

Users Manual

Digital Surge/DC HiPot/Resistance Tester Models D30R

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D30R Users Manual

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PREFACE

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- Power Source Precautions
- Ground the Product
- Terms and Symbols
- Warranty Notes
- Authorized Service Centers
- Training Seminars
- Environment
- Shipment
- List of Items Furnished



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Safety Precautions

Note: The general safety information presented here is for both operating and service personnel. Specific warnings and cautions will be found throughout this manual where they apply.

DANGER

High-voltage test equipment should be handled with CAUTION. High-voltage test procedures should be followed, including the use of high-voltage gloves!

Operation of the tester by persons who are using a pacemaker may present unusual safety risks. Such person should take special precautions!

- Do **NOT** touch the test leads, winding or component under test while a test is being performed. Severe electric shock may result.
- **Never** attempt a two-party operation. Always know what test is being performed and **when**.
- Never attempt to test an energized motor.
- Be sure the surge test instrument is grounded. Use a three lead grounded supply (or an extra ground lead if unsure of supply ground).
- For capacitor start motors or systems with surge arrestors/power factor correction capacitors; be sure to **disconnect** all capacitors from the test circuit **before** testing.
- The surge test is **NOT approved** for use in an explosive environment.
- Upon completion of a DC High Potential test, short the winding, motor, etc., to ground and allow time for discharge before disconnecting the test leads.
- Ensure the tester leads are disconnected before the motor is energized or powered up.
- Do not operate the tester without the covers and panels properly installed.

Power Source Precautions

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This product is intended to operate from a power source that applies 85-264 VAC RMS 50/60Hz between the supply conductor or between either supply conductor and ground.

Ground the Product

This product is grounded through the grounding conductor of the power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting the product test leads.

Danger from Loss of Ground

Upon loss of the protective ground connection, all accessible conductive parts, including knobs and controls that may appear to be insulated, can render an electric shock!

Terms & Symbols

- Caution statements identify conditions or practices that could result in damage to the equipment or other property.
- Warning/Danger statements appearing in boxes identify conditions or practices that could result in personal injury or loss of life.
- Notices that are bolded indicate operational cautionary information.
- **Notes:** are important information and hints on the operation of the equipment.

Warranty Notes

Important notice concerning the Warranty and Repairs

The warranty is **Void** if tester is shipped in any container other than the original container it was shipped in **or** factory specified packaging. For replacement factory specified packaging and instructions for proper shipment of the tester see the Shipment section at the end of this chapter. Also, be sure to complete the **Warranty Return Form** when sending the tester to Baker Instrument Company.

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If there is a failure of the Baker tester, regardless of whether it is under warranty or not, the customer should **Call the Baker Instrument Company Service Department BEFORE returning the unit for repair**. In some cases, the repair may be done by the customer at significant savings. If under warranty, the customer may still save costly shipping charges and lost time while the unit is being shipped and repaired. Our service staff may also direct the customer to ship the unit to one of our Authorized Service Centers for repairs.

When calling the Baker Service Department or one of the Service Centers, please have the Model and Serial Numbers (located on the rear panel of the unit) available. If the unit is out of warranty, a purchase order will be required if the unit is returned for repair.

The Baker Instrument Company Service Department phone number is 800-752-8272 or 970-282-1200.

Authorized Service Centers

Europe	Baker Instrument GmbH	49-911-984600
	Hutbergstrasse 21	49-911-832169
	D-90475 Nurnberg 50	
	West Germany	
United States	Baker Instrument Company	970-282-1200
	4812 McMurry Avenue	970-282-1010
	Fort Collins, CO 80525	800-752-8272

Training Seminars

Extensive training seminars are conducted by Baker Instrument Company to help the user get the most out of the Surge/HiPot Tester in a wide variety of applications. **In-House Seminars** are available at plant/shop site. In these seminars, tailor the training for your specific needs. Please contact the Sales Department at Baker Instrument Company, 800-752-8272 or 970-282-1200 to schedule an In-House Seminar.

Environmental

The tester should only be operated in temperatures ranging from 0 to 100 degrees Fahrenheit (-17.8 to 37.8 degrees Celsius).

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Due to corrosion, humidity will affect the condition of the instrument's components over time. The storage environment of this instrument should be less than 50% humid. The instrument certainly should not be stored in any location where water entry could occur as the instrument is **NOT** waterproof.

Due to the possibility of arcing in the test leads or in the motor being tested, the D30R is **NOT approved for use in an explosive environment**.

Shipment

All Baker testers are shipped using factory foam-filled containers. Should the tester be returned to Baker Instrument Company for any reason, we recommend using the original packaging the unit came in or the following factory specified packaging:

Contact Baker Instrument Company to order factory-specified packaging for the testers. Baker Instrument Company is not responsible for damage due to shipping testers back to the factory in inadequate materials.

