GENERAL RADIO COMPANY

engineering department

INSTRUMENT NOTES

IN-104 August, 1964

HOW ONTARIO HYDRO SUPPRESSES ELECTRICAL INTERFERENCE WHEN MEASURING DISSIPATION FACTOR OF BUSHINGS AND INSULATION

The information contained herein is a condensation of an article that appeared in the Ontario Hydro Research Quarterly, Volume 15, Second Quarter 1963, Number 2. We are grateful to The Hydro Electric Power Commission of Ontario for their cooperation and for their permission to publish this material.

Dissipation factor (D) is most commonly expressed as the ratio of resistance to reactance, a quantity that is directly proportional to the energy dissipation per cycle. Another way of expressing dissipation factor is in terms of the ratio of watts loss to reactive voltamperes. This is a more meaningful expression to people working in the power field, where the types of equipment on which dissipation-factor measurements are made include such apparatus as large oil-filled transformers and breaker bushings. When you test transformer insulation you are actually measuring D of a capacitor whose two sides, the high-voltage terminal and ground, are separated by the insulation. Since this measurement gives you an indication of the condition of the insulation, it is a quantity that should be checked periodically as insurance against deterioration and possible equipment breakdown. At Ontario Hydro, such tests are performed not only on operating equipment as routine maintenance checks but also on newly installed apparatus to appraise its suitability for service.

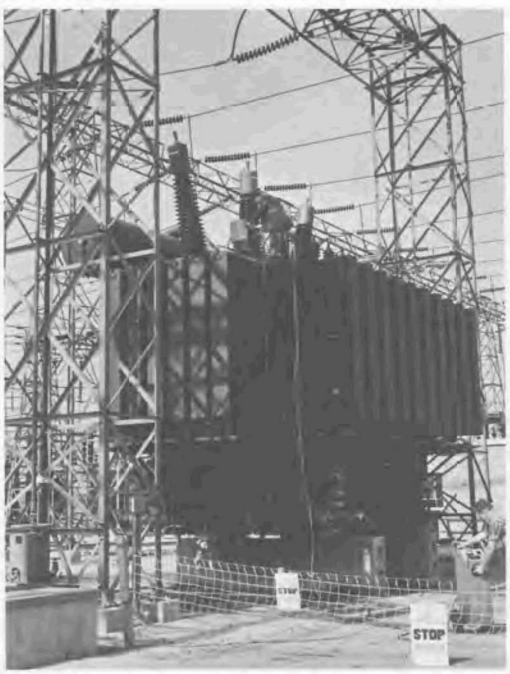


Figure 1. Cameron Hot Box in use with the measuring unit located on top of the transformer and power supply on the ground.

If there is no electrical interference from nearby operating equipment, it is relatively simple to measure dissipation-factor at the power-line frequency with a capacitance bridge. However, electrical interference is frequently present. Often a power transformer whose insulation is to be tested is located directly below a high-voltage transmission line, and the line cannot be de-energized during testing. Since the high-voltage line induces an interfering voltage across the bridge's detector terminals, the measured dissipation factor may be in error when a simple capacitance bridge is used.

The General Radio Type 1611 Capacitance Test Bridge, which is widely used for insulation testing, applies some 125 volts to the insulation under test. The bridge contains a 3-position rotary switch (DIR-STAND-BY-REV), which allows you to reverse the connections to the bridge input transformer, thus reversing the phase of the applied voltage. By averaging the readings for the direct and reverse positions, you eliminate the effect of extraneous voltages that may be induced from adjacent electromagnetic fields at the power-line frequency. Under some conditions, however, the effect of the induced voltages can be so severe that it is impossible to balance the bridge on one or both the DIR and REV positions.

Ontario Hydro has devised two methods for overcoming the interference problem. One method involves the use of high-voltage test equipment; the other, accessory equipment for the low-voltage capacitance bridge.

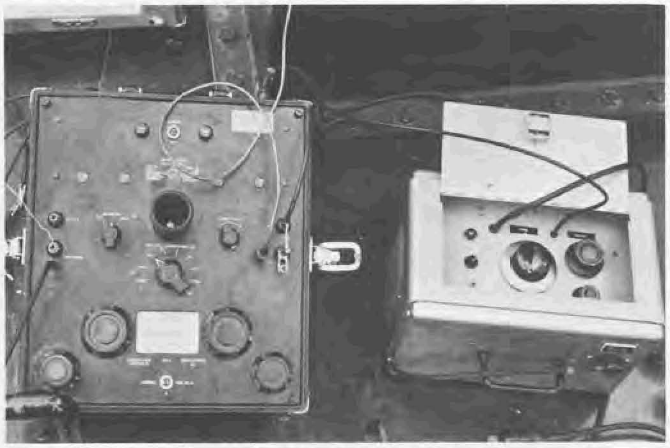


Figure 2. Type 1611 Capacitance Test Bridge and the Phase Shifter Mark IIIA connected ready for use.

