

AVTM810130
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Instruction Manual AVTM810130
for
Capacitance And Dissipation Factor Bridge
Catalog No. 810130

High Voltage Equipment
Read the entire manual before operating.
Aparato de Alto Voltaje
Antes de operar este producto lea este manual enteramente.

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1.0 GENERAL INFORMATION

1.1 GENERAL DESCRIPTION

The Model CB100 Guarded Capacitance Bridge is a self-contained instrument designed for the accurate measurement of capacitance and dissipation factor of electrical insulation. The bridge is suitable for making two-terminal, or three-terminal measurements on a specimen that may be grounded or floating. In the guarded, three-terminal, configuration the bridge is especially suitable for the measurement of the capacitance and dissipation factor of high voltage bushings with the aid of the capacitor tap, and for separately measuring the capacitances associated with multi-terminal electrical equipment.

The bridge operates at a frequency of 100 Hz, with the unknown excited at 30 volts. It features a tuned, synchronous and phase sensitive detector which allows independent and quick balancing of the capacitance and dissipation factor controls.

The bridge frequency, 100 Hz, is close enough to the 60 Hz power frequency so that the bridge indicates the same capacitance and dissipation factor as one would measure using the power frequency. However, the bridge frequency is sufficiently removed from the power frequency so that the stray power frequency currents do not interfere with the operation of the instrument. This makes the measurement of insulation quality possible in high voltage yards without the use of high voltage equipment to overcome the interference, or the use of complex interference suppressors.

1.2 CB100 FEATURES

The CB100 Capacitance Bridge is a light-weight, compact, precision instrument designed for testing electrical insulation of power apparatus in hostile environments. The instrument's low operating voltage simplifies safety precautions, reduces shock hazard while increasing portability. A specially designed detector circuit allows independent balance of capacitance and dissipation factor while overcoming power frequency interference. The CB100 is a "HOT GUARD" bridge. The guard potential is therefore "ground" for the UST test, and at bridge voltage (30V, 100/80Hz) for the GST test.

1.3 SPECIFICATIONS

The detailed specifications for this model are given in Table I below.

TABLE I - SPECIFICATIONS

SPECIFICATIONS:	25°C ±5°C, 6 mos., 50 or 60 Hz, ±2 Hz.
BRIDGE:	Transformer ratio bridge type circuit with hot guard.
BRIDGE OUTPUT TEST VOLTAGE:	Internally generated.
	28 Vnom/25 mA max, 100 Hz for 60 Hz systems.
	28 Vnom/25 mA max, 80 Hz for 50 Hz systems.
	Maximum output voltage: 30V rms.

CAPACITANCE MEASUREMENTS:

<u>Multiplier</u>	<u>Resolution</u>	<u>Maximum Range</u>
20 pF	0.02 pF	240 pF
50 pF	0.05 pF	600 pF
100 pF	0.1 pF	1200 pF
200 pF	0.2 pF	2400 pF
500 pF	0.5 pF	6000 pF
0.001 μF	1.0 pF	0.012 μF (12000 pF)
0.002 μF	2.0 pF	0.024 μF (24000 pF)
0.005 μF	5.0 pF	0.060 μF (60000 pF)
0.01 μF	10 pF	0.12 μF
0.05 μF	50 pF	0.60 μF
0.1 μF	100 pF	1.2 μF

Accuracy: ±0.25%, Reading ±4 pF.

DISSIPATION FACTOR:

Range (D.F.)	Resolution (D.F.)
0 - 1%	0.001
0 - 10%	0.01
10 - 20%	0.01
20 - 30%	

Accuracy: ±2%, Reading ±1% F.S. on all ranges.

OPERATION:

Environmental:

Operating:	0°C to 50°C; R.H. to 80%
Storage:	-40°C to +65°C.
Temperature Coefficients:	±0.02% of applicable accuracy spec. per °C of both capacitance and dissipation factor.

PHYSICAL:

Instrument and accessories supplied with portable foam lined carrying case. Case has hinged opening from above with a lockable latch.

Sizes:

Model CB100	290W x 240H x 175D mm (11.5W x 9.5H x 7D in)
Transport Case	430W x 375H x 330D mm (17W x 14.7H x 13D in)

Weight:

Instrument	5 kg (11 lbs)
Shipping	11.8 kg (24 lbs)

1.4 ACCESSORIES FURNISHED

Each instrument is supplied complete with:

- two color coded leads-coaxial cable-10m long.
- one color coded ground lead cable-10m long.
- three wire line input cord.
- one instruction-service manual.
- one transport case.

1.5 ACCESSORIES AVAILABLE

810132	Range Extension Adaptor
810133	Calibrator
810200	Oil Test Cell
810210	Oil Test Cell Heater

1.6 CHANGES

Please note that this instrument is subject to continuous development and improvement. This instrument may therefore incorporate minor changes in detail from the information contained herein.

1.7 WARRANTY

Multi-Amp warrants this instrument sold by us or our authorized agents to be free from defects in material and workmanship for a period of 12 months from date of shipment. During the warranty period Multi-Amp will, at our option, repair or replace the instrument or part thereof which proves to be defective providing:

1. The instrument is returned properly packed and transportation prepaid with prior authorization from us or our appointed agent.
2. The instrument has not been altered, modified or repaired by unauthorized personnel and
3. That our examination discloses to our satisfaction that any improper operation or failure was not the result of improper use, negligence or accident, exceeding environmental limits, or connecting the instrument to incompatible equipment.

This warranty is exclusive and is given and accepted in lieu of all other warranties, expressed or implied, and constitutes fulfillment of all our liabilities to the purchaser. Multi-Amp specifically disclaims the implied warranties of merchantability and fitness for a specific purpose. We assume no liability, in any event, for consequential damages, for anticipated or lost profits, for personal injury due to use or accident, for incidental damages or loss of time or other losses incurred by the purchaser or any third party in connection with instruments covered by this warranty.

2.0 INSTALLATION

2.1 UNPACKING AND INSPECTION

Prior to shipment this instrument was electrically tested and mechanically inspected and found to meet specifications and be free of mechanical defects.

After unpacking the instrument, visually inspect the instrument and accessories for damage. If evidence of damage is present, you must contact the carrier who transported the unit and file a claim in writing. The shipping container and packing material should be retained for inspection by the carrier's agent. Electrical operation as per section 3 should be checked as soon as possible after receipt.

2.2 PREPARATION FOR USE

INSURE THAT THE APPARATUS TO BE TESTED IS CLEARED AND DE-ENERGIZED PRIOR TO TEST. It is highly recommended that the user familiarize himself with the controls, functions and features detailed in section 3 prior to use.

2.3 LINE SUPPLY VOLTAGE

This instrument is shipped from the factory for operation on either 120V, 60 Hz line or 220V, 50 Hz.

2.4 REPACKING AND SHIPMENT

To insure proper shipment of this instrument it is recommended that the original reusable container and packing material be retained. If being returned for calibration or service please attach a card to the instrument specifying the owner, model and serial number and service required.

3.0 OPERATING INSTRUCTIONS

3.1 PANEL CONTROLS AND OPERATING FUNCTIONS

This section details and describes the operating features of the CB100 and is keyed in Figure 1 (next page).

1. Line Input Socket - Standard input for line cord provided.
2. Instrument On - Flipping this switch upwards activates the instrument, immediately sending test voltage to output BNC.
3. Power On Indicator - This red L.E.D. illuminates when instrument is energized.
4. Detector Phasing Switch - State of bridge balance of capacitance or dissipation factor selected. Null meter (5) is indicator for balance condition.
5. Null Meter - Indicator for balance condition of capacitance or dissipation factor. Detector phasing switch (4) determines which is being balanced.
6. Dissipation Factor Range Switch - The approximate magnitude of dissipation factor is first determined by this switch.
7. Dissipation Factor Dial - The precise value of dissipation factor is determined by this setting in conjunction with the D.F. range switch.
8. Capacitance Multiplier Switch - The approximate value of the capacitance being tested is determined with this switch.
9. Capacitance Switch - This switch determines the approximate value of capacitance being measured.
10. Capacitance Dial - The PRECISE VALUE of capacitance measured with this dial in conjunction with the capacitance multiplier (8) and capacitance switch (9).
11. UST-GST Switch - Determines the type of measurement being taken. UST stands for "Ungrounded Specimen Test". GST stands for "Grounded Specimen Test".
12. Test Voltage Outputs, CH, CL, G - Connected to specimen via test leads provided. CH is the bridge sensitive terminal.

3.1 PANEL CONTROLS AND OPERATING FUNCTIONS (continued)

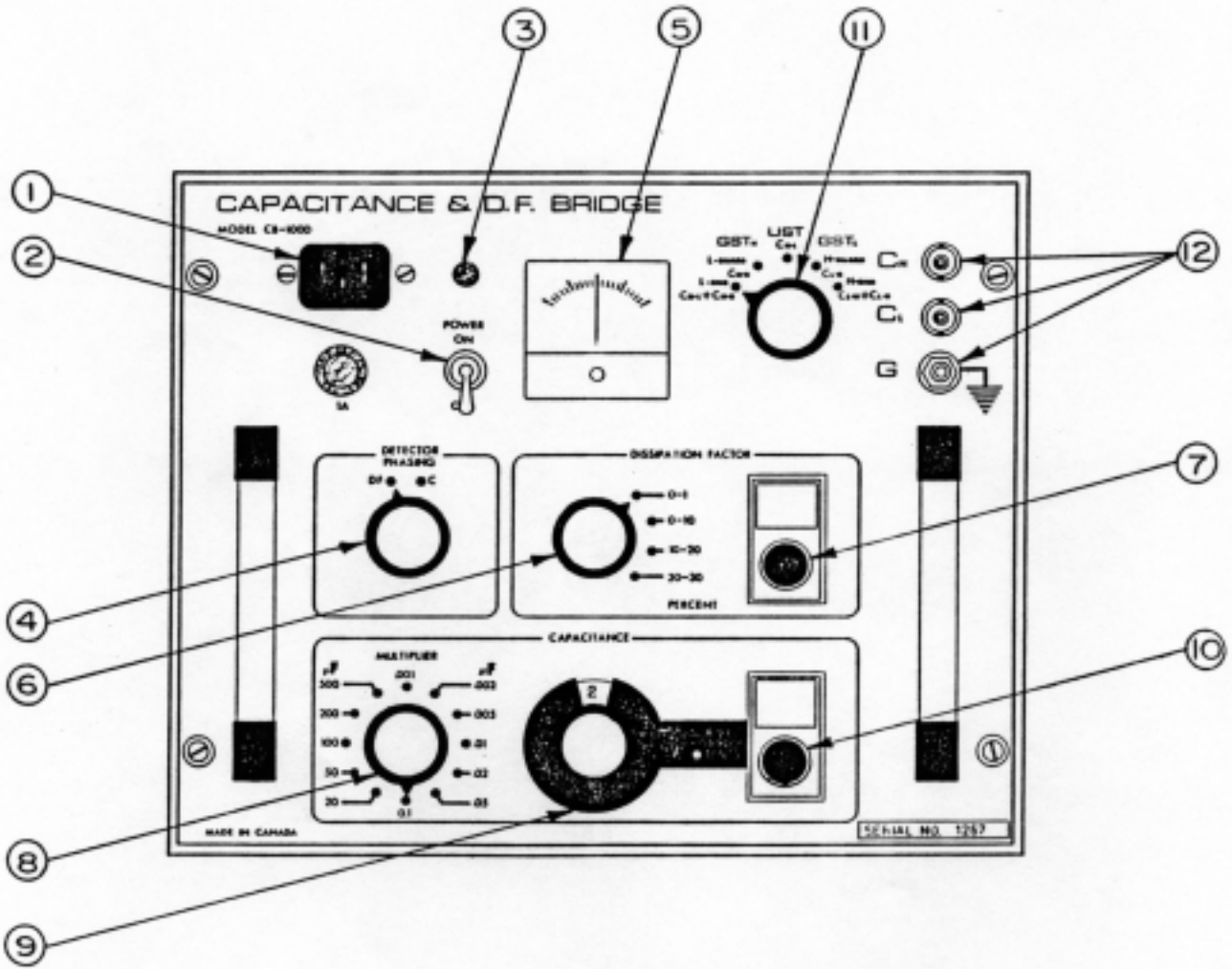


FIGURE 1 - PANEL CONTROLS AND OPERATING FUNCTIONS

3.2 SAFETY CONSIDERATIONS

It should be noted, that, although the instrument outputs no dangerous voltage, it could be a source of electrical shock hazard.

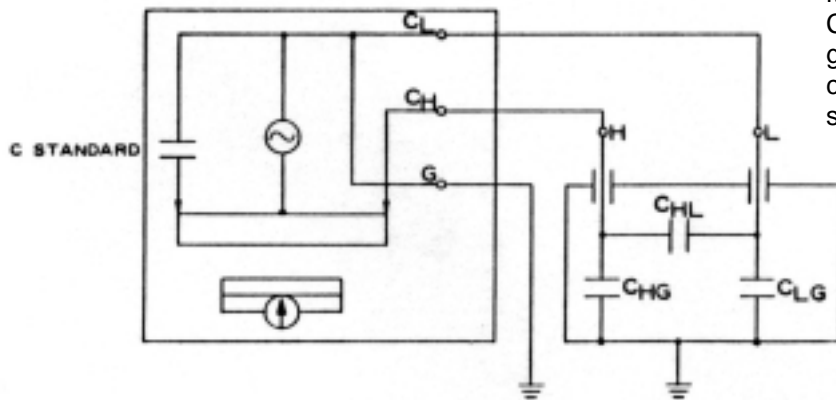
THIS INSTRUMENT MUST ALWAYS BE CONNECTED TO GROUND WITH THE SUPPLIED LEAD AND FRONT PANEL GROUND BINDING POST PRIOR TO AND DURING ALL MEASUREMENTS.

THE APPARATUS BEING TESTED MUST BE CLEARED AND CORRECTLY GROUNDED TO AVOID ANY POSSIBILITY OF LETHAL FLOATING POTENTIAL.

3.3 GENERAL OPERATING INSTRUCTIONS FOR CB100

1. Connect the CB100 case ground terminal to station ground.
2. Select UST-GST switch position (Figure 1, 11) for required position.
3. Connect the CB100 to the specimen to be measured as outlined in the specific instructions for apparatus under test.
4. Set detector phasing switch to "C".
5. Set dissipation factor range to 0 - 10%
6. Set capacitance multiplier to 0.1 μF .

See Figures 2, 3, and 4.



APPLICATION

Measurement taken is CH-L & CH-G. CB100 internally grounds CL in this configuration, thus effectively shorting out CL-G.

FIGURE 2 - UST-GST switch set to "L-GND" (CH-L & CH-G in red)

GENERAL OPERATING INSTRUCTIONS (continued)

APPLICATION

Measurement taken is CH-G.
 CB100 guards out the "L" in
 this configuration, thus nulling
 out its effect.

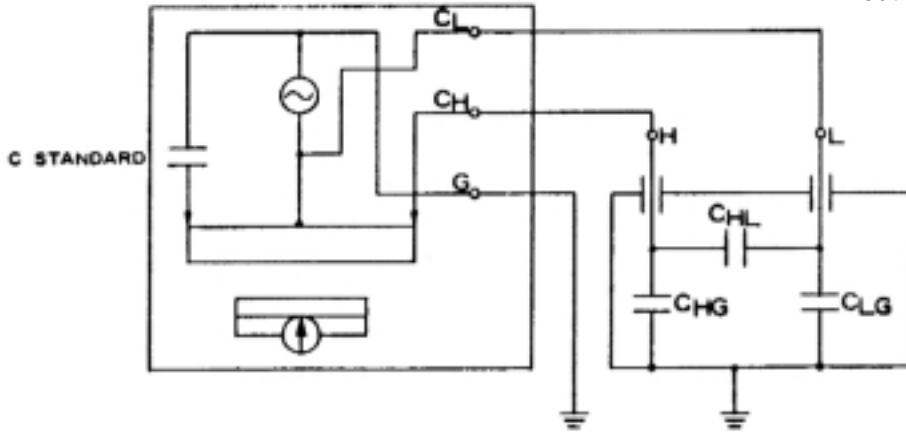


FIGURE 3 - UST-GST switch set to "L-GUARD" (CH-G in red)

APPLICATION

Measurement taken is CH-L.
 Ground is effectively guarded
 out, nulling its effect on the

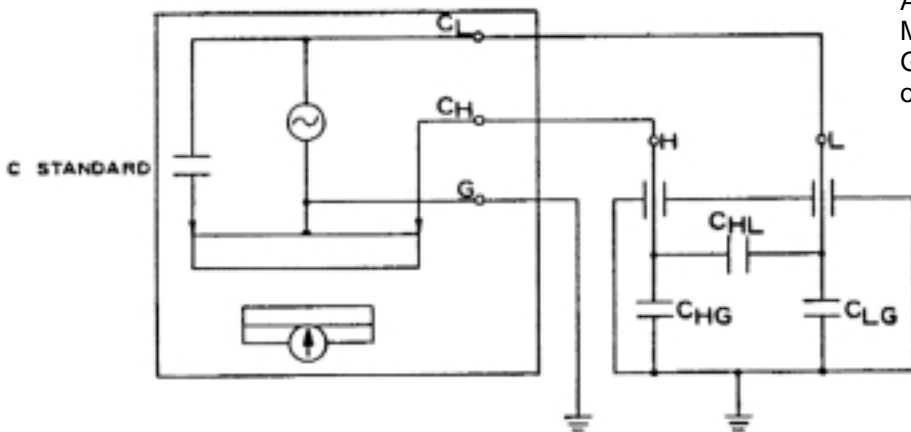


FIGURE 4 - UST-GST switch set to "UST" (CH-L in red)

3.3 GENERAL OPERATING INSTRUCTIONS FOR CB100 (continued)

7. Set capacitance switch to 5 and capacitance dial to 000.
8. Turn bridge power switch on.
9. If the detector swings to the right, turn the capacitance multiplier switch counter-clockwise until the detector swings to the left. Allow about 1 second for the detector to respond between switch positions.
10. Advance the capacitance switch clockwise until the detector swings to the right. Then turn the switch back one step.
11. Adjust the multi-turn capacitance dial to bring the detector to zero.
12. Turn the detector phasing switch to D.F.
13. Bring the detector to zero by the dissipation factor range switch and dissipation factor dial.
14. Turn the detector phasing switch to "C" and repeat step 11.
15. Repeat steps 12, 13, & 14 until no further adjustment is required.
16. The sum of the capacitance switch and dial multiplied by the capacitance multiplier is the capacitance of the specimen.
17. Examples:

Multiplier	Switch	Dial	Capacitance	
			Microfarads	Picofarads
0.1 μF	6	542	0.654200	654,200
0.01 μF	11	023	0.110230	110,230
0.002 μF	10	234	0.020468	20,468
500 pF	5	050	-	2,525

Best accuracy is obtained when the capacitance switch is between 4 and 11. A balance in such a position should always be possible except for certain low capacitance specimens when the capacitance multiplier is 20 pF.

18. The dissipation factor dial reading, adjusted for the range switch position, is the dissipation factor of the specimen.

3.3 GENERAL OPERATING INSTRUCTIONS (continued)

19. Examples:

D.F. Range	Dial	Dissipation Factor %
0 - 1	032	0.032
0 - 1	542	0.542
0 - 10	345	3.45
10 - 20	542	15.42

Best accuracy will be obtained on the lowest D.F. Range for which a balance is possible.

20. Turn bridge power switch off before disconnecting specimen.

NOTES:

- (a) When measuring a number of similar specimens it is not necessary to reset the switches to the values in steps 5, 6 & 7.
- (b) If on the basis of previous tests the approximate values of capacitance and dissipation factor are known, these values may be pre-set on the switches and dials.
- (c) With the bridge at sub zero temperatures the operation of the null detector may be sluggish and the sensitivity degraded. Under these circumstances it is recommended that the bridge be kept in a warm vehicle, or building, between tests.
- (d) Periodically check the two 10 turn dials to see that the mechanical stops coincide with "000" and "999" within several digits on the extreme right hand decade. If a significant error is apparent, corrective action should be taken.
- (e) Periodically check continuity of all test leads with an ohmmeter on the low ohms range.
- (f) Periodically check isolation between conductor and sheath of all coaxial cables using an ohmmeter on the high ohms range.

3.4 MEASUREMENT OF TWO WINDING TRANSFORMERS

A. Preparation for Test

1. Clear transformer in the normal manner.
2. Remove risers and/or bus-bars and cables from all bushings.
3. Leave working grounds attached to the risers and/or bus-bars and cables.
4. The porcelain surface of bushings should be clean and dry. Remove any dirt and oil with clean, dry rags.
5. Tests should not be carried out when rain is falling or when there is condensation on the porcelain.
6. Short the high voltage bushings with a bare braided jumper. The jumper should not be allowed to sag (Figure 5).

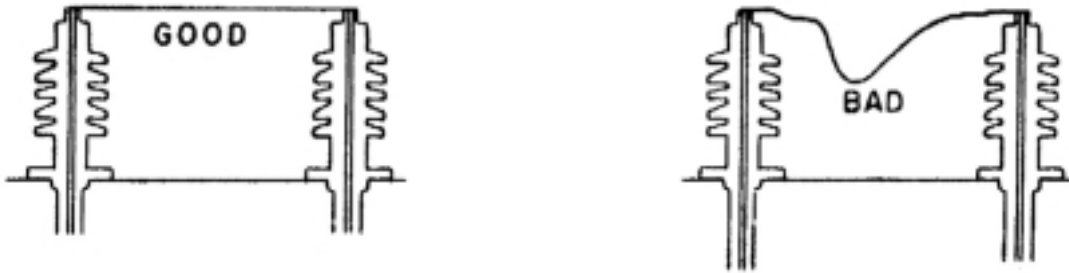


FIGURE 5

7. Short the low voltage bushings as in (Figure 5).

NOTE: The neutral, or starpoint bushing of a three phase transformer winding should be connected to the other bushings of that winding by means of the shorting jumper (Figure 6).