List of Items Furnished

- 1 each – Surge Tester with attached test leads
- 1 each – Removable line power cord
- 1 each – Set of removable Resistance Test Leads
- 1 each – Instruction Manual

CHAPTER 2: INSTRUMENT OVERVIEW

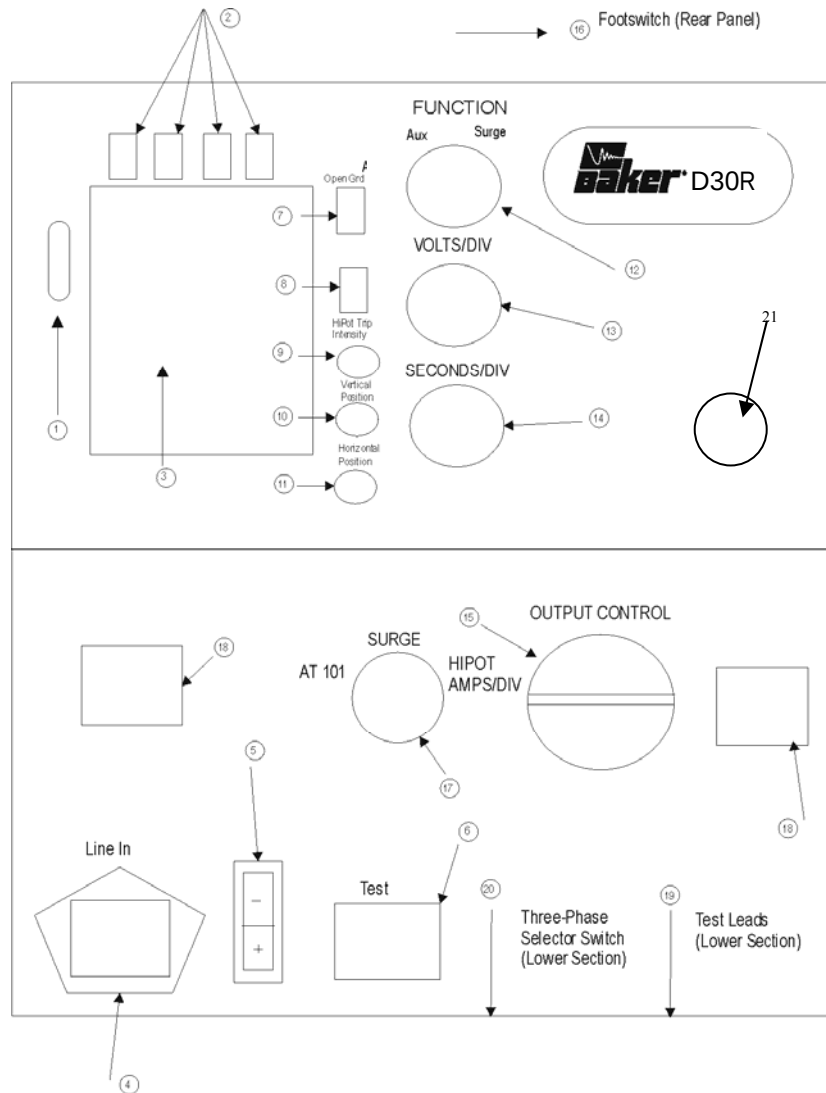
Inside.....

- Front Panel Controls
- Initial Tester Power Up & Checkout



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Digital Front Panel Diagram

Front Panel Controls

1) PRINTER PORT

Parallel port for printing waveforms and summaries displayed by the Digital Tester. This port may also be used for interfacing with the Motor Test Acquisition for Windows program (MTA for Windows) on a personal computer.

2) FUNCTION KEYS

Function key for data collection, recall, and printing of tests. The keys correspond to choices provided on the CRT display below them. See the chapter on Storage and Print Capabilities, for a detailed description of the tester's storage capability.

3) CRT DISPLAY

The Cathode Ray Tube (CRT) is the location where the tester displays test information. At the Top, menus corresponding to the four function keys above the CRT are shown. The main portion of the screen displays the waveforms being measured and/or recalled with corresponding graticules for reference. The bottom portion shows the volts/division for the waveform, the name of the test on display, and the micro-seconds/division (micro-amps/division for hipot tests). When using the function keys, the screen will display options pertinent to the storage, recall, and print capacities of the unit. Error messages are also displayed here.

4) LINE IN

The external AC power-supply plug.

5) ON/OFF

The on off switch for the unit. On/off switch is combined with the AC power entry and a fuse.

6) TEST

The TEST button activates the high voltage output of the tester. One of the selected modes, Surge, or Hipot will be enabled and a voltage will be impressed on the device being tested. This button automatically disengages when released.

7) OPEN GROUND WARNING LIGHT

When the AC line source is not properly grounded, the red Open Ground light will illuminate. The test set will power up, but high voltage will be withheld by internal electronics.

8) HIPOT TRIP WARNING LIGHT

This lamp illuminates to indicate a DC HIPOT trip circuit has stopped the test. The red lamp will stay illuminated until the TEST button is released.

9) INTENSITY

Rotation of this control will adjust the intensity or brightness of the display. Clockwise (CW) will increase intensity. Counterclockwise (CCW) will decrease intensity. Intensity has a slight effect on the focus and can be adjusted to a blank screen.

