements to the design and processing of bushings. GE implemented an oil flushing procedure for all bushings in order to reduce the particles that may have originated with the bushing core insulation.
Testing of Bushings
Bushings consist of three basic designs which are bulk porcelain, compound filled, and condenser types. The condenser types usually have capacitance taps that are brought out for power factor testing, but there are a few bushing designs that do not have these taps. Bulk porcelain, compound filled, and condenser bushings without capacitance taps that are being tested in equipment have to be tested with the hot collar test. Bushings with capacitance taps can be power factored with the use of the capacitance tap.
1. Disconnect leads from bushings.
2. Remove all ground on H0 and X0 bushings if on transformers, regulators, or pots.
Test procedures for condenser type bushings with capacitance taps.

This bushing consists of an intercapacitor C1 and an outer capacitor C2. Each of these capacitance sections is to be power factored individually by using the following two hookups.

a. Bushing test for a C1 Capacitor
Bushing test for a C2 Capacitor
Test procedures for bushings without capacitance taps. Bushings without capacitance taps will have to be tested with the hot collar test which tests for leakage current.

a. Hook up for Hot Collar Test

4.7.5 Testing
Bushings - General *Rules of Thumb* for Interpreting Bushing Power Factors:
If PF is approximately **two** times the value given on the nameplate, then monitor the bushing closely; it is deteriorating.
If PF is approximately **three** times the value given on the nameplate, then replace the bushing.
If the capacitance (C1 or C2) value changes (increase or decrease) by 10% from the nameplate value, then replace the bushing.
If a GE Type U bushing has a power factor of >1.0%, then replace it.
Type “U” Bushing – Over 100C at center stud.
ABB Article on Type U Bushings
Oil Expansion Chamber on GSU bushing
Disassembly of bushing
ABB bushing Report