TOGETHER WE POWER THE WORLD

Doble® Testing Voltage (Potential) Transformers and Metering Units

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Voltage Transformers

VoltageTransformers

Agenda

- Terminology
- Voltage transformer tests
- Power factor test
  - applicable policies
  - procedures
  - analysis of results
  - diagnostic tests

Agenda

- Case studies
  - 1: typical DTA screens
  - 2: voltage transformer in satisfactory condition
  - 3: voltage transformers in satisfactory condition
  - 4: affect of winding inductance

Design Types

- 1-bushing, line-to-neutral voltage transformers
  - conventional
  - cascade
  - inaccessible neutral terminal
- 2-bushing, line-to-line voltage transformers

Design Types

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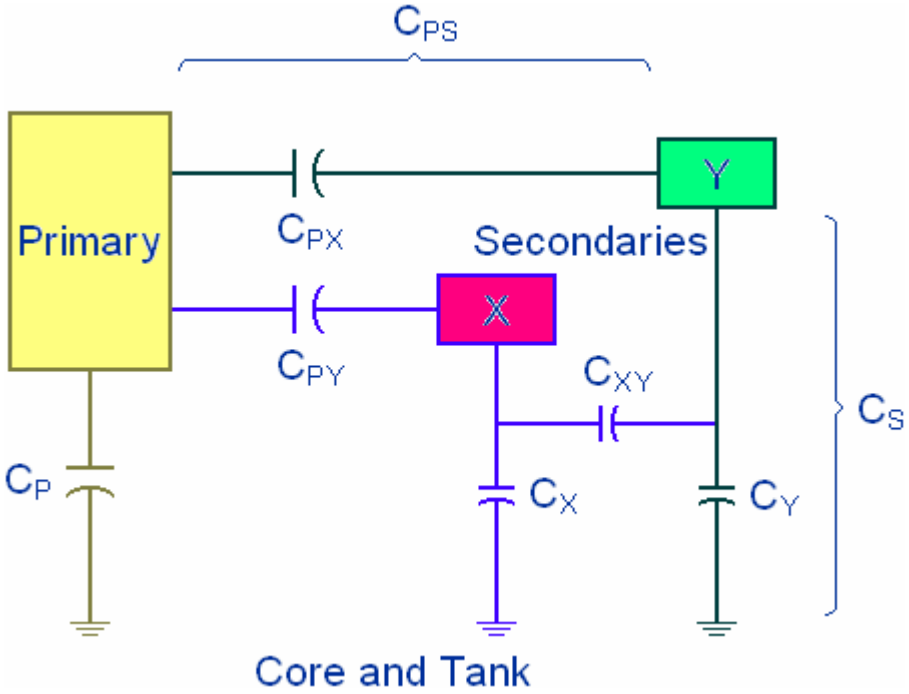
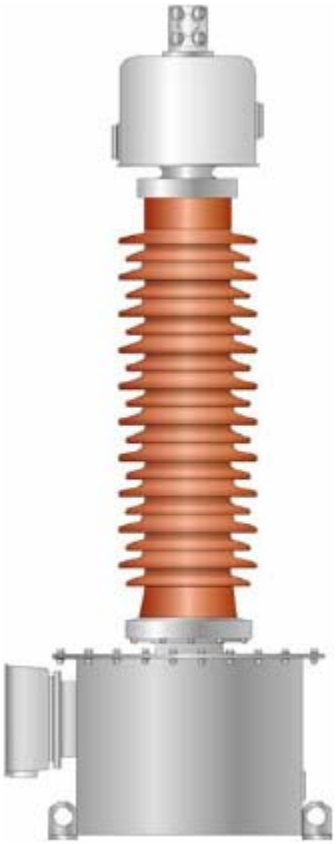
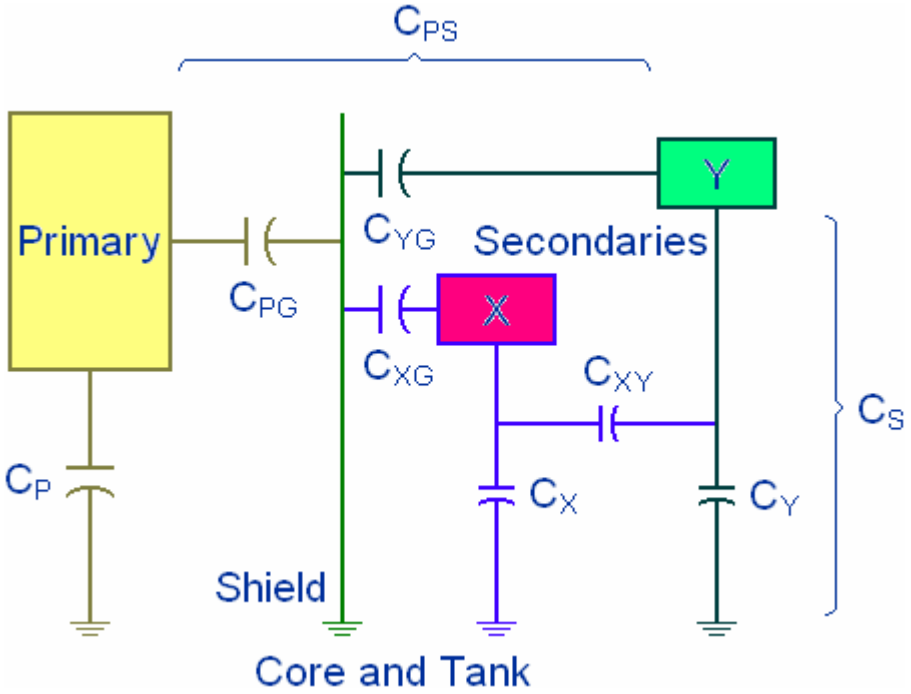
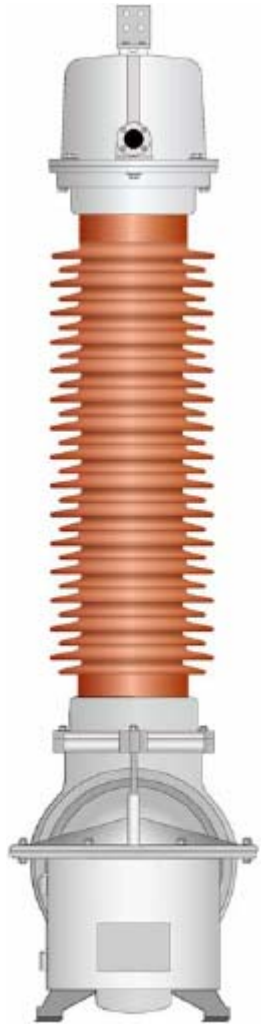
Dielectric Circuit





Diel. Circuit with Interwinding Shield





Terminology

- C_P: insulation between primary (high-voltage) conductor and grounded core and tank (bushings, winding insulation, structural insulating members and insulating fluid or material)
- C_{PS}: insulation between primary- and secondary-conductors (winding insulation, barriers and insulating or material)
- C_S: insulation between secondary (low-voltage) conductors and grounded core and tank (bushings and terminal board, winding insulation, structural insulating members and oil)

Terminology

- H_2: designation of second terminal of primary winding, regardless of its design. In earlier years, H_0 was designation of neutral terminal of line-to-neutral voltage transformer.

  Connection to H_2 terminal must be restored before energizing this apparatus at operating voltage.

- Line-to-neutral (L-N) voltage rating: equals system voltage rating divided by 1.73.

Modern Dry-Type Insulating Materials

- Butyl rubbers
- Cycloaliphatic epoxies
- Aromatic polyurethanes elastomers
- Hydrophobic cycloaliphatic epoxies

Voltage Transformer Tests

Routinely includes these measurements:

- Power factor and capacitance
- Excitation current
- Doble® ratio and polarity
- Infra-red

  sensitive to hot-spots

Voltage Transformer Tests

May also include these measurements:

- Insulation resistance and polarization index (IR_{10}/IR_1)

  sensitive to contamination and deterioration

- Winding resistance

  sensitive to quality of connections and continuity of conductors

Voltage Transformer Tests

- Insulating fluid tests
  - mineral oil
    - physical, chemical and electrical properties
    - dissolved gases and metals
  - SF6 gas
    - moisture and purity
    - acidity and arc by-products

Power Factor Test

Routine procedure varies with the design type, type of insulation and accessible neutral terminal:

- 1-bushing, line-to-neutral voltage transformer
  - liquid-filled and gas-filled
    - conventional
    - cascade
  - dry-type insulated
    - conventional
    - unaccessible neutral terminal

Power Factor Test

- 2-bushing, line-to-line voltage transformer
  - liquid-filled
  - dry-type insulated

Test Policies

Necessary to address specific aspects of testing, to include:

- Applied test voltage »

  test dry-type insulated voltage transformers at 2 voltages

Applied Test Voltage

Liquid-Filled, 2-Bushing, Line-to-Line Voltage Transformers

System kV Rating	Test Voltage, kV
15 and higher	10

Below 15 kV, test at L-N voltage, to the nearest 500 Volts. Line-to-neutral (L-N) voltage is system voltage divided by 1.73. Do not exceed 125 % L-N voltage rating.

System kV Rating	Test Voltage, kV
13.8 and 14.4	8
13.2	7.5
12.47	7.0
11	6.5
7.2 to 8.7	4
4 to 5	2.5
2.4	2

Applied Test Voltage

Liquid-Filled and Gas-Filled, 1-Bushing, Line-to-Neutral Voltage Transformers

H2 Neutral Terminal

System kV Rating	Test Voltage, kV
92 and higher	5
Below 92	2

Overall test performed at H2 neutral terminal test voltage.

H1 Line Terminal

System kV Rating	Test Voltage, kV
15 and higher	10

Below 15 kV, refer to test voltage applied to line-to-line voltage transformers.

Applied Test Voltage

Dry-Type Insulated, 2-Bushing, Line-to-Line Voltage Transformers

System kV Rating	Test Voltage, kV
15 and higher	2 and 10

Below 15 kV, test at 2 kV and L-N voltage, to the nearest 500 Volts. Line-to-neutral (L-N) voltage is system voltage divided by 1.73. Do not exceed 125 % L-N voltage rating.

System kV Rating	Test Voltage, kV
13.8 and 14.4	2 and 8
13.2	2 and 7.5
12.47	2 and 7.0
11	2 and 6.5
7.2 to 8.7	2 and 4
4 to 5	2.5
2.4	2

Applied Test Voltage

Dry-Type Insulated, 1-Bushing, Line-to-Neutral Voltage Transformers

H2 Neutral Terminal

System kV Rating	Test Voltage, kV
Below 92	2

Overall test performed at H2 neutral terminal test voltage.

H1 Line Terminal

System kV Rating	Test Voltage, kV
15 and higher	2 and 10

Below 15 kV, refer to test voltage applied to line-to-line voltage transformers.

Test Policies

- Winding inductance effect

  connect terminals of primary winding together for Overall Test

- Disposition of secondary windings
  - isolate secondary windings
  - ground one terminal of each secondary winding

Test Policies

- Temperature correction »
  - correct power factor for liquid-filled voltage transformers with ambient temperature
  - power factor for SF_6 and dry-type insulated voltage transformers not corrected

M4000 instrument measures ambient temperature and relative humidity automatically

Temperature Correction

TABLE OF MULTIPLIERS FOR USE IN CONVERTING POWER FACTOR AT TEST TEMPERATURES TO POWER FACTORS AT 20°C

Test Temperature		Oil-Filled VTs, CTs and MUs	
		Modern	
°C	°F	rated 220 kV and above	All other
0	32.0	1.57	1.67
4	39.2	1.44	1.55
8	46.4	1.31	1.43
12	53.6	1.19	1.30
16	60.8	1.09	1.16
20	68.0	1.00	1.00
24	75.2	0.92	0.86
28	82.4	0.84	0.74
32	89.6	0.76	0.65
36	96.8	0.70	0.56
40	104.0	0.65	0.48
44	111.2	0.59	0.42
48	118.4	0.54	-
52	125.6	0.49	-
56	132.8	0.45	-
60	140.0	0.41	-