10) VERTICAL POSITION

This control adjusts the up or down positioning of the surge wave pattern. Optimum positioning is usually on the center of one major graticule line below center for surge testing.

11) HORIZONTAL POSITION

This control adjusts the side to side positioning of the surge wave pattern. A trace beginning at the far left is suggested for surge testing.

12) FUNCTION SELECTOR

This control selects the type of test to be performed and the sensitivity of the DC HiPot leakage current display. The name of the test chosen is displayed on the lower portion of the CRT for reference. There are four primary position as follows.

- **AUX:** The auxiliary position is for the D30R is used for Surge and HiPot modes.
- **SURGE:** This position selects the Surge Test. The name of the test and the microseconds per division measured is displayed on the lower portion of the CRT for reference. A digital readout for the peak voltage of the test is also displayed in the upper right portion of the screen for reference.
- **HIPOT- uA/dIV:** This position is used for DC HiPot testing. The name of the test is displayed on the lower portion of the CRT for reference. A digital readout for the leakage current (in micro-amps)

of the test and the resultant resistance in mega-ohms is also displayed on the screen for reference. There are three positions associated with the HiPot test. The three positions are 100uA/div, 10uA/div, and 1uA/div. The chosen micro-amps per division setting is displayed on the lower right portion of the CRT for reference during testing. u-Amps/Div controls the sensitivity of the current displayed. It also automatically selects the overcurrent trip point, which will be ten times these settings or 1000, 100, and 10 micro-amps respectively.

13) VOLTS/DIV

This control sets the sensitivity of the display or scale factor in volts per division for both the Surge and DC HIPOT traces. There are four settings corresponding to 1250, 2500, 5000, and 7500 volts per division. **Note:** this knob setting does not limit the output voltage of the tester.

14) SECONDS/DIV

This control adjusts the seconds per division or sweep rate of the trace on the horizontal axis of the surge display. There are ten settings corresponding to 2, 6, 10, 20, 60, 100, 200, 500, micro-seconds and 1 and 2 milli-seconds per division. The seconds per division setting is displayed on the lower right portion of the display for the reference during Surge Testing. This control will have the effect of zooming in or out on the wave pattern.

Caution

For the surge test, with the SECONDS/DIV control at the lowest possible setting, the ringing pattern must be at least one division in length for one full cycle. Less than one division for the first cycle indicates a very low inductive load. **DAMAGE to the instrument is possible when operated more than ten (10) seconds into a low inductive load.**

15) OUTPUT CONTROL

This control adjusts the output voltage of the tester. Clockwise (CW) rotation increases output and counterclockwise (CCW) rotation decreased output. Full CCW is the MIN (minimum) point output and full CW is MAX (maximum) or 100% of the testers rated output.

Note: A “Zero Start Interlock” is connected to the output control for use during Surge and HiPot testing. The user must return the output control to MIN each time before pressing the Test button (6). In other words, if the Test button is pressed while the Output control is above zero the instruments output is disabled until the Output control is rotated to MIN.

16) FOOTSWITCH CONNECTOR (REAR PANEL)

A footswitch may be connected to this socket which is in parallel to the Test button. The footswitch will operate the tester in a manner identical to the Test button, freeing the user’s hands from having to operate the switch.

17) SURGE/HIPOT SELECTOR. This function, like Function selector (12), is a relay that selects the type of test, Surge or HiPot, to be performed. The name of the test chosen is displayed on the lower portion of the CRT for reference.

For testing windings and stators, it should always agree with the position of the Function Selector.

Three Phase Selector Switch

This is an optional high-voltage rotary switch that selects which test lead is hot, open, or ground. If this switch is present on the tester, refer to Appendix D: Three Phase Operation for a description and instructions to use this switch for surge testing.

18) LEADS ENERGIZED INDICATOR LIGHT

This indicator light will illuminate when voltage is applied during a test.

19) TEST LEADS (LOWER SECTION)

Test leads, one red and three black or ground leads, are provided for contact to the windings. Test leads are insulated to 60kV.

20) THREE PHASE SELECTOR SWITCH (LOWER SECTION)

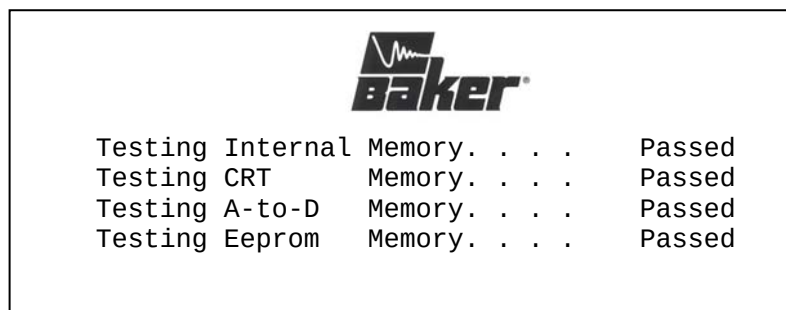
This switch enables the operator to connect all motor leads of a three phase winding to the tester to facilitate surge comparisons.

