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TESTING AND MAINTENANCE OF HIGH-VOLTAGE BUSHINGS

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TABLES

I. Types of Bushings

High-voltage bushings for use on transformers and breakers are made in several principal types, as follows:

A. Composite Bushing.- A bushing in which insulation consists of two or more coaxial layers of different insulating materials.

B. Compound-Filled Bushing.- A bushing in which the space between the major insulation (or conductor where no major insulation is used) and the inside surface of a protective weather casing (usually porcelain) is filled with a compound having insulating properties.

C. Condenser Bushing.- A bushing in which cylindrical conducting layers are arranged coaxially with the conductor within the insulating material. The length and diameter of the cylinders are designed to control the distribution of the electric field in and over the outer surface of the bushing. Condenser bushings may be one of several types:

1. Resin-bonded paper insulation;

2. Oil-impregnated paper insulation; or

3. Other.

D. Dry or Unfilled Type Bushing.- Consists of porcelain tube with no filler in the space between the shell and conductor. These are usually rated 25 kV and below.

E. Oil-Filled Bushing.- A bushing in which the space between the major insulation (or the conductor where no major insulation is used) and the inside surface of a protective weather casing (usually porcelain) is filled with insulating oil.

F. Oil Immersed Bushing.- A bushing composed of a system of major insulations totally immersed in a bath of insulating oil.

G. Oil-Impregnated Paper-Insulated Bushing.- A bushing in which the internal structure is made of cellulose material impregnated with oil.

H. Resin-Bonded, Paper-Insulated Bushing.- A bushing in which the major insulation is provided by cellulose material bonded with resin.

I. Solid (Ceramic) Bushing.- A bushing in which the major insulation Is provided by a ceramic or analogous material.

II. Bushing Troubles

Operating records show that about 90 percent of all preventable bushing failures are caused by moisture entering the bushing through leaky gaskets or other openings. Close periodic inspection to find leaks and make repairs as needed will prevent most outages due to bush-Ing failures. Such an external inspection requires little time and expense and will be well worth the effort. High-voltage bushings, if allowed to deteriorate, may explode with considerable violence and cause extensive damages to adjacent equipment.

Flashovers may be caused by deposits of dirt on the bushings, particularly in areas where there are contaminants such as salts or conducting dusts in the air. These deposits should be removed by periodic cleaning.

Table 1 lists the common causes of bushing troubles and the inspection methods used to detect them.

III. Safety

At all times, safety is the most important consideration. All testing work on bushings shall be performed in accordance with the ROMSS (Reclamation Operation and Maintenance Safety Standards) which establish safety standards and safe work practices for operations and activities performed by the Bureau. The

Table 1. - Bushing troubles

Trouble	Possible results	Methods of detection
Cracked porcelain	Moisture enters. Oil and/or gas leaks. Filler leaks out.	Visual inspection. Power factor test. Hot collar test
Deterioration of cemented joints	Moisture enters, Oil and/or gas leaks. Filler leaks out.	Visual inspection. Power factor test. Hot collar test.
Gasket leaks	Moisture enters. Oil and/or gas leaks. Filler leaks out.	Visual inspection. Power factor test. Hot collar test. Hot-wire test for moisture. Insulation resistance.
Moisture in insulation	Moisture enters.	Power factor test, Hot collar test.
Solder seal leak	Moisture enters. Filler leaks out.	Visual inspection. Power factor test. Hot collar test. Hot-wire test for moisture. Leak detector.
Broken connection between ground sleeve and flange	Sparking in apparatus tank or within bushing. Discolored oil.	Power factor test.
Voids in compound	Internal corona.	Hot collar test. Power factor tip-up test.
Oil migration	Filler contamination.	Visual inspection. Power factor test. Hot collar test.
No oil	Oil leaks out. Moisture enters.	Visual inspection, Power factor test. Hot collar test.
Displaced grading shield	Internal sparking discolors oil.	Hot collar test.
Electrical fiashover	Cracked or broken porcelain. Complete failure.	Visual inspection. Hot collar test.
Lightning	Cracked or broken porcelain. Complete failure.	Visual inspection. Test lightning arrestors.

Table 1. - Bushing troubles - Continued

Trouble	Possible results	Methods of detection
Corona	Internal breakdown. Radio interference. Treeing along surface of paper or internal surfaces.	Power factor test Hot collar test. Hot-wire test. RRIV
Short-circuited condenser sections	Increased capacitance. Reduced voltage at capacitance tap terminal. Adds internal stress to insulation.	Power factor test. Voltage test at capacitance tap. Capacitance test.
Darkened oil	Radio interference, Poor test results.	Power factor test. Hot collar test.

following are minimum suggestions for safety and are not intended to supersede safety practices established by individual regions or the ROMSS.