Test Procedure

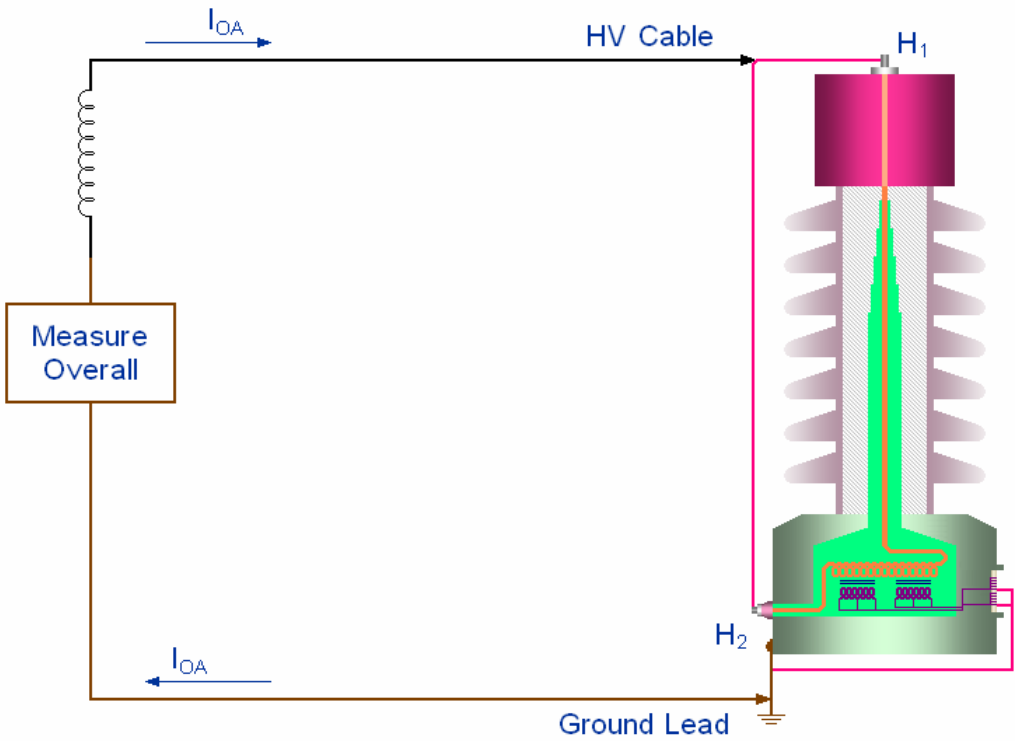
Routine procedure for voltage transformers, with accessible neutral terminal

Test	HV Cable	LV Leads Red	LV Leads Blue	Test Mode
1	H1, H2	-	-	GST Ground Red Blue
2	H1	H2	-	GST Guard Red Ground Blue
3	H2	H1	-	GST Guard Red Ground Blue
4	H1	H2	-	UST Measure Red Ground Blue
5	H2	H1	-	UST Measure Red Ground Blue

Tests 1, 2 and 3: power factor tests

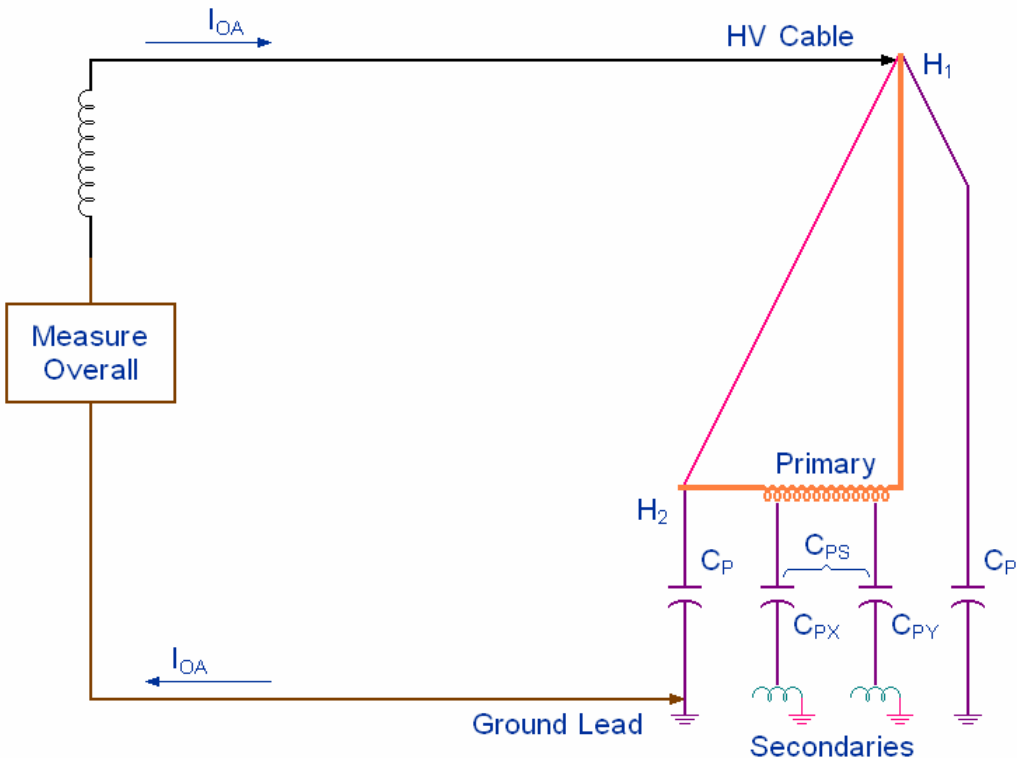
Tests 4 and 5: excitation current tests

Overall Test



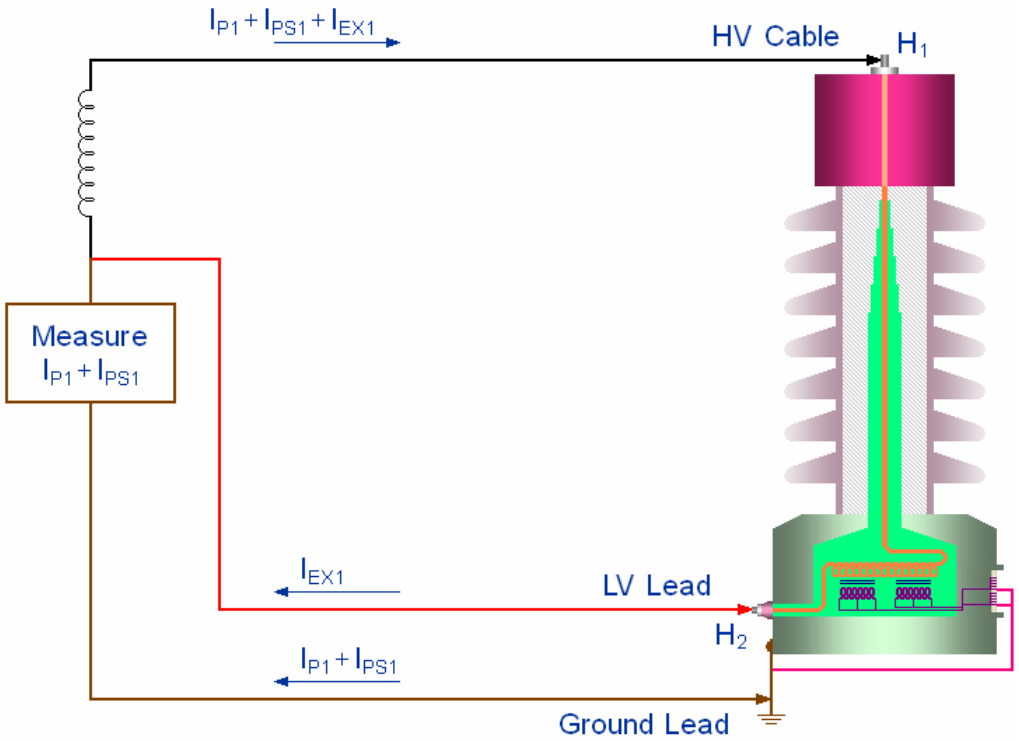
HV Cable	LV Leads Red	LV Leads Blue	Test Mode
H1,H2	-	-	GST Ground Red Blue

Overall Test Dielectric Circuit



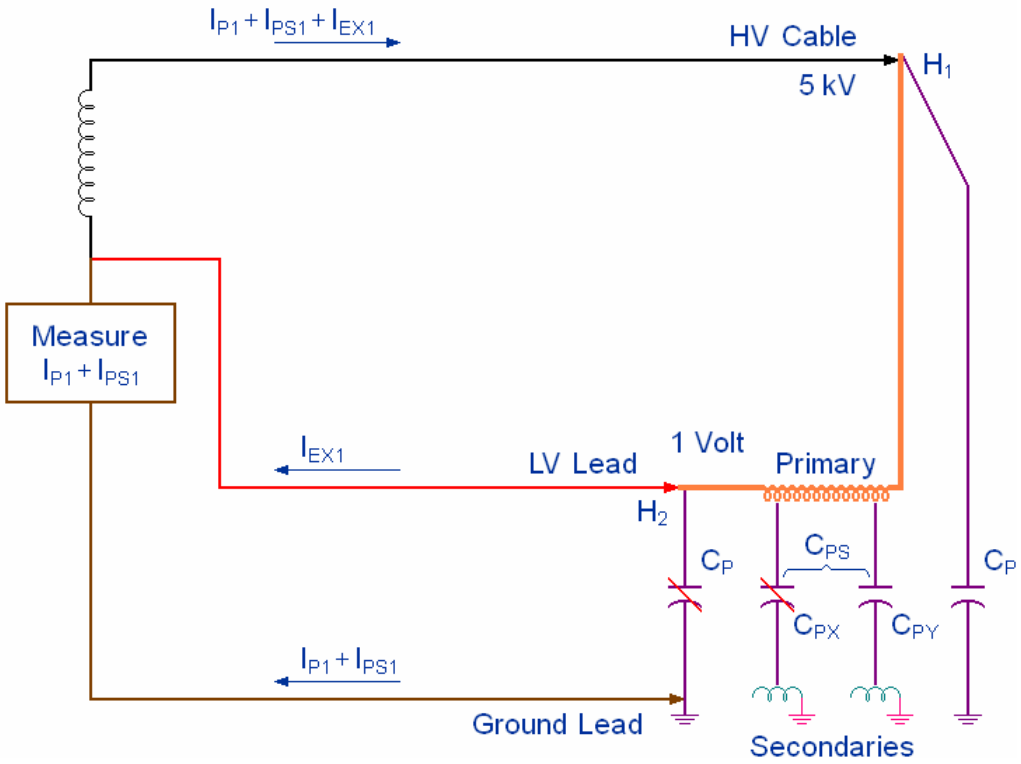
Measures $C_P + C_{PS}$

Cross-Check 1 Test



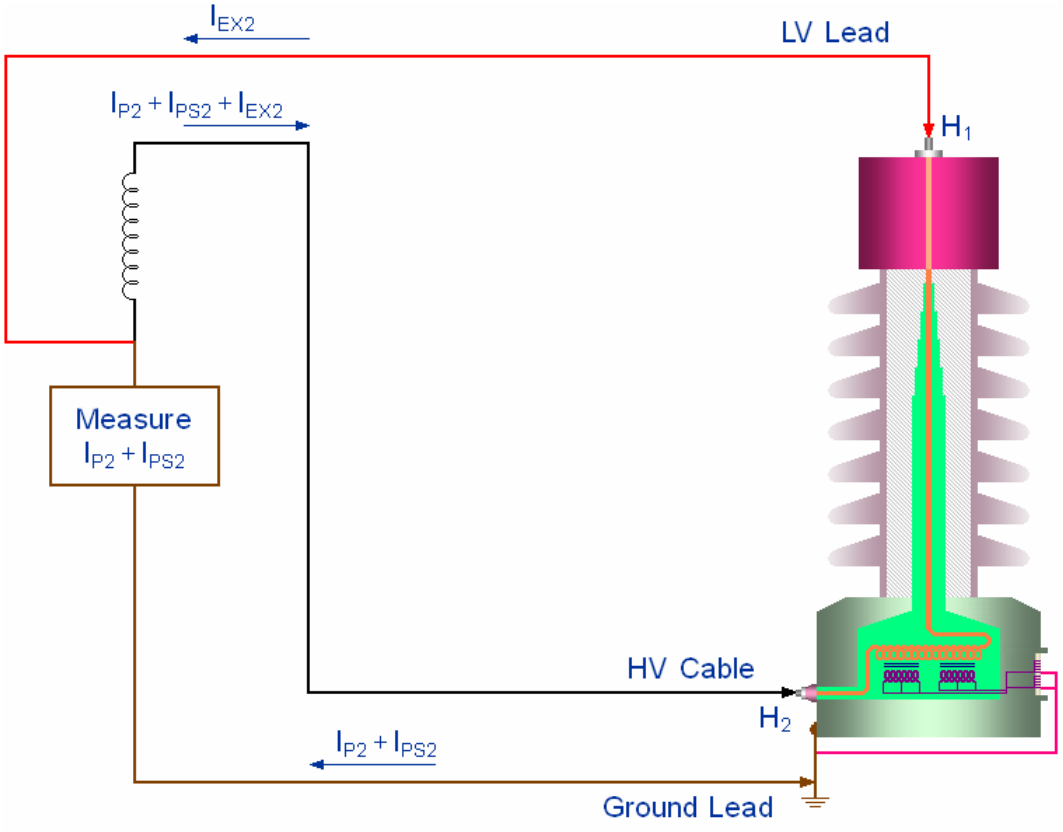
HV Cable	LV Leads		Test Mode
	Red	Blue	
H1	H2	-	GST Guard Red Ground Blue