21) Kelvin Resistance Test Leads

Initial Power-Up and Check-Out

Note: Each Baker Instrument Company Tester incorporates a supply ground detection circuit. This circuit assures a positive grounding of the tester. If the instrument is not properly ground, the OPEN GRN indication will light and testing cannot proceed. Check the supply to the tester (broken ground, bad extension cord, excessive ground to neutral voltage) and assure that a low impedance ground is provided to the unit.

1. Check that the On/Off switch is in the Off position.
2. Connect the tester power cord to a 110-120 VAC outlet (or 220-240 VAC outlet if appropriate). The tester will work on either 60 Hz or 50 Hz.
3. Set the Output control to Min (fully counterclockwise).
4. Turn the tester On/Off switch to On. Allow a brief period for CRT warm-up. The following message should appear on the screen.



A SELF-TEST PERFORMED ON THE TESTER FOR ALL INTERNAL MEMORY MODULES WHEN THE TESTER IS POWERED UP. ANY FAILURES WILL BE NOTED ON THE CRT DISPLAY.

CHAPTER 2: RECOMMENDED TEST SEQUENCE, VOLTAGES AND TESTING PRECAUTIONS

Inside....

- Recommended Test Sequence
 - Coil Resistance
 - Megohm Test
 - Dielectric Absorption (DA)
 - Polarization Index (PI)
 - DC HiPot
 - Surge
- Recommended Test Voltage DC HiPot & Surge
- Applicable Standards



Recommended Testing Sequence

In order to test motors adequately and to have effective predictive maintenance programs, Baker Instrument Company suggests using a specific test sequence. The general idea is to perform the test sequence as a series of progressively more rigorous tests, accepting the idea that if a test fails, troubleshooting and repair should begin at that time. Further, more rigorous testing should only commence after satisfactory diagnosis and/or repair.

The suggested testing sequence is: (1)Resistance test, (2)Meg-ohm, (3)HiPot and finally (4) Surge.

1. Coil Resistance Test

A coil resistance test looks for resistance imbalance between phases, discrepancies between measured resistance values, previous measurements and nameplate values. If a problem is found, the motor should be inspected for the cause of the discrepancies. Typical problems that may exist are 1) hard shorts to the motor's core, 2) hard shorts between coils either within the same phase or between phases, 3) coils rewound with the improper gauge wire, 4) loose or corroded connections. Further HiPot or Surge testing is not necessary until the resistance measurement is acceptable.

2. Megohm Test

A megohm test is performed using a test voltage based on the operating voltage of the motor and the appropriate standards/company testing guidelines. Look for an unusually low megohm value when compared to previous measurements or industry accepted limits for the type of insulation in the motor. If a low megohm value is measured, the motor should be inspected for ground wall insulation damage. Some part of the ground wall insulation has failed. Possible problems include: 1) slot liner insulation or enamel wire insulation may be burned or damaged, 2) the motor might be full of dirt, carbon dust, water or other contaminants, 3) connections to the actual coils may be bad, 4) wrong insulation may have been used to connect the coils to the motor's junction box, etc. No further testing is necessary until the reason for low megohm readings is found and corrected.

3. Principles of the Dielectric Absorption (DA) Test

The Dielectric Absorption (DA) Test is essentially a short-duration PI test and is usually intended for smaller motors. Larger motors whose insulation does not easily polarize are also good candidates for the DA Test. Other than the shorter test time, all other principles are the same as the PI test, explained in the next section.

While the PI test is recommended only for motors 200 horsepower or greater, the DA test is useful for motors in approximately the 50 to 200 horsepower range. The DA value is the ratio of the ground wall insulation resistance (IR) at 3 minutes to the IR value at 30 seconds.

4. Principles of the Polarization Index (PI) Test

The **Polarization Index Test (PI test)** is the most confusing HVDC test in use due to the subtleties in the interpretation of the results. The PI test is performed in order to quantitatively measure the ability of an insulator to polarize. When an insulator polarizes, the electric dipoles distributed throughout the insulator align themselves with an applied electric field. As the molecules polarize, a “polarization current”, also called an absorption current, is developed that adds to the insulation leakage current. This additional polarization current decreases over time and drops to zero when the insulation is completely polarized.

The PI result becomes confusing when attempting to attribute variations in the PI value to the polarizability of the insulator or other affects such as humidity or moisture, surface leakage or instrument error. The result is even more confusing when attempting to reconcile a PI of 1 when one is expecting some other PI.

The PI test is typically performed at 500, 1000, 2500 or 5000 volts, depending on the operating voltage of the motors being tested and takes 10 minutes to complete. The PI value is calculated by dividing the insulation resistance at 10 minutes by the resistance at 1 minute as shown below:

$$PI = \frac{IR(10 \text{ min})}{IR(1 \text{ min})}$$

In general, insulators that are in good condition will show a “high” polarization index while insulators that are damaged will not. IEEE 43-2000 recommends minimum acceptable values for the various thermal classes of motor insulation.