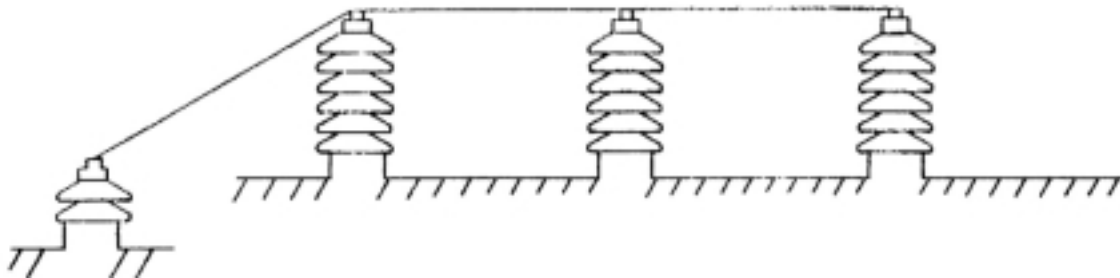
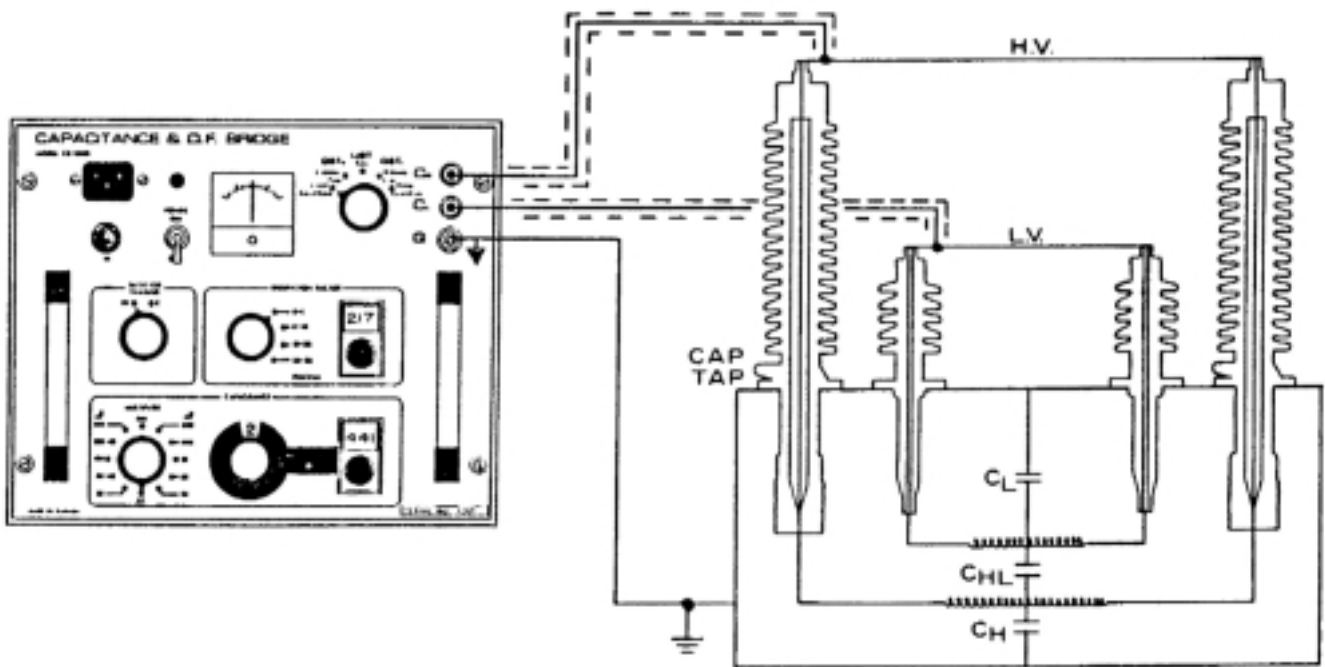


FIGURE 6

3.4 MEASUREMENT OF TWO WINDING TRANSFORMERS (continued)

8. Measure and record, on the field sheet, the ambient temperature and relative humidity.
9. Record readings of transformer temperature gauge(s) - liquid and winding if present (use standard test report sheet).
10. It is preferable that the transformer be tested after it has been allowed to cool to ambient temperature and that ambient be in the range of 10 to 30°C.
11. If the transformer has an ON LOAD tap changer it should be OFF neutral, otherwise Thyrites in the tap changer may effect results.

B. Measurement of Insulation Power Factor



TRANSFORMER UNDER TEST

FIGURE 7

3.4 MEASUREMENT OF TWO WINDING TRANSFORMERS (continued)

B.1 Measurement of H-L (U.S.T.)

1. Place UST-GST switch at "UST" (CH-L in red).
2. Connect the "CH" coax lead (red) to one of the high voltage bushings, keeping the rest of the lead clear of the porcelain.
3. Connect the "CL" coax lead (black) to one of the low voltage bushings. The path of this lead is not important so long as it does not come close to the high voltage bushing.
4. Personnel should keep several feet away from the high voltage bushings to avoid any influence on the readings.
5. Balance the CB100 as described in the "General Instructions" (section 3.3).

B.2 Measurement of H-GND (G.S.T.)

1. Place UST-GST switch at "L-GUARD" (CH-G in red).
2. Connect the "CH" coax lead (red) and "CL" coax lead (black) as specified in section B.1 parts 2 to 5 (above).

B.3 Measurement of L-GND (G.S.T.)

1. Place UST-GST switch at "H-GUARD" (CL-G in red).
2. Connect the "CH" coax lead (red) and "CL" coax lead (black) as specified in section B.1 parts 2 to 5 (above).

B.4 Measurement of H-GND & H-L (G.S.T.)

1. Place UST-GST switch at "L-GND" (CH-L & CH-G in red). This grounds the low side and parallels CH-G with CH-L.
2. Connect the "CH" coax lead (red) and "CL" coax lead (black) as specified in section B.1 parts 2 to 5 (above).

3.4 MEASUREMENT OF TWO WINDING TRANSFORMERS (continued)

B.5 Measurement of L-GND & L-H (G.S.T.)

1. Place UST-GST switch at "H-GND" (CH-L & CL-G in red). This grounds the high side and parallels CL-G with CL-H.
2. Connection the "CH" coax lead (red) and "CL" coax lead (black) as specified in section B.1 parts 2 to 5 (page 19).

NOTE: For all of section B, all connections are made once and UST-GST switch on CB100 is used to do interconnecting, thus avoiding the trouble of sending someone up to the transformer to do interchanging of leads.

C. Recording of Identification and Test Data Using Test Sheet 01-100 and 02-100

Before any testing is started it is very important that identification data of transformer and environmental data be recorded. Without this information, accurate translation of results cannot be made, and filing of results not possible. A sample test sheet type 01-100 is shown on page 22.

For the "Two Winding Transformer Test", it may be required to test "Bushings" located on the transformer. For this requirement, test sheet type 02-100 is required and a sample sheet is shown on page 22. (For specific instructions on filling out this sheet (02-100) see section 3.8).

C.1 Identification & Supporting Data for Type 01-100 Data Sheet

Record the following:

- Date of test.
- Equipment designation and location.
- Transformer name plate data.
- Environmental condition at test time including transformer temperature gauge readings.
- Reason for test and work order number (if any).
- Refer to previous test (if any).
- CB100 serial number.
- Name of individual(s) performing test.
- Date of previous test (if any).
- Sheet number of last test (if any).
- Sheet number of bushing test 02-100 (if any).

3.4 MEASUREMENT OF TWO WINDING TRANSFORMERS (continued)

C.2 Recording Test Data

Record the following:

- Position of capacitance and dissipation factor switches and dials for each bridge balance.
- Calculated value of capacitance in picofarads.
- Total dissipation factor value as shown in section 3.3 part 19.
- A total of up to 6 sets of readings may be required (including the oil sample).

D. Temperature Corrections

Dissipation factor values are corrected to 20°C to facilitate comparison between tests at different times and on different transformers.

A temperature correction factor chart for transformers is on page 24. Two temperature correction curves are to be found on page 25.

Curve 1

This correction curve applies to:

- all oil filled power transformers manufactured prior to 1939.
- all oil filled power transformers manufactured subsequent to 1945 having varnished coils. This may be assumed to include:
 - Pioneer Electric transformers 66 kV and below, manufactured prior to 1955.
 - Pioneer Electric transformers 33 kV and below, manufactured prior to 1965.

Curve 2

This correction curve applies to:

- power transformers insulated with oil/paper materials (no varnish impregnation of coils), manufactured subsequent to 1945.

Application to Corrections

1. Using the appropriate curve from Figure 8 and the transformer top oil (gauge) temperature, determine the temperature correction factor.
2. Multiply all measured values of dissipation factor by the temperature correction factor and enter these corrected values on the field test sheet.

CB100 POWER FACTOR TEST REPORT
" TWO WINDING TRANSFORMERS "

APPARATUS INFORMATION					MULTI-AMP CANADA LIMITED			
DATE: ___/___/___					TYPE: 01-100 TWO WINDING TRANSFORMERS			
TRANSFORMER LOCATION: _____					ENVIRONMENT			
TRANSFORMER DESIGNATION: _____					WEATHER: _____			
TRANSFORMER NAME PLATE READINGS					AIR TEMP.: _____ °C			
MFGRER: _____ S/N: _____ YEAR: _____					OIL TEMP.: _____ °C			
TYPE: _____ KVA: _____ FORM: _____					WINDING TEMP.: _____ °C			
HIGH SIDE KV: _____ Y _____ LOW SIDE KV: _____ Y _____					REL. HUMIDITY: _____ %			
TEST CONNECTIONS		CAPACITANCE READING			DISSIPATION (POWER) FACTOR			
TEST NO.	MEASUREMENT UST-GST SW.POS.	MULT. SWITCH	CAP. SW.+DIAL	TOTAL (PF)	RANGE (%)	READING (DIAL)	TOTAL (%)	CORR. TO 20°C (%)
1	CAP. H-L	X	=					
2	CAP. H-G	X	=					
3	CAP. L-G	X	=					
4	CAP. H-L + H-G	X	=					
5	CAP. L-H + L-G	X	=					
6	(OIL) CAP. H-L	X	=					
REASON FOR TESTING: _____								
WORK ORDER NO.: _____ CB100 SERIAL NO.: _____								
REMARKS: _____								
SHEET NO. OF BUSHING TEST, TYPE 02-100 (if any): _____								
TESTED BY: _____					DATE CHECKED: ___/___/___			
CHECKED BY: _____					LAST DATE TESTED: ___/___/___			
COMPANY: _____					SHEET NO. OF LAST TEST: _____			
DEPARTMENT: _____					SHEET NO.: _____			

01-100 TWO WINDING TRANSFORMERS

CB100 POWER FACTOR TEST REPORT										
" BUSHING TEST "										
APPARATUS INFORMATION DATE: ___/___/___ OCB: ___ or XFMR: ___ TEST SHEET NO. (if any): _____ TRANSFORMER LOCATION: _____ TRANSFORMER DESIGNATION: _____							MULTI-AMP CANADA LIMITED TYPE: 02-100 BUSHING TEST			
BUSHING INFORMATION H.V. SIDE: RATED KV: _____ MFGRER: _____ TYPE: _____ FORM: _____ DRAWING NO.: _____ L.V. SIDE: RATED KV: _____ MFGRER: _____ TYPE: _____ FORM: _____ DRAWING NO.: _____ NEUTRAL SIDE: RATED KV: _____ MFGRER: _____ TYPE: _____ FORM: _____ DRAWING NO.: _____							ENVIRONMENT WEATHER: _____ AIR TEMP.: _____ °C OIL TEMP.: _____ °C WINDING TEMP.: _____ °C REL. HUMIDITY: _____ %			
							DIAGRAM 			
NAME PLATE			CAPACITANCE READING				DISSIPATION (POWER) FACTOR			
POSN.	SERIAL NO.	P.F. (%)	CAP. (PF)	MULT. SWITCH	CAP. SW. +DIAL	TOTAL (PF)	RANGE (%)	READING (DIAL)	TOTAL (%)	CORR. TO 20°C (%)
H1				X	=					
H2				X	=					
H3				X	=					
H0				X	=					
X1				X	=					
X2				X	=					
X3				X	=					
X4				X	=					
REASON FOR TESTING: _____										
WORK ORDER NO.: _____ CB100 SERIAL NO.: _____										
REMARKS: _____										
TESTED BY: _____ DATE CHECKED: ___/___/___										
CHECKED BY: _____ LAST DATE TESTED: ___/___/___										
COMPANY: _____ SHEET NO. OF LAST TEST: _____										
DEPARTMENT: _____ SHEET NO.: _____										

02-100 BUSHING TEST

TABLE II - TEMPERATURE CORRECTION FACTOR FOR LIQUIDS,
TRANSFORMERS, AND REGULATORS

TEST TEMPERATURE		OIL-FILLED POWER TRANSFORMERS			
°C	°F	ASKAREL FILLED XFMRs	FREE - BREATHING & CONSERVATOR TYPE	SEALED & GASKET BLANKETED TYPE	OIL-FILLED INSTRUMENT XFMRs
0	32.0		1.56	1.57	1.67
1	33.8		1.54	1.54	1.64
2	35.6		1.52	1.50	1.61
3	37.4		1.50	1.47	1.58
4	39.2		1.48	1.44	1.55
5	41.0		1.46	1.41	1.52
6	42.8		1.45	1.37	1.49
7	44.6		1.44	1.34	1.46
8	46.4		1.43	1.31	1.43
9	48.2		1.41	1.28	1.40
10	50.0		1.38	1.25	1.36
11	51.8		1.35	1.22	1.33
12	53.6		1.31	1.19	1.30
13	55.4		1.27	1.16	1.27
14	57.2		1.24	1.14	1.23
15	59.0		1.20	1.11	1.19
16	60.8		1.16	1.09	1.16
17	62.6		1.12	1.07	1.12
18	64.4		1.08	1.05	1.08
19	66.2		1.04	1.02	1.04
20	68.0	1.00	1.00	1.00	1.00
21	69.8	0.95	0.96	0.98	0.97
22	71.6	0.90	0.91	0.96	0.93
23	73.4	0.85	0.87	0.94	0.90
24	75.2	0.81	0.83	0.92	0.86
25	77.0	0.76	0.79	0.90	0.83
26	78.8	0.72	0.76	0.88	0.80
27	80.6	0.68	0.73	0.86	0.77
28	82.4	0.64	0.70	0.84	0.74
29	84.2	0.60	0.67	0.82	0.71
30	86.0	0.56	0.63	0.80	0.69
31	87.8	0.53	0.60	0.78	0.67
32	89.6	0.51	0.58	0.76	0.65
33	91.4	0.48	0.56	0.75	0.62
34	93.2	0.46	0.53	0.73	0.60
35	95.0	0.44	0.51	0.71	0.58
36	96.8	0.42	0.49	0.70	0.56
37	98.6	0.40	0.47	0.69	0.54
38	100.4	0.39	0.45	0.67	0.52
39	102.2	0.37	0.44	0.66	0.50
40	104.0	0.35	0.42	0.65	0.48
42	107.6	0.33	0.38	0.62	0.45
44	111.2	0.30	0.36	0.59	0.42
46	114.8	0.28	0.33	0.56	
48	118.4	0.26	0.30	0.54	
50	122.0	0.24	0.28	0.51	
52	125.6	0.22	0.26	0.49	
54	129.2	0.21	0.23	0.47	
56	132.8	0.19	0.21	0.45	
58	136.4	0.18	0.19	0.43	
60	140.0	0.16	0.17	0.41	
62	143.6	0.15	0.16	0.40	
66	150.8	0.14	0.14	0.36	
70	158.0	0.12	0.12	0.33	

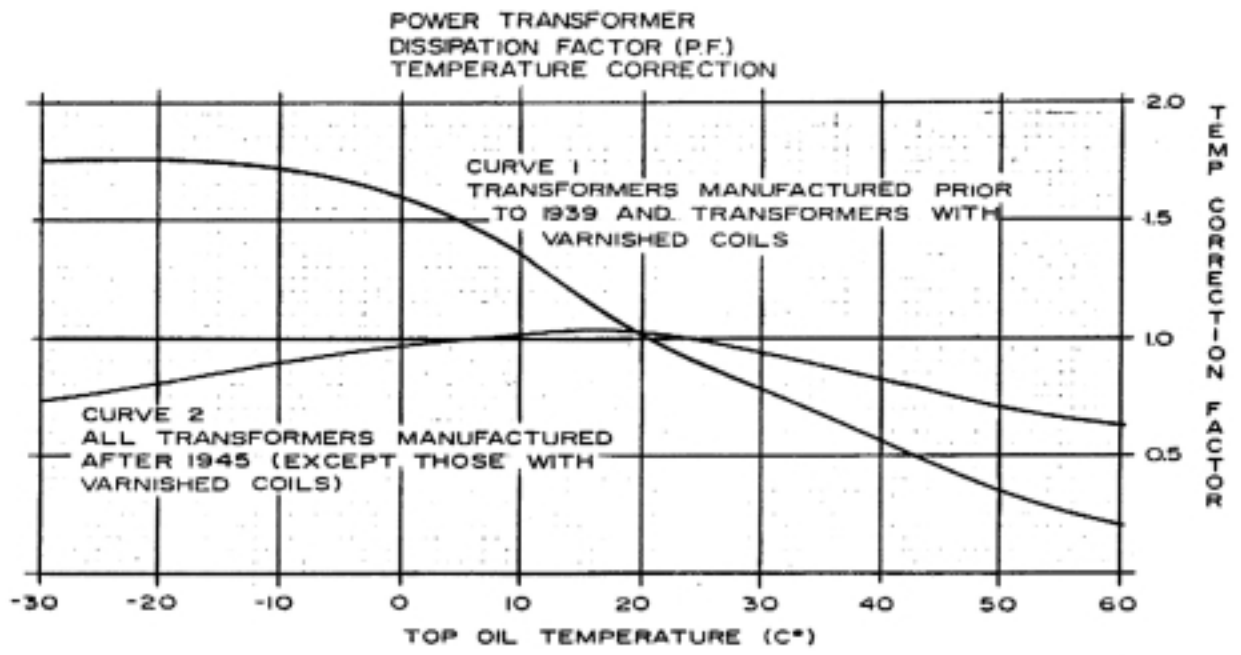


FIGURE 8

3.5 MEASUREMENT OF BULK OIL CIRCUIT BREAKER (O.C.B.)

A. Preparation for Test

1. Clear the circuit breaker in the normal manner.
2. Remove risers from all bushings.
3. Leave working grounds attached to the risers.
4. The porcelain surface of bushings should be clean and dry. Remove any dirt or oil with clean, dry rags.
5. Tests should not be carried out when rain is falling, or when there is condensation on the porcelain.
6. Measure and record on the field test sheet the environmental conditions on test sheet 03-100 (Bulk Oil Circuit Breaker).
7. Record the reading of the oil temperature gauge of the breaker.

B. Measurement of Individual Bushings & De-Ion Grids (O.C.B. Open)

1. The breaker should be OPEN.
2. Place UST-GST switch in "CH-GND" position (in red).
3. The "CL" coax lead is not required for this test.
4. Connect "CH" coax lead (red) to the high voltage bushing in position 1 (see Figure 9-next page). Keep the rest of the lead clear of the porcelain.
5. Make sure CB100 ground is connected to system ground.
6. Personnel should keep several feet away from the high voltage bushing. This will minimize influence of the test readings.
7. Balance the CB100 as described in the general operating instructions, section 3.3 and record the measured values on the O.C.B. test sheet; 03-100, see page 29. This measurement is for one bushing and its associated De-Ion grid.

3.6 MEASUREMENT OF BULK OIL CIRCUIT BREAKER (continued)

- Repeat steps 3-6 on each bushing in turn (Positions 2-6, Figure 9).



FIGURE 9

C. Measurement of Bushings and Lift Rods (O.C.B. Closed)

- The breaker should be in the CLOSED position.
- Place the UST-GST switch in the CH-GND position (in red).
- The CL coax lead (black) is not required for this test.
- Connect the "CH" coax lead (red) to the high voltage bushing in position 1 or 2 (see Figure 9; both are shorted together). Keep the rest of the lead clear of the porcelain.
- Make sure CB100 ground is connected to system ground.
- Personnel should keep several feet away from the high voltage bushing. This will minimize influence of the test readings.
- Balance the CB100 as described in the general operating instructions, section 3.3 and record the measured values on the O.C.B. test sheet; 03-100, see page 29. This measurement is for two bushings and their associated lift rods.
- Repeat steps 3-6 on each set of bushings and lift rods (3 sets total).

D. Recording of Identification & Test Data using Test Sheet 03-100 (O.C.B.)

3.5 MEASUREMENT OF BULK OIL CIRCUIT BREAKER (continued)

Before any testing is started it is very important that identification data of oil circuit breaker and environmental data be recorded. Without this information, accurate translation of results cannot be made, and filing of results not possible. A sample test sheet type 03-100 is shown on page 29.

D.1 Identification & Supporting Data for Type 03-100 Test Sheet

Record the following:

- Date of test.
- Equipment designation & location.
- O.C.B. nameplate data.
- Environmental conditions at test time including oil circuit breaker (O.C.B.) temperature gauge readings.
- Diagram of bushing position designations.
- Bushing nameplate data.
- Reason for test and work order number (if any).
- Refer to previous test (sheet number of last test).
- Date of previous test (last test date).
- CB100 serial number.
- Name of individual(s) performing test.
- Company name and department.

D.2 Recording Test Data

Record the following:

- Position of bushing.
- Serial number of bushing.
- Nameplate power factor.
- Nameplate capacitance.
- Position of capacitance and dissipation factor switches and dials for each bridge balance.
- Calculated value of capacitance in picofarads.
- Total dissipation factor value as shown in section 3.3, part 19.
- A total of 6 sets of readings for the bushings and 3 sets of readings for closed breaker test (2 bushings and lift rod).

E. Temperature Corrections

Dissipation factor values are corrected to 20°C to facilitate comparison between tests at different times and on different bushing and oil circuit breakers.

Temperature correction factor should be followed according to the particular bushings on the O.C.B.

This is found in section 3.8, page 44.