Cross-Check 1 Dielectric Circuit



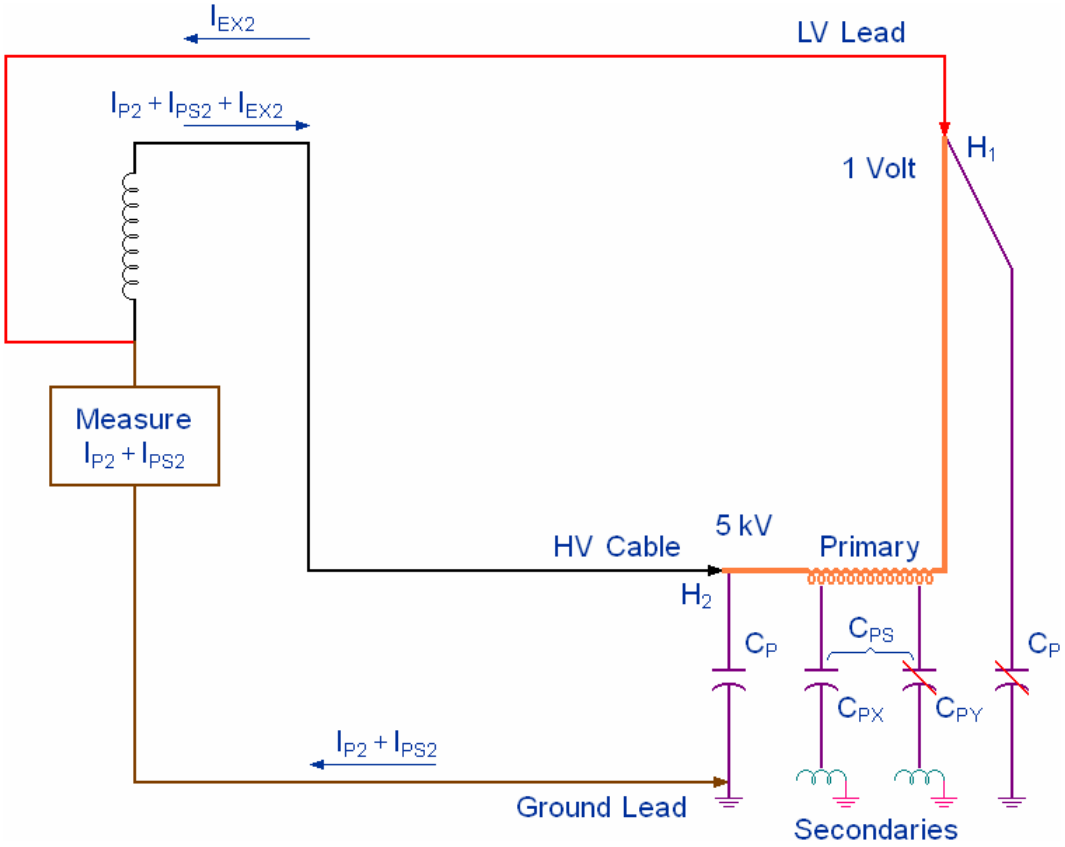
Measures $C_{P1} + C_{PS1}$ (isolates H_1 terminal insulation)

Cross-Check 2 Test



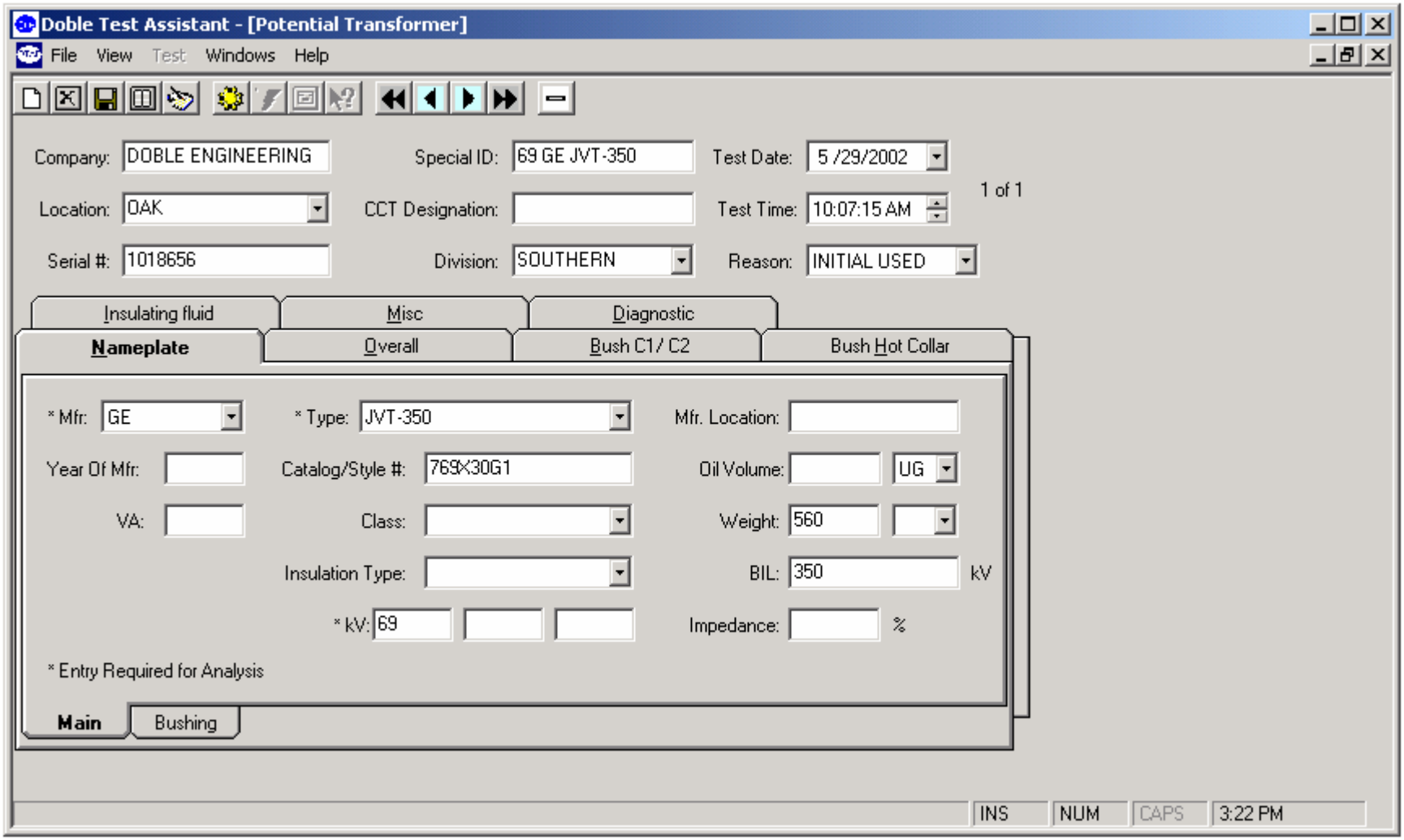
HV Cable	LV Leads Red	LV Leads Blue	Test Mode
H2	H1	-	GST Guard Red Ground Blue

Cross-Check 2 Dielectric Circuit

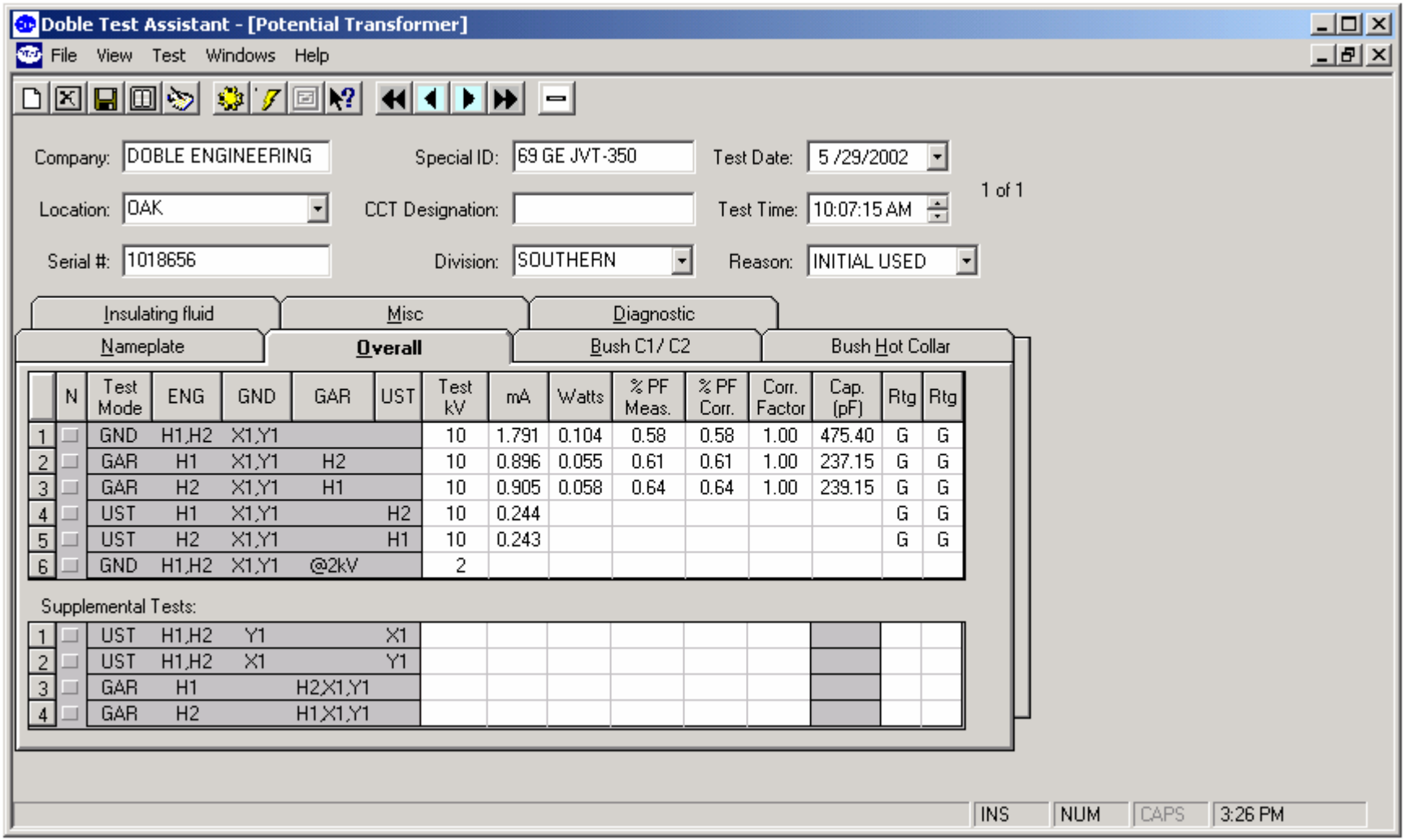


Measures $C_{P2} + C_{PS2}$ (isolates H_2 terminal insulation)

Case 1: DTA Nameplate Screen



Case 1: DTA Overall Test Screen



Overall Test Analysis

Power factor compared with:

- Initial test
  - purchase specification
  - manufacturer's specification
  - similar voltage transformers
  - Doble's typical results and database
- Later tests compared with initial test value

  Questionable results in later tests
  - manufacturer's specification
  - Doble's typical results and database

Overall Test Analysis

General guidelines:

- Power factor »
  - modern oil-impregnated paper-insulated voltage transformers

    less than 1.0 % at 20°C
  - SF_6 insulated voltage transformers

    less than 1.0 % at test temperature
  - voltage transformers with other insulations

    refer to Doble's typical results and database

Tabulated Overall Test Results

Mfr.	Type	Rated System kV	* Design	No. of Units Tested	Percent Power Factor at 20°C or Test Temperature									
					0.00 to 0.29	0.30 to 0.49	0.50 to 0.69	0.70 to 0.89	0.90 to 1.09	1.10 to 1.99	2.00 to 2.99	3.00 to 3.99	4.00 to 4.99	5.00 to 5.99
GE	EW-650	138	O	145	8	32	42	32	11	14	6			
	-750	161	O	31	3	9	7	6	6					
	-900	230	O	95	2	21	43	14	7	8				
	-1050	345	O	23	4	5	5	5	4					
	-1175	345	O	44		10	9	12	11	2				
	-1300	345	O	58	2	5	23	10	8	10				
	-1675	500	O	10		5	3	2						
	-1800	500	O	6		2	4							
	JVM-5	4.8	R	4			1	1	2					
		7.2	R	134	5	10	26	17	20	36	17	3		
		8.4	R	61			8	17	17	11	5	3		
		12	R	20			6	6	1	6	1			
		14.4	R	182		8	29	22	29	39	24	17	9	5
		18	R	6			1	5						
	JVS-150	25	R	127		17	18	24	37	27				
	-200	34.5	R	55		16	20	8	3	8	4			
	-250	46	R	16		3	7	6						
	-350	69	R	121	30	62	19	8	1	1				
	JVT-150	25	R	69		2	9	14	18	20	4	2		
	-200	34.5	R	175	5	47	60	21	16	16	9	1		
	-250	46	R	45	6	19	12	4	3	1				
	-350	69	R	50	8	25	9	6	1	1				

Cross-Check Analysis

- Power factors generally similar to Overall power factor.
- Assist in evaluating questionable Overall test results. Isolate localized condition to one end of primary winding versus a general condition.
- Sum of two cross-check currents should approximate overall current. Same is true for Watts (and capacitance). Unsatisfactory comparison could indicate an open circuit or high resistance connection.
- Line-to-line voltage transformers produce similar current, Watts and capacitance values. Line-to-neutral voltage transformers produce dissimilar current, Watts and capacitance values.