Unfortunately, most the insulating materials developed recently (last 20 years) do not easily polarize. For example the newer inverter grade wires and epoxy resins do not readily polarize. As recommended in IEEE 43-2000, if the one-minute insulation resistance is greater than 5000Mohms, the PI measurement may not be meaningful.

To address the situation where the PI may not be meaningful, the Dielectric Absorption (DA) is widely used instead. The DA is the IR value at 3 minutes divided by the IR value at 30 seconds. The motivation for even doing the DA test is to reduce the test time to 3 minutes instead of 10 minutes for the PI test when the PI test may not be worthwhile. To date there are no accepted values for the DA. However, some usefulness can be obtained by trending the DA value over time.

5. DC HiPot Test

A DC HiPot test is performed using a test voltage that is substantially higher than the Megohm Test, but, once again, based on operating voltage of the motor and the appropriate standards/company guidelines. Look for unusually high leakage currents or a leakage current that doesn't stay constant or intermittently jumps up and down. Breakdowns or high leakage currents are an indication of damaged ground wall insulation. Inspect the motor's slot liner, wedges, conductors between the junction box and the coils, etc.

6. Surge Test

A Surge test is performed on each phase of the motor, again using an appropriate test voltage based on the operating voltage of the machine and the appropriate standards/company guidelines. Look for a jump to the left of the surge waveform pattern as the test voltage is increased. This is the signature of the turn – to – turn short. If a jump is observed, an inspection of the motor should be made to look for damaged insulation between adjacent conductors. The insulation may be hard to see visibly, so the motor may have to be disassembled to find the problem. If no jump in the wave patterns is observed, the likelihood of motor failure due to insulation failure is greatly reduced.

Recommended Test Voltages – DC HiPot and Surge Tests

A recommended test voltage for HIPOT testing a motor, generator or transformer is twice the AC line voltage plus 1000 volts. This test voltage is consistent with NEMA MG-1, IEEE 95-1977 (for test voltage greater than 5000 volts), and IEEE 43-2000 (test voltages less than 5000V).

View the enclosed tables for a comparison of IEEE 95, EASA DC HiPot, IEEE 522 Surge Testing, IEC 34-15 & Baker recommended testing voltages. Note: Representations of motors are listed. The formulas to calculate voltages are also listed so that test voltage on any size motor can be calculated.

IEEE 95-1977

V Line	Per Unit	Min Test Vline*1.25 x 1.7	Max Test Vline * 1.5 x 1.7
480	392	1020	1224
575	469	1222	1466
600	490	1275	1530
2300	1878	4888	5865
4160	3397	8840	10608
6900	5634	14663	17595
13800	11268	29325	35190

EASA DC HiPot

V Line	Per Unit	New 3.4*Vline +1700	In Service 65% of New
480	392	3332	2165.8
575	469	3655	2375.75
600	490	3740	2431
2300	1878	9520	6188
4160	3397	15844	10298.6
6900	5634	25160	16354
13800	11268	48620	31603

IEEE 522 Surge Testing

V Line	Per Unit	New 3.5* pu	In Service 75% of New
480	392	1372	1029
575	469	1643	1232
600	490	1715	1286
2300	1878	6573	4930
4160	3397	11888	8916
6900	5634	19718	14789
13800	11268	39437	29578

IEC 34-15

V Line	Per Unit	1.2 x 50 4E +5000	0.2us 65%
480	392	6920	4498
575	469	7300	4745
600	490	7400	4810
2300	1878	14200	9230
4160	3397	21640	14066
6900	5634	32600	21190
13800	11268	60200	39130

Baker Instrument Company

V Line	Per Unit	In Service 2E + 1000
480	392	1960
575	469	2150
600	490	2200
2300	1878	5600
4160	3397	9320
6900	5634	14800
13800	11268	28600

Note: Although the CRT display is accurately calibrated, it is not possible to set the voltage exactly. It is suggested that the test voltages be rounded off to the nearest graticule discernable on the display.

Applicable Standards

EASA Standard AR100-1998 Recommended Practice for the Repair of Rotating Electrical Apparatus

D30R Users Manual

IEC 60034-1 (1999-08) Consolidated Edition, Rotating Electrical Machines Part I: Rating & Performance Ed. 10.2

IEEE 43-2000 Recommended Practice for Testing Insulation Resistance of Rotating Machinery

IEEE 95-2002 Guide for Insulation Maintenance of Large AC Rotating Machinery

IEEE 112-1991 Test Procedures for Polyphase Induction Motors and Generators

IEEE 113-1985 Guide on Test Procedures for DC Machines

IEEE 115-1983 Test Procedures for Synchronous Machines

IEEE 118-1978 Standard Test Code for Resistance Measurements

IEEE 429-1972 Evaluation of Sealed Insulation Systems for AC Electric Machinery Employing Form-Wound Stator Coils

IEEE 432-1992 Guide for Insulation Maintenance for Rotating Electrical Machinery (5hp to less than 10,000hp)

IEEE 434-1973 Guide for Functional Evaluation of Insulation Systems for Large High-Voltage Machines

IEEE 522-1992 Guide for Testing Turn-To-Turn Insulation on Form-Wound Stator Coils for Alternating-Current Rotating Electric Machines.