HIGH-VOLTAGE TEST METHOD

About 10 years ago, the Research Division of Ontario Hydro developed a device called the Cameron Hot Box for measuring dissipation factor in the presence of interference. This test equipment operates at a voltage that is sufficiently high to swamp out the interference, thus producing intelligible results. The test apparatus consists of a form of ac bridge with a built-in 10-kV standard air capacitor, and it is packaged in two units that are interconnected by a cable. The measuring unit is placed as close as possible to the insulator being tested; the other unit, which is the power supply, remains on the ground. Because the power supply contains a 60-cycle, 2-kVA, 110-V to 10-kV transformer, it is necessarily a heavy piece of equipment. Two people are required to operate it, and the usual high-voltage safety precautions must be observed. Figure 1 shows the Cameron Hot Box in use in the field.

LOW-VOLTAGE TEST METHOD

A more recently developed method for measuring dissipation-factor utilizes the General Radio Type 1611 Capacitance Test Bridge and an Ontario Hydro-developed Interference Suppressor. The specially designed Interference Suppressor applies to the bridge's detector terminals a pure sine-wave voltage that is continuously variable in phase and adjustable from zero to about 75 volts in amplitude. Figure 2 shows the Type 1611 Capacitance Test Bridge connected to the Interference Suppressor, which Ontario Hydro designates as the Phase Shifter Mark IIIA. Mounted on the inside of the Mark IIIA lid are instructions (Figure 4) for connecting and operating the test equipment. The schematic diagram of Mark IIIA appears in Figure 5.

When the bridge is used with interference-suppressing apparatus such as the Phase Shifter Mark IIIA, it is possible to cancel out the interference completely and obtain identical direct and reverse readings. This is true even when tests are made on apparatus that is located directly below a live 230-kV transmission line.

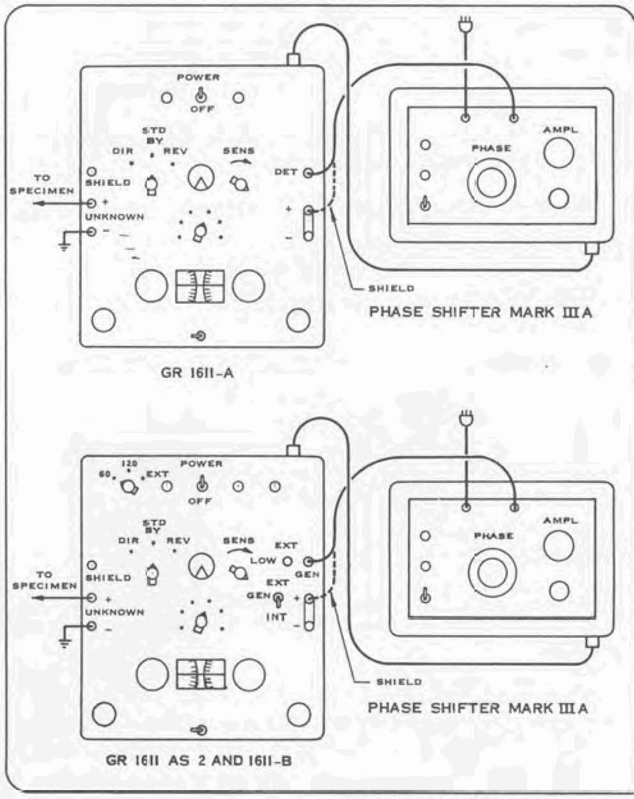
A second model of the Phase Shifter, designated the Mark V, was designed for use in areas where there is no 120-V service available and where the output of a portable gasoline generator would not be synchronized with the interference voltage. The Mark V contains a free-running, three-phase oscillator with a pick-up antenna to lock the oscillator frequency to the frequency of the interfering voltage. Output of the oscillator is phase-shifted, filtered, amplitude-adjusted, and then fed to the bridge's detector terminals.

COMPARISON OF RESULTS

Good agreement in field measurements on 115-kV and 230-kV apparatus has been obtained with both the high-voltage and low-voltage test methods. The latter method has the advantage of using equipment that is relatively inexpensive, lightweight, and easily transportable. In addition, testing by this method requires only one person, and high-voltage safety precautions need not be observed, since only low voltages are involved.