Case 2: Typical Results

Results measured for oil-filled line-to-neutral potential transformer

Test	Description	Test kV	Equiv. 10 kV I (mA)	Equiv. 10 kV Watts	% Power Factor Meas.	% Power Factor Corr.	Corr. Factor	Cap. (pF)
1	Overall	2	2.100	0.105	0.50	0.50	1.00	556.50
2	Cross-Check 1	10	0.400	0.020	0.50	0.50	1.00	106.00
3	Cross-Check 2	2	1.700	0.085	0.50	0.50	1.00	450.50
	Cross-Check Sum		2.100	0.105				556.50

Sum of Cross-Check currents approximate Overall current. Same is true for Watts (and capacitance).

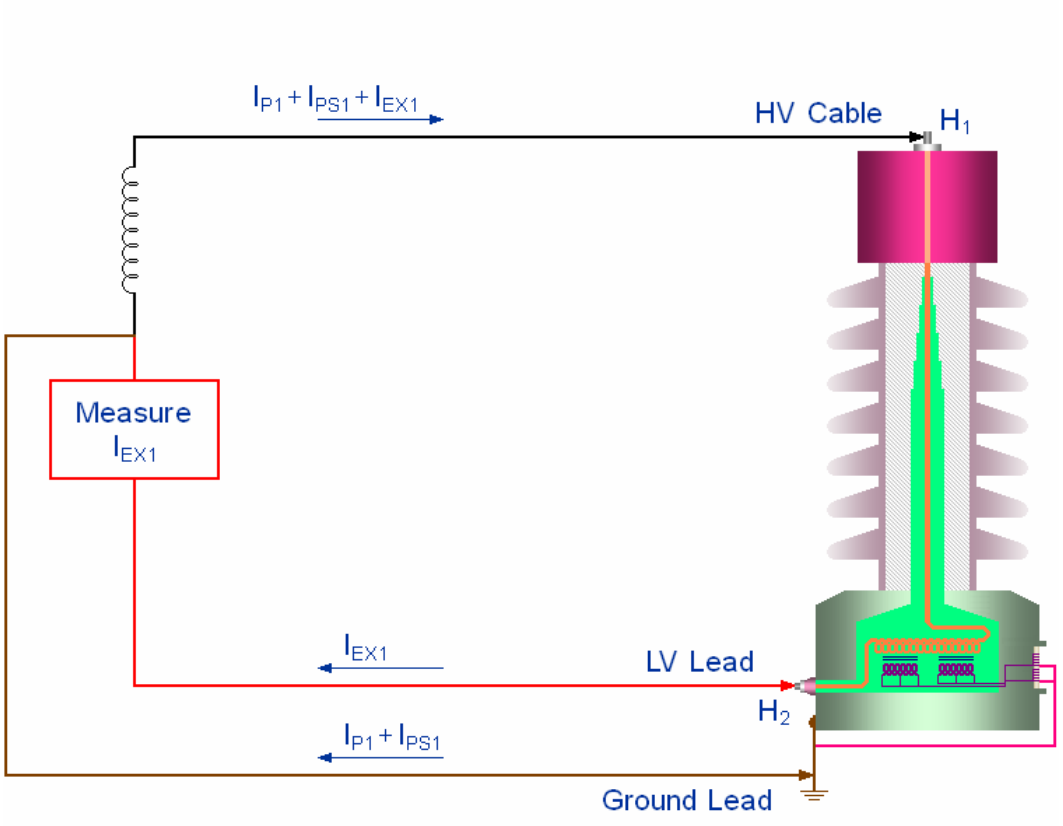
Line-to-neutral potential transformers measure dissimilar current, Watts and capacitance values.

Overall Test Analysis

Capacitance compared with:

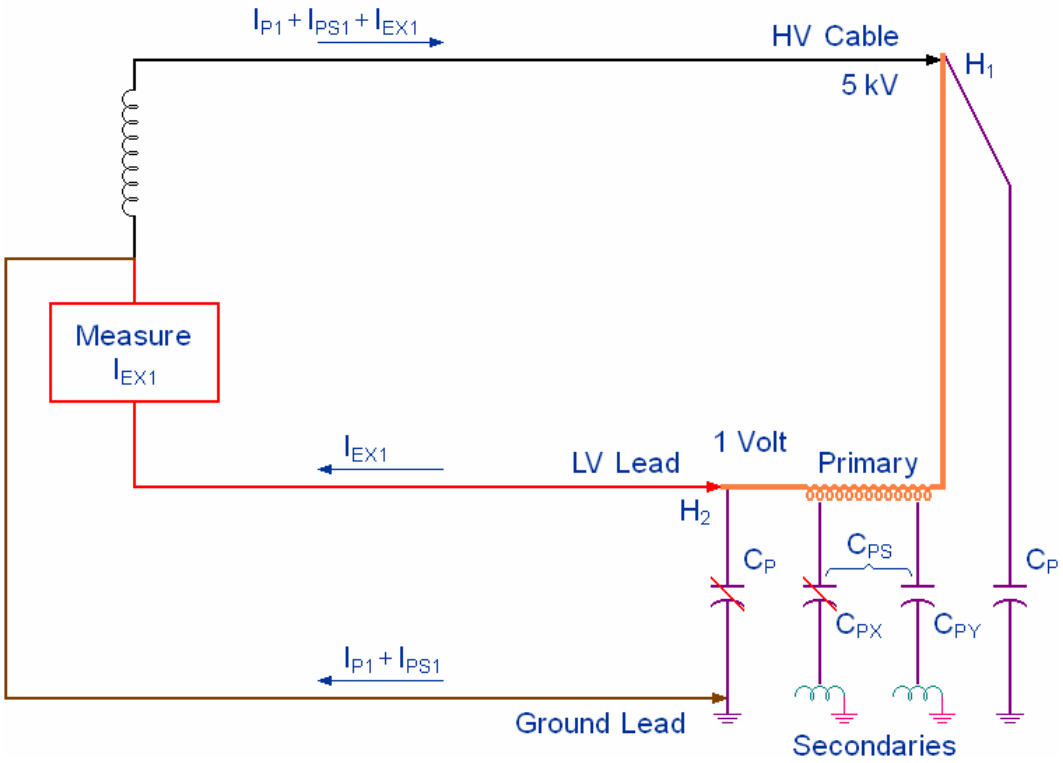
- Initial test
  - similar voltage transformers
  - Doble's database
- Later tests compared with initial test value (% diff.)
  - good — less than 5 %
  - deteriorated — from 5 % to less than 10 %
  - investigate — 10 % and higher

Excitation Current 1 Test



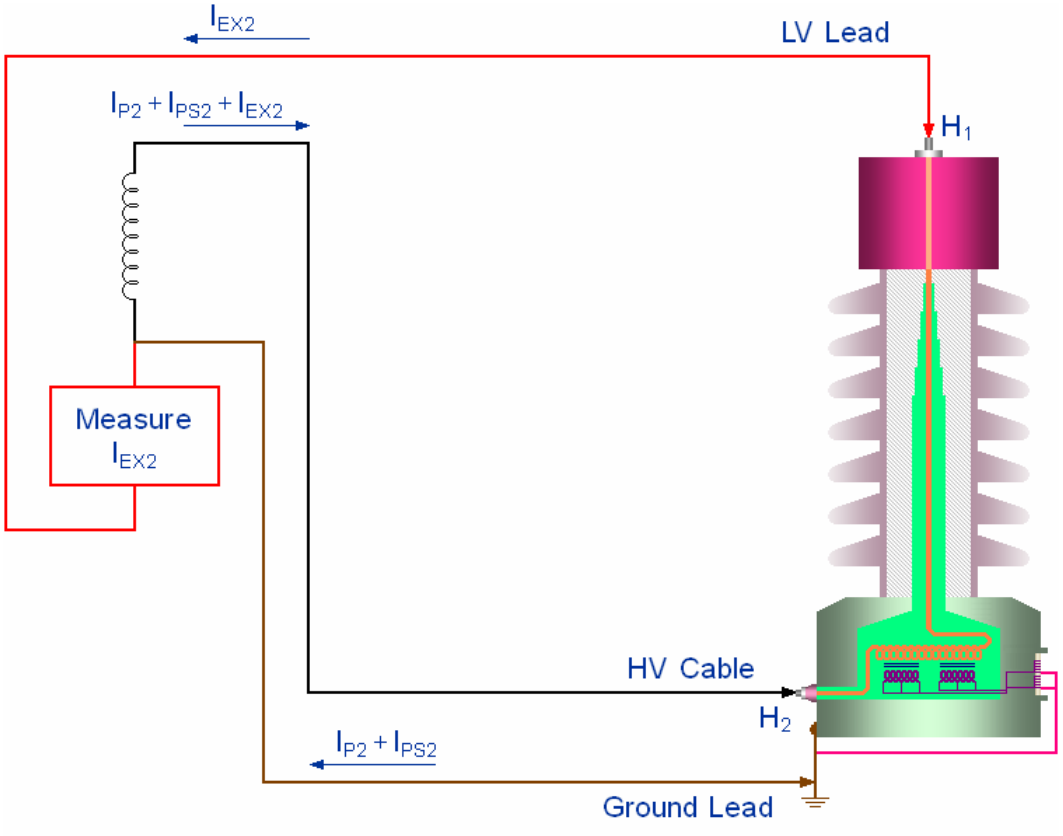
HV Cable	LV Leads		Test Mode
	Red	Blue	
H1	H2	-	UST Measure Red Ground Blue

Excitation Current 1 Diel. Circuit



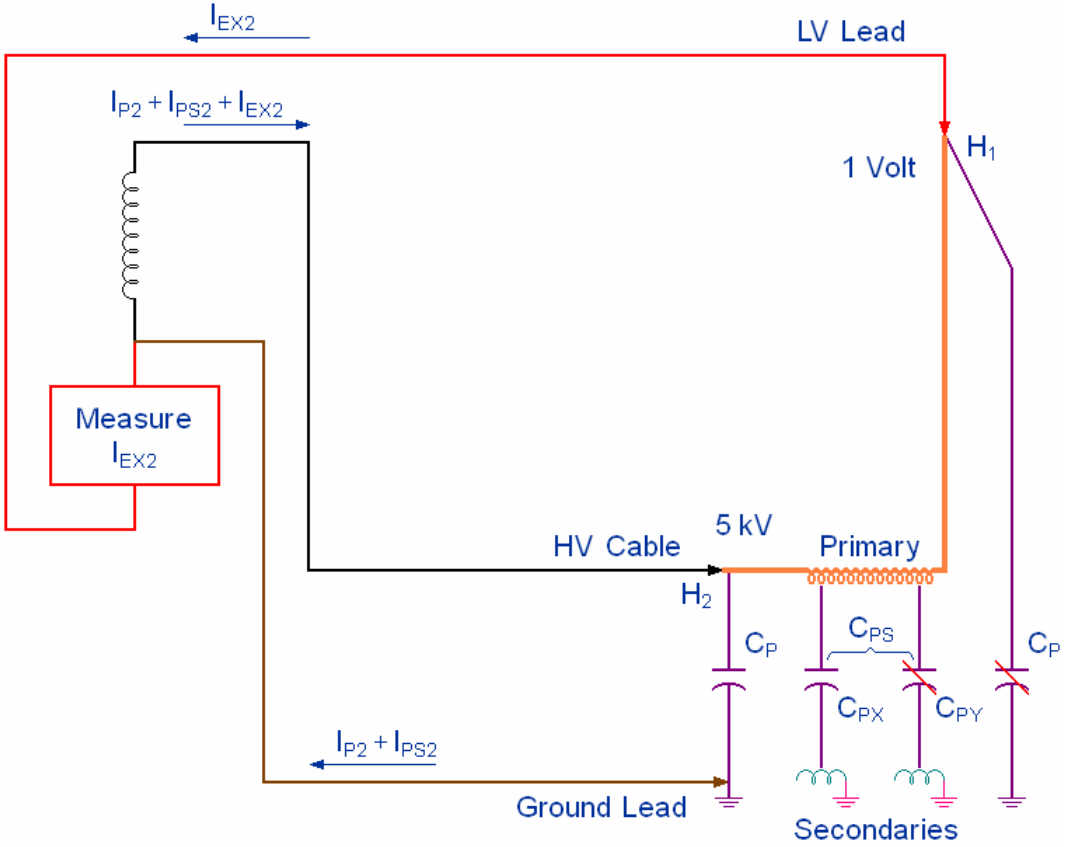
Checks turn insulation integrity and continuity of primary conductor

Excitation Current 2 Test



HV Cable	LV Leads		Test Mode
	Red	Blue	
H2	H1	-	UST Measure Red Ground Blue

Excitation Current 2 Diel. Circuit



Checks turn insulation integrity and continuity of primary conductor in reverse direction

Excitation Current Analysis

- Initial test compared with:
  - current in reverse direction (within 10 %)

    requires normal and reverse tests at same voltage
  - similar metering units
  - Doble's database
- Later tests compared with initial test values

Diagnostic Tests

Perform when questionable results are measured for routine tests. Questionable results include high, abnormally low or negative power factor. Also, high or low capacitance.