NEMA MG1-1993 Motors & Generators

Reprints or EASA standards are available from:

www.easa.com

1331 Baur Boulevard

St. Louis, MO 63132

Phone: 314-993-2220

FAX: 314-993-1269

Reprints of IEC standards are available from:

International Electrotechnical Commission (IEC)

www.IEC.ch

Reprints of IEEE standards are available from:

D30R Users Manual

IEEE Customer Service
445 Hoes Lane
P.O. Box Piscataway, NJ 08855-1331
Phone: 1-800-678-IEEE
Fax: 908-981-9667

Reprints of NEMA standards are available from:
National Electrical Manufacturers Association (NEMA)
Global Engineering Documents
Phone: 1-800-854-7179
International: 303-379-2740

CHAPTER 3: COIL RESISTANCE TESTING

Inside:

- Principles of Coil Resistance Testing
 - Resistance Test Display
 - Resistance Test Checklist
 - Auto Ranging Resistance Measurements
 - Saving & Recalling Measurements
 - Indications of problems in a motor



Principles of Coil Resistance Testing

The coil resistance test is a very simple test to perform and is an immediate indication of the health of the conductor(s) in a winding. The coil resistance test consists of injecting a known constant current through the winding, measuring the voltage drop across the winding, and calculating the coil resistance using Ohm's law. If a coil is shorted somewhere in the interior of the winding the resistance will be lower than normal. This lower coil resistance can be compared to previous measurements of the same coil, measurements of identical coils, or compared to the motor name-plate value to identify a "bad" coil.

The measured resistance is affected by the variation of copper conductivity with temperature. Therefore, the measured resistance value should be "corrected" to a common temperature, usually 25°C, before comparing two different measurements. MTA for Windows, a data logging application for the D30R, does this correction. See IEEE 118 for more information on correcting resistance measurements to 25°C.

Since the windings found in many motors have very low resistances, the injected current might have to be as high as 10 amps to accurately measure the voltage drop across the coil. One of the difficulties encountered measuring the voltage drop across the coil itself is, the affect of the contact resistance of the clip leads used to connect to the motor's winding. Contact resistances can be comparable or even greater than the resistance of some coils. The effects of contact resistance are reduced by using a "four wire" or Kelvin measurement. Baker testers use this technique.

Resistance Test Display

Store	Recall	Run Test	Clear
Res			
1-2	Gain = 1	8-200Ω	
	Current = 20mA		
	Resistance = 13.40Ω		
2-3	Gain = no test - no data		
	Current =		
	Resistance = .0 mΩ		
3-1	Gain = no test - no data		
	Current =		
	Resistance = .0 mΩ		
Resistance Test			

Fig 3-1: Test Display

Do Not Touch Test Leads while test is in Progress!

Resistance Test Checklist

1. Disconnect the high voltage test leads and move them aside. Baker tester resistance test circuitry is protected internally by relays, which ground the resistance test leads when a surge or HiPot test is selected. However, the protection relays are in no way rated for any type of live electrical buss or circuit. It is possible to cause severe damage to the instrument if the resistance test leads are attached while surge testing, HiPot testing, or while line voltage is present at the motor leads.
2. Connect the RESISTANCE TEST LEADS to leads 1-2 of the motor.
3. Set the FUNCTION KNOB to the Res 1-2 position.
4. Press the RUN TEST button to start the test.
5. The Baker will begin measuring the coil's resistance using an auto-ranging algorithm described below. The test results will be displayed on the Baker's screen.

Store	Recall	Run Test	Clear
-------	--------	----------	-------

Test in Progress		
Current	Gain	Resistance
20mA	1	13.40mΩ
Max Stabilize Time		1s

Resistance Test

Fig 3-2: Test in Progress Screen

6. When the measurement for leads 1-2 are complete, move the RESISTANCE TEST LEADS to leads 2- 3 on the motor.
7. Set the FUNCTION KNOB to Res 2-3.
8. Again, press the Run Test resistance test button again to start the test.
9. Once again, the Baker will make an auto-ranging measurement of the coil's resistance. The result will be displayed on the tester's screen.

10. When the test is complete, connect the Resistance Test leads to leads 3 and 1 of the motor.
11. Set the Function Knob to Res 3-1.
12. Again, press the Run Test button to begin another resistance test.
13. Once again, the Baker tester will make another auto-ranging resistance measurement and the result will be displayed on the tester's screen.

At the end of the test, press the Store button to save the resistance measurements to the Baker's internal memory.