On 15-kV class equipment, the Hot Box permits measurement of the relationship between dissipation-factor and voltage for voltages up to and above normal service values. The curve of dissipation-factor versus voltage may provide a significant indication of the presence and severity of corona under service conditions in generators, metalclad switchgear, instrument transformers, and similar equipment. For the insulation of equipment operating at voltages considerably higher than 10-kV to ground, and where there is high corona inception, no significant difference is apparent in the result whether dissipation-factor is measured by the high-voltage or low-voltage method.

Figure 3. Current model of the Capacitance Test Bridge.



PHASE SHIFTER MARK III A
SERIAL NO.............

120 VOLTS 60 CYCLES 0.2 AMPERE

INSTRUCTIONS

THIS DEVICE IS DESIGNED FOR USE WITH THE GENERAL RADIO CAPACITANCE BRIDGE, WHEN INTERFERENCE IS ENCOUNTERED IN FIELD MEASUREMENTS.

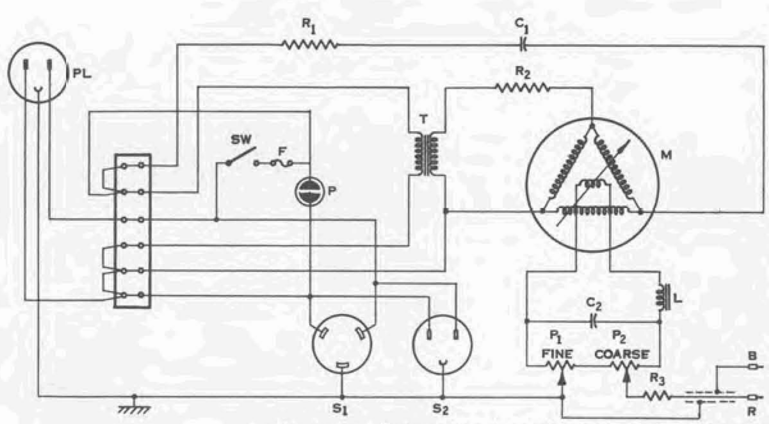
1. CONNECT THE EQUIPMENT AS SHOWN. SWITCH ON THE PHASE SHIFTER AND THE CAPACITANCE BRIDGE, AND WAIT FOR THE "EYE" ON THE BRIDGE TO LIGHT UP.

2. WITH THE SWITCH ON THE BRIDGE IN THE "STAND BY" POSITION, ADJUST THE "PHASE" AND "AMPLITUDE" CONTROLS ON THE PHASE SHIFTER TO OPEN THE INDICATOR "EYE" ON THE BRIDGE TO ITS MAXIMUM POSITION. INITIAL ADJUSTMENT IS SOMETIMES MORE EASILY MADE WITH THE SENSITIVITY ON THE BRIDGE REDUCED. FINAL BALANCE SHOULD BE OBTAINED WITH THE SENSIVITY HIGH. TO LOCATE THE APPROXIMATE BALANCE, SET THE AMPLITUDE CONTROLS ON THE PHASE SHIFTER TO SOME LOW VALUE, AND SWEEP THROUGH 360° OF PHASE POSITION. THIS REQUIRES NOT LESS THAN FIVE COMPLETE TURNS OF THE PHASE DIAL. LOOK FOR A FLICKER IN THE "EYE", WHEN THIS IS FOUND ADJUST THE PHASE DIAL, AND BOTH THE COARSE AND FINE AMPLITUDE DIALS, FOR THE MAXIMUM OPENING OF THE "EYE".

3. SWITCH THE BRIDGE TO "DIRECT", AND ADJUST THE CAPACITANCE AND DISSIPATION FACTOR DIALS FOR BALANCE (MAXIMUM EYE OPENING). RECORD CAPACITANCE AND DISSIPATION FACTOR. REPEAT WITH THE SWITCH IN THE "REVERSE" POSITION. THE CORRECT CAPACITANCE AND DISSIPATION FACTOR ARE OBTAINED BY AVERAGING DIRECT AND REVERSE READINGS. THE BEST ADJUSTMENT OF THE PHASE SHIFTER WILL MAKE DIRECT AND REVERSE READINGS ALMOST IDENTICAL.

NOTE: WHEN THE SWITCH IS ON EITHER DIRECT OR REVERSE, THE SPECIMEN LEAD IS LIVE.

Figure 4. Operating instructions for Mark IIIA phase shifter, as mounted on the inside of the instrument lid.



R_1 – 550 ohm, 10 w
R_2 – 1000 ohm, 20 w
R_3 – 180 K ohm, 0.5 w
P_1 – 50 K ohm
P_2 – 1 megohm
C_1 – 2.60 μf, 450 v
C_2 – 2.0 μf, 450v
T – 115/115 v, 15 va
L – 2h, 100 ma dc
M – magslip transmitter, 3 inch, 60 cps, 115/90 v

Figure 5. Schematic diagram of Mark IIIA phase shifter. The supply is single-phase, 120v, 60-cycle.