Diagnostic tests include:

- Hot-Collar test

  detects localized condition and monitors surface losses

- Test at several voltages (power factor tip-up)

  detects voltage sensitive condition, e.g. carbonized path

Diagnostic Tests

- Primary to secondary winding tests »
  checks interwinding insulation
- Insulating fluid tests
  - mineral oil
    - physical, chemical and electrical properties
    - dissolved gases and metals
  - SF6 gas
    - moisture and purity
    - acidity and arc by-products

Don't Open a Voltage Transformer with Negative Pressure

Diagnostic Tests

Perform when questionable results are measured for routine tests.

Isolate all secondary windings from ground for these diagnostic tests.

	HV	LV Leads			
Test	Cable	Red	Blue	Test Mode	Measure
6	H1,H2	X3	*Y3	UST Measure Red Ground Blue	CPX
7	H1,H2	Y3	*X3	UST Measure Red Ground Blue	CPY
8	H1	H2	**X3,Y3	GST Guard Red Blue	CP1
9	H2	H1	**X3,Y3	GST Guard Red Blue	CP2

*Some voltage transformers have less or more secondary windings. Test each primary to secondary path separately.

**Connect any one terminal of each secondary winding to guard.

Summary

Routine procedure for voltage transformers, with accessible neutral terminal

Test	HV Cable	LV Leads Red	LV Leads Blue	Test Mode
1	H1, H2		-	GST Ground Red Blue
2	H1	H2	-	GST Guard Red Ground Blue
3	H2	H1	-	GST Guard Red Ground Blue
4	H1	H2	-	UST Measure Red Ground Blue
5	H2	H1	-	UST Measure Red Ground Blue

Tests 1, 2 and 3: power factor tests

Tests 4 and 5: excitation current tests

Safety Comments

Before placing a voltage transformer in operation:

- One terminal of each secondary winding must always be grounded, either directly or through an interconnection. The electrostatic voltage coupled to a secondary winding may reach a dangerous and destructive value unless it's connected to ground.
- The reduced insulation neutral terminal of a graded insulation line-to-neutral voltage transformer must always be solidly grounded.
- Never short-circuit a voltage transformer secondary winding. This will produce very high current in this secondary winding and cause it to overheat and fail.

DTA Data Entry Requirements

- File saving

  location and serial number

- File merging

  location, serial number and *special identification

  *special identification field can be blank but it must be blank in both files

- Temperature correction

  kV rating, year of manufacture and ambient temperature

- Analysis of results

  manufacturer, type, insulation type and kV rating

DTA Data Entry Requirements

- Total functionality

  location, *special identification, manufacturer, serial number, year of manufacturer, type, insulation type, kV rating and ambient temperature

Case 3: Typical Results

Test	Description	Test kV	Equiv. 10 kV I (mA)	Watts	% Power Factor Meas.	Corr.	Corr. Factor	Cap. (pF)
1	Overall	5	3.775	0.134	0.35	0.39	1.11	1,000.38
2	Cross-Check 1	10	1.281	0.029	0.23	0.26	1.11	339.47
3	Cross-Check 2	5	2.429	0.105	0.43	0.48	1.11	643.69
	Cross-Check Sum		3.710	0.134				983.16
4	Excitation Current 1	5	0.197					
5	Excitation Current 2	5	0.205					
1	Overall	5	3.823	0.133	0.35	0.42	1.11	1,013.10
2	Cross-Check 1	10	1.324	0.031	0.23	0.27	1.11	350.86
3	Cross-Check 2	5	2.426	0.102	0.42	0.50	1.11	642.89
	Cross-Check Sum		3.750	0.133				993.75
4	Excitation Current 1	5	0.205					
5	Excitation Current 2	5	0.205					
1	Overall	5	3.724	0.127	0.34	0.38	1.11	986.86
2	Cross-Check 1	10	1.275	0.028	0.22	0.24	1.11	337.88
3	Cross-Check 2	5	2.389	0.099	0.41	0.46	1.11	633.09
	Cross-Check Sum		3.664	0.127				970.97
4	Excitation Current 1	5	0.201					
5	Excitation Current 2	5	0.205					

Case 4: Winding Inductance Affect

Results measured without and with primary winding terminals connected together for Overall test.

Test	Description	Test kV	Equiv. 10 kV I (mA)	Equiv. 10 kV Watts	% Power Factor Meas.	% Power Factor Corr.	Corr. Factor	Cap. (pF)
1	Overall	5	1.323	1.744	13.18	14.63	1.11	350.60
2	Cross-Check 1	10	1.275	0.029	0.23	0.26	1.11	337.88
3	Cross-Check 2	5	2.393	0.101	0.42	0.47	1.11	634.15
	Cross-Check Sum		3.668	0.130				972.03
1	Overall	5	3.775	0.134	0.35	0.39	1.11	1,000.38
2	Cross-Check 1	10	1.281	0.029	0.23	0.26	1.11	339.47
3	Cross-Check 2	5	2.429	0.105	0.43	0.48	1.11	643.69
	Cross-Check Sum		3.710	0.134				983.16

Connecting H1 and H2 terminals together for Overall test eliminates winding inductance effect.

Trench 115 kV oil-filled line-to-neutral potential transformer, Catalog No. UT5-550-115

Inaccessible Neutral Terminal

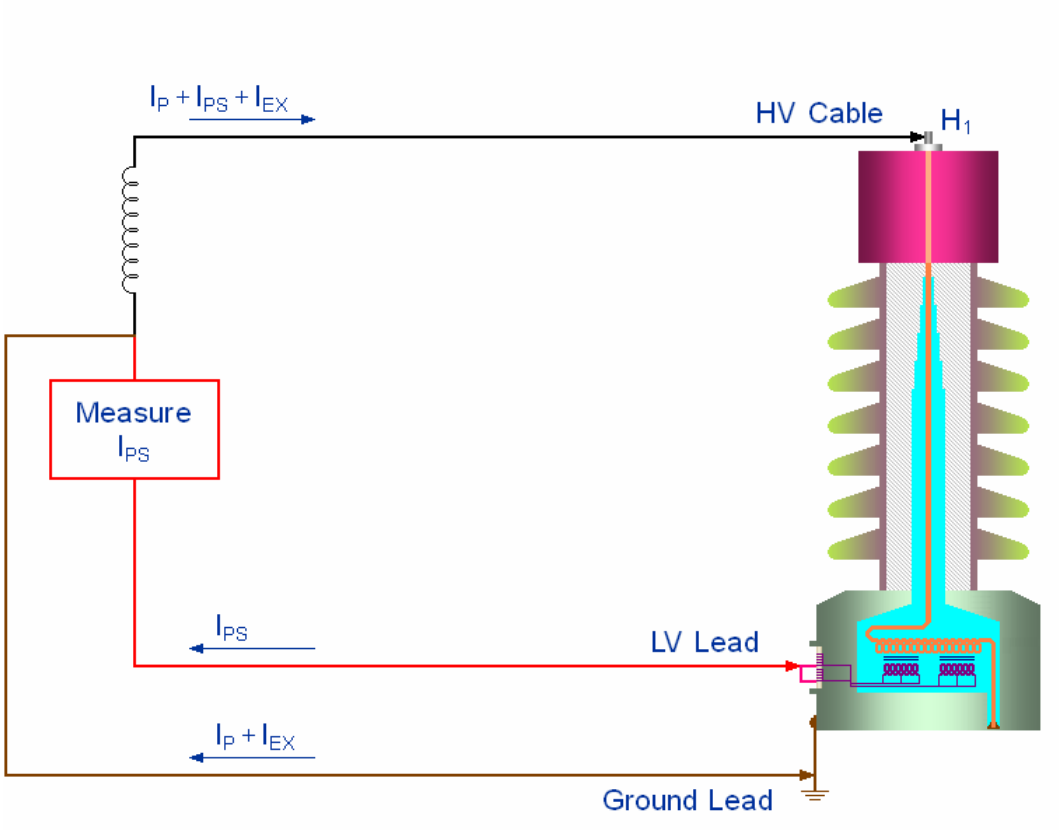
Routine procedure for voltage transformers with inaccessible neutral terminal

	HV	LV Leads		
Test	Cable	Red	Blue	Test Mode
1	H1	X3,Y3	-	UST Measure Red Ground Blue
2	H1	X3,Y3	-	GST Guard Red Ground Blue

Test 1: power factor test

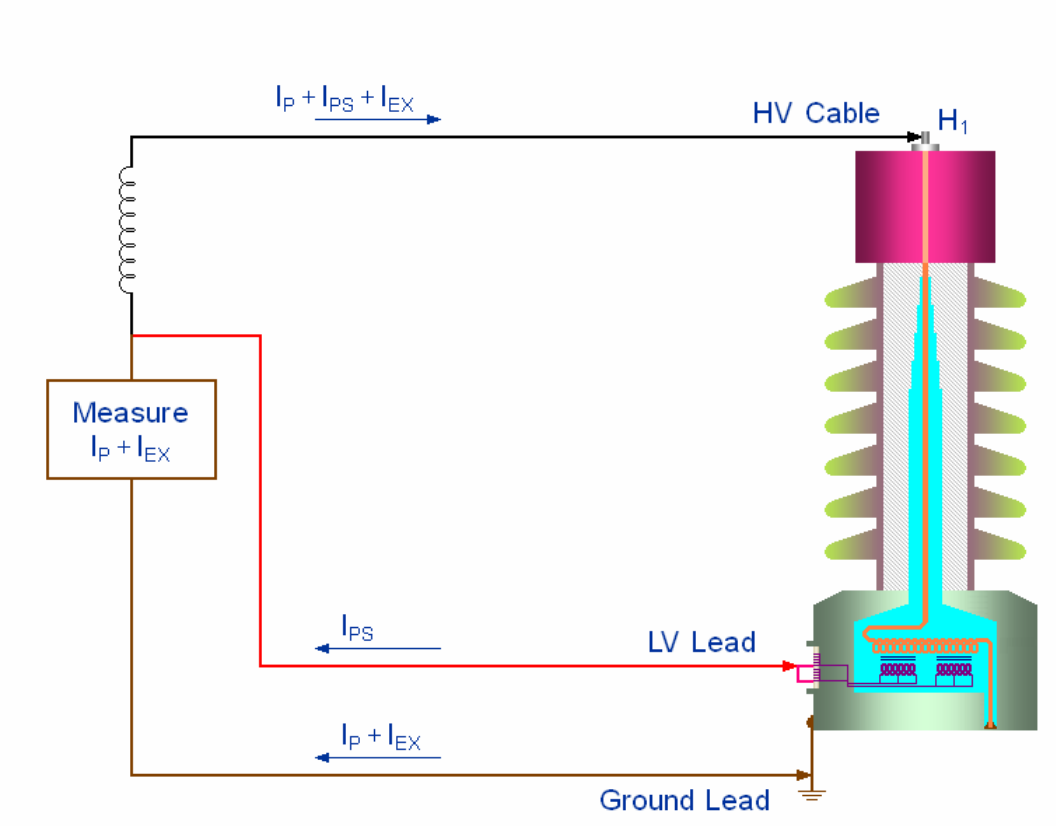
Test 2: excitation current test

Power Factor Test



HV Cable	LV Leads		Test Mode
	Red	Blue	
H1	X3,Y3	-	UST Measure Red Ground Blue

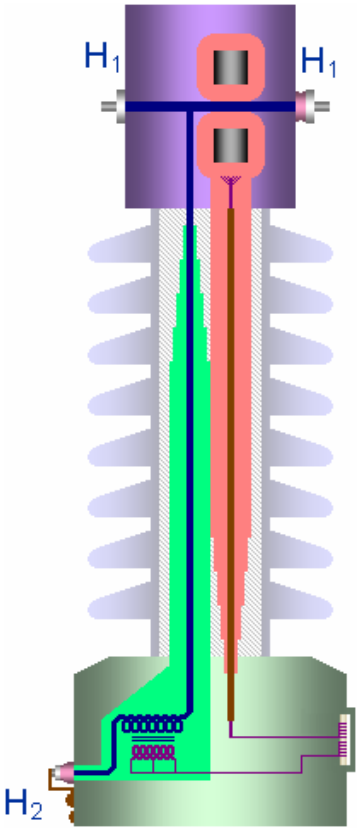
Excitation Current Test



HV Cable	LV Leads		Test Mode
	Red	Blue	
H1	X3,Y3	-	GST Guard Red Ground Blue

Single-Phase Metering Units

Single-Phase Metering Unit



Includes current and voltage elements

Test Procedure

Routine procedure for single-phase metering units

Test	HV Cable	LV Leads Red	LV Leads Blue	Test Mode
1	H1, H2		-	GST Ground Red Blue
2	H1	H2	-	GST Guard Red Ground Blue
3	H2	H1	-	GST Guard Red Ground Blue
4	H1	H2	-	UST Measure Red Ground Blue
5	H2	H1	-	UST Measure Red Ground Blue

Tests 1, 2 and 3: power factor tests

Tests 4 and 5: excitation current tests

Test Policies

Necessary to address specific aspects of testing, to include:

- Applied test voltage »

  same voltage as for potential transformers

Applied Test Voltage

Line-to-Line Metering Units

System kV Rating	Test Voltage, kV
15 and higher	10

Below 15 kV, test at L-N voltage, to the nearest 500 Volts. Line-to-neutral (L-N) voltage is system voltage divided by 1.73. Do not exceed 125 % L-N voltage rating.