Auto Ranging Resistance Measurement Algorithm

The Baker tester performs an auto-ranging resistance measurement by injecting a low current (20-50mA) into the coil and measuring the voltage drop across the coil. If the Baker tester does not detect a voltage drop, the current will be increased to approximately 0.2 amps and the voltage drop measured again. If a sufficient voltage is still not developed across the coil, the current will be raised to 2 amps. Once the voltage is detected, the measured voltage will be used to calculate the coil's resistance using Ohm's law. If the Baker tester is still unable to detect a voltage drop after injecting the maximum current, the Baker will increase the gain in the voltage measurement circuit until a voltage is detected. If voltage drop still cannot be detected, the tester will indicate 0.000 ohms on the display.

Saving & Recalling Measurements

1. After test is run, select store. The following screen appears.

CANCEL	UP	DOWN	SELECT
Store			
	RECORD	1	
	RECORD	2	
	RECORD	3	
	RECORD	4	
	RECORD	5	
	RECORD	6	
	RECORD	7	
	RECORD	8	
	RECORD	9	
	RECORD	10	
RESISTANCE TEST			

Fig 3-3: Saving & Recalling Screen

Do Not Touch Test Leads while test is in Progress!

2. Use the UP and DOWN keys to select the appropriate Record to store the test in.
3. Press SELECT. The tester then displays a clear test screen.
4. To Recall the Record, Select RECALL.
5. The Record screen will reappear. Using the UP and DOWN keys, select the appropriate record.
6. Press Select.

Indications of problems in a motor

If the resistance readings are significantly different from the motor nameplate data or a single lead is more than a few percent different from the others, there is probably a short in one or more of the motor's windings. If one of the values is significantly higher, there could be problems, such as:

1. A loose or corroded wire nut connection.
2. An incorrect amount of turns or an incorrect sized wire gauge used during a re-wind job.
3. An incorrect gauge of cable/feeder used from motor control to motor terminals.
4. Poor or incorrect solder technique used to connect phases.
5. Phases/coil groups connected wrong.

CHAPTER 4: PRINCIPLES & THEORY OF DC TESTING

Inside.....

- Principles of DC Testing
- Principles of the Megohm Test



Principles of DC Testing

High voltage DC testing of electric motors is performed in order to determine the integrity of the ground wall insulation system of a motor's coil. The ground wall insulation system consists of the wire's insulation, slot liner insulation, wedges, varnish, and sometimes, phase paper.

There are three types of DC tests performed by Baker test instruments:

Megohm tests, **HiPot** tests, and **PI** tests. Each type of test is designed to answer a specific question regarding the properties of or the integrity of the ground wall insulation system. There is also a **Stepped HiPot** test that can be performed with Baker testers. A brief discussion on each of these tests follows below.

Before going further the meaning of "HiPot test" needs to be discussed. The phrase "HiPot test" is used to describe the general idea of high voltage testing as well as to describe a specific type of high voltage insulation stress test. One must differentiate between the concept HiPot testing and the specific HiPot test based on the context of the discussion.

To perform any of the DC Tests, the motor's windings are isolated from ground, the red test leads from the Baker Tester are connected to the motor's three phase coils and the black test lead is connected to the motor's steel core/frame. The output voltage on the red test leads is raised to a predetermined test voltage and the leakage current flowing from the motor's coils, through the ground wall insulation, to the motor frame is measured. The Digital Tester then calculates the resulting insulation resistance (IR) using Ohm's law.

The **Megohm Test** consists of applying a DC voltage to the windings of a machine after first isolating the winding from ground. Internal relays inside the Analyzer automatically isolate with windings – no operator action is required. The test voltage is usually chosen to be at or near the operating voltage of the machine (see IEEE 43). Recommended test voltages can be found in the previous chapter titled "Recommended Test Sequence, Voltages and Applicable Standards".

The intended purpose of the Megohm test is to make an accurate measurement of the insulation resistance of the ground wall insulation. The insulation resistance, abbreviated IR, is a function of many variables: the physical properties of the insulating material, temperature, humidity, contaminants etc. The IR value is calculated using Ohm's law – the applied voltage is divided by the measured leakage current. This leakage current is that current which is actually able to pass from the winding through the ground wall insulation to the

motor's steel core **plus** any surface leakage currents. The surface leakage currents flow through moisture or contaminants on the surface of the insulation. To accurately determine the insulation resistance, the surface leakage must be reduced to an inconsequential level.

$$IR = \frac{\text{Applied Voltage}}{\text{Measured Leakage Current}}$$

The insulation resistance is a function of many variables: the physical properties of the insulating material, temperature, humidity, contaminants on the surface of the winding's insulation, etc. The effects of temperature can be compensated for by converting the IR value to a standard temperature 40°C as shown later in this chapter. The effects of humidity and contaminants can not be readily taken into account. Good judgment must be used when analyzing IR values from motors that may be wet, dirty, loaded with carbon dust, etc.

As mentioned above, a suggested test voltage for the Megohm test is 1.7 times the applied/operating line voltage for the motor. For example a 480 volt motor would be tested at 480V*1.7=816VDC. Recommended test voltages can also be found in IEEE 43-2000, NEMA MG-1-1993 and EASA technical manuals (see chapter 2).