CB100 POWER FACTOR TEST REPORT										
" BULK OIL CIRCUIT BREAKER (O. C. B.) TEST "										
APPARATUS INFORMATION						MULTI-AMP CANADA LIMITED				
DATE: ____/____/____						TYPE: 03-100 OIL CIRCUIT BREAKER TEST				
O.C.B. LOCATIONS: _____						ENVIRONMENT				
O.C.B. DESIGNATION: _____						WEATHER: _____				
O.C.B. NAMEPLATE DATA						AIR TEMP.: _____ °C				
MFGRER: _____ S/N: _____ YEAR: _____						OIL TEMP.: _____ °C				
TYPE: _____ RATED VOLTAGE: _____ & CURRENT: _____						REL. HUMIDITY: _____ %				
BUSHING NAMEPLATE DATA						DIAGRAM				
MFGRER: _____										
TYPE: _____ RATED VOLTAGE: _____ & CURRENT: _____										
FORM: _____ DRAWING NO.: _____										
OPEN BREAKER TEST (BUSHING AND ION GRID)										
NAME PLATE				CAPACITANCE READING			DISSIPATION (POWER) FACTOR			
POSN.	SERIAL NO.	P.F. (%)	CAP. (PF)	MULT. SWITCH	CAP. SW. +DIAL	TOTAL (PF)	RANGE (%)	READING (DIAL)	TOTAL (%)	CORR. TO 20°C (%)
1				X	=					
2				X	=					
3				X	=					
4				X	=					
5				X	=					
6				X	=					
CLOSED BREAKER TEST										
PHASE 1				X	=					
PHASE 2				X	=					
PHASE 3				X	=					
REASON FOR TESTING: _____										
WORK ORDER NO.: _____ CB100 SERIAL NO.: _____										
REMARKS: _____										
TESTED BY: _____						DATE CHECKED: ____/____/____				
CHECKED BY: _____						LAST DATE TESTED: ____/____/____				
COMPANY: _____						SHEET NO. OF LAST TEST: _____				
DEPARTMENT: _____						SHEET NO.: _____				

03-100 OIL CIRCUIT BREAKER TEST

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS

A. Preparation for Test

1. Clear transformer in the normal manner.
2. Remove risers and/or bus-bars and cables from all bushings.
3. Leave working grounds attached to the risers and/or bus-bars and cables.
4. The porcelain surface of bushings should be clean and dry. Remove any dirt and oil with clean, dry rags.
5. Tests should not be carried out when rain is falling, or when there is condensation on the porcelain.
6. Short the high voltage bushings with a bare braided jumper. The jumper should not be allowed to sag (Figure 10).



FIGURE 10

7. Short the low voltage bushings as in (6).
8. Short the tertiary bushings as in (6).

NOTE: The neutral, or starpoint bushing of a three phase transformer winding should be connected to the other bushings of that winding by means of the shorting jumper (Figure 11, below).

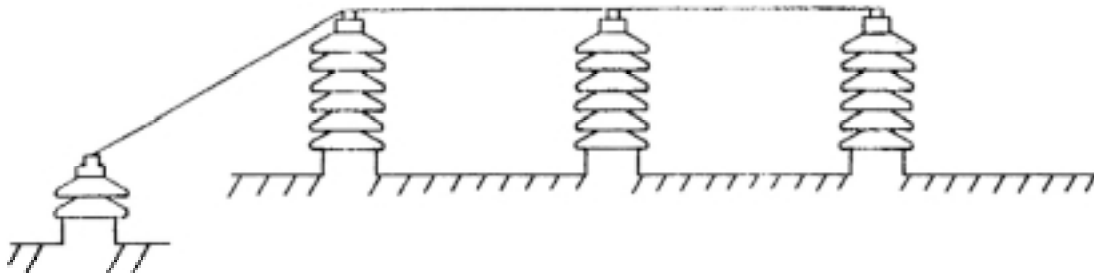


FIGURE 11

9. Measure and record on the field sheet the ambient temperature and relative humidity.

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS (continued)

B. Measurement of Insulation Power Factor

B.1 Measurement of H-L (U.S.T.)(C1)

1. Place UST-GST switch at "UST" (CH-L in red).
2. Connect the "CH" coax lead (red) to one of the high voltage bushings, keeping the rest of the lead clear of the porcelain.
3. Connect the "CL" coax lead (black) to one of the low voltage bushings. The path of this lead is not important so long as it does not come close to the high voltage bushing.
4. Ground the tertiary winding, keeping lead clear of high side.
5. Personnel should keep several feet away from the high voltage bushings to avoid any influence on the readings.
6. Balance the CB100 as described in the "General Instructions" (section 3.3).

See Figure 12.

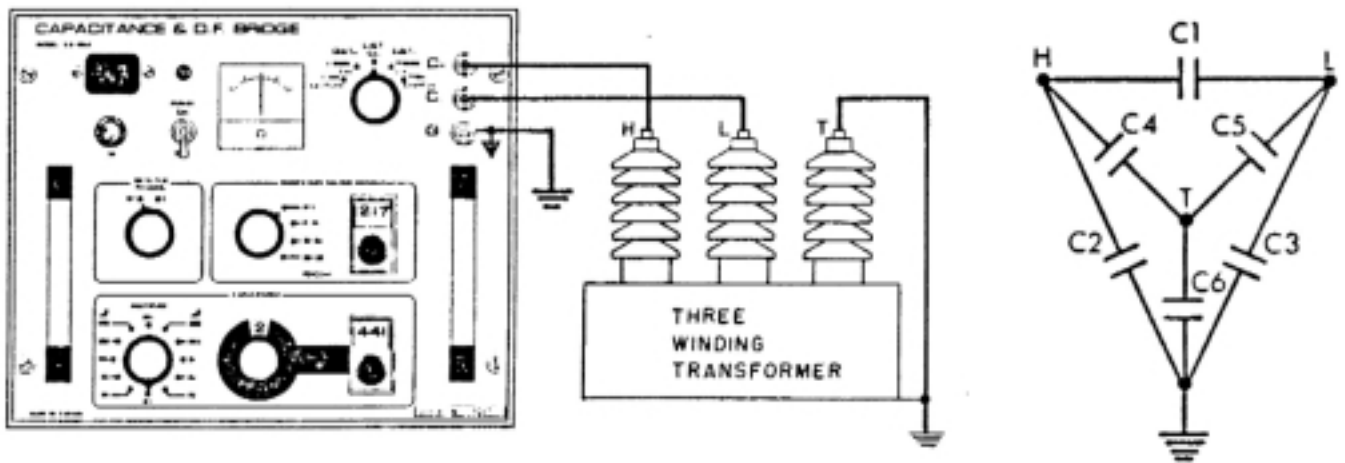


FIGURE 12

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS (continued)

B.2 Measurement of H-GND (G.S.T.)(C2)

1. Place UST-GST switch at "L-GUARD" (CH-G in red).
2. Connect the "CH" coax lead (red) to one of the high voltage bushings, keeping the rest of the lead clear of the porcelain.
3. Connect the "CL" coax lead (black) to one of the low voltage bushings and short the tertiary bushing to the low voltage bushings.
4. Balance the CB100 as described in "General instructions" (section 3.3).

See Figure 13.

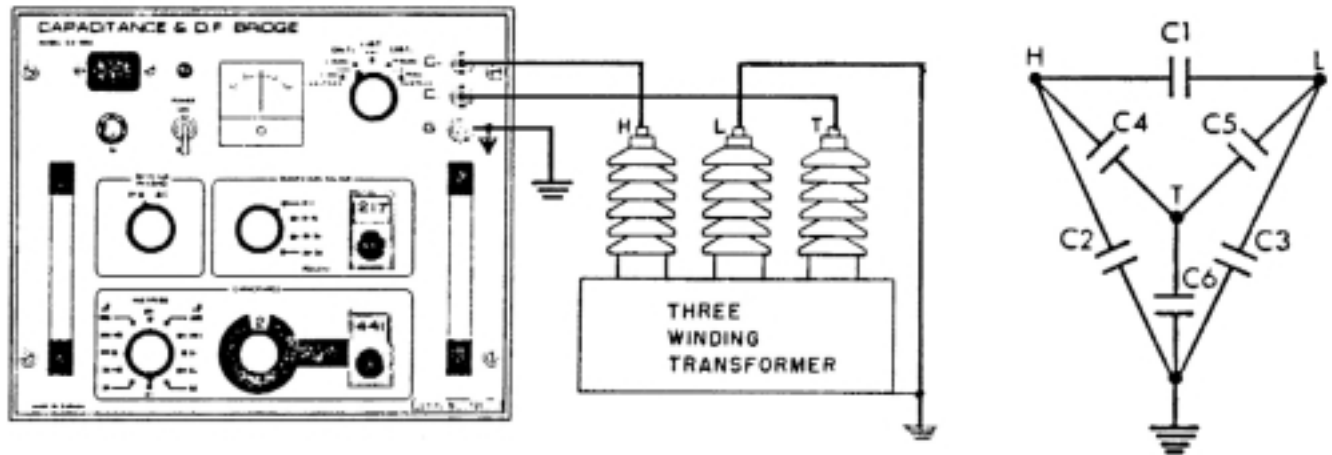


FIGURE 13

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS (continued)

B.3 Measurement of L-GND (G.S.T.)(C3)

1. Place UST-GST switch at H-GUARD (CL-G in red).
2. Connect the bushings keeping the rest of the lead clear of the porcelain.
3. Short the high voltage bushing to the tertiary bushings and connect "CH" coax (red) to the high voltage bushings.
4. Connect the "CL" coax lead (black) to the low winding.
5. Balance the CB100 as described in the "General Instructions" (section 3.3).

See Figure 14.

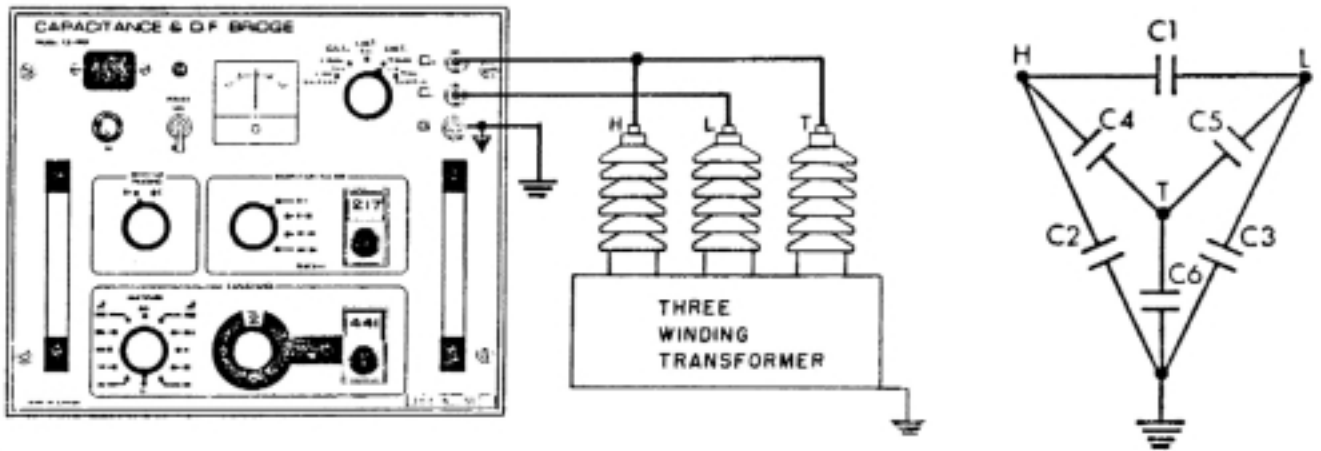


FIGURE 14

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS (continued)

B.4 Measurement of Tertiary-H (U.S.T.)(C4)

1. Place UST-GST switch on UST (CH-L in red).
2. Connect the "CH" coax lead (red) to the high voltage bushing keeping the rest of the lead clear of the porcelain.
3. Connect the "CL" coax lead (black) to the tertiary winding.
4. Short the low voltage bushing to ground, keeping leads clear of other bushings.
5. Balance the CB100 as described in "General Instructions" (section 3.3).

See Figure 15.

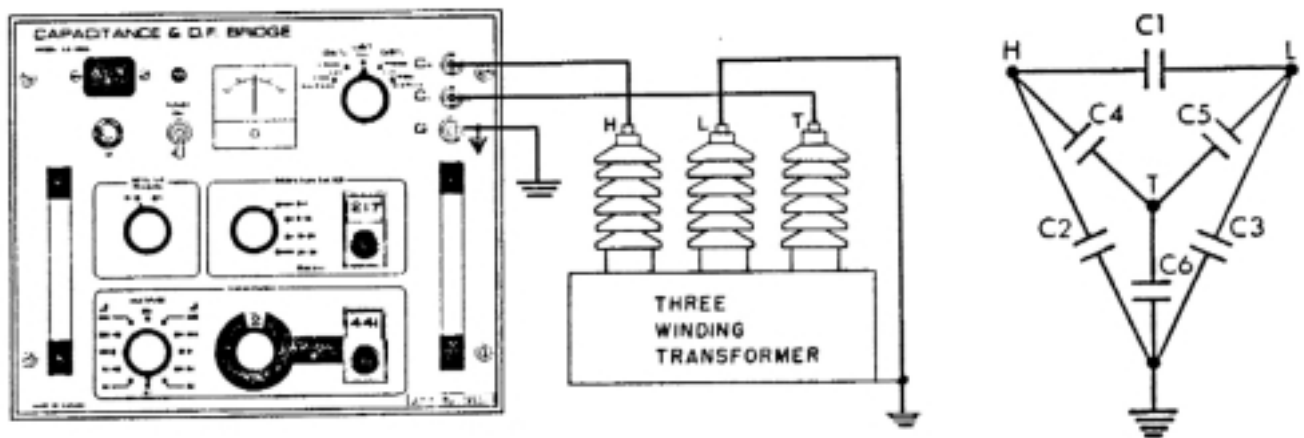


FIGURE 15

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS (continued)

B.5 Measurement of Tertiary-L (U.S.T.)(C5)

1. Place UST-GST switch on UST (CH-L in red).
2. Connect the "CH" coax lead (red) to the low voltage bushing keeping the rest of the lead clear of the porcelain.
3. Connect the "CL" coax lead (black) to the tertiary winding.
4. Short the high voltage bushing to ground, keeping leads clear of other bushings.
5. Balance the CB100 as described in "General Instructions" (section 3.3).

See Figure 16.

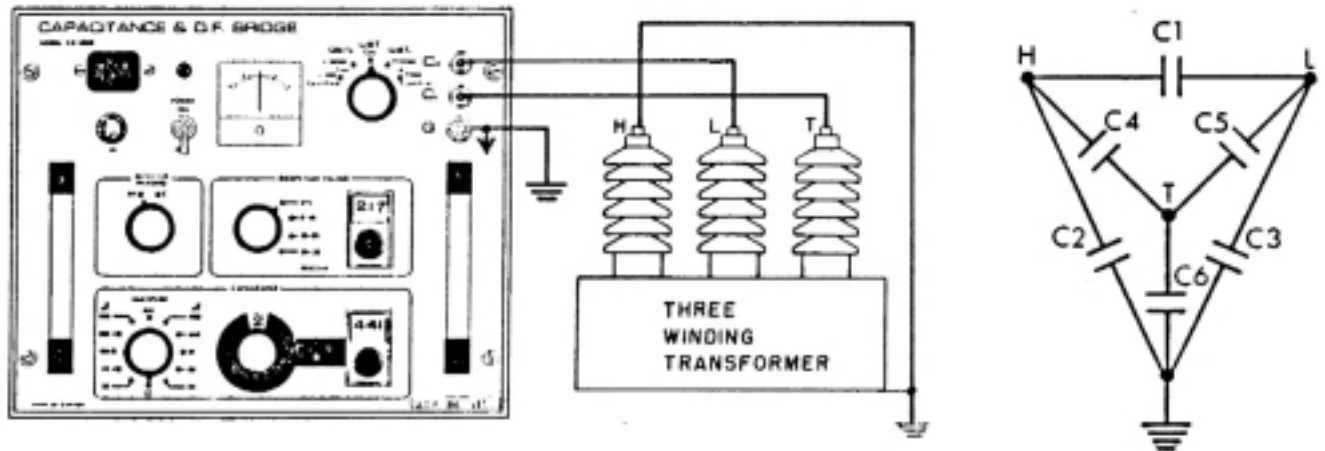


FIGURE 16

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS (continued)

B.6 Measurement of Tertiary-GND (G.S.T.)(C6)

1. Place UST-GST switch on L-GUARD (CH-G in red).
2. Connect the "CH" coax (red) to the tertiary bushing keeping the rest of the lead clear of the porcelain.
3. Short the high voltage bushing to the low voltage bushing. Connect the "CL" coax lead (black) to the low voltage bushing.
4. Balance the CB100 as described in "General Instructions" (section 3.3).

See Figure 17.

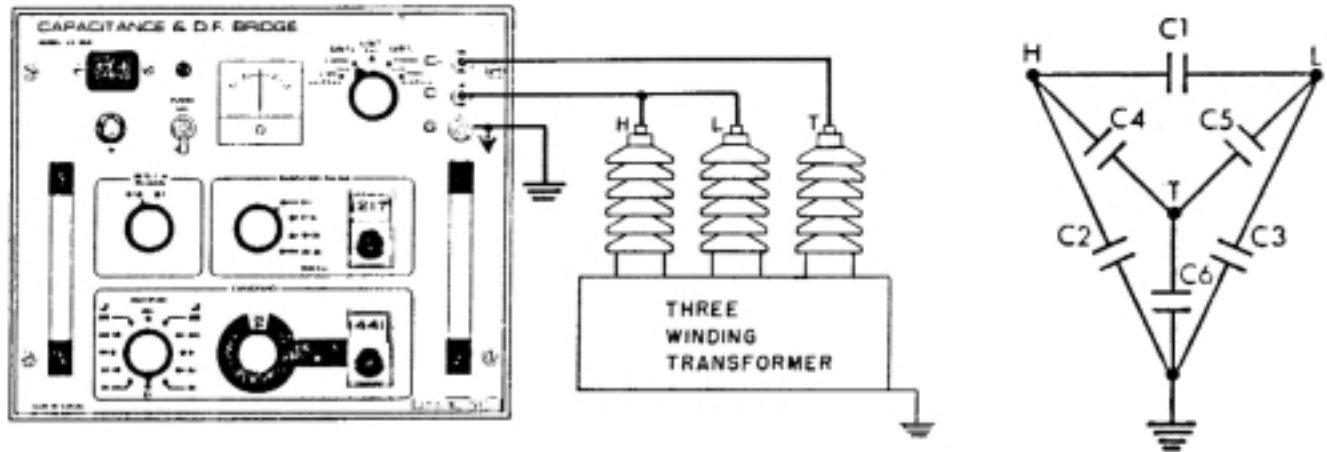


FIGURE 17

3.6 MEASUREMENT OF THREE WINDING TRANSFORMERS (continued)

C. Recording of Identification & Test Data using Test 04-100

Before any testing is started it is very important that identification data of the three-winding transformer and environmental data be recorded.

Without this information, accurate translation of results cannot be made, and filing of results not possible.

A sample test sheet type 04-100 is shown on page 38.

C.1 Identification & Supporting Data for Type 04-100 Data Sheet

Record the following:

- Date of test.
- Equipment designation and location.
- Transformer nameplate data.
- Environmental condition at test time including transformer temperature gauge readings.
- Reason for test and work order number (if any).
- Refer to previous test number (if any).
- CB100 serial number.
- Name of individual(s) performing test.
- Date of previous test.
- Sheet number of bushing test (02-100).

C.2 Test Data

Record the following:

- Position of capacitance and dissipation factor switches and dials for each bridge balance.
- Calculated value of capacitance in picofarads.
- Total dissipation factor value as shown in section 3.3, part 19.
- A total of 7 sets of readings may be required (including the oil sample).

D. Temperature Corrections

Refer to "Measurement of Two Winding Transformers", section 3.4, part D. This is identical for three winding transformers (page 21).

CB100 POWER FACTOR TEST REPORT								
" THREE WINDING TRANSFORMERS "								
APPARATUS INFORMATION DATE: ____/____/____ TRANSFORMER LOCATION: _____ TRANSFORMER DESIGNATION: _____					MULTI-AMP CANADA LIMITED TYPE: 04-100 THREE WINDING XFMRs			
TRANSFORMER NAME PLATE READINGS MFGGR: _____ S/N: _____ YEAR: _____ TYPE: _____ KVA: _____ FORM: _____ HIGH SIDE KV: _____ Y _____ LOW SIDE KV: _____ Y _____ TERTIARY SIDE KV: _____ Y _____					ENVIRONMENT WEATHER: _____ AIR TEMP.: _____ °C OIL TEMP.: _____ °C WINDING TEMP.: _____ °C REL. HUMIDITY: _____ %			
TEST CONNECTIONS		CAPACITANCE READING			DISSIPATION (POWER) FACTOR			
TEST NO.	MEASUREMENT UST-GST SW.POS.	MULT. SWITCH	CAP. SW.+DIAL	TOTAL (PF)	RANGE (%)	READING (DIAL)	TOTAL (%)	CORR. TO 20°C (%)
1	CAP. H-L	X	=					
2	CAP. H-G	X	=					
3	CAP. L-G	X	=					
4	CAP.T-H(Sw on H-L)	X	=					
5	CAP.T-L(Sw on H-L)	X	=					
6	CAP.T-G(Sw on H-G)	X	=					
7	(OIL) CAP. H-L	X	=					
REASON FOR TESTING: _____ WORK ORDER NO.: _____ CB100 SERIAL NO.: _____ REMARKS: _____ _____								
SHEET NO. OF BUSHING TEST, TYPE 02-100 (if any): _____ TESTED BY: _____ DATE CHECKED: ____/____/____ CHECKED BY: _____ LAST DATE TESTED: ____/____/____ COMPANY: _____ SHEET NO. OF LAST TEST: _____ DEPARTMENT: _____ SHEET NO.: _____								

04-100 THREE WINDING XFMRs

3.7 MEASUREMENT OF BUSHINGS

A. Preparation for Test

1. Clear the apparatus in the normal manner.
2. Remove risers and/or busbars and cables from all bushings.
3. Leave working ground attached to the risers and/or bus bars and cables.
4. The porcelain surface of the bushings should be clean and dry. Remove any dirt or oil with clean, dry rags.
5. Tests should not be carried out when rain is falling, or when there is condensation on the porcelain.
6. Remove the covers from the tap compartments except if the bushings are Westinghouse Type 0 115 kV or higher voltage. For these latter bushings remove only the 1/2" pipe plug from the tap compartment.
7. If the bushings to be tested are located on a transformer the terminals of the bushings of each winding should be shorted using bare braided jumpers. These jumpers should not be allowed to sag. Transformer windings whose bushings are not being tested should be grounded.
8. Measure and record on the field test sheet the ambient temperature and relative humidity.
9. Record readings of liquid (oil) temperature gauge of the associated transformer or circuit breaker.
10. Record the nameplate data of the bushings on the field test sheet, including the factory capacitance and power factor test data (if any). Where only one power factor value is given, assume this to be for the C1 portion of the bushing.