Applied Test Voltage

Liquid-Filled and Gas-Filled, Line-to-Neutral Metering Units

Neutral Terminal

System kV Rating	Test Voltage, kV
92 and higher	5
below 92	2

Line Terminals

System kV Rating	Test Voltage, kV
15 and higher	10

Below 15 kV, test at L-N voltage, to the nearest 500 Volts. Line-to-neutral (L-N) voltage is system voltage divided by 1.73. Do not exceed 125 % L-N voltage rating.

Test Policies

- Winding inductance effect

  connect terminals of current and potential primary windings together for Overall Test

- Disposition of secondary windings
  - isolate secondary windings
  - ground one terminal of each secondary winding
- Temperature correction »

  correct power factor with ambient temperature

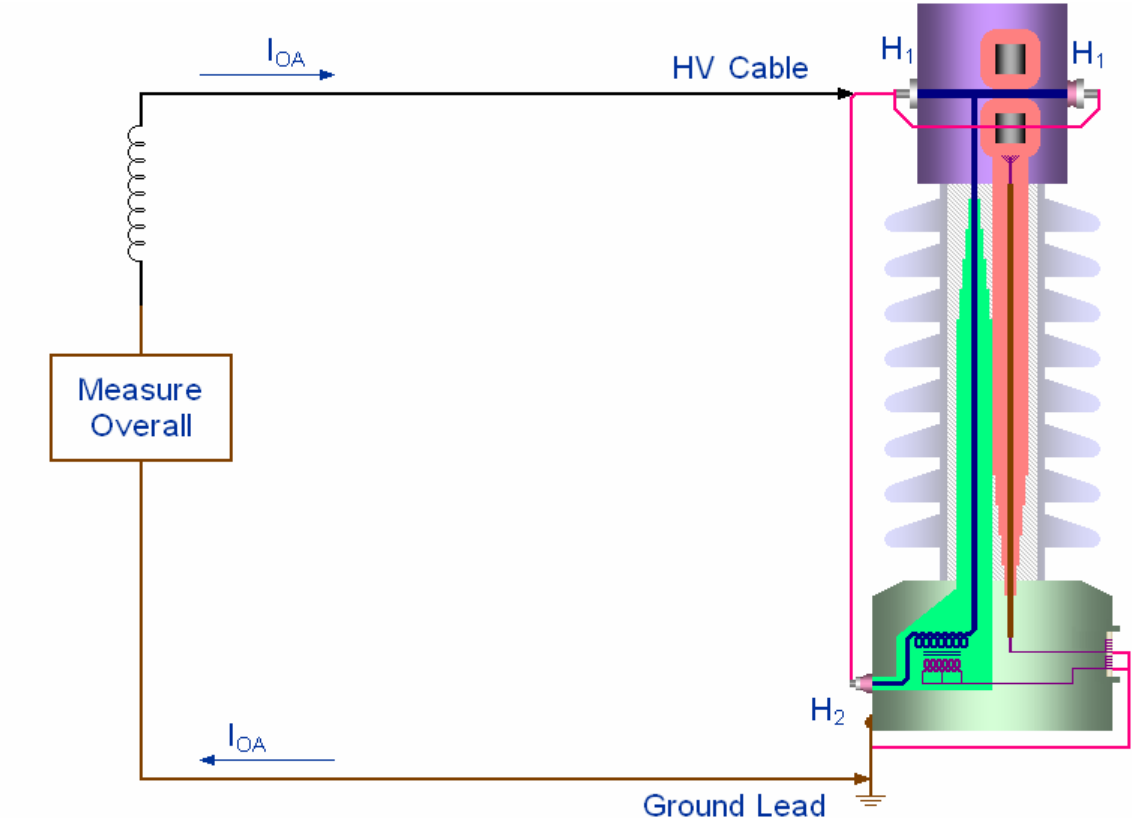
  M4000 instrument measures ambient temperature and relative humidity automatically

Temperature Correction

TABLE OF MULTIPLIERS FOR USE IN CONVERTING POWER FACTOR AT TEST TEMPERATURES TO POWER FACTORS AT 20°C

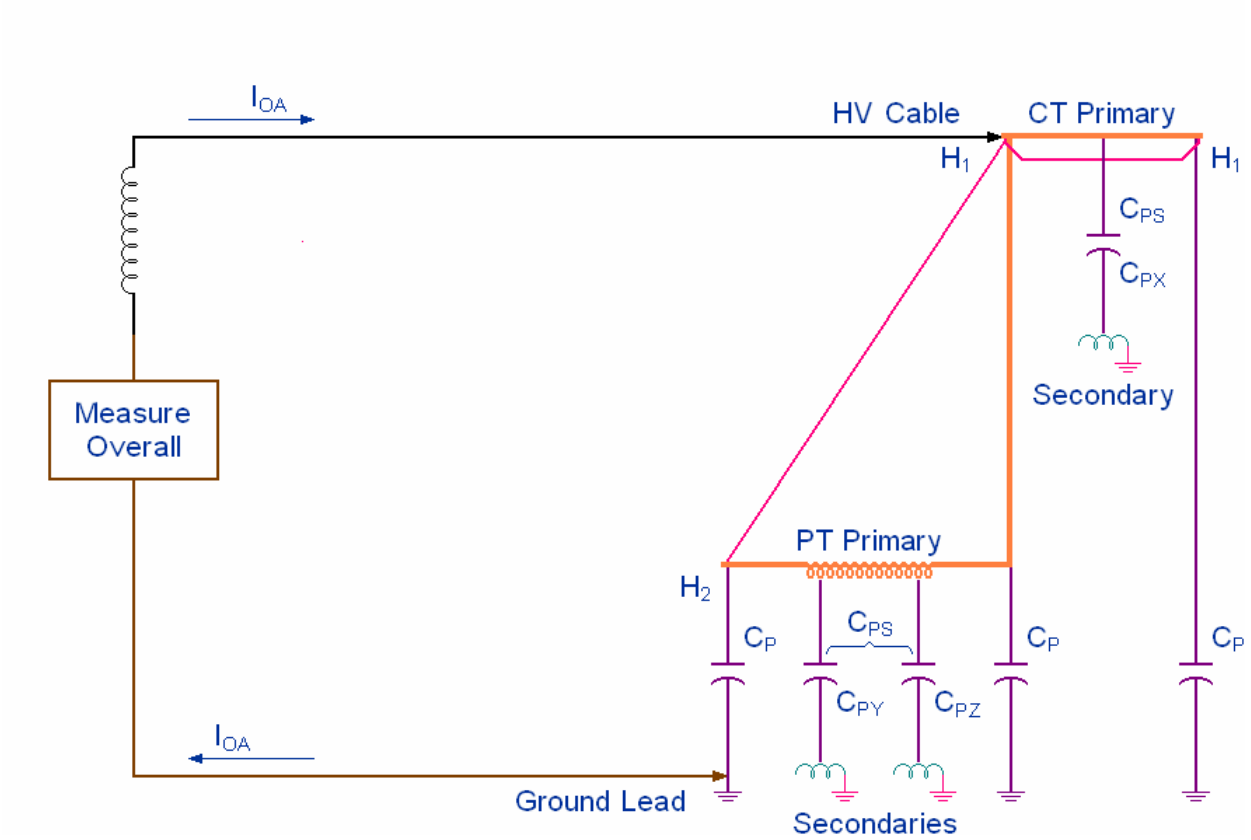
Test Temperature		Oil-Filled VTs, CTs and MUs	
		Modern	
°C	°F	rated 220 kV and above	All other
0	32.0	1.57	1.67
4	39.2	1.44	1.55
8	46.4	1.31	1.43
12	53.6	1.19	1.30
16	60.8	1.09	1.16
20	68.0	1.00	1.00
24	75.2	0.92	0.86
28	82.4	0.84	0.74
32	89.6	0.76	0.65
36	96.8	0.70	0.56
40	104.0	0.65	0.48
44	111.2	0.59	0.42
48	118.4	0.54	-
52	125.6	0.49	-
56	132.8	0.45	-
60	140.0	0.41	-

Overall Test



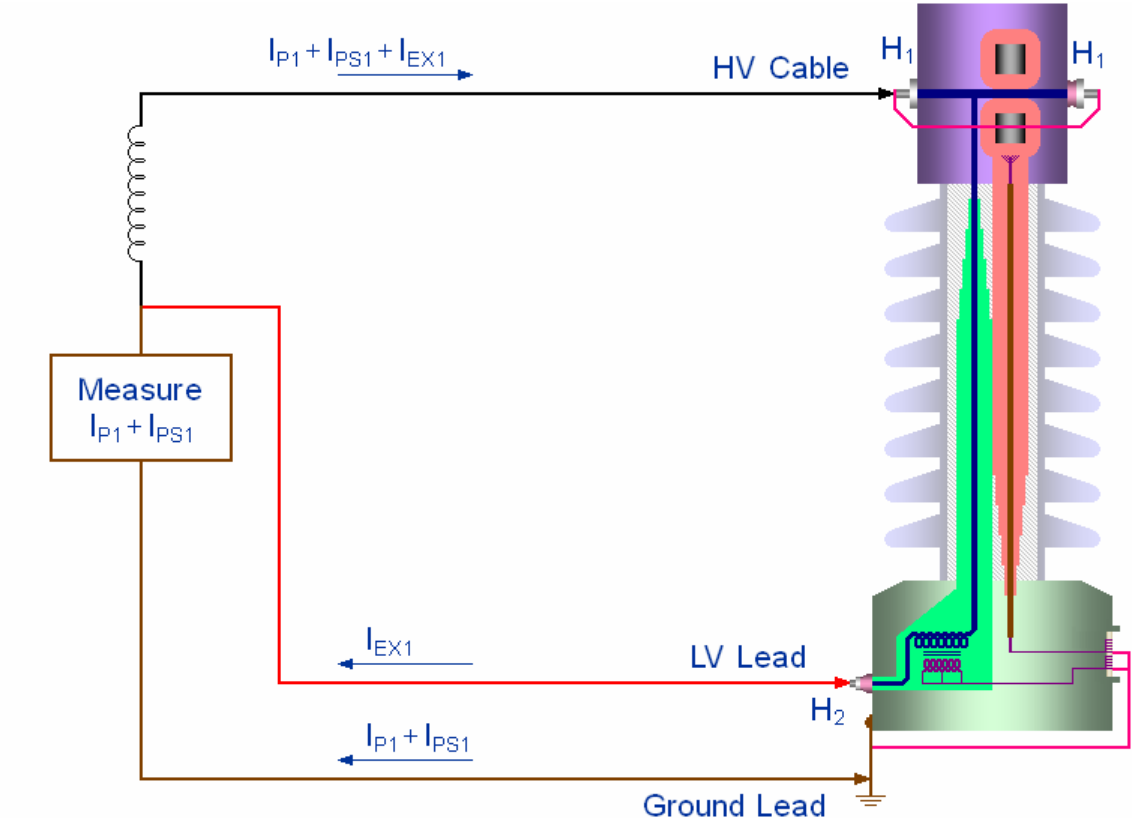
HV Cable	LV Leads Red	LV Leads Blue	Test Mode
H1,H2	-	-	GST Ground Red Blue