When first applying the voltage to a motor or when increasing the voltage, an unusually high current is observed. This high current is not a leakage current, but the charging current of the capacitor formed by the motor's copper coils, the ground wall insulation and the motor's steel core. This capacitor is usually called the "machine capacitance".

The **polarization index test (PI test)** is performed to quantitatively measure the ability of the ground wall insulation to polarize. The PI test is the most confusing DC test in use due to the subtleties in the interpretation of the results. When an insulator polarizes, the electric dipoles distributed in the insulator align themselves with an applied electric field. As the molecules polarize, a "polarization current", also called an absorption current, is developed that adds to the insulation leakage current. The test results become confusing when attempting to attribute variations in the PI value to the polarizability of the insulator or other affects such as humidity, moisture and instrument error.

The PI test is typically performed at the same voltage as the megohm test and takes 10 minutes to complete. The PI value is calculated by dividing the IR at 10 minutes by the resistance at 1 minute as shown below:

$$PI = \frac{IR(10 \text{ min})}{IR(1 \text{ min})}$$

In general, insulators that are in good condition will show a “high” polarization index while insulators that are damaged will not. IEEE 43 recommends minimum acceptable values for the various thermal classes of motor insulation:

NEMA Class A	1.5
NEMA Class B	2.0
NEMA Class F	2.0
NEMA Class H	2.0

The Baker tester will automatically calculate the PI value at the end of a 10-minute test. At the test’s conclusion, the PI value may be stored in one of the 10 memory locations in the Baker tester for later recall.

Note: Some insulating materials developed in recent years for wire insulation do not readily polarize. For example the newer inverter grade wire insulation do not significantly polarize. As recommended in IEEE 43, if the one-minute insulation resistance is greater than 5000Mohms, the PI measurement may not be meaningful. In these situations the leakage current is often very low – almost zero. Such low leakage currents are difficult to accurately measure and as a result, instrument errors become very evident. However, the operator must use judgment before declaring the PI test to be meaningless. The indication of damaged insulation based on the PI test can be a very low leakage current and a low PI value.

The **dielectric absorption test (DA test)** is often substituted for the PI test for the following reasons:

- 1) Some insulation systems do not polarize or polarize so fast the process is not observed
- 2) Some motors are so small that doing a PI test offers no useful information
- 3) Some motors have such a small total leakage current, it is not possible to resolve the polarization current
- 4) Sometimes users don’t have or want to take the time to do the full 10 minute PI test.

The DA test is basically a shortened version of the PI test. Instead of forming the ratio of insulation resistances at 10 minutes and 1 minute, the DA test, as Baker Instrument Company has it implemented, is the IR ratio at 3 minutes and 30 seconds:

$$DA = \frac{IR(3min)}{IR(30s)}$$

There are no accepted minimum or maximum values of the DA test. However, the DA value is considered to be trendable. Any change in the DA value indicates that something is changing in the ground wall insulation system. The stator may be contaminated or wet. The stator may also be running hot and burning insulation. Usually, changes in the DA will be accompanied by a change in one of the other “recognized” tests such as the Megohm test, PI test or the DC Over Voltage test.

The **HiPot** test demonstrates that the ground wall insulation system can withstand a “high” applied voltage without exhibiting an extraordinarily high leakage current or actually breaking down. The test consists of applying a DC voltage to the windings of the machine, same as a Megohm test, but at a higher voltage – usually more than twice the voltage of the machine’s operating voltage. Therefore, the HiPot test is often called a “Proof” test. The insulation resistance value at the high applied voltage is not of interest with the HiPot test. However, the value of the leakage current is and, more specifically, whether or not the observed leakage current is within acceptable limits.

The choice of test voltage depends on whether a new motor (or coil) is being tested for acceptance or whether an existing motor is being tested for continued service. Consult your organizations’ policies regarding the HiPot test voltage to be used. The simple formula of “2V+1000” generally results in a good test voltage for the HiPot test for motors already in service. Other recommended HiPot test voltages can be found in IEEE 95, ANSI C50.10-1977, IEC 34.1 and NEMA MG-1 (see chapter 2).

The HiPot test usually lasts one minute and the leakage current recorded at the end of the minute. The leakage current at the end of this minute is to be recorded for future comparisons. Between the time when the voltage is applied to the motor and the time when the leakage current measurement is taken, the operator should carefully observe the leakage current and watch for sporadically varying leakage current that might indicate weak insulation. Such variations should be considered a failure of the insulation.

CHAPTER 5: PERFORMING HIGH VOLTAGE DC TESTS

Inside.....

- The Test Display
- General User Cautions & Notes
- Test Precautions
- High Voltage DC Test Checklist
 - DC Testing
 - Full DC Testing of a Motor
 - Performing Only a Megohm Test
 - Performing Only DC Over Voltage Test (DC HiPot Test)
 - Sample Data Showing Good & Poor Insulation
- Storing the Test Results in Memory Insulation
- Using the Footswitch
- The HiPot Over Current Trip Indicator
- Effects of Temperature
- Step Voltage Test
 - Step Voltage Procedure



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The Test Display