3.7 MEASUREMENT OF BUSHINGS (continued)

B. Measurement of Bushing Power Factor

B.1 Bushings other than Westinghouse

1. Place UST-GST switch in U.S.T. (CH-L in red)(C1).
2. Connect the "CL" coax lead (black) to the tap of the bushing. In the case of Westinghouse bushings follow the procedure outlined in section B.2 immediately following this procedure for bushings with capacitance taps rated at 115 kV and up.
3. Connect the "CH" coax lead (red) to the high voltage terminal of the bushing keeping the lead clear of the porcelain.
4. Personnel should keep several feet away from the bushing under test to minimize influence on the readings.
5. Balance the CB100 as described in the "General Instructions" (section 3.3).

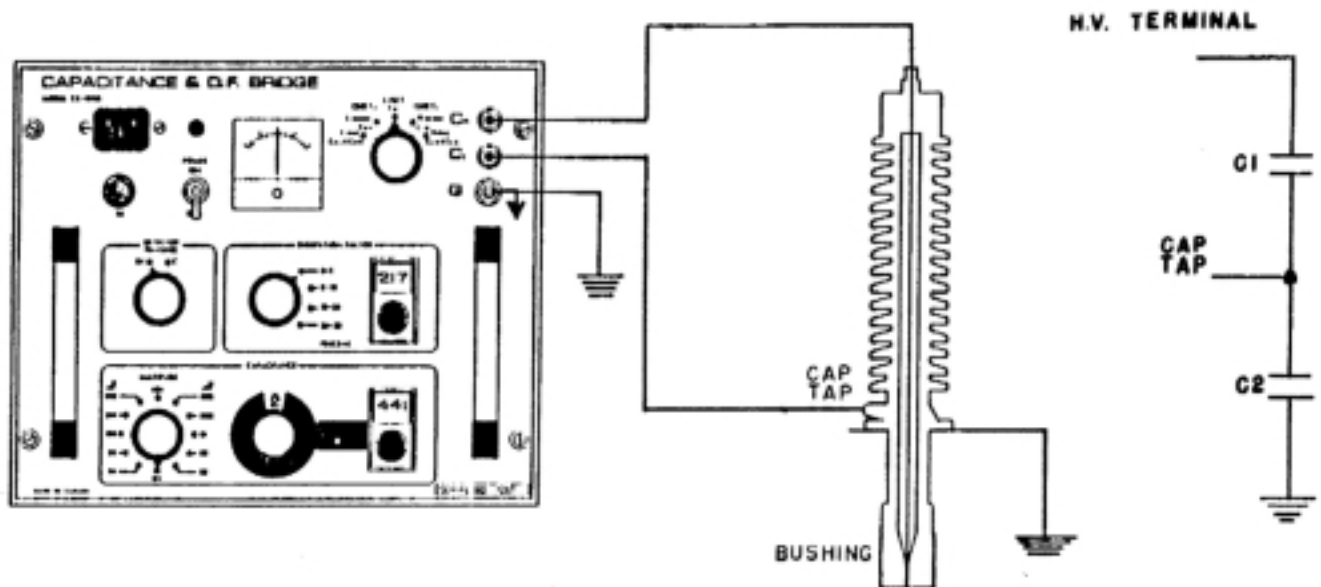


FIGURE 18 - MEASUREMENT OF C1

3.7 MEASUREMENT OF BUSHINGS (continued)

B.2 Westinghouse Bushings of 115 kV and Up. (Test prong for making power tests through voltage tap).

1. Remove the pipe plug in the voltage tap cover.
2. Connect the terminal end of the test prong to ground with a flexible connector, so an electrostatic charge left on the bushing after it has been removed from service will be discharged to ground when the test prong is inserted in the voltage tap.
3. Insert the prong through the hole in the cover to make contact with the female contact in the rear of the voltage tap assembly.
4. Disconnect the test prong from ground and connect it to the proper power factor test lead.
5. Proceed to make a power factor test in the conventional manner used for testing ungrounded specimens.
6. After completing, the power factor tests, remove the test prong.
7. If necessary add new oil to have level even with bottom of hole in cover if necessary.
8. Replace the pipe plug in a weatherproof manner in the cover.

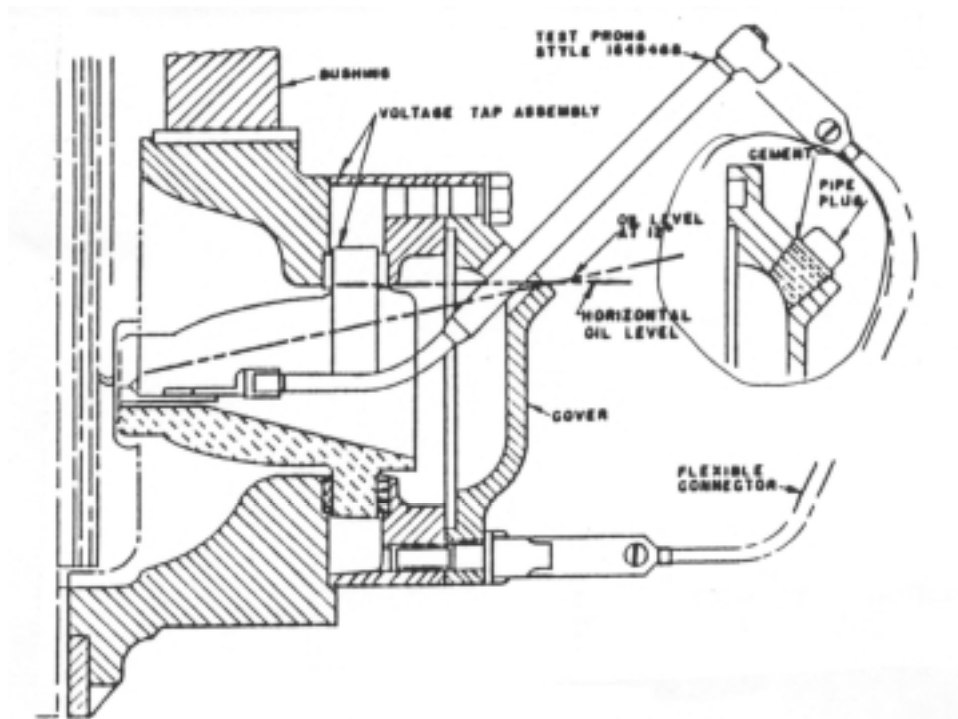


FIGURE 19

3.7 MEASUREMENT OF BUSHINGS (continued)

Measurement of Insulation between the Tap and the Flange of the Bushing

1. Place GST-UST switch on L-GUARD (CH-G in red)(C2).
2. Connect the "CL" coax lead (black) to the bushing tap.
3. Connect the "CH" coax lead (red) to the high voltage terminal of the bushing keeping the lead clear of the porcelain.
4. Personnel should keep several feet away from the bushing to minimize influence on the test results.
5. Balance the CB100 as described in "General Instructions" (section 3.3).

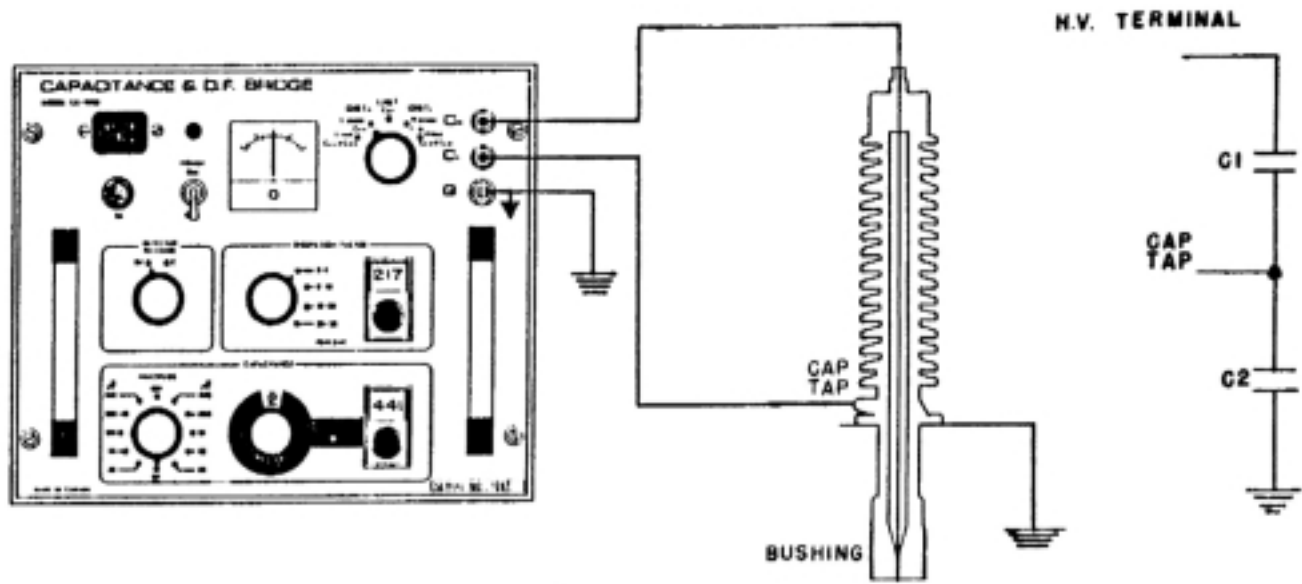


FIGURE 20 - MEASUREMENT OF C2

3.7 MEASUREMENT OF BUSHINGS (continued)

C. Recording of Identification & Test Data using Test Sheet 02-100

C.1 Identification & Supporting Data for Test Sheet 02-100

Record the following:

- Date of test.
- Apparatus information.
- Bushing information.
- Environmental conditions and transformer gauge readings.
- Diagram of apparatus configuration.
- Reason for test and work order number (if any).
- Refer to previous test number (if any).
- CB100 serial number.
- Name of individual(s) performing test.
- Date of previous test (if any).
- Sheet number of apparatus test (type 01-100 or 03-100 or 04-100).

C.2 Test Data

Record the following:

- Position of capacitance and dissipation factor switches and dials for each bridge balance.
- Calculated value of capacitance in picofarads.
- Total dissipation factor value as shown in section 3.3, part 19.
- A total of 7 sets of readings may be required (including the oil sample).

D. Temperature Corrections

Dissipation factor values are corrected to 20°C to facilitate comparison between tests at different times on the same or similar bushings.

1. If the bushing is installed in a bulk oil circuit breaker or power transformer use the average of the ambient air temperature and the liquid (gauge) temperature of the OCB or transformer in order to determine the appropriate correction factor from Tables III, IV, and V, pages 47, 48 and 49.
2. Multiply all measured values of dissipation factor by the temperature correction factor and enter these corrected values on the field test sheet.

A test report (02-100) is found on page 53.

3.8 MEASUREMENT OF TRANSFORMER BUSHINGS WITH DRAW LEADS

Most transformer bushings rated 69kV and above are of the draw lead type. Certain transformer bushings rated 34.5kV and 24kV may also have draw leads but may be rather difficult to test by this method because the draw lead terminal must be removed and at this voltage the terminal may be below the oil level in the conservator. The conservator can, of course, be valve off and some oil drained from the tank to prevent loss of oil via the exposed draw lead. Newer transformer bushings rated at 69kV and above usually have capacitance or power factor test taps and where present, these taps should be used in testing the bushing in preference to the draw lead method.

A. Preparation for Test

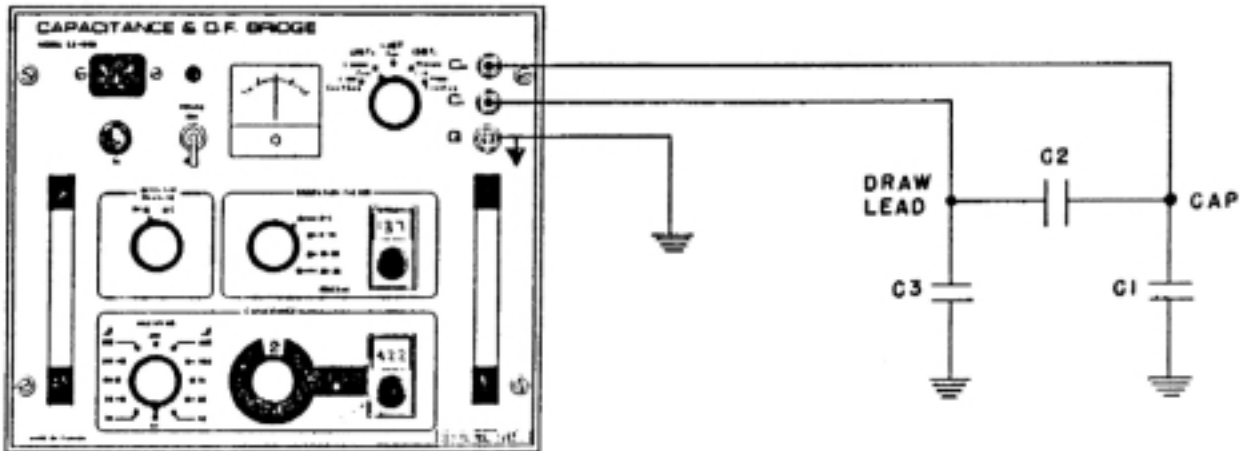
As for power transformers, and then proceed as follows:

1. Remove the threaded draw lead terminal.
2. Secure draw lead to bushing cap by means of a length of Barbour's twine (doubled) with about 6 inches slack.
3. Remove pin from draw lead and put it in a safe place.
4. Insert a piece of light fish paper around the draw lead terminal to insulate it from the bushing conductor for at least 1 megohm as measured on an ohmmeter. To accomplish this, the draw lead terminal may be raised, by hand, to a maximum of 1 inch. Do not use leverage to raise the draw lead and do not extend it, by hand, more than 1 inch as unseen damage may result to internal ties, bracing, connectors, etc.
5. Using the bare braided jumpers, connect the draw lead to the terminals of all the other bushings common to the winding involved.
6. Ground all other windings.

3.8 MEASUREMENT OF TRANSFORMER BUSHINGS WITH DRAW LEADS (continued)

B. Measurement of Bushing Power Factor

1. Place the UST-GST switch at "L-GUARD" (CH-GND in red)
2. Connect the "CH" coax lead to the cap of the bushing. Ensure that good contact is made with the metal of the bushing cap.
3. Connect the "CL" coax lead to the other bushing on the same winding as the bushing being tested.
4. Personnel should keep several feet away from the bushing to minimize the influence on the reading.
5. Balance the CB100, as described in the "General Instructions" (Section 3.3).
6. If there is any difficulty in balancing the bridge, or if the results appear incorrect, check:
 - contact with bushing cap.
 - isolation of draw lead with ohmmeter (CH coax lead (red) disconnected).



C1 MEASURED WHILE C2 AND C3 ARE GUARDED

FIGURE 21

3.8 MEASUREMENT OF TRANSFORMER BUSHINGS WITH DRAW LEADS (continued)

C. Recording of Identification and Test Data using Test Sheet 02-100.

Follow the same format as per "Bushings" (Section 3.7, section C, page 43).

D. Temperature Corrections

Dissipation factor values are corrected to 20°C to facilitate comparison between tests at different times on the same or similar bushings.

1. To determine temperature correction factor. Obtain the average of the transformer top oil (gauge) and ambient air temperature and use tables III, IV and V, pages 47, 48 and 49.
2. Multiply all measured values of dissipation factor by the temperature correction factor and enter these corrected values on the bushing power factor test report, sheet 02-100.

Sample Test Sheet 02-100 is found on page 53.

Due to uncertainty as to the actual bushing temperature, it is best if the difference between top oil and ambient temperature is minimal. This can best be accomplished if the transformer is allowed to cool to ambient temperature prior to test.

TABLE III - BUSHING TEMPERATURE CORRECTION FACTORS

TEST TEMPERATURE		GENERAL ELECTRIC					
°C	°F	TYPE B	TYPE F	TYPES L - L C LI-LM	TYPES OF-OFI OFM	TYPES S-SI- SM	TYPE U
0	32.0	1.09	0.93	1.00	1.18	1.26	1.02
1	33.8	1.09	0.94	1.00	1.17	1.25	1.02
2	35.6	1.09	0.95	1.00	1.16	1.24	1.02
3	37.4	1.09	0.96	1.00	1.15	1.22	1.02
4	39.2	1.09	0.97	1.00	1.15	1.21	1.02
5	41.0	1.09	0.98	1.00	1.14	1.20	1.02
6	42.8	1.08	0.98	1.00	1.13	1.19	1.01
7	44.6	1.08	0.98	1.00	1.12	1.17	1.01
8	46.4	1.08	0.99	1.00	1.11	1.16	1.01
9	48.2	1.07	0.99	1.00	1.11	1.15	1.01
10	50.0	1.07	0.99	1.00	1.10	1.14	1.01
11	51.8	1.07	0.99	1.00	1.09	1.12	1.01
12	53.6	1.06	0.99	1.00	1.08	1.11	1.01
13	55.4	1.06	0.99	1.00	1.07	1.10	1.01
14	57.2	1.05	1.00	1.00	1.06	1.08	1.01
15	59.0	1.05	1.00	1.00	1.05	1.07	1.01
16	60.8	1.04	1.00	1.00	1.04	1.06	1.00
17	62.6	1.03	1.00	1.00	1.03	1.04	1.00
18	64.4	1.02	1.00	1.00	1.02	1.03	1.00
19	66.2	1.01	1.00	1.00	1.01	1.01	1.00
20	68.0	1.00	1.00	1.00	1.00	1.00	1.00
21	69.8	0.98	0.99	1.00	0.99	0.98	1.00
22	71.6	0.97	0.99	0.99	0.97	0.97	1.00
23	73.4	0.95	0.98	0.99	0.96	0.95	1.00
24	75.2	0.93	0.97	0.99	0.94	0.93	1.00
25	77.0	0.92	0.97	0.99	0.93	0.92	1.00
26	78.8	0.90	0.96	0.98	0.91	0.90	0.99
27	80.6	0.88	0.95	0.98	0.90	0.89	0.99
28	82.4	0.85	0.94	0.97	0.88	0.87	0.99
29	84.2	0.83	0.93	0.96	0.87	0.86	0.99
30	86.0	0.81	0.92	0.96	0.86	0.84	0.99
31	87.8	0.80	0.91	0.95	0.84	0.83	0.99
32	89.6	0.77	0.89	0.95	0.83	0.81	0.99
33	91.4	0.75	0.88	0.95	0.81	0.79	0.99
34	93.2	0.73	0.87	0.94	0.80	0.77	0.99
35	95.0	0.71	0.85	0.94	0.78	0.76	0.98
36	96.8	0.69	0.84	0.93	0.77	0.74	0.98
37	98.6	0.67	0.83	0.92	0.75	0.72	0.98
38	100.4	0.65	0.81	0.91	0.74	0.70	0.98
39	102.2	0.63	0.80	0.90	0.72	0.68	0.98
40	104.0	0.61	0.78	0.89	0.70	0.67	0.98
42	107.6		0.74	0.87	0.67	0.63	0.98
44	111.2		0.70	0.85	0.63	0.60	0.98
46	114.8		0.64	0.83	0.61	0.56	0.97
48	118.4		0.58	0.82	0.58	0.53	0.97
50	122.0		0.52	0.80	0.56	0.50	0.97
52	125.6			0.79	0.53	0.47	0.97
54	129.2			0.78	0.51	0.44	0.97
56	132.8			0.77	0.49	0.41	0.96
58	136.4			0.76	0.46	0.38	0.96
60	140.0			0.74	0.44	0.36	0.96
62	143.6			0.73	0.40	0.33	
66	150.8			0.70	0.39	0.28	
70	158.0			0.66	0.36	0.23	

TABLE IV - BUSHING TEMPERATURE CORRECTION FACTORS

TEST TEMPERATURE		LAPP INSULATOR COMPANY		MICANITE AND INSULATORS COMPANY	
*C	*F	CLASS P O C 15 TO 69 KV	P R C	25 TO 69 KV	ABOVE 69 KV
0	32.0	1.00	0.80	1.55	1.13
1	33.8	1.00			
2	35.6	1.00			
3	37.4	1.00			
4	39.2	1.00			
5	41.0	1.00	0.86	1.40	1.09
6	42.8	1.00			
7	44.6	1.00			
8	46.4	1.00			
9	48.2	1.00			
10	50.0	1.00	0.91	1.25	1.06
11	51.8	1.00			
12	53.6	1.00			
13	55.4	1.00			
14	57.2	1.00			
15	59.0	1.00	0.95	1.12	1.03
16	60.8	1.00			
17	62.6	1.00			
18	64.4	1.00			
19	66.2	1.00			
20	68.0	1.00	1.00	1.00	1.00
21	69.8	1.00			
22	71.6	1.00			
23	73.4	1.00			
24	75.2	1.00			
25	77.0	1.00	1.04	0.89	0.97
26	78.8	1.00			
27	80.6	1.00			
28	82.4	1.00			
29	84.2	1.00			
30	86.0	1.00	1.08	0.80	0.94
31	87.8	1.00			
32	89.6	1.00			
33	91.4	1.00			
34	93.2	1.00			
35	95.0	1.00	1.11	0.72	0.91
36	96.8	1.00			
37	98.6	1.00			
38	100.4	1.00			
39	102.2	1.00			
40	104.0	1.00	1.13	0.64	0.88
41	105.8	1.00			
42	107.6	1.00			
43	109.4	1.00			
44	111.2	1.00			
45	113.0	1.00	1.13	0.56	0.86
46	114.8	1.00			
47	116.6	1.00			
48	118.4	1.00			
49	120.2	1.00			
50	122.0	1.00	1.11	0.50	0.83
52	125.6	1.00			
54	129.2	1.00			
56	132.8	1.00			
58	136.4	1.00			
60	140.0	1.00	1.01		