Overall Test Dielectric Circuit



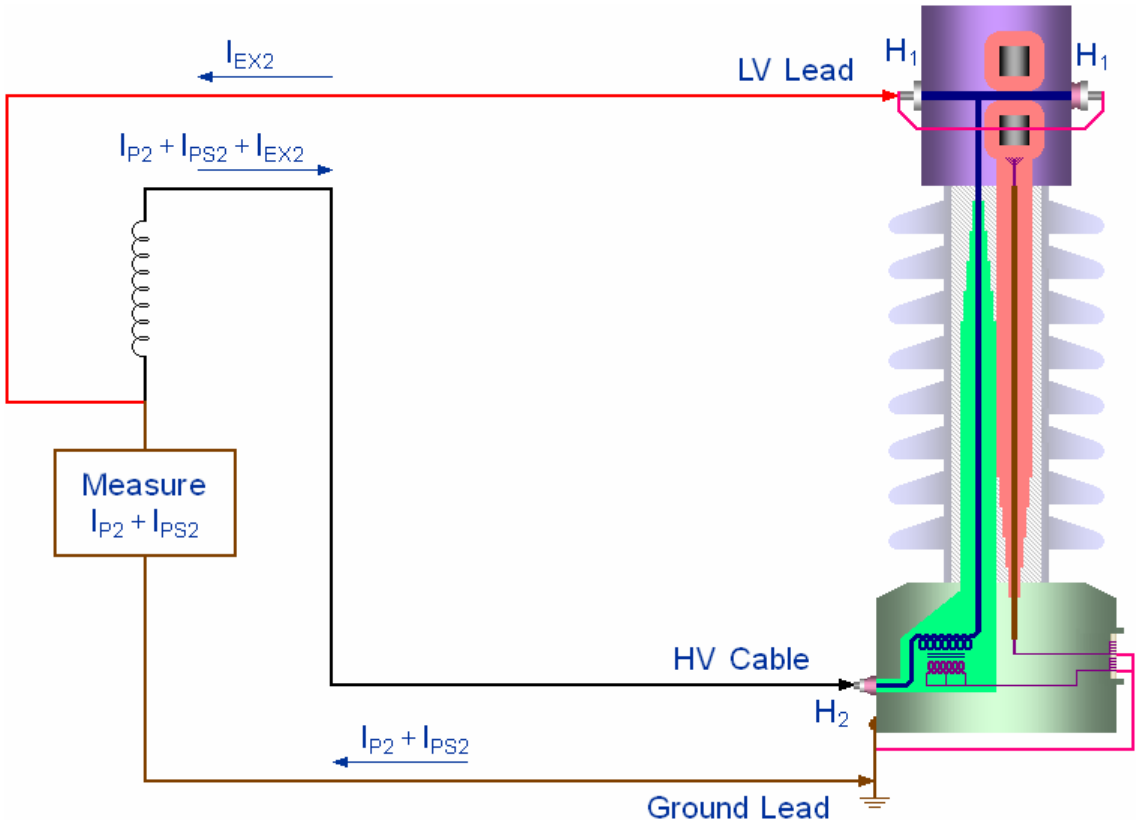
Measures $C_P + C_{PS}$

Cross-Check 1 Test



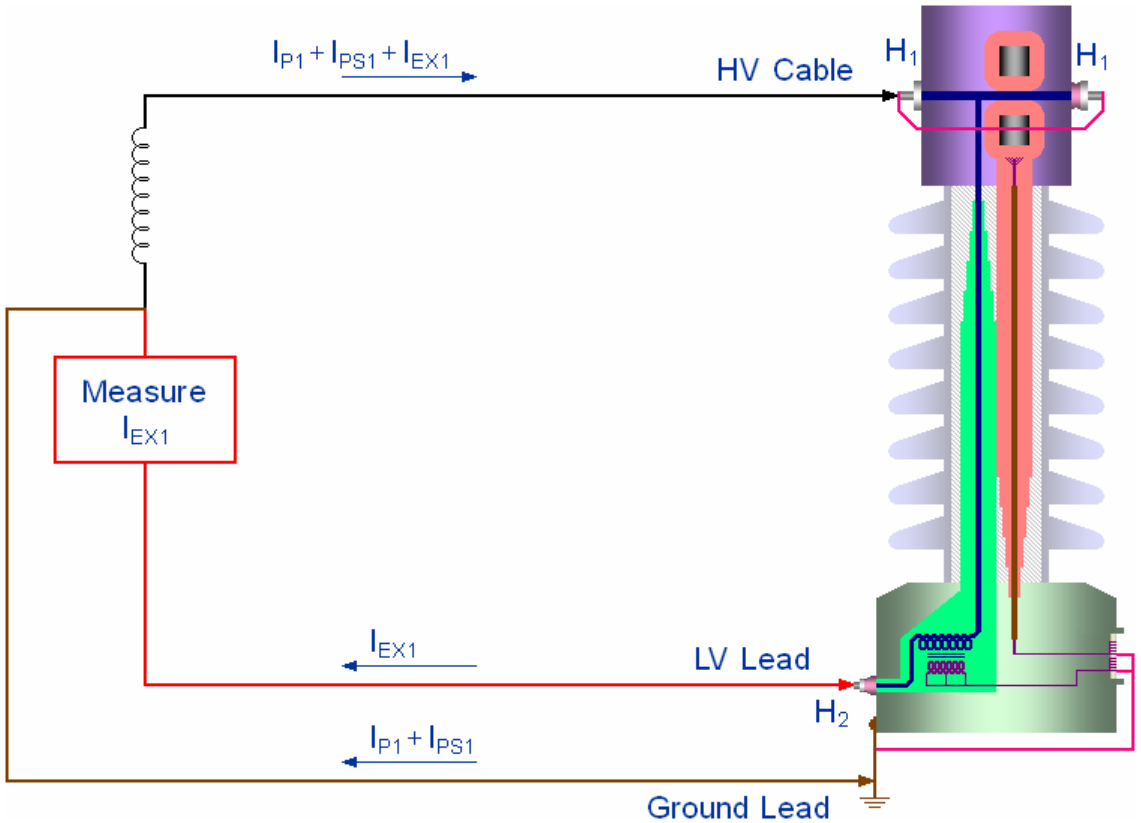
HV Cable	LV Leads		Test Mode
	Red	Blue	
H1	H2	-	GST Guard Red Ground Blue

Cross-Check 2 Test



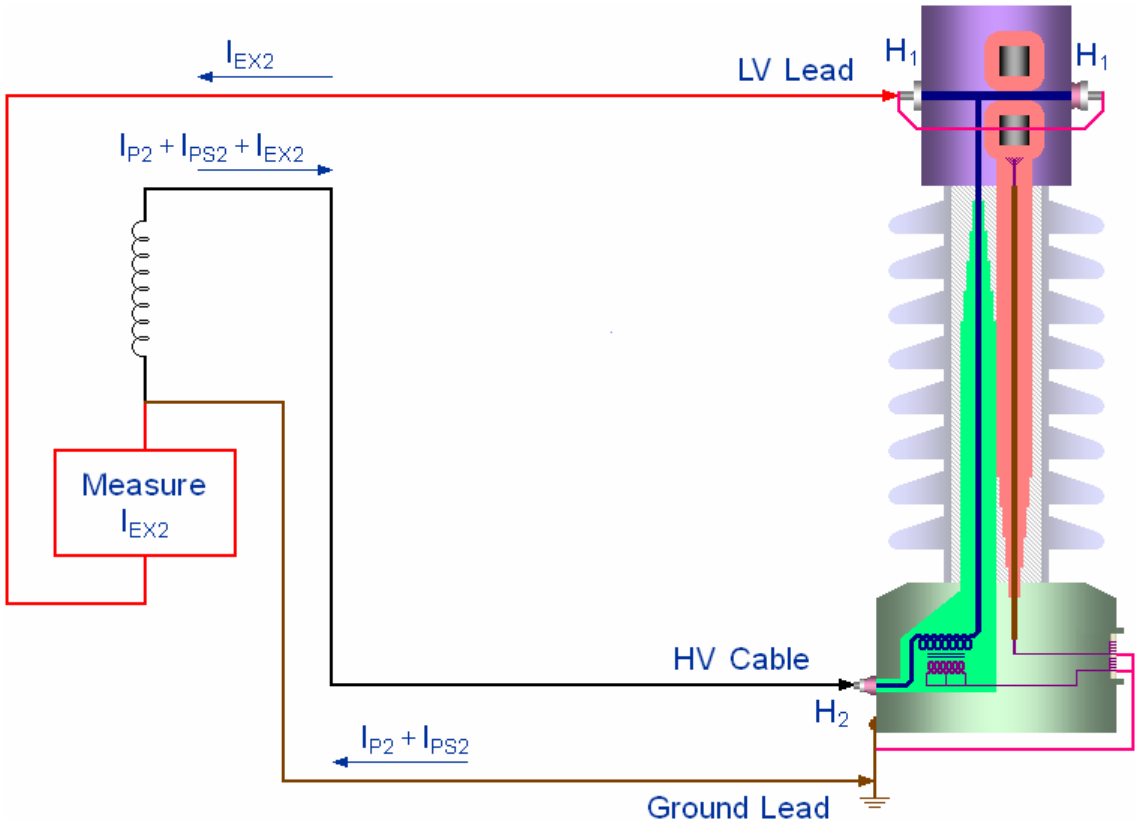
HV Cable	LV Leads Red	LV Leads Blue	Test Mode
H2	H1	-	GST Guard Red Ground Blue

Excitation Current 1 Test



HV Cable	LV Leads		Test Mode
	Red	Blue	
H1	H2	-	UST Measure Red Ground Blue

Excitation Current 2 Test



HV Cable	LV Leads		Test Mode
	Red	Blue	
H2	H1	-	UST Measure Red Ground Blue

Overall Test Analysis

Power factor compared with:

- Initial test
  - purchase specification
  - manufacturer's specification
  - similar metering units
  - Doble's typical results and database
- Later tests compared with initial test value

  Questionable results in later tests
  - manufacturer's specification
  - Doble's typical results and database

Overall Test Analysis

General guidelines:

- Power factor »
  - modern oil-impregnated paper-insulated metering units

    less than 1.0 % at 20°C
  - SF_6 insulated metering units

    less than 1.0 % at test temperature
  - older metering units

    refer to Doble's database and typical results

Tabulated Overall Test Results

Mfr.	Type	Rated System kV	* Design	No. of Units Tested	Percent Power Factor at 20°C or Test Temperature									
					0.00 to 0.29	0.30 to 0.49	0.50 to 0.69	0.70 to 0.89	0.90 to 1.09	1.10 to 1.99	2.00 to 2.99	3.00 to 3.99	4.00 to 4.99	5.00 to 5.99
A-C	PCW	7.6	O	7		2			1	2	1	1		
		14.4	O	13					2	1	2	8		
		24	O	4								4		
		34.5	O	26		8	2	2	3	4	4	2		
		46	O	8		3	1		1	2		1		
GE	KFE	13.8	O	8					1	1	3	1		2
		24	O	125			4	6	71	6	13	18	5	2
		34.5	O	104		4	8	18	29	12	19	14		
		46	O	2					1	1				
		69	O	53		1	8	7	9	4	15	9		
West	MP-8.7	8.4	O	5			1			1	3			
	-15	14.4	O	13			3	2	1	4	3			
	-25	24	O	23		5	3		1	2	5	4	1	2
	-34.5	34.5	O	9		1	5	2	1					
	-46	46	O	9		4	3		2					
	-69	69	O	13		8	2	3						
	-115	115	O	16		5	5	6						
	-138	138	O	2				2						

Cross-Check Analysis

- Power factors generally similar to Overall power factor.
- Assist in evaluating questionable Overall test results. Isolate localized condition to one end of primary winding versus a general condition.
- Sum of two cross-check currents should approximate overall current. Same is true for Watts (and capacitance). Unsatisfactory comparison could indicate an open circuit or high resistance connection.
- Line-to-neutral metering units produce dissimilar current, Watts and capacitance values.

Overall Test Analysis

Capacitance compared with:

- Initial test
  - similar metering units
  - Doble's database
- Later tests compared with initial test value (% diff.)
  - good — less than 5 %
  - deteriorated — from 5 % to less than 10 %
  - investigate — 10 % and higher

Excitation Current Analysis

- Initial test, compared with:
  - current in reverse direction (within 10 %)

    requires normal and reverse tests at same voltage
  - similar metering units
  - Doble's database
- Later tests compared with initial test values

Diagnostic Tests

Perform when questionable results are measured for routine tests. Questionable results include high, abnormally low or negative power factor. Also, low or high capacitance.

Diagnostic tests include:

- Hot-Collar test

  detects localized condition and monitors surface losses

- Test at several voltages (power factor tip-up)

  detects voltage sensitive condition, e.g. carbonized path

Diagnostic Tests

- Primary to secondary winding tests »
  checks interwinding insulation
- Insulating fluid tests
  - mineral oil
    - physical, chemical and electrical properties
    - dissolved gases and metals
  - SF6 gas
    - moisture and purity
    - acidity and arc by-products

Don’t Open a Metering Unit with Negative Pressure

Diagnostic Tests

Perform when questionable results are measured for routine tests.