A. Handling. - When handling bushings, care must be taken to be sure that rigging is applied properly to prevent damage to the bushing and/or to adjacent equipment and personnel.

Cracked or chipped porcelain produce sharp edges which can result in severe cuts on the hands and arms of personnel working around them.

B. Static Charges. - Static charges induced by test potentials provide a source for serious accidents through falls caused by reflex action, High- static voltages may be encountered at the bushings installed in apparatus during cold weather and oil-handling operations. Protective or safety grounds should be used to bleed off static charges. High-static charges may also be encountered at the bushing capacitance taps if the covers are removed. These also should be grounded before being handled.

Induced voltages from nearby energized lines can cause serious accidents if they are not handled properly. Employees should be constantly reminded of the possibility of induced charges and the dangers Involved.

Induced voltages of steady-state nature are often encountered when the deenergized circuit closely parallels another energized circuit. In such instances, protective grounds should be applied to the circuit at the bushings to be inspected. If electrical tests are to be conducted, the grounded leads may be removed which would prevent such tests. Refer to FIST Volume 1-1.

C. Field Testing.- Field testing generally requires work in the proximity of energized equipment. A hazard analysis should be performed and a short safety meeting on the site should be conducted prior to beginning field tests on bushings.

Adjacent high-voltage equipment which may be hazardous to workmen shall be marked off with visible warning devices, such as tape, rope, or portable fence sections. Signs reading **"DANGER - DO NOT PASS THIS BARRIER, -- DANGER - HIGH VOLTAGE,"** or similar notice shall be placed along the barriers facing the working area.

IV. Maintenance, Inspection, and Testing

A. General.- All high-voltage bushings should be inspected periodically to intervals of not over 3-5 years. The inspections should include power-factor tests for all bushings rated above 115 kV. Lower voltage bushings should also be tested if there is reason to suspect they may be deteriorated. Bushings showing signs of deterioration should be tested at intervals of 6 months to 1 year and removed from service if the tests show a dangerous condition.

1. Terminal caps end connectors. Check for tightness to avoid poor contact and resultant heating.

2. Capacitance taps and power-factor test electrodes.- Check to determine proper grounding for bushings with a grounded capacitance tap and for power-factor test electrodes. Examine for proper gasketing to prevent entrance of moisture.

3. Cement.- Check for crumbling or chipped and repair as required.

4. Gaskets.- Check gaskets for deterioration, looseness, and leaking. Loose gaskets should be replaced or painted with General Electric lacquer or other suitable oil-proof sealer, and tightened. Finding a loose gasket or seal may mean that moisture has entered the bushing, and checks should be made to determine if moisture is present. The bushing should be dried out if necessary.

5. Metal pads.- Check and paint as necessary. Examine structural parts, such as clamping rings and washers, for cracks or breaks.

6. Solder seals.- Check for cracks and leaks and repair as necessary.

B. Visual Inspection Annually with Binoculars.- The visual inspection should include the following items:

1. Porcelain.- Check for chips, cracks, and contamination. Minor chips may be painted with an insulating varnish to obtain a glossy finish which will shed dirt and moisture. Superficial cracks that do not affect the mechanical or electrical strength of the bushing may be sealed with insulating varnish or epoxy. Bushings with major chips or cracks which appreciably decrease the creepage distance should be replaced. The surface of the porcelain should be cleaned as needed to remove dirt, oil, and other deposits that may reduce the flashover value.

2. Oil level.- Check the oil level on bushings equipped with sight gauges or other types of oil-level indicators and add oil as necessary. Low-oil levels with no sign of an external leak may Indicate a leak within the bushings which may require replacement of the bushing as field corrections would be difficult to accomplish. The oil level of bushings without oil-level indicators is not normally checked unless there is evidence of leakage.

C. Maintenance Tests.- Common maintenance tests are power factor, RIV (radio-influence-voltage), dc insulation resistance, and testing oil or compound for moisture. Descriptions of these various tests follow:

1. Power-factor Doble Tests.- The power-factor test is the most effective known field test procedure for the early detection of bushing contamination and deterioration. This test also provides measurement of ac test current which is directly proportional to bushing capacitance.