TABLE V – BUSHING TEMPERATURE CORRECTION FACTORS

TEST TEMPERATURE U S E		OHIO BRASS				WESTINGHO		
°C	°F	CLASS G & I 46 TO 138 KV	CLASS L 7.5 T 0 3 4 . 5 KV	CLASS OK 69 TO 196 KV	CLASS LK 23 TO 69 KV	TYPE D	CONDEN - S E R TYPE D	TYPE D
0	32.0	1.54	1.29	0.90	0.85	1.26	1.61	1.11
1	33.8	1.50	1.27	0.90	0.86	1.24	1.56	1.10
2	35.6	1.47	1.26	0.91	0.86	1.23	1.52	1.10
3	37.4	1.43	1.25	0.91	0.86	1.22	1.48	1.09
4	39.2	1.40	1.24	0.91	0.87	1.20	1.44	1.09
5	41.0	1.37	1.23	0.91	0.88	1.19	1.40	1.08
6	42.8	1.34	1.21	0.92	0.89	1.18	1.36	1.08
7	44.6	1.32	1.20	0.92	0.89	1.16	1.33	1.07
8	46.4	1.29	1.19	0.92	0.90	1.15	1.30	1.07
9	48.2	1.26	1.17	0.93	0.91	1.14	1.26	1.06
10	50.0	1.24	1.16	0.93	0.92	1.12	1.23	1.05
11	51.8	1.21	1.14	0.94	0.92	1.10	1.21	1.05
12	53.6	1.18	1.12	0.94	0.93	1.09	1.18	1.04
13	55.4	1.16	1.11	0.95	0.94	1.07	1.16	1.04
14	57.2	1.14	1.09	0.95	0.95	1.06	1.13	1.03
15	59.0	1.11	1.07	0.96	0.95	1.05	1.11	1.03
16	60.8	1.09	1.06	0.97	0.96	1.04	1.09	1.02
17	62.6	1.07	1.04	0.97	0.97	1.03	1.06	1.02
18	64.4	1.04	1.03	0.98	0.98	1.02	1.04	1.01
19	66.2	1.02	1.02	0.99	0.99	1.01	1.02	1.01
20	68.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	69.8	0.98	0.99	1.01	1.01	0.99	0.98	0.99
22	71.6	0.95	0.97	1.02	1.02	0.97	0.96	0.99
23	73.4	1.93	0.96	1.03	1.03	0.96	0.94	0.98
24	75.2	0.91	0.94	1.04	1.04	0.95	0.92	0.98
25	77.0	0.89	0.93	1.05	1.05	0.94	0.90	0.97
26	78.8	0.88	0.91	1.06	1.06	0.92	0.88	0.96
27	80.6	0.86	0.90	1.08	1.07	0.91	0.86	0.96
28	82.4	0.84	0.88	1.09	1.08	0.90	0.84	0.95
29	84.2	0.82	0.87	1.10	1.09	0.89	0.83	0.94
30	86.0	0.80	0.86	1.11	1.10	0.87	0.81	0.94
31	87.8	0.79	0.84	1.12	1.11	0.86	0.79	0.93
32	89.6	0.77	0.83	1.13	1.12	0.85	0.77	0.93
33	91.4	0.75	0.82	1.14	1.13	0.83	0.75	0.92
34	93.2	0.74	0.80	1.15	1.14	0.82	0.74	0.92
35	95.0	0.72	0.79	1.16	1.15	0.81	0.72	0.91
36	96.8	0.71	0.78	1.17	1.15	0.79	0.70	0.91
37	98.6	0.69	0.76	1.18	1.16	0.78	0.69	0.90
38	100.4	0.68	0.75	1.19	1.17	0.77	0.67	0.89
39	102.2	0.66	0.74	1.20	1.18	0.75	0.66	0.88
40	104.0	0.65	0.72	1.21	1.18	0.74	0.64	0.88
42	107.6			1.22	1.19	0.71	0.62	0.87
44	111.2			1.24	1.20	0.69	0.59	0.86
46	114.8			1.26	1.21	0.65	0.56	0.85
48	118.4			1.27	1.21	0.62	0.53	0.83
50	122.0			1.29	1.22	0.59	0.51	0.82
52	125.6			1.30	1.22	0.58	0.50	0.81
54	129.2			1.31	1.22	0.57	0.48	0.80
56	132.8			1.33	1.22	0.56	0.47	0.79
58	136.4			1.34	1.21	0.55	0.46	0.78
60	140.0			1.35	1.21	0.54	0.45	0.77
62	143.6					0.53	0.44	0.76
66	150.8					0.51	0.42	0.74
70	158.0					0.49	0.40	0.73

3.9 MEASUREMENT OF APPARATUS BUSHINGS AND CABLE POTHEADS BY HOT COLLAR METHOD

Apparatus bushings with neither draw leads nor capacitance power factor test taps can be tested in situ only by the use of the hot collar method. The same is true of cable potoheads. Also, dissipation factor tests on draw lead and tap equipped bushings which indicate a deteriorated condition may be supplemented by hot collar tests.

A. Preparation for Test

1. Clear apparatus in the normal manner.
2. Leave working grounds attached to the risers and/or bus-bars and cables.
3. The porcelain surface of bushings should be clean and dry. Remove dirt or oil with clean, dry rags.
4. Measure and record on the field test sheet the ambient temperature and relative humidity.
5. Tests should definitely not be carried out when rain is falling, or when there is condensation on the porcelain. Preferably, tests should not be carried out when the relative humidity is in excess of 75%.
6. Record reading of apparatus oil (liquid) temperature gauge (if present).
7. Place metal collar under the uppermost petticoat or rainshed. The collar should be snug against the surface of the porcelain.

B. Measurement by Hot Collar Method

1. Place the UST-GST switch in L-GUARD (CH-G in red).
2. Connect the CH coax leads (red) to the "D" ring of the metal collar (see Figure 22).
3. Keep the CH coax lead clear of the porcelain.

3.9 MEASUREMENT OF APPARATUS BUSHINGS AND CABLE POTHEADS BY HOT COLLAR METHOD (continued)

4. In this test the CL coax lead need not be connected. It can be left off the instrument.
5. Personnel should keep away from the bushing under test to avoid any influence on the readings.
6. Balance the CB100 as described in the "General Operating Instructions" (Section 3.3).

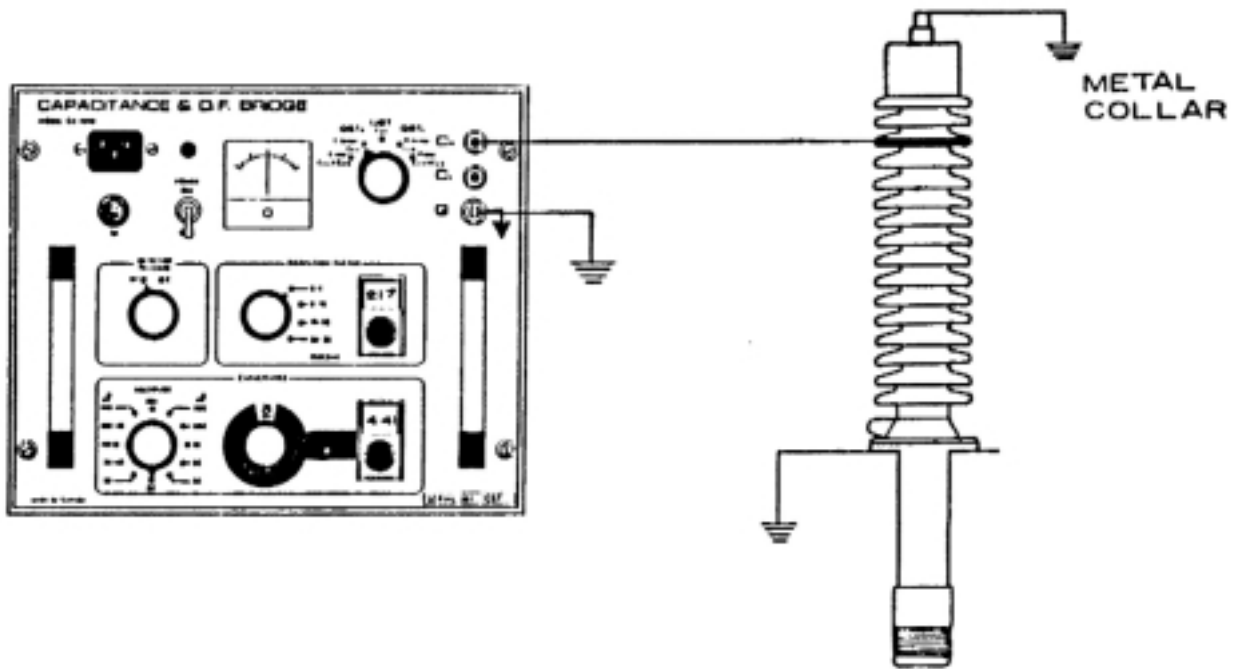


FIGURE 22

A breakdown of the different capacitances is shown below. In this test, all three values shown below (C1, C2, C3) are combined. Their values represent the following:

- C1 - Capacitance between collar and high voltage conductor of bushing ACROSS porcelain surface.
- C2 - Capacitance between collar and high voltage conductor of bushing THROUGH porcelain and other insulation surrounding the conductor.
- C3 - Capacitance ACROSS porcelain surface to ground flange.

3.9 MEASUREMENT OF APPARATUS BUSHINGS AND CABLE POTHEADS BY HOT COLLAR METHOD (continued)

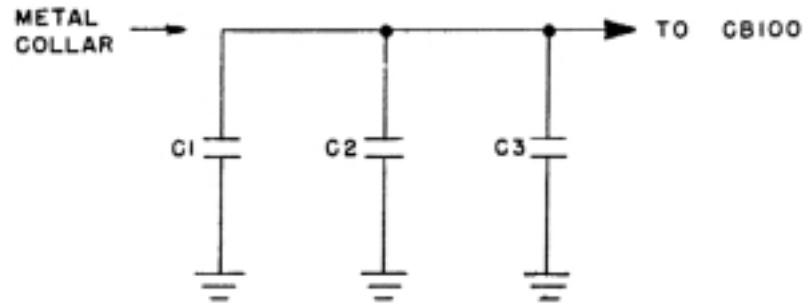


FIGURE 23

C. Identification and Test Data Using Test Sheet 02-100

Follow the same format as per "Bushings", Section 3.7, part C.

NOTE: In this application, the capacitance multiplier is almost always "20 PF".

D. Temperature Correction

For this particular test temperature correction are not applied, thus leaving part of test sheet 02-100 unfilled.

CB100 POWER FACTOR TEST REPORT										
" BUSHING TEST "										
APPARATUS INFORMATION DATE: ____/____/____ OCB: ____ or XFMR: ____ TEST SHEET NO. (if any): ____ TRANSFORMER LOCATION: _____ TRANSFORMER DESIGNATION: _____						MULTI-AMP CANADA LIMITED TYPE: 02-100 BUSHING TEST <hr/> ENVIRONMENT WEATHER: _____ AIR TEMP.: _____ °C OIL TEMP.: _____ °C WINDING TEMP.: _____ °C REL. HUMIDITY: _____ %				
BUSHING INFORMATION H.V. SIDE: RATED KV: _____ MFG RER: _____ TYPE: _____ FORM: _____ DRAWING NO.: _____ L.V. SIDE: RATED KV: _____ MFG RER: _____ TYPE: _____ FORM: _____ DRAWING NO.: _____ NEUTRAL SIDE: RATED KV: _____ MFG RER: _____ TYPE: _____ FORM: _____ DRAWING NO.: _____						DIAGRAM				
NAME PLATE				CAPACITANCE READING			DISSIPATION (POWER) FACTOR			
POSN.	SERIAL NO.	P.F. (%)	CAP. (PF)	MULT. SWITCH	CAP. SW. +DIAL	TOTAL (PF)	RANGE (%)	READING (DIAL)	TOTAL (%)	CORR. TO 20°C (%)
H1				X	=					
H2				X	=					
H3				X	=					
H0				X	=					
X1				X	=					
X2				X	=					
X3				X	=					
X4				X	=					
REASON FOR TESTING: _____ WORK ORDER NO.: _____ CB100 SERIAL NO.: _____ REMARKS: _____										
TESTED BY: _____ DATE CHECKED: ____/____/____ CHECKED BY: _____ LAST DATE TESTED: ____/____/____ COMPANY: _____ SHEET NO. OF LAST TEST: _____ DEPARTMENT: _____ SHEET NO.: _____										

02-100 BUSHING TEST

3.10 OPERATION WITH RANGE EXTENSION (Cat. No. 810132)

A. General

The CB100 Range Extension Adaptor increases the capacitive measurement from 1.2uF on the highest range to 480uF on the same range. One item to note is the accuracy change on capacitance and dissipation factor; it increases as per the table VI below.

TABLE VI - ACCURACY TABLE FOR RANGE EXTENSION ADAPTOR

CB100 CAP SWITCH MULT. POS'N.	RANGE EXTENSION MULT. POS'N.	MULTIPLY BRIDGE READING BY	ACCURACY CAPACITANCE % READING	ACCURACY DISSIPATION FACTOR
0.05μF	4	0.2	0.3	±0.2% D.F.
0.1μF	4	0.4	0.3	±0.3% D.F.
0.05	25	1.25	0.4	±0.4% D.F.
0.1	25	2.5	0.4	±0.4% D.F.
0.05	100	5.0	0.5	±0.5% D.F.
0.1	100	10.0	0.5	±0.5% D.F.
0.05	400	20.0	0.6	±0.6% D.F.
0.1	400	40.0	0.6	±0.6% D.F.

NOTE: D.F. range switch not to be used on 0-1%. When the range extension adaptor is used, the guard feature of the CB100 is lost and readings, therefore, have to be carried out in the more simple two-terminal configuration.

3.10 OPERATION WITH RANGE EXTENSION (continued)

B. Test Procedure

1. Ensure that specimen to be tested is completely DISCHARGED. Charged capacitors can be LETHAL.
2. Connect BNC on Range Extension to "CH" on bridge using BNC - BNC lead provided.
3. Connect binding post (black, located adjacent to BNC) on Range Extension to "G" terminal on CB100.
4. Place UST-GST switch on "L-GUARD" (CH-G in red).
5. Connect "C" on Range Extension to specimen common.
6. Connect appropriate range of Range Extension to C high of specimen. Use sufficient wire to ensure wire resistance does not influence reading (Typically 12 or 14 gauge wire).
7. Balance the CB100 as described in "General Instructions", Section 3.3.

NOTE: DF range switch not to be used on 0-1%. Capacitance range switch to be used on 0.1 μ F or 0.05 μ F.

For detailed connection, see Figure 24, below.

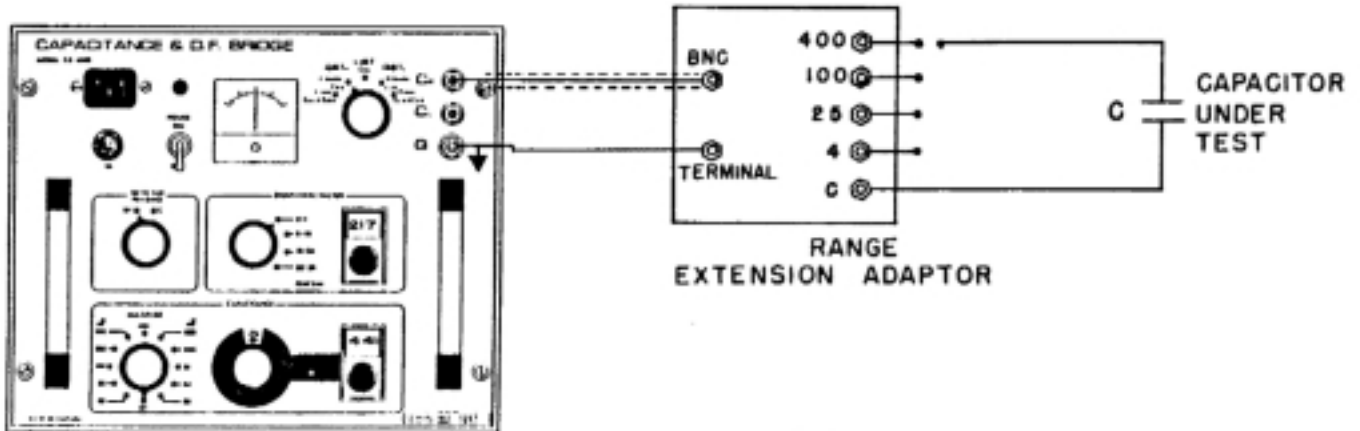


FIGURE 24

3.11 OPERATION WITH CALIBRATOR, Cat. No. 810133

A. General

The Multi-Amp Calibrator (Cat. No. 810133) gives an operator a quick reference source for verifying the correct operation of the CB100. The calibrator ensures that each position on the UST-GST switch functions correctly and that its accuracy is within allowable tolerance. The calibrator fits quite conveniently in the CB100 transport case, taking up very little room.

B. Operation

1. Connect red BNC from calibrator (marked "HI") to "CH" on bridge.
2. Connect black BNC from calibrator (marked "LO") to "CL" on bridge.
3. Connect center terminal from calibrator to ground terminal on bridge.
4. Compare the values obtained, to values on calibration report for calibrator (see next page for sample sheet).
5. Set UST-GST switch as per each indicated position.

See Figure 25, below, for correct connection.

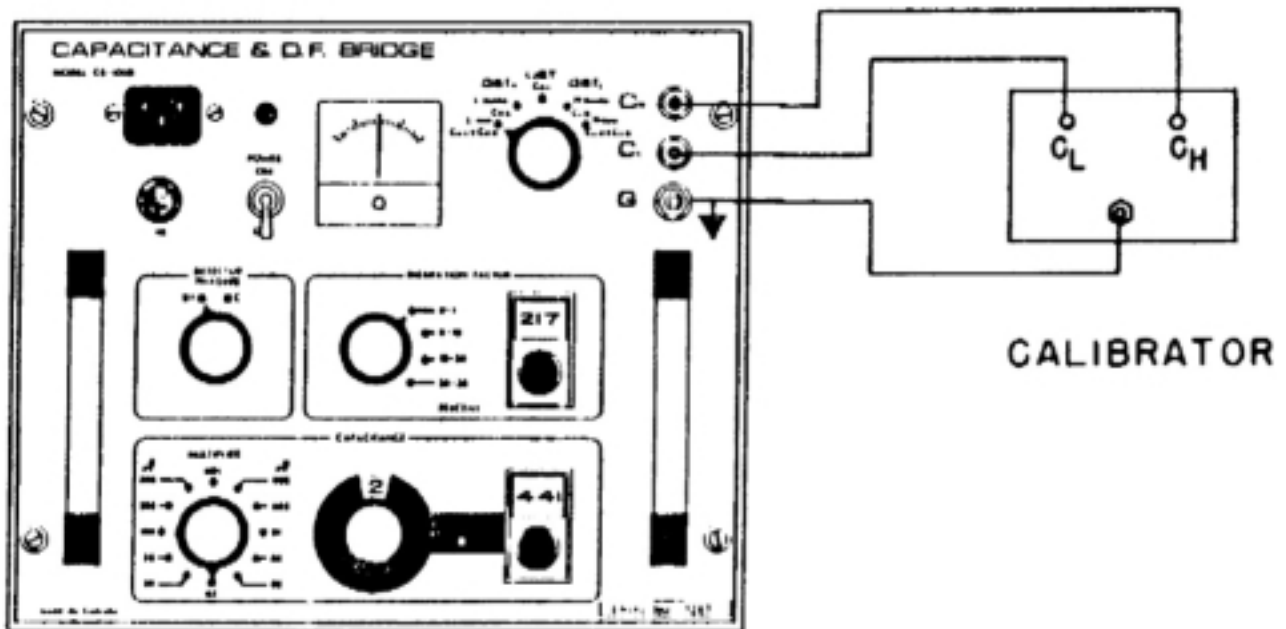


FIGURE 25 - UST-GST SWITCH TESTS ON ALL FIVE POSITIONS

C A L I B R A T I O N R E P O R T				
C B 1 0 0 C A L I B R A T O R				
CAT. NO. 810133		SERIAL NO. 2005		DATE: 83/07/28
U S T - G S T S W I T C H P O S I T I O N	N O M I N A L		A C T U A L	
	C A P A C I T A N C E (P F)	D F V A L U E (%)	C A P A C I T A N C E (P F)	D F V A L U E (%)
CH-L & CH-G	3000	0.54	3008	0.49
CH-G (RED)	2000	0.65	1997	0.56
CH-L (RED)	1000	0.33	1013	0.30
CL-G (RED)	10000	6.33	9979	6.20
CH-L & CL-G	11000	5.78	10987	5.70

NOTE: Connect the red lead to CxH; the black lead to CxL; the ground must be connected to the bridge ground.

NOTE: This calibrator is designed as a quick check and verifactor of correct capacitance bridge operation and is not intended for absolute bridge calibration. For this service, please return the instrument to the manufacturer or appointed service agent.

4.0 ANALYSIS OF RESULTS

4.1 POWER TRANSFORMERS

- Two winding transformers, three winding transformers, regulators and reactors.

The results from tests in Sections 3.4 and 3.6 provide valuable information regarding the general condition of the ground and interwinding insulation of transformers. They provide valuable information concerning the dryness of the transformer, and are helpful in detecting undesirable operating conditions and failure hazards resulting from:

Moisture

- Moisture can be absorbed by the paper insulation.
- Free water in the liquid state which is lying in pools on the insulation surface.
- Both the above conditions may be detected by the dissipation factor test. However, free water in the form of ice will not be detected.

Chemical Contamination

Reaction between acids in the transformer oil and residue from materials used in treating the core iron may result in the production of sodium soaps. These high loss materials result in:

- high dissipation factor on winding measurements.
- high dissipation factor on testing oil samples.

While increased winding dissipation factor due to chemical contaminants in the oil may not result in any failure hazard, it can mask more serious defects.

Core Grounds

In two winding power transformers the low voltage winding is usually next to the core. If the dissipation factor of the low voltage winding to ground insulation appears to increase from one test to the next and the capacitance appears to decrease, then it is possible that the core ground circuit is discontinuous.

On Load Tap Changers

If one performs dissipation factor tests with the on load tap changer on neutral high values of dissipation factor may result. When on the neutral position, the regulating winding is often tied in only through a resistor. If the ohmic value of this resistor at low voltage is high then the apparent dissipation factor of the regulating winding will increase. Therefore it is good practice to always move an on load tap changer off the neutral position before dissipation factor measurements are made.