NOTE

The Mark IIIA and Mark V Phase Shifters described in this article are manufactured and sold by Muirhead Instruments Limited, Stratford, Ontario, Canada. Please direct inquires regarding these particular items to them. For additional information on the Type 1611-B Capacitance Test Bridge, call or write to General Radio Company, West Concord, Massachusetts, or the GR Sales Engineering Office nearest you.

Type 1611-B CAPACITANCE TEST BRIDGE

FEATURES:

- Wide range — 0 to 11,000 μf.
- Measures both 2- and 3-terminal capacitors.
- Visual null indicator.
- External polarizing voltage can be applied.
- Measures polarized electrolytics under conditions of actual use — with 120-cycle ripple.
- Measurements are unaffected by moderate electrostatic fields.

USES: Capacitance and dissipation-factor measurements can be made quickly and conveniently with this bridge. Among its uses in shop and laboratory are the measurement and test of:

Paper and mica capacitors.

Polarized electrolytic capacitors (also tantalytics) at 60 cps without external generator (50 cps for TYPE 1611-BQ1).

Dielectric properties of solid insulation and transformer oil.

Cables — testing and fault location.

Insulators and insulation — bushings, transformers, rotating machines.

Capacitance components for electric equipment.

Transformer interwinding and intershield capacitance.

DESCRIPTION: The series-resistance capacitance bridge circuit is used. A shield terminal is provided for 3-terminal measurements. The null detector consists of a tuned amplifier and electron-ray tube. Measurements are made at the power-line frequency. External generator can be connected for 120 cps and other frequencies.

SPECIFICATIONS

RANGES OF MEASUREMENT

Capacitance: 0 to 11,000 μf at 60 cps; 1 μf to 11,000 μf at 120 cps and other externally supplied frequencies.

Dissipation Factor: TYPE 1611-B, 0 to 60% at 60 cps; TYPE 1611-BQ1, 0 to 50% at 50 cps. Range is proportional to frequency (0 to 120% at 120 cps).

ACCURACY

Capacitance: $\pm(1\% + 1 \text{ pf})$.

Dissipation Factor: $\pm\left(2\% \text{ of dial reading} + 0.05\% \times \frac{f}{60^*}\right)$.

VOLTAGE

AC Voltage on Capacitor under Test: Varies from a maximum of approximately 125 volts at 100 pf to less than 1 volt at 10,000 μf. A maximum of one voltampere of reactive power is delivered to the sample. Voltage can be reduced by an external rheostat on the four highest ranges for measurement of tantalum capacitors.

* $\frac{f}{50}$ for TYPE 1611-BQ1.

Polarizing Voltage: A dc polarizing voltage of up to 500 volts can be applied externally for measurements on capacitors of 1 to 11,000 μf.

GENERAL

Sensitivity: Capacitances from 100 pf to 10,000 μf can be balanced to a precision of at least 0.1%.

Selectivity: Detector filter is tuned to power-line frequency or 120 cps, selected by switch. External filter can be connected at panel jack for other frequencies.

External Fields: For bushing testing, the fields usually encountered in shop and laboratory, even up to several thousand volts, will not affect the accuracy. For measurements in locations where the overhead voltages are very high, the unknown should be shielded.

External Generator: Required for frequencies other than 60 cps. TYPE 1214-D Unit Oscillator is recommended for 120- cycle measurements.

Environmental Effects: The readings of the bridge are unaffected by temperature and humidity variations over the range of room conditions normally encountered (18 to 35 C, 0 to 90% RH).

Power Requirements: 105 to 125 (or 210 to 250) volts, 60 cps for TYPE 1611-B, 50 cps for TYPE 1611-BQ1. Power input is 15 watts.

Accessories Supplied: TYPE CAP-22 Power Cord and spare fuses.

Accessories Required: 120-cycle oscillator, if 120-cycle measurements are to be made. TYPE 1214-D Unit Oscillator is recommended.

Cabinet: Luggage-type, completely shielded to ensure freedom from electrostatic pickup.

Dimensions: Width 14¼, height 16, depth 10 inches (370 by 410 by 255 mm), over-all.

Net Weight: 30½ pounds (14 kg).

Shipping Weight: 37 pounds (17 kg).

Type		*Code Number*	*Price*
1611-B	**Capacitance Test Bridge**	1611-9702	**$665.00**
1611-BQ1	**Capacitance Test Bridge, for 50-cycle supply**	1611-9914	
1214-D	**120-cycle oscillator (including power supply)**	1214-9704	**115.00**

WIDE-RANGE TEST BRIDGE FOR SHOP, FIELD, OR LABORATORY

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS, USA

Printed in USA