Bushings may be tested by one or more of four methods depending upon the type of bushing and the power-factor test set available. For more complete detailed instructions on the method of test and test procedure, please see the appropriate power-factor test set instruction book. The four test methods are as follows:

a. *The GST (grounded specimen test).*- This test measures the insulating qualities of the insulation between the current carrying or center conductor and the mounting flange of a bushing. The application of such a test is necessarily limited to bushings out of the apparatus such as spare bushings, or bushings which have been isolated from connected windings and interrupters. The test is performed by energizing the bushing conductor and grounding the flange.

Large variations in temperature have a significant effect on power-factor readings on certain types of bushings. For comparative purposes, readings should be taken at the same temperature, or corrections should be applied before comparing readings taken at different temperatures.

b. The hot-guard test.- This test measures the insulation between the current-carrying or center conductor and the mounting flange of a bushing. The test was designed specifically for "draw-lead" type bushings but is applicable to any bushing in apparatus which can be isolated from connecting windings and bus, but not sufficiently to withstand test potential. Both the bushing and the draw-lead, winding, and bus are energized at the same test potential, but only the current and losses of the bushing are measured.

c. The UST (ungrounded-specimen test).- This test measures the insulation between the current-carrying or center conductor and the capacitance tap, power-factor tap, and/or ungrounded flange of a bushing. This test may be applied to any bushing in or out of apparatus which is either equipped with capacitance or power-factor taps or the flange of which can be isolated from the grounded tank in which the bushing is installed. The insulation resistance between the taps or insulated flanges and ground should be 0.5 meg-ohm or better. While in this case, anything that is attached to the bushing (such as contact assemblies or transformer windings) would also be energized; only the insulation of the bushing between the center conductor and the ungrounded tap or flange would be measured. In the case of bushings equipped with capacitance taps, a supplementary test should always be made on the insulation between the tap and the flange.

d. The hot-collar test.- This test measures the condition of a specific small section of bushing insulation between an area of the upper porcelain rainshed and the current-carrying or center conductor. It is performed by energizing one or more electrodes (collars) placed around the bushing porcelain with the bushing center conductor grounded. This test is used to supplement the three tests described above or to test bushings in apparatus when the above-mentioned three tests are either inapplicable or impractical. Hot-collar tests are effective in locating cracks in porcelain, deterioration or contamination of insulation in the upper section of a bushing, low compound or liquid level, or voids in compound, often before such defects are noticeable with the tests outlined in subparagraphs a., b., and c.

When bushings with capacitance or potential taps (92 kV and above) are tested by the ungrounded test specimen method, it is recommended practice to include a separate power-factor test on the tap Insulation as well. The exception to this is General Electric Company type of bushings built prior to 1932, which have tap outlets designed to operate at less than 100 volts. On all other capacitance or potential taps, tests are performed at some voltage from 2 to 5 kV. The procedure is to energize the tap with the bushing center conductor and flange grounded. The power factor of a capacitance or potential tap will generally be of the order of 1.0 percent or less.

PermissibleTest Potentials to be Applied to Power-Factor Taps

Manufacturer	Bushing type or class	Test volts
General Electric	LC, U	2000
Lapp	POC	2000
Ohio Brass	L	250
Ohio Brass	GK, LK	500
Pennsylvania (Federal Pacific)	P	500
Westinghouse	S, OS	500

Routine tap-insulation tests are not normally recommended for bushings rated 69 kV and below with power-factor taps. However, a power-factor test of the tap insulation should be performed when questionable ungrounded specimen test results or visual examination cast suspicion on the condition of the power-factor tap. The test procedure is as outlined above for capacitance taps. In such cases, the maximum permissible test potentials should be limited to the following table.

The power factor of the power-factor tap insulation for most of the above- mentioned bushings will generally be of the order of 1.0 percent or less. The principal exception to this is the Ohio Brass, type L bushing. The inherent properties of the fibrous-bakelite material used for the tap insulator have resulted in power factors up to 10 percent for apparently satisfactory taps.