4.1 POWER TRANSFORMERS (continued)

Bushings

The lower the capacitance to ground of a given winding the greater will be the effect of the condition of the associated bushings on the overall winding dissipation factor. Certain bushings such as the COB Class L may have quite high dissipation factor without being a serious failure hazard. However when in this condition they mask measurements on the winding. Often an oil change will significantly lower the dissipation factor of such bushings.

1. Modern transformers insulated with oil/paper materials (no varnish impregnation of coils) have dissipation factors of less than 1.0% and often less than 0.5% at 20°C.
2. Transformers built prior to 1939 often have varnished coils and other high loss insulating materials employed. Consequently dissipation factors as high as 2 or 3% at 20°C are not uncommon for these transformers.

In each case the most important criterion is the comparison with previous test data on the same transformer and other similar transformers. Remember also that when testing power transformers include the transformer oil and the bushings in the measurement. These should always be tested separately.

The following percentages are to be used in evaluating the results on ASKAREL and OIL-FILLED (free-breathing and conservator types) transformers at 20°C.

- Good - Up to 2.0 percent power factor.
- Investigate - 2.01 to 4.0 percent power factor.
- Bad - 4.01 percent power factor and above.

The following percentages are to be used in evaluating the results on OIL-FILLED (SEALED and GAS-BLANKETED types) transformers at 20°C.

- Good - Up to 1.5 percent power factor.
- Investigate - 1.51 to 3.0 percent power factor.
- Bad - 3.01 percent power factor and above.

Oil-Filled Reactors

Test and evaluation as on oil-filled power transformers should be used.

4.1 POWER TRANSFORMERS (continued)

Voltage Regulators

The following values are to be used in evaluating the results on regulators at 20°C.

Good - Up to 2.0 percent power factor.

Investigate - 2.01 to 4.0 percent power factor.

Bad - 4.01 percent power factor and above.

4.2 BUSHINGS

A. General Electric and Locke Bushings (Locke is subsidiary of General Electric and the same types are manufactured by both companies).

1. Type A (Dry-Type)

Type A is a through-type porcelain bushing assembly with a support flange, bushing cap, and terminal. Generally, bushings rated 500 Amperes and above have a solid rod or tube for the central conductor. Below this, they have an insulated cable for a conductor.

Bushings are to be rated as follows (no temperature corrections are to be applied).

Voltage Rating	Good	Investigate	Bad
8.7-15 kV	0-7.0% PF	7.01-9.0% PF	9.01% PF and above

2. Type B (Compound Filled)

Type B bushings are cable-type, and usually the cable insulation is varnished cambric. The top half of the bushing has insulating compound between the porcelain and the insulated conductor. The insulated cable projects below the mounting flange. Hot-collar tests are to be made as well as standard power factor tests.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
7.5-24 kV	0-10.0% PF	10.01-12.0% PF	12.01% PF and above

4.2 BUSHINGS (continued)

3. Type F (Oil-Filled)

This bushing has a number of concentrically spaced Herkolite cylinders and concentric oil ducts around a central metal tube or rod. The outer part of the bushing consists of two one-piece porcelains assembled against the flanges of a metal support. The bushing has a large metallic expansion chamber with a magnetic oil gauge.

On transformers that have considerable vibration, it has been necessary to modernize the 161 kV bushings and to install springs in the cap to hold all parts under pressure. Normally, the bushings have a power factor around 0.5 percent after they are modernized. Experience has proved this modification to be very dependable, and these bushings should be rated as all other type F bushings. However, a special comparison should be made to previous values; and any significant change should be investigated.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
46-69 kV	0-3.0% PF	3.01-4.5% PF	4.51% PF and above
1156-161 kV	0-2.5% PF	2.51-4.0% PF	4.01% PF and above

4. Types L, LC, LI, and LM (Oil-Filled)

These bushings have a central copper tube or rod wound with laminated paper (herkolite) insulation which is impervious to the insulating liquid, which may be either insulating oil or pyranol. A fairly large bushing cap includes a sealed reservoir space to allow for thermal expansion of the insulating liquid. A ground shield is pressed over the Herkolite core below the support flange.

The type L bushings are built by winding paper layers impregnated with Bakelite around a center conductor. A void can be created when the impregnation is missing. Corona in the voids in the paper around the center conductor causes the bushing to fail. A bushing may have a good power factor test and fail the next day. The lowest voltage at which corona starts on a bushing is usually above 10 kV, and any test made below this voltage will be of little value in detecting corona.

4.2 BUSHINGS (continued)

A new feature has been added to the type LC bushings. These bushings now have a floating equalizer spaced from the center conductor, such that when or if corona deterioration progresses to this barrier a 20 to 35 percent increase in capacitance takes place. The bushing is then to be given an "investigate" rating.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
15-73 kV	0-3.50% PF	3.51-5.0% PF	5.01% PF and above

5. Type OF, OFI, and OFM (Oil-Filled)

These bushings are oil-filled. There are a number of concentrically spaced herkolite cylinders and concentric oil ducts around a central metal tube or rod.

Older models have a glass oil expansion reservoir forming a part of the bushing cap so the oil level can be visually checked. Later models have a sealed, metallic expansion chamber with a magnetic oil gauge.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
46-69 kV	0-3.5% PF	3.31-6.0% PF	6.01% PF and above
115-161 kV	0-3.0% PF	3.01-5.0% PF	5.01% PF and above

6. Types S, SI, and SM (Compound-Filled)

These are all of the same general construction and have a maximum voltage rating of 69 kV. The bushing embodies a rigid core consisting of a metal tube covered with Herkolite insulation wound into cylindrical form. The upper part of the core is encased in porcelain with the space between the core and porcelain filled with compound. A metal ground sleeve insulated with varnished cambric extends from the support flange far enough to be in the oil of the apparatus to have a single hot-collar test as well as a standard power factor test.

Bushings are to be rated as follows at 20°C.

Voltage	Good	Investigate	Bad
15-37 kV	0-4.0% PF	4.01-6.5% PF	6.51 PF and above
46-69 kV	0-3.5% PF	3.51-6.0% PF	6.01% PF and above

7. Type U (Oil-Filled)

The type bushing is similar to type F, being oil-filled and hermetically sealed, but is considerably reduced in size and weight. The principal design feature is a combination of voltage stress equalizers and oil-impregnated paper on a central metal tube or rod. This produces a core of high dielectric strength and makes possible smaller over-all diameter and lighter weight. All standard 161 kV type U bushings have a capacitance tap outlet. On oil circuit breaker bushings this tap chamber is filled with compound, but on transformer bushings usually no filler is used. The type U bushings were initially designed for applications between 92 and 330 kV. They are now being built for application from 23 through 69 kV and have a tap outlet for power factor measurements.

Bushings are to be rated as follows at 30°C.

Voltage Rating	Good	Investigate	Bad
46-69 kV	0-2.5% PF	2.51-3.5% PF	3.51% PF and above
92-161 kV	0-2.0% PF	2.01-3.0% PF	3.01% PF and above

4.2 BUSHINGS (continued)

B. Westinghouse Bushings

1. Condenser (Compound-Filled)-All types except D, N, and O

This is a standard voltage bushing and is used on practically all electrical apparatus. It is made by winding alternate layers of paper and foil on a central tube or rod. The layers are tapered to distribute the dielectric stresses evenly. The upper part of the bushing has a porcelain shell, and a special compound or plastic is used to fill the space between the paper-foil core and the porcelain. Transformer bushings have a tube with a draw lead. Circuit breaker bushings have solid rod for a conductor. Single hot-collar tests are to be made as well as standard power factor tests.

In general, the power factor values at 20°C given below apply to all types of condenser bushings except types D, N, and O.

Voltage Rating	Good	Investigate	Bad
15-25 kV	0-4.0% PF	4.01-6.5% PF	6.51% PF and above
46-69 kV	0-3.5% PF	3.51-6.0% PF	6.01% PF and above
92-161 kV	0-3.0% PF	3.01-5.0% PF	5.01% PF and above

The capacitance of any of the above condenser bushings should not be more than 15 percent above that of the average similar type and rated bushings. An increase in capacitance indicates shorted condenser sections. If above 15 percent, the bushing is to be given an "investigate" rating.

2. Type D (Semicondenser)

This is a transformer bushing and consists of a heavily insulated cable surrounded by a condenser. The condenser extends only a relatively short distance below the mounting flange. This type has, in general, higher power factors than full condenser bushings. A single hot-collar and also a multiple hot-collar test should be made as well as a standard power factor test on these bushings.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
33-46 kV	0-5.0% PF	5.01-7.0% PF	7.01% PF and above

4.2 BUSHINGS (continued)

3. Type H (Dry-Type)

This is a bulk-type, multipiece porcelain bushing. Porcelain parts are cemented together and the flange is cemented to the lower porcelain tube. A heavily insulated cable is used for a conductor. The space between the tube and top porcelain rain shed is filled with a hard-setting compound. A single hot-collar test should be made as well as standard power factor tests on these bushings.

Bushings are to be rated as follows with no temperature corrections to be applied.

Voltage Rating	Good	Investigate	Bad
33-46 kV	0-109.0% PF	Above 10.0% PF	12.0% PF and above

4. Type N (Condenser, Compound-Filled)

This is a condenser bushing with a spun expansion cap and multiple coil springs in it to maintain constant pressure on all gaskets. The space between the porcelain rain shed and the condenser core is filled with a plastic compound. Transformer bushings have a center tube for a draw lead. Oil circuit breaker bushings have a center rod. Single-collar tests should be made as well as standard power factor tests.

There have been failures of the type N bushings, and the trouble has been determined as being caused by shorted condenser layers inside the bushing. The condenser layers progressively short out to where there is not enough insulation to withstand the voltage stress on the bushing. When condenser layers short out, usually there is a slight increase in power factor. A standard test with the bushing in the transformer cannot be made unless the winding is disconnected from the bushing. When the bushing is in an oil circuit breaker, the UST position eliminates the effect of the interrupters, etc., from the meter readings.

In addition to the standard and single-collar tests, a UST and a capacitance tap test should be made. Any bushing which has a measured capacitance value of 10 percent above the average for similar type and rated bushings is to be given an investigate rating.

4.2 BUSHINGS (continued)

4. Type N (Condenser, Compound-Filled) (continued)

The standard, UST, and capacitance tap tests on the bushings are to be rated at 20°C, using the same temperature corrections from the table at the end of this section for all three tests. (Use table for "Condenser except type O").

Voltage Rating	Good	Investigate	Bad
92-161 kV	0-2.5.0% PF	2.51-4.0% PF	4.01% PF and above

5. Type O (Condenser, Oil-Filled)

This is a condenser type bushing made of oil-impregnated kraft paper and is oil filled. All parts are held under pressure by springs in the cap. Ample expansion space is provided in the cap for thermal expansion of the oil. There is a magnetic oil gauge on the cap.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
92-161 kV	0-1.5% PF	1.51-2.5% PF	2.51% PF and above

Any type O bushing which has a measured capacitance 10 percent above the average for similar type and rated bushings is to be given an investigate rating. An increase in capacitance indicates shorted condenser sections.

4.2 BUSHINGS (continued)

C. Ohio Brass Bushings

Starting approximately in 1940, Ohio Brass bushing name-plates give over-all power factor at 10 kV as measured at the factory in air. However, prior to 1943, readings were not corrected at 20°C; and this must be taken into consideration. Bushings tested in good oil will usually have a slightly lower power factor. Power factor readings on bushing nameplates should be recorded on the data sheet.

The factory test data with the year should be on the bushing nameplates starting approximately in 1940. The exception would probably be on the old type ODOF bushings which may not have any nameplate. Practically all the type G and type L bushings should have the year and factory test on the nameplate. If no factory test and there is a shop tag with power factor test data, use it for a base for evaluation. After reconditioning a bushing at the shop, the reading for a good bushing should not be more than 2 percent above factory test, above 2.01 percent to 5.0 percent investigate, and above 5.0 percent bad.

1. Class ODOF

These are oil-filled bushings consisting of several concentric porcelain cylinders around the center conductor. The bushings can be identified by a pronounced bulge of the porcelain just above the mounting flange and a smooth porcelain stocking below the flange. They were superseded in 1932 by type G. They were built for both transformers and oil circuit breakers.

Factory or previous test values are to be used as a base for evaluation. Bushings are to be rated as follows at 20°C. THE FOLLOWING POWER FACTOR READINGS ARE NUMERICAL DIFFERENCE INCREASE OVER FACTORY VALUES.

Manufactured 1926 to 1938 inclusive - Bushings in this period will have an initial value for a new bushing of 2 to 4 percent.

Voltage Rating	Good	Investigate	Bad
115-161 kV	0-8.0% PF	8.1-15.9% PF	16.0% PF and above

4.2 BUSHINGS (continued)

Manufactured before 1926 and after 1938 - Bushings in these periods will have an initial value for a new bushing of 1 to 12 percent.

Voltage Rating	Good	Investigate	Bad
115-161 kV	0-11.0% PF	11.1-21.9% PF	22.0% PF and above

2. Class G

These bushings are similar to class L bushings. Bushings built between 1932 and 1938 were vented to the atmosphere. Bushings built since 1938 are completely sealed and usually equipped with magnetic-type oil gauges. Factory or previous test values are to be used as a base for evaluation. Bushings are to be rated as follows at 20°C.

THE FOLLOWING POWER FACTOR READINGS ARE NUMERICAL DIFFERENCE INCREASE OVER FACTORY VALUES.

Manufactured 1926 to 1938 inclusive - Bushings in this period will have an initial value for a new bushing of 2 to 4 percent.

Voltage Rating	Good	Investigate	Bad
46-161 kV	0-8.0% PF	8.1-15.9% PF	16.0% PF and above

Manufactured before 1926 and after 1938 - Bushings in these periods will have an initial value for a new bushing of 1 to 12 percent.

Voltage Rating	Good	Investigate	Bad
46-161 kV	0-11.0% PF	11.1-21.9% PF	22.0% PF and above

3. Class L

These are oil-filled bushings with concentric porcelain cylinders around the center conductor. Bushings manufactured between 1932 and 1938 had a cylindrical oil chamber which was vented to the atmosphere in fixed conductor designs and vented down through the conductor tube in draw-lead designs. The complete assembly is held together in compression by a top and bottom washer and a spring with the rod conductor acting as a tie rod. Present class L bushings are completely sealed and can be identified by a spherical oil chamber. Factory previous test values are to be used as a base for evaluation. Bushings are to be rated as follows at 20°C.

4.2 BUSHINGS (continued)

THE FOLLOWING POWER FACTOR READINGS ARE NUMERICAL DIFFERENCE INCREASE OVER FACTORY VALUES.

Manufactured 1926 to 1938 inclusive - Bushings in this period will have an initial value for a new bushing of 2 to 4 percent.

Voltage Rating	Good	Investigate	Bad
15-69 kV	0-8.0% PF	8.1-15.9% PF	16.0% PF and above

Manufactured before 1926 and after 1938 - Bushings in these periods will have an initial value for a new bushing of 1 to 12 percent.

Voltage Rating	Good	Investigate	Bad
15-69 kV	0-11.0% PF	11.1-21.9% PF	22.0% PF and above

4. Class GK

This is a condenser core-type bushing with oil-impregnated paper insulation, and it is oil filled. The cores are completely encased with porcelain housings at both top and bottom of the bushings, permitting full oil immersion. The complete assembly is held together in compression by top springs with the central conductor acting as a tie rod. Bushings are completely sealed. Oil reservoirs are equipped with a magnetic-type oil gauge.

Bushings are to be rated at 20°C as follows (Use table at end of this section for temperature corrections).

Voltage Rating	Good	Investigate	Bad
69-161 kV	0-1.5% PF	1.51-2.50% PF	2.51% PF and above

4.2 BUSHINGS (continued)

5. Class LK

This is a condenser core-type bushing with resin paper insulation and is also oil filled. Above the mounting flange the core is encased with porcelain and the core is immersed in oil. On top of the bushing is an oil reservoir. Below the flange is a ground sleeve, and at the lower end of the ground sleeve the core is exposed. This exposed portion is protected and sealed by multiple coatings of baked oil and moisture proof varnish. Bushings are completely sealed and normally do not have an oil level gauge on the reservoir. The complete assembly is held together in compression by top springs with the central conductor acting as a tie rod.

Bushings are to be rated at 20°C as follows. (Use table at end of this section for temperature corrections).

Voltage Rating	Good	Investigate	Bad
23-69 kV	0-2.0% PF	2.01-3.0% PF	3.01% PF and above

D. Lapp Bushings

1. Type POC

This type bushing, as the type designation indicates, is paper-oil, condenser-type, totally enclosed. The condenser core is composed of oil-impregnated high dielectric paper and aluminum foil layers wrapped on a solid copper conductor for fixed stud and on a copper tubing for draw-lead bushing. The porcelain housings, top and bottom, and metal housing form a leak-proof protective cover over the full length of the core. The entire housing assembly is sealed, and maintained leak-proof, by compression spring loading of gaskets. There is an oil space the entire length of the bushing.

Bushings are to be rated at 20°C as follows.

Voltage Rating	Good	Investigate	Bad
23-69 kV	0-1.0% PF	2.01-3.0% PF	3.01% PF and above

4.2 BUSHINGS (continued)

2. Type PRC

This type bushing is a paper-resin core, as the name indicates. The condenser core is constructed of paper and epoxy resin, either on a solid conductor or on a tube for draw-lead use. The porcelain hood and aluminum ground sleeve are bonded to the core by a special potting compound. All units are sealed together by epoxy sealant. The bushing construction is completely oil free.

Bushings are rated at 20°C as follows.

Voltage Rating	Good	Investigate	Bad
15-69 kV	0-2.0% PF	2.01-3.01% PF	3.01% PF and above

E. Micanite and Insulators Company (Used on English Electric Company Transformers)

1. Above 69 kV Bushings, Oil-Impregnated Paper Type

These bushings are completely sealed, condenser-type with a metallic expansion chamber and a magnetic oil gauge. The 161 kV bushings have a capacitance tap outlet.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
92-161 kV	0-1.5% PF	1.51-2.5% PF	2.51% PF and above

2. 25-69 kV Bushings, Synthetic Resin-Bonded-Paper Type

These bushings are condenser-type, completely sealed with a visible prismatic red indication oil gauge on the 46-69 kV bushings. Below the flange the ground shield is a wire wrapped around the insulation of the center core. Both the core and wire are covered with varnish below the flange. These bushings have test terminals for making ungrounded specimen tests.

Bushings are to be rated as follows at 20°C.

Voltage Rating	Good	Investigate	Bad
25-69 kV	0-2.5% PF	2.51-3.5% PF	3.51% PF and above

4.2 BUSHINGS (continued)

3. 15 kV Class Bushings

The 15 kV class bushings are not a condenser type but a simple porcelain shell type with a mounting flange. Hot-collar tests should be made as well as standard power factor test.

Bushings are to be rated as follows (no temperature corrections are to be applied).

Voltage Rating	Good	Investigate	Bad
15 kV	0-4.0% PF	4.01-6.0% PF	6.01% PF and above

4.3 NEGATIVE DF SYNDROME

This section discusses the negative dissipation factor that can be measured on certain pieces of electrical power equipment.

1. The CB100 is not capable of measuring a negative DF. When such a condition exists, its magnitude can be only estimated based on the other readings as readings below ZERO are not possible. The Doble set, being a readout instrument, can easily reverse the polarity of the meter to indicate a negative DF. It is much more difficult to generate a negative resistance in a bridge circuit.
2. Negative readings occur when there is resistive coupling within the test specimen.

The normal situation is:

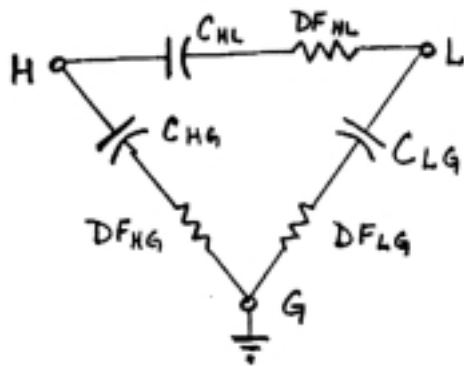


FIGURE 26

4.3 NEGATIVE DF SYNDROME (continued)

Whenever you have a connection as shown below, it will depress the DF reading of the CH-L measurement. This happens on all instruments, CB100, CB61, Doble, Biddle, etc. The value of R, in Figure 2, in relation to the values of associated capacitances depresses the measured value of DF H-L.

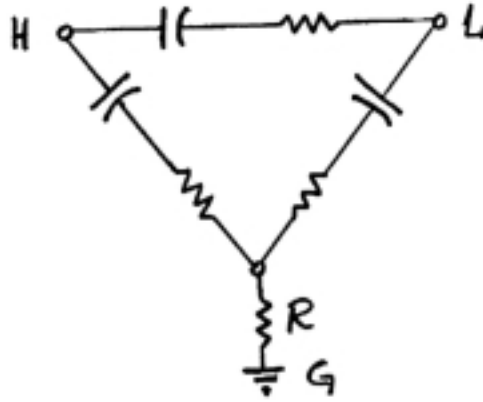


FIGURE 27

As an illustration consider the following:

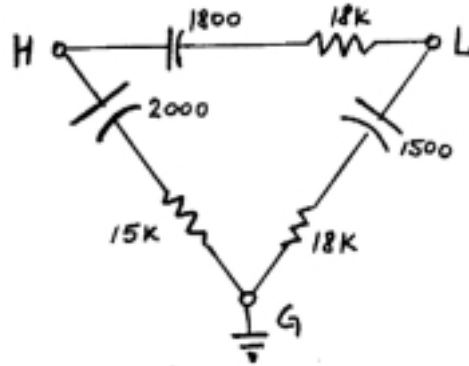


FIGURE 28

- | | | | | |
|----|-----------|---|------|-------|
| 1. | H-L + H-G | = | 3795 | 1.87% |
| 2. | H-G | = | 1970 | 1.77% |
| 3. | H-L | = | 1826 | 2.01% |
| 4. | L-G | = | 1512 | 1.63% |
| 5. | L-G + L-H | = | 3338 | 1.81% |

4.3 NEGATIVE DF SYNDROME (continued)

If the circuit is modified, as shown, the reading change to:

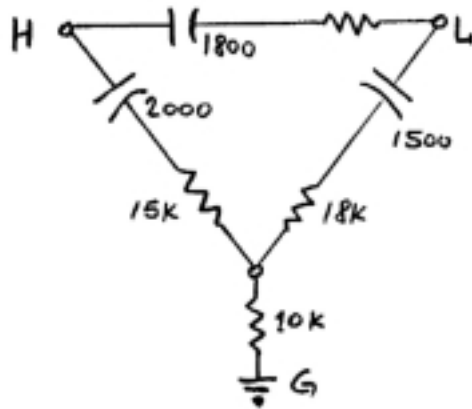


FIGURE 29

1.	H-L + H-G	=	3795	2.49%
2.	H-G	=	1970	3.96%
3.	H-L	=	1826	0.98%
4.	L-G	=	1512	3.82%
5.	L-G + L-H	=	3338	2.24%

The reduction in DF of test #3 (UST) is quite noticeable, as is the increase of the DF of test #2 and #4.