Isolate all secondary windings from ground for these diagnostic tests.

	HV	LV Leads			
Test	Cable	Red	Blue	Test Mode	Measure
6	H1,H2	X3	*Y3,Z3	UST Measure Red Ground Blue	CPX
7	H1,H2	Y3	*Z3,X3	UST Measure Red Ground Blue	CPY
8	H1,H2	Z3	*X3,Y3	UST Measure Red Ground Blue	CPZ
9	H1	H2	**X3,Y3,Z3	GST Guard Red Blue	CP1
10	H2	H1	**X3,Y3,Z3	GST Guard Red Blue	CP2

*Some metering units have less or more secondary windings. Test each primary to secondary path separately.

**Connect any one terminal of each secondary winding to guard.

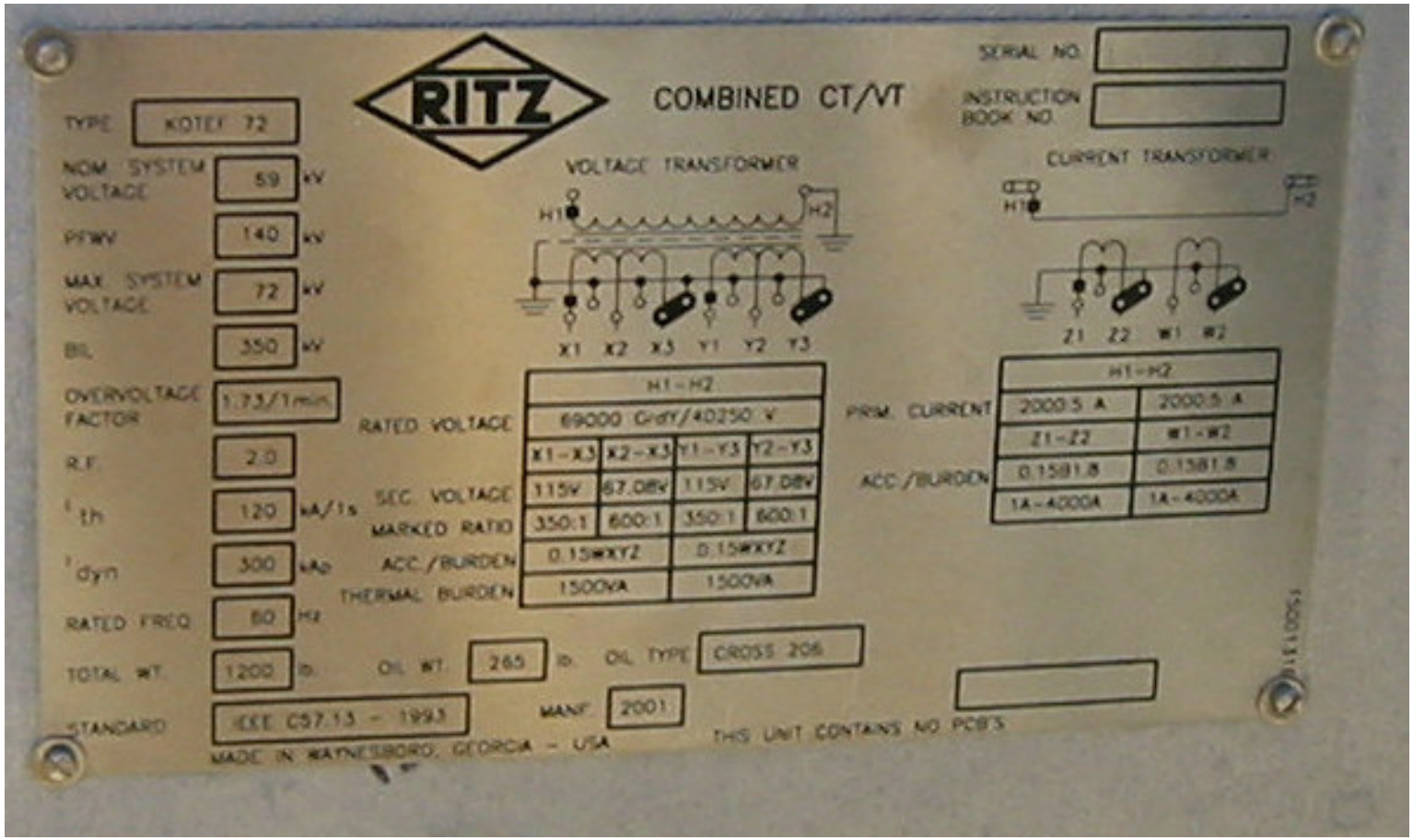
Safety Comments

Before placing a metering unit in operation:

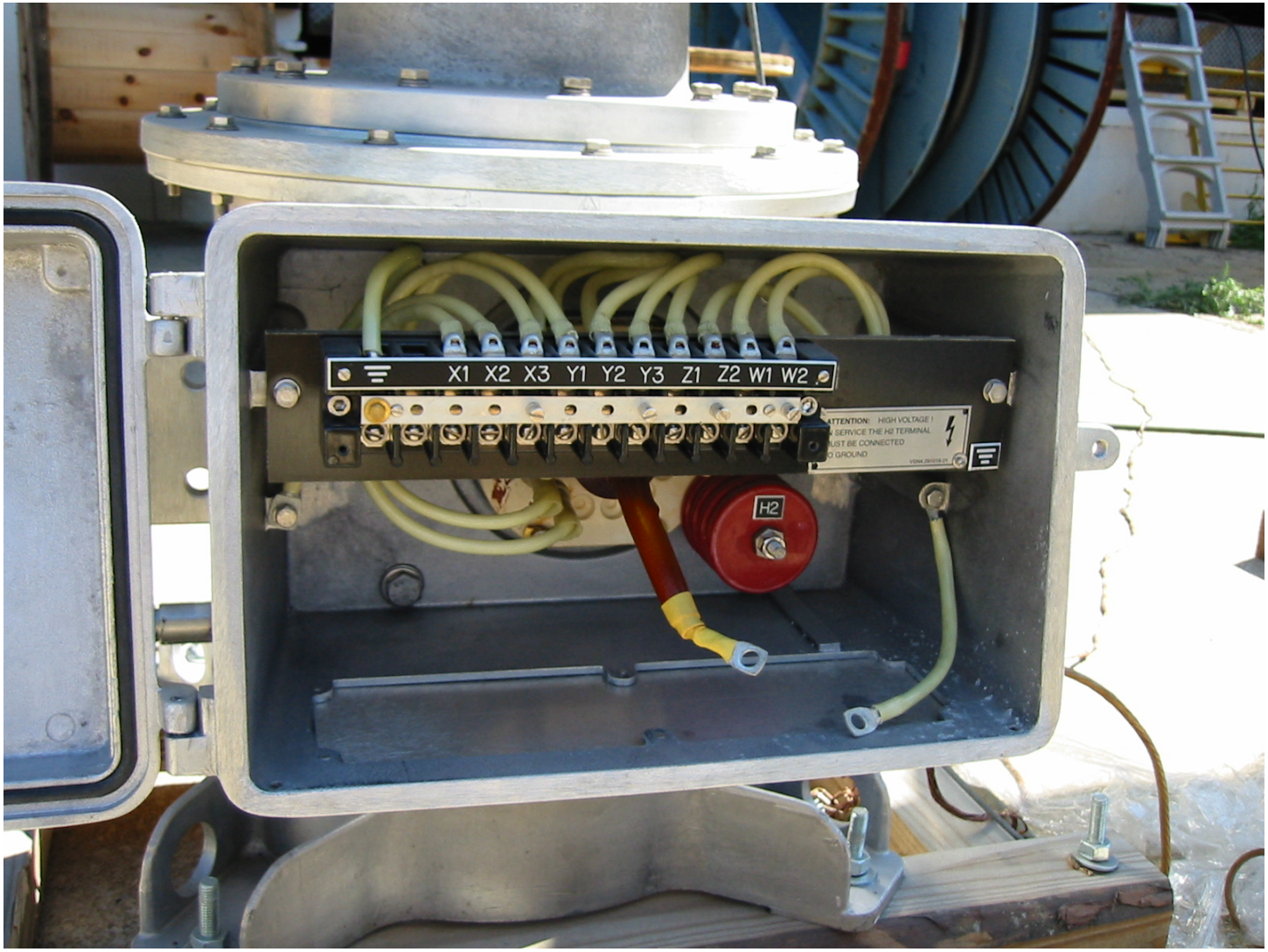
- One terminal of each secondary winding must always be grounded, either directly or through an interconnection.
- The reduced insulation neutral terminal of a graded insulation line-to-neutral voltage element must always be solidly grounded.
- Never short-circuit a voltage element secondary winding. This will produce very high current in this secondary winding and cause it to overheat and fail.
- Never open-circuit a current element secondary winding. This will produce very high voltage on this secondary winding and cause it to fail.

Metering Units

Ritz Type KOTEF 72.5 kV Meter Unit



Ritz Type KOTEF 72.5 kV Meter Unit



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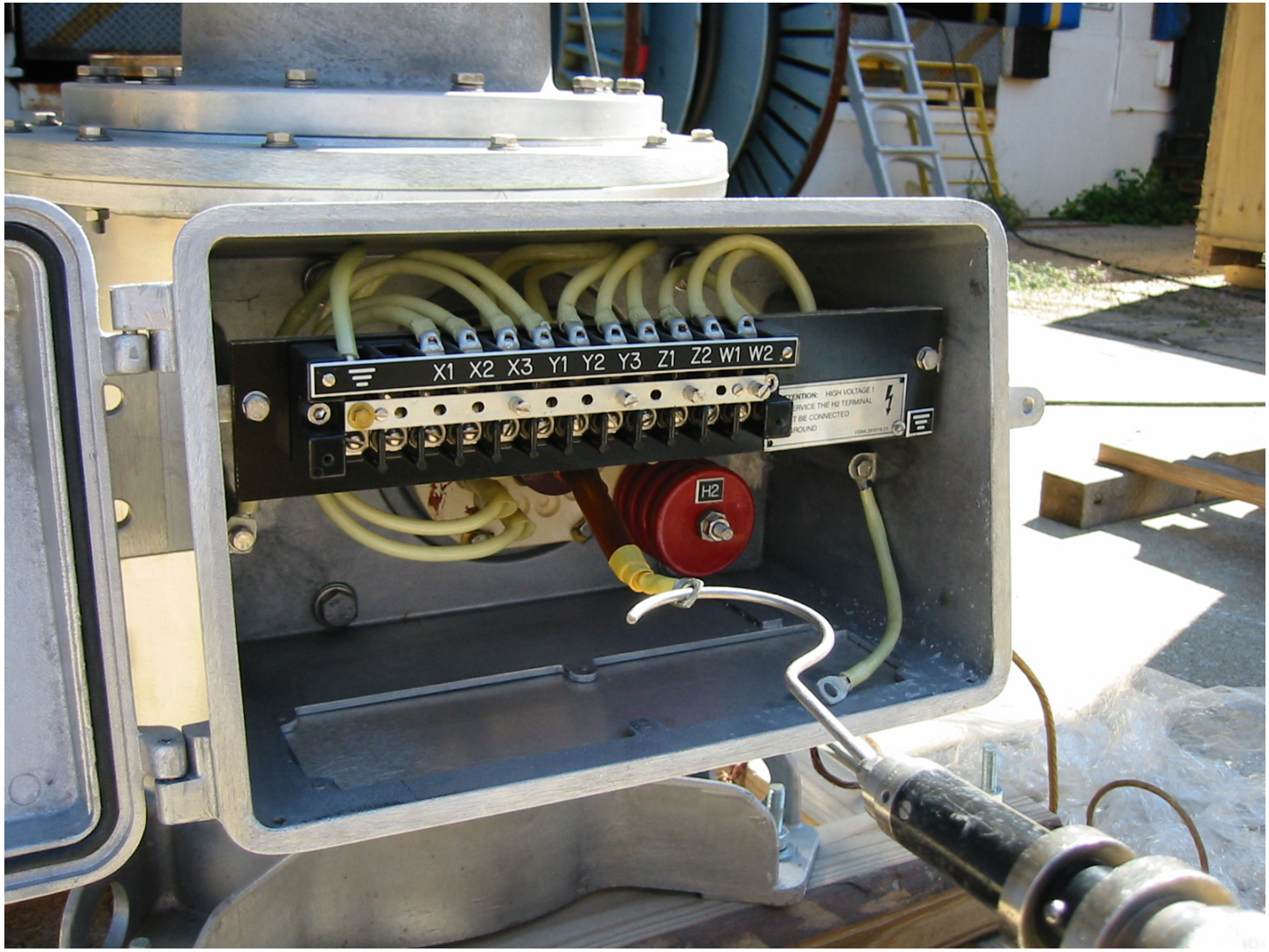

Ritz Type KOTEF 72.5 kV Meter Unit