The tabulations of factory power factors and power-factors limits in table 2 are as published by the manufacturers or otherwise listed by them. Please note, however, that many bushings have the factory power factor listed on the nameplate. In such cases, field measurement, particularly ungrounded specimen tests, should compare with and the bushings be rated on the basis of nameplate power factors. In general, any bushing that exhibits a history of continued

Table 2. - Manufacturer's P. F. (power factor) limits for bushings			
Manufacturer	**Bushing type or class**	**Initial P.F. for new bushings, at**	**Dangerous P. F. value at 20 EC (%)**
General electric	A	6.0	8.0
	B	10.0	12.0
	F	1.5	2.0
	L	3.0	4.0
	LC	2.5	3.5
	OF	2.6	6.0
	S	3.5	6.0
	U	1.0	1.5
Lapp bushings	POC	0.5	
	PRC	0.7-1.2	
Ohio Brass manufactured prior to 1926 and after 1938	ODOF G L	1-10	Initial P.F. = 22
Ohio Brass manufactured 1926 to 1938, inclusive	ODOF G L	2-4	Initail P.F. = 16
Ohio Brass	Class GK type C	04.-0.6	
	Class LK type A	0.6-0.7	
Pennsylvania Transformer	P PA PB	0.5	1.0
Westinghouse	D		6.0
	O		1.4
	OCB & Inst. Trans. 69-kV and Below		3.5
	OCB & Inst. Trans. 92-kV to 138-kV		2.8
	Power & Dist. Trans. OCB & 161-kV to 288-kV.		2.0

increase in power factor should be questioned and scheduled for removal from service. Measured power-factor values should be temperature corrected to 20 EC for comparison with table 2.

2. The RIV test.- The RIV test can provide detection of corona in resin- bonded, solid-core noncondenser bushings. Methods of measurement of RIV are described in NEMA Publication No. 107. Copies of this publication may be obtained from D-8440 or D-8450.

Liquid-filled bushings generally have a low RIV value. A high RIV value on this type of bushings which cannot be reduced by cleaning the porcelain indicates the level of the filling liquid should be checked.

3. The dc insulation resistance test. The dc insulation resistance test generally cannot be relied on to detect early contamination in bushings. When bushing deterioration can be detected by dc insulation resistance, it is generally in an advanced stage requiring immediate attention. A 2500-volt insulation resistance meter may be used for an insulation resistance check, but a high reading should not be completely relied upon as indicating a good bushing. Any bushing testing less than 20,000 megohms has questionable insulating value.

4. Hot-wire test for moisture.- Plastic type compound used in compound filled bushings may absorb moisture if there are leaks through the shell or cap. A moisture content of as little as 0.15 percent in soft compounds can be detected by pushing a red-hot rod into the compound. If moisture is present, a crackling, sputtering, or hissing sound will be heard. If no moisture is present, the compound will melt quietly. Another test is to put some compound on a wire and melt it in the flame of a match. If moisture is present, there will be a sputtering sound and small sparks will be thrown off. Dry compound will melt without disturbance.

5. Testing oil for moisture. - Whenever the presence of moisture in the oil of an oil-filled bushing is suspected or found by a bushing power-factor test, the oil should be drained out and a sample tested by a dielectric or power-factor test. Since the quantity of oil in a bushing is small, the old oil should be discarded and new oil put in. If moisture is found in the oil, the bushing should be dried out before returning to service.

V. Storage of Bushings

The manufacturer's instructions for storage should be followed for all bushings. The following are general guidelines for the storage of bushings:

A. Bushings should be stored where they will not be subject to mechanical damage.

B. Bushings having exposed paper insulation on the lower end require special protection to prevent moisture contamination. This can be accomplished with a tank or tub filled with oil or with a special moisture- proof wrapping. Completely sealed outdoor bushings may be stored out of doors.

C. Liquid- and plastic-filled bushings should never be stored in a horizontal position. Storage in a horizontal position can introduce voids or air bubbles into the filler insulation.

The condition of stored bushings should be checked periodically for oil level, mechanical damage, and power factor as described in section IV - Maintenance, Inspection, and Testing. The power factor of a stored bushing should be checked before putting it in service.

BIBLIOGRAPHY

[1] Manual of Westinghouse Outdoor Bushings Technical Data 33-360.

[2] Apparatus Bushing Reference Book, General Electric Co., Bulletin GET- 2525.

[3] NEMA Publication No. 107-1964, Reaffirmed by NEMA 1976 - Methods of Measurement of Radio Influence Voltage (RIV) of High-Voltage Apparatus, National Electrical Manufacturers Association, 2101 L Street NW, Washington, D.C. 20037.

[4] IEEE Standard 21-1976 - IEEE General Requirements and Test Procedure for Outdoor Apparatus Bushings, Published by the Institute of Electrical and Electronic Engineers, Inc.

[5] Hubert, Charles L., Preventive Maintenance of Electrical Equipment, McGraw-Hill Book Co., New York, N.Y., 1969.