3. The various mechanisms that may result in a circuit similar to Figures 2 or 4 include:
 - a. Deterioration of semiconductive shields within the transformer.
 - b. A floating tertiary winding, usually with a high resistance ground.
 - c. High resistance connection between core and tank.

The mere presence of a NEGATIVE DF should be a warning sign for the maintenance staff, and should be investigated. A deteriorating shield will probably deteriorate to failure, but a high resistance connection to ground on the core may not be a serious situation.

4.3 NEGATIVE DF SYNDROME (continued)

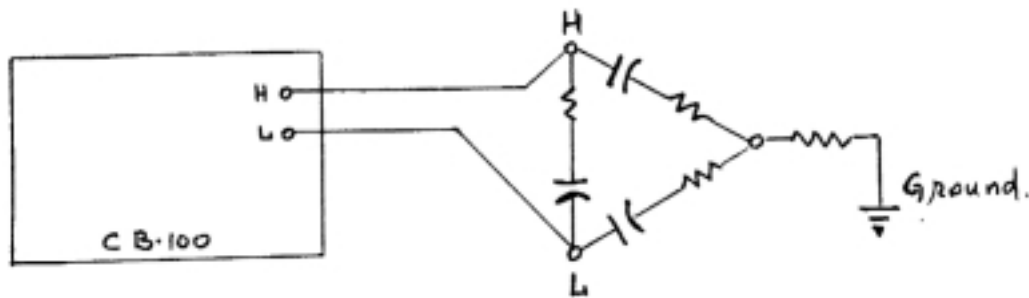
4. The CB100 is very versatile, and is capable of more measurements than the 5 functions on the switch. Some of these are useful in checking the readings, while others can shed a light on the negative DF syndrome.

a. Reverse the H and L leads.

This will give the operator another set of numbers, where he can compare the "H" values of one, with the "L" values of the other. Problems with leads, etc., will result in substantial differences and should be checked.

b. Short the H and L terminals on the transformer and measure (H-G) + (L-G). Compare this value to the individual (H-G) And (L-G) readings.

c. Operate the CB100 without a ground on the front panel, and with the power cord ground disabled. In the UST position, the instrument will measure (H-L), in parallel with (H-G) in series with (L-G). Compare this value with individual readings. The NEGATIVE DF is eliminated from this measurement.



NO GROUND ON BRIDGE!

FIGURE 30

5.0 THEORY OF OPERATION

5.1 TRANSFORMER RATIO ARM BRIDGE PRINCIPLE

A simplified diagram of the bridge is shown below. Connected to the bridge is a three terminal capacitor with a power factor (D.F.) represented as Rx. This could very well be a transformer with low winding (L), high winding (H) and ground (G).

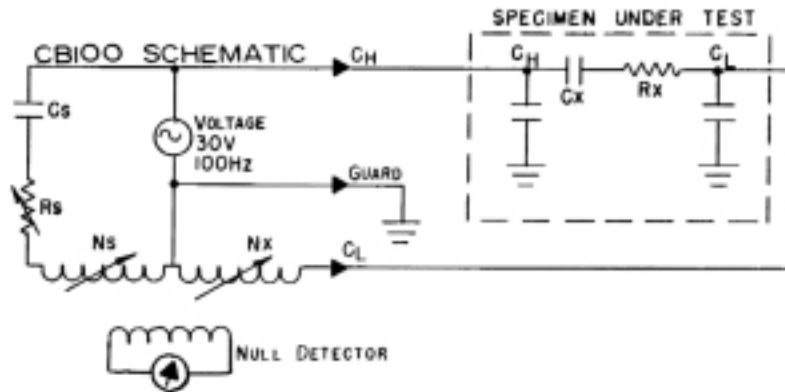


FIGURE 31

The voltage supply energizes Cs (standard capacitor) and Cx (specimen under test). Current of Cs travels through the transformer winding and returns to the voltage supply. Current of Cx does the same, but travels in the opposite direction, therefore generating an opposite polarity magnetic flux.

The output winding of the ratio arm transformer detect the difference in the Cs current vs Cx current. This difference is displayed as an unbalanced null meter.

To balance the null meter, both magnetic fluxes (Cs and Cx) must cancel each other out. To achieve this, the ratio-arm transformer has multiple taps to which currents of Cs and Cx are directed. In the balanced condition, the following formula applies:

$$C_s \cdot N_s = C_x \cdot N_x$$

where: Cs = Capacitor standard.

Cx = Specimen capacitor.

Ns = Number of turns on standard side of ratio-arm.

Nx = Number of turns on specimen side of ratio-arm.

5.1 TRANSFORMER RATIO ARM BRIDGE PRINCIPLE (continued)

The ratio adjustment, N_s , is shown on the face plate of the instrument as "Capacitance Switch and Dial" and the ratio adjustment, N_x , is shown on the face plate of the instrument as the "Capacitance Multiplier". C_s has been arranged to be a suitable fixed value to make the instrument read directly.

The null meter is then made sensitive only to dissipation factor (P.F.) and balance is achieved by adjusting R_s (resistance added to capacitor standard). R_s is shown on the front plate as "Dissipation Factor Switch and Dial". Value is presented in percent.

5.2 COMPARISON OF "DISSIPATION FACTOR" VS "POWER FACTOR"

For all practical purposes P.F. and D.F. are the same. Dissipation factor/power factor are both expressed as a percentage, however it is how one arrives at this number that differs. Consider the example (see Figure on this page) when voltage is applied to a capacitor. The current which flows has two components. The larger component (I_c) is the capacitive current which is determined by the dimensions of the capacitor and the dielectric constant of the insulating material. The small component (I_r) is the resistive current which is determined by the resistive losses of the insulating material. The capacitive component (I_c) leads the test voltage (E) by 90 degrees. The resistive component (I_r) is in phase with the test voltage, we may now determine the power factor and dissipation factor.

The power factor (PF) is defined as the cosine of θ , or as the watt component divided by the volt-amperes.

Similarly, the dissipation factor (DF) is defined as the cotangent of θ , or as the ratio of the loss component of current divided by the capacitive component of current.

The European term used here is the "tan delta", which is the tangent of the loss angle "delta". It is equal to the dissipation factor summarizing:

$$\text{Power Factor (PF)} = W/VA = \cos \theta$$

$$\text{Dissipation Factor (DF)} = I_r/I_c = \cot \theta = \tan \delta.$$

5.2 COMPARISON OF "DISSIPATION FACTOR" VS "POWER FACTOR"
(continued)

Angle δ	Dissipation Factor ($\cos \delta$)	Dissipation Factor ($\tan \phi$)
90	0.0000 (0%)	0.0000 (0%)
89.5	0.0087 (0.87%)	0.0087 (0.87%)
89	0.0175 (1.75%)	0.0175 (1.75%)
88	0.0349 (3.49%)	0.0349 (3.49%)
87	0.0523 (5.23%)	0.0523 (5.23%)
86	0.0698 (6.98%)	0.0698 (6.98%)
85	0.0872 (8.72%)	0.0872 (8.72%)

As can be seen, the power factor and the dissipation factor (\tan) values differ only at the very high values, and even then only a small amount.

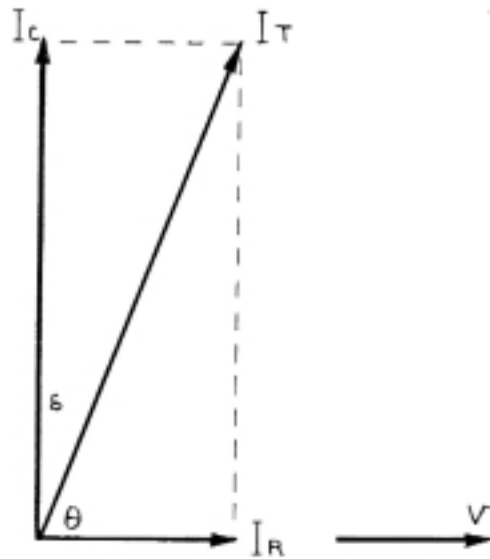


FIGURE 32

Vector equivalent of capacitive current I_C vs resistive current I_R and their vector total I_T . The phase angle ' δ ' is used in power factor calculation whereas ' θ ' is used in dissipation factor calculation.

6.0 SERVICE AND MAINTENANCE

6.1 CALIBRATION

The adjustment of this instrument should be attempted only by a qualified technologist, and only if the necessary equipment is available. It would be preferable to send the instrument to the manufacturer for adjustment or repair.

A. Equipment Required

Oscilloscope with external triggering.

Standard capacitors.

Standard resistors.

22 pin extension card.

B. Adjustment Procedure

The purpose of the adjustment procedure is to assure that the instrument is operating properly before any calibration adjustments are attempted.

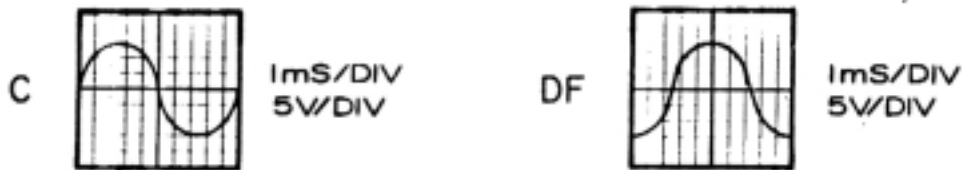
1. Open the instrument by means of four screws on the front panel and removing the bottom rear rubber feet.
2. Remove the oscillator (OSB PCB), detector (DTB PCB) and calibrator (CLB PCB) boards from the instrument.
3. Set UST-GST switch to UST.
4. Connect instrument to 120V, 60Hz, and turn it on.
5. Check for presence of 15 volts on the output of the power supply at the oscillator (OSB PCB) and detector (DTB PCB) sockets.
6. Plug in the oscillator board (OSB PCB).
7. With the scope connected to the CL terminal, adjust R16 potentiometer to obtain an amplitude of 90 volts, peak-to-peak.
8. Should the voltage be distorted, check the operation of the oscillator, the follower and transistor booster. A partial collapse will also cause distortion.

6.1 CALIBRATION (continued)

9. Synchronize the scope, in the external triggering mode to the voltage at CL and display it as shown below.



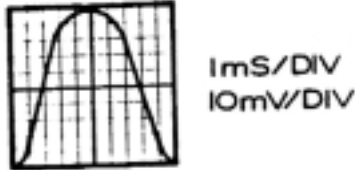
10. The frequency of the oscillator may be checked using a counter. It should be between 99.5 and 100.5 cycles per second. Values of R18 and C4 should be checked (79.6 to 80.4 for 50Hz supply).
11. Check the output of the reference voltage generator (pin 14) on the oscillator board. With the C-DF switch in the C position the amplitude of the voltage should be 20V p-p, and in phase with CL voltage.



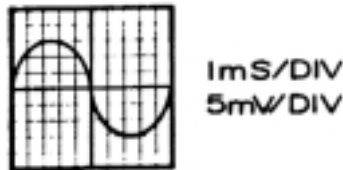
12. Plug in the calibrator and detector boards.
13. Set the capacitance multiplier switch to 0.1 and capacitance switch to 1 and dial to 000.

6.1 CALIBRATION (continued)

14. Check the signal input to the detector on pin 6 (TP2). The signal should be about 80 millivolts p-p, and 90 degrees behind CL voltage. The phase position of this voltage is controlled by capacitor C5 on the Mother Board. It is approximately 0.47 μ F for 60Hz operation and 1 μ F for 50Hz.



15. Check the output of the amplifier following the reject filter (TP3). The signal should be about 20mV p-p and 0 degrees behind CL voltage.



16. Check the signal output of the first tuned stage (TP4). Output should be a sine wave 0.5V p-p, and 180 degrees behind CL voltage. Adjust R23.



17. Set Capacitance Multiplier Switch to 0.1 and Capacitance Switch to 0 and dial to 100.

6.1 CALIBRATION (continued)

18. Check the signal output of the second tuned stage (TPS). Output should be a sine wave 1.2V p-p and 0 degrees behind CL voltage. Adjust R24.



19. If 14 is 5 degrees outside the specified phase relationship, change the tuning of the ratio transformer by changing the voltage of C5. If the output is much below specified amplitude level, check for shorted turns on the ratio transformer.
20. If 16 or 18 are 5 degrees outside the specified phase relationship, adjust the tuning of the stages by means of R23 and R24. Note that each tuned stage should have a gain of about 25.
21. If any of the stages are below the specified gain, replace the integrated circuit amplifiers.
22. Set Capacitance Range Switch to 0.1.
Set Capacitance Switch to 0.
Set Capacitance Dial to 000.
23. Put scope on P1N16 (output of detector) and Adjust the UST C & DF trimmers on the calibrator board for null on scope (A voltage less than 0.1 p-p is sufficient).
24. Adjust R26 on Detector Card to zero the DC signal. This should null the meter.
25. Balance Bridge by means of 1000pF capacitor connected externally to terminals CL & CH. Adjust R25 to obtain symmetrical sine wave on either side of balance.
26. Repeat steps 23 through 25.
27. Check the overall sensitivity of the null indicator. With C & DF switch in C, the null indicator should deflect 4 divisions for a change of 005 on the capacitance dial.

6.1 CALIBRATION (continued)

C. Calibration Procedure

NOTE: The calibration procedure must be performed with the instrument mounted inside the case. To allow access to the trimming potentiometers, the panel should be replaced with a piece of aluminum which has five access holes drilled in it. The rear panel is held in place with the foot mounting screws.

1. Set Capacitance Range Switch to 0.1uF.
Capacitance Switch to 0.
Capacitance Dial to 000.
Dissipation Factor Range to 0^X-1^Y .
Dissipation Factor Dial to 000.
UST-GST switch to UST.
All calibration potentiometers shown on following page.
2. With the C-DF switch in the C position, adjust the UST-C trimmer for zero on null indicator.
3. With the C-DF switch in the DF position, adjust the UST-DF trimmer for zero on null indicator.
4. Repeat 2 and 3 until zero in both C and DF positions is obtained.
5. Set UST-GST switch to GST (GST-H or GST-L).
6. Repeat steps 2, 3, and 4, adjusting the GST-C, and GST-DF trimmers for zero on null indicator.
7. Connect a loss-free three terminal, 1000pF capacitor to the bridge using coaxial leads.
8. Balance the bridge on the 100pF range in the UST position.
9. Use the DF-O trimmer for balancing the bridge in the DF phase position, with the DF dial set to 000.
10. The bridge should indicate the value of the loss-free capacitor within 2pF, and 000 +20 for dissipation factor.
11. If the indicated capacitance is outside of the range the standard capacitor (C2) needs replacing. Use only a low loss polystyrene, capacitor for C2.

6.1 CALIBRATION (continued)

12. Insert a 10 Kohm precision (non-inductive) resistor in series with the 1000pF loss-free capacitor (connected between CL and CH terminals).
13. Re-balance the bridge. Assuming the capacitor to be exactly 1000pF, the bridge should now indicate a loss of 0.63%.
14. If the reading is too high, add capacitance to C1. If the reading is too low, remove some capacitance from C1. C1 should be about 600pF.
15. Insert a 100K precision (non-inductive) resistor in series with the 1000pF loss-free capacitor.
16. Re-balance the bridge using the 0-10 DF range. Assuming the capacitor to be exactly 1000pF, the bridge should now indicate a loss of 6.3%.
17. Increase value of C3 if reading is too high and decrease value of C3 if reading is too low.
18. Check the 10-20% DF range using 200K resistor (DF = 12.5%).
19. Check the 20-30% DF range using a 400K resistor (DF = 25%).
20. There are no adjustments provided for the 10-20% or the 20-30% ranges. An overlap of about 2% is provided between the ranges so that a balance is always obtainable. (e.g. - A loss of 9.9% may be indicated as 9.9% on the 0-10% range, or as a loss of about 10.1% on the 10-20% range).

7.0 ACKNOWLEDGEMENTS

BILL McDERMID, P. ENG.

Manitoba Hydro

Waverly S. C.

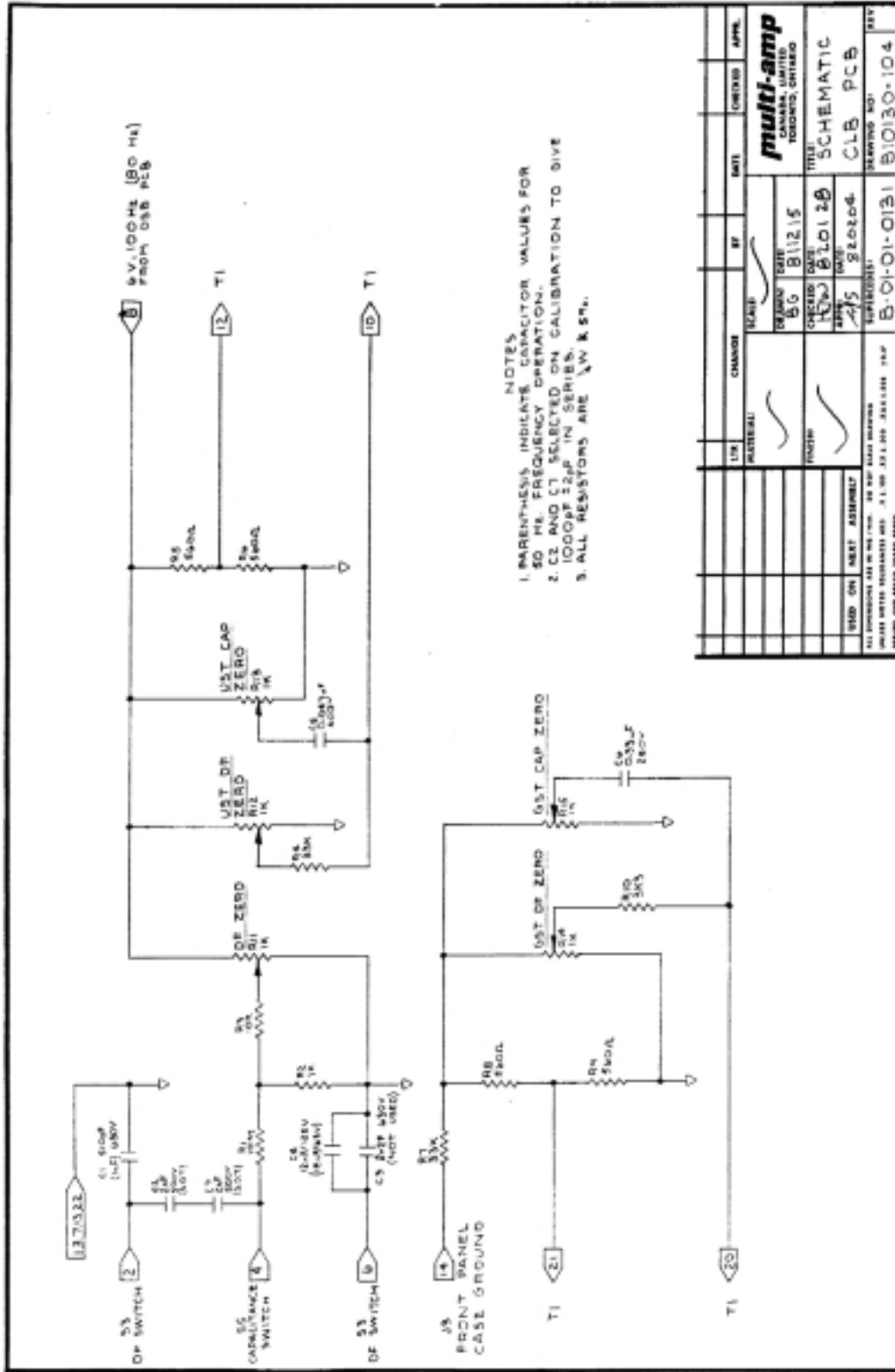
Winnipeg, Manitoba

Special thanks to Bill McDermid and Manitoba Hydro for the use of their outline on field use of the CB100.

8.0 DOCUMENTATION

The following drawings are included for reference purposes only:

Drawing Number	Title
B10130-051	Calibration Adjustments
B10130-104	Schematic, CLB PCB
B10130-105	Schematic, DTB PCB
B10130-106	Schematic, OSB PCB
C10130-108	Schematic, Chassis-MBB PCB
B10130-109	Schematic, PWR PCB
A10132-101	Schematic, R.E.A.



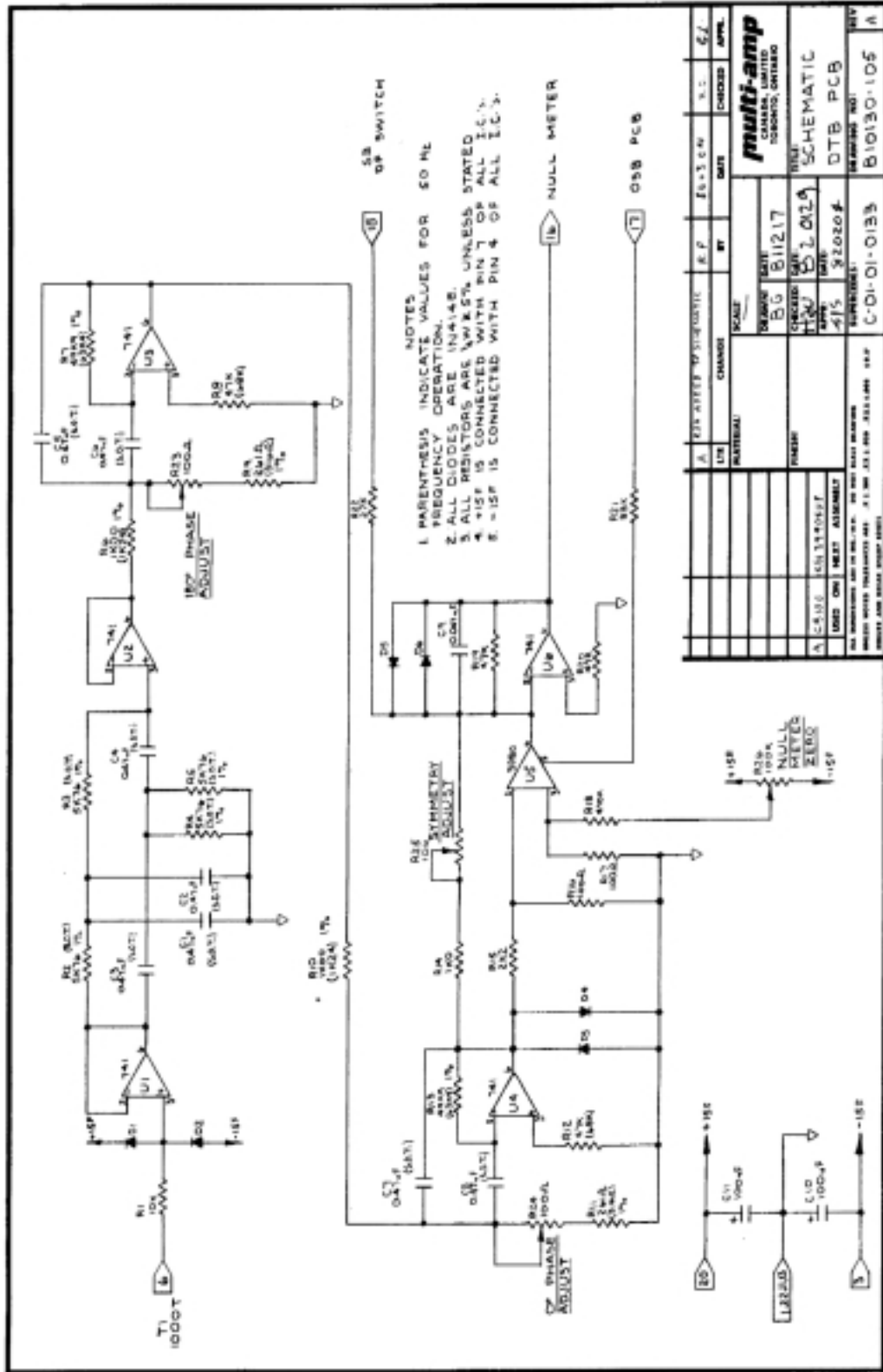
NOTES
 1. PARENTHESIS INDICATE CAPACITOR VALUES FOR 50 MHz FREQUENCY OPERATION.
 2. C2 AND C3 SELECTED ON CALIBRATION TO GIVE 1000PF 22PF IN SERIES.
 3. ALL RESISTORS ARE 1/4W 5%.

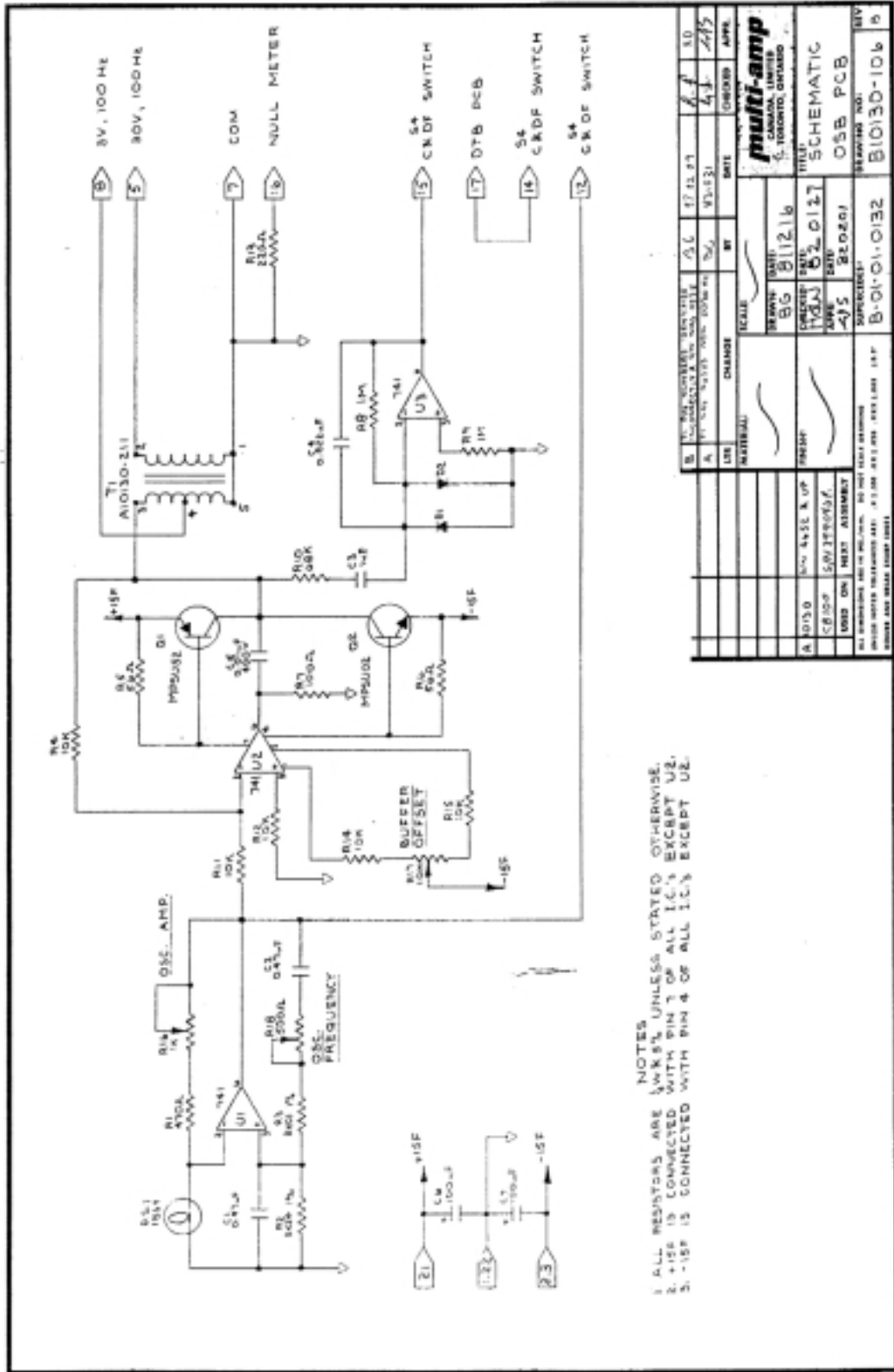
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multi-amp
 COMMERCIAL INSTRUMENTS
 TORONTO, ONTARIO

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 PROJECT B-01-01-0131
 DRAWING NO. CLB PCB
 SERIAL NO. B-01-01-0131
 PART NO. B10130-104

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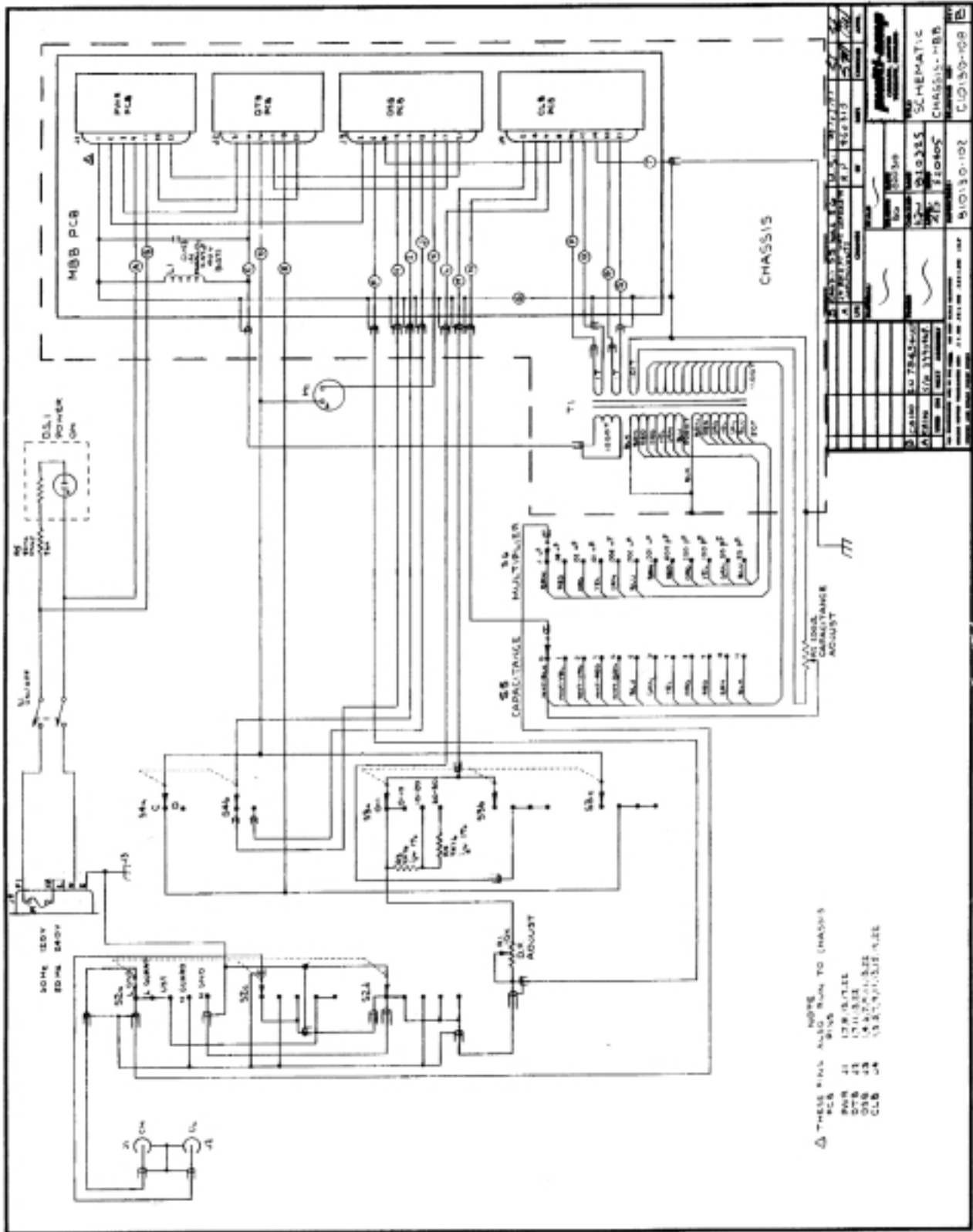
1 ALL RESISTORS ARE 1/4W 5% UNLESS STATED OTHERWISE.
2 +15V IS CONNECTED WITH PIN 7 OF ALL I.C.'S EXCEPT U2.
3 -15V IS CONNECTED WITH PIN 4 OF ALL I.C.'S EXCEPT U2.

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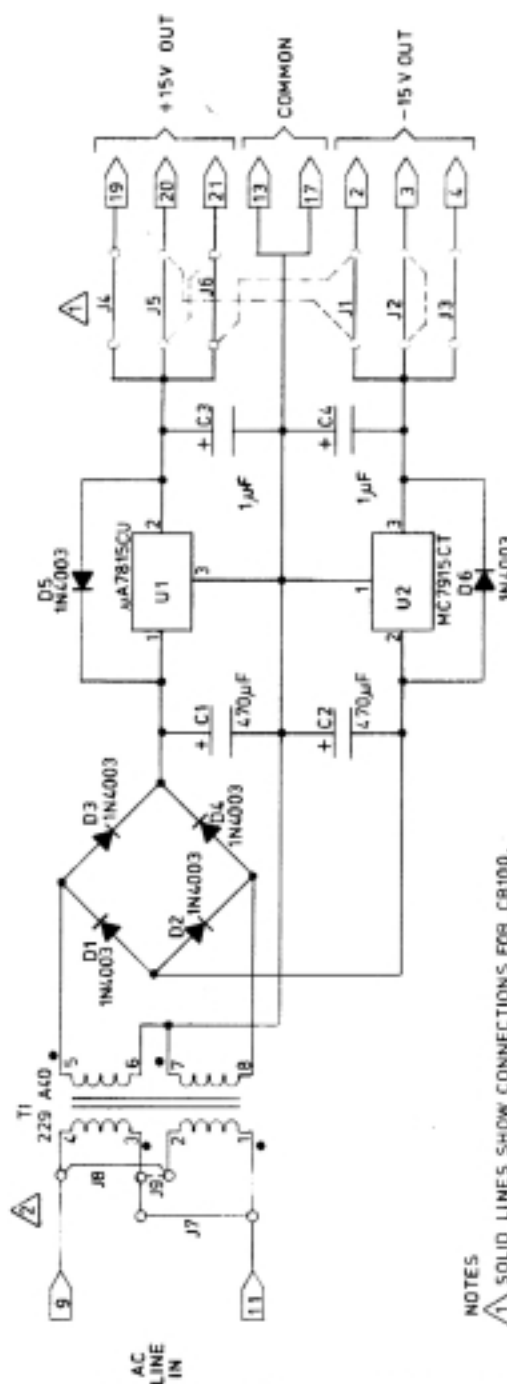
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PROJECT	OSB PCB
REVISION NO.	B10130-106
DATE	18

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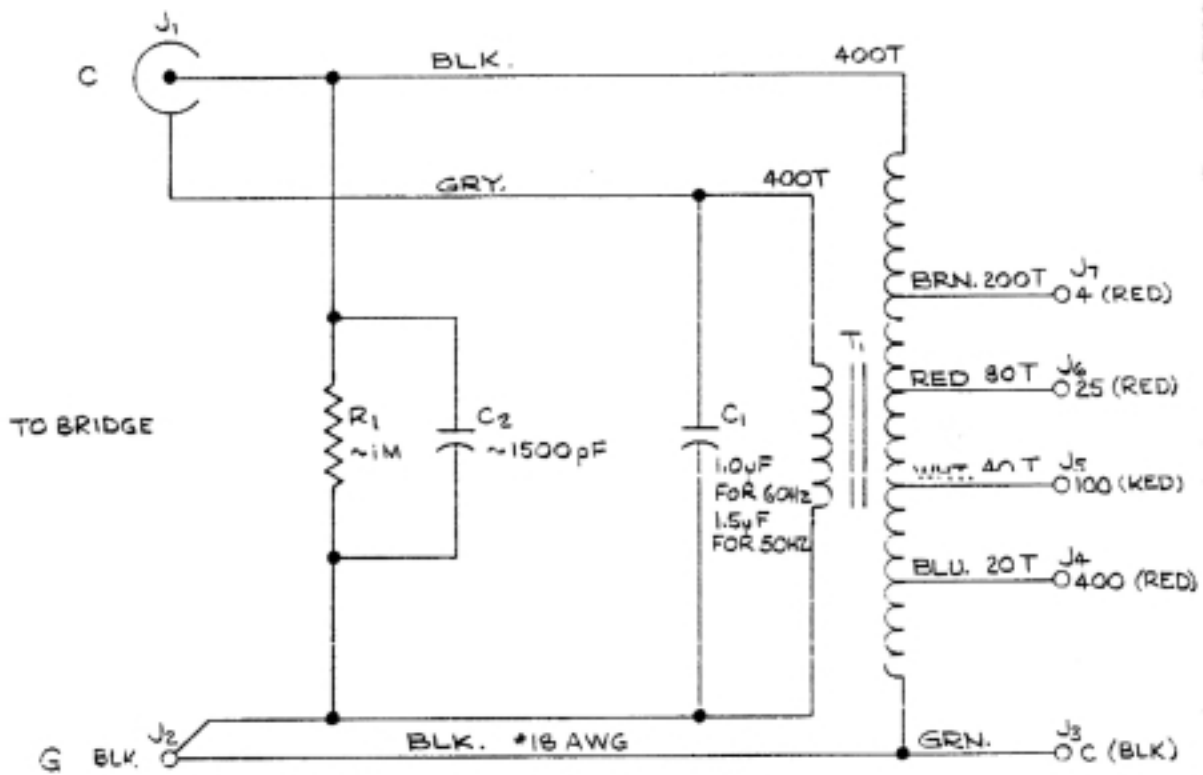
Δ THESE PINS ALSO RUN TO CHASSIS
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 QTR 22 170-15-111
 OIB 23 170-15-111
 CLB 24 170-15-111

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18	10/13/02	WJ	WJ	WJ
19	10/13/02	WJ	WJ	WJ
20	10/13/02	WJ	WJ	WJ
21	10/13/02	WJ	WJ	WJ
22	10/13/02	WJ	WJ	WJ
23	10/13/02	WJ	WJ	WJ
24	10/13/02	WJ	WJ	WJ
25	10/13/02	WJ	WJ	WJ
26	10/13/02	WJ	WJ	WJ
27	10/13/02	WJ	WJ	WJ
28	10/13/02	WJ	WJ	WJ
29	10/13/02	WJ	WJ	WJ
30	10/13/02	WJ	WJ	WJ
31	10/13/02	WJ	WJ	WJ
32	10/13/02	WJ	WJ	WJ
33	10/13/02	WJ	WJ	WJ
34	10/13/02	WJ	WJ	WJ
35	10/13/02	WJ	WJ	WJ
36	10/13/02	WJ	WJ	WJ
37	10/13/02	WJ	WJ	WJ
38	10/13/02	WJ	WJ	WJ
39	10/13/02	WJ	WJ	WJ
40	10/13/02	WJ	WJ	WJ
41	10/13/02	WJ	WJ	WJ
42	10/13/02	WJ	WJ	WJ
43	10/13/02	WJ	WJ	WJ
44	10/13/02	WJ	WJ	WJ
45	10/13/02	WJ	WJ	WJ
46	10/13/02	WJ	WJ	WJ
47	10/13/02	WJ	WJ	WJ
48	10/13/02	WJ	WJ	WJ
49	10/13/02	WJ	WJ	WJ
50	10/13/02	WJ	WJ	WJ
51	10/13/02	WJ	WJ	WJ
52	10/13/02	WJ	WJ	WJ
53	10/13/02	WJ	WJ	WJ
54	10/13/02	WJ	WJ	WJ
55	10/13/02	WJ	WJ	WJ
56	10/13/02	WJ	WJ	WJ
57	10/13/02	WJ	WJ	WJ
58	10/13/02	WJ	WJ	WJ
59	10/13/02	WJ	WJ	WJ
60	10/13/02	WJ	WJ	WJ
61	10/13/02	WJ	WJ	WJ
62	10/13/02	WJ	WJ	WJ
63	10/13/02	WJ	WJ	WJ
64	10/13/02	WJ	WJ	WJ
65	10/13/02	WJ	WJ	WJ
66	10/13/02	WJ	WJ	WJ
67	10/13/02	WJ	WJ	WJ
68	10/13/02	WJ	WJ	WJ
69	10/13/02	WJ	WJ	WJ
70	10/13/02	WJ	WJ	WJ
71	10/13/02	WJ	WJ	WJ
72	10/13/02	WJ	WJ	WJ
73	10/13/02	WJ	WJ	WJ
74	10/13/02	WJ	WJ	WJ
75	10/13/02	WJ	WJ	WJ
76	10/13/02	WJ	WJ	WJ
77	10/13/02	WJ	WJ	WJ
78	10/13/02	WJ	WJ	WJ
79	10/13/02	WJ	WJ	WJ
80	10/13/02	WJ	WJ	WJ
81	10/13/02	WJ	WJ	WJ
82	10/13/02	WJ	WJ	WJ
83	10/13/02	WJ	WJ	WJ
84	10/13/02	WJ	WJ	WJ
85	10/13/02	WJ	WJ	WJ
86	10/13/02	WJ	WJ	WJ
87	10/13/02	WJ	WJ	WJ
88	10/13/02	WJ	WJ	WJ
89	10/13/02	WJ	WJ	WJ
90	10/13/02	WJ	WJ	WJ
91	10/13/02	WJ	WJ	WJ
92	10/13/02	WJ	WJ	WJ
93	10/13/02	WJ	WJ	WJ
94	10/13/02	WJ	WJ	WJ
95	10/13/02	WJ	WJ	WJ
96	10/13/02	WJ	WJ	WJ
97	10/13/02	WJ	WJ	WJ
98	10/13/02	WJ	WJ	WJ
99	10/13/02	WJ	WJ	WJ
100	10/13/02	WJ	WJ	WJ



- NOTES
- △ SOLID LINES SHOW CONNECTIONS FOR CR100, TR700, AND TR800
 - △ DOTTED LINES SHOW CONNECTIONS FOR CB78, M400, AND MTB
 - △ SOLID LINES SHOW CONNECTIONS FOR 120V, 60Hz SERVICE
 - △ DOTTED LINE SHOWS CONNECTION FOR 240V, 50Hz SERVICE

MTB	REV	CHANGE	BY	DATE	CHECKED	APPR.
M400						
CB78						
TR800						
TR700						
CR100						
USED ON						
TEST ASSEMBLY						
<small>ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED</small>						
<small>THIS DRAWING IS THE PROPERTY OF PERMANENT RECORDS AND ANY REPRODUCTION OR DISSEMINATION OF THIS DRAWING WITHOUT THE WRITTEN PERMISSION OF PERMANENT RECORDS IS PROHIBITED.</small>						
<small>PERMANENT RECORDS 10000 WALKER HIGHLANDS AVE. SUITE 200 FORT WORTH, TEXAS 76116</small>					<small>SCALE: A: 10:130-101A</small>	
<small>TITLE: PWR PCB SCHEMATIC</small>					<small>DATE: 83 06 21</small>	
<small>DESIGNED BY: R P</small>					<small>DATE: 83 06 21</small>	
<small>CHECKED BY: G S</small>					<small>DATE: 83 06 22</small>	
<small>APPROVED BY: J B</small>					<small>DATE: 83 06 22</small>	
<small>SUPERSEDED BY: A: 10:130-101A</small>					<small>DATE: 83 06 22</small>	
<small>ORIGINAL NO: B10130-109</small>					<small>REV: 007</small>	



NO:	REVISION:	DATE:	SCALE:	DATE: 13 MAR 80	OLMAN INSTRUMENTS
A - ADDED WIRE COLORS. 10 3141/13		REFERENCE:	DRAWN BY: <i>PG</i>	TORONTO - CANADA	TITLE: SCHEMATIC
PART NO:		APPROVED: <i>MS</i>	DRAWING NO: A10132 - 101 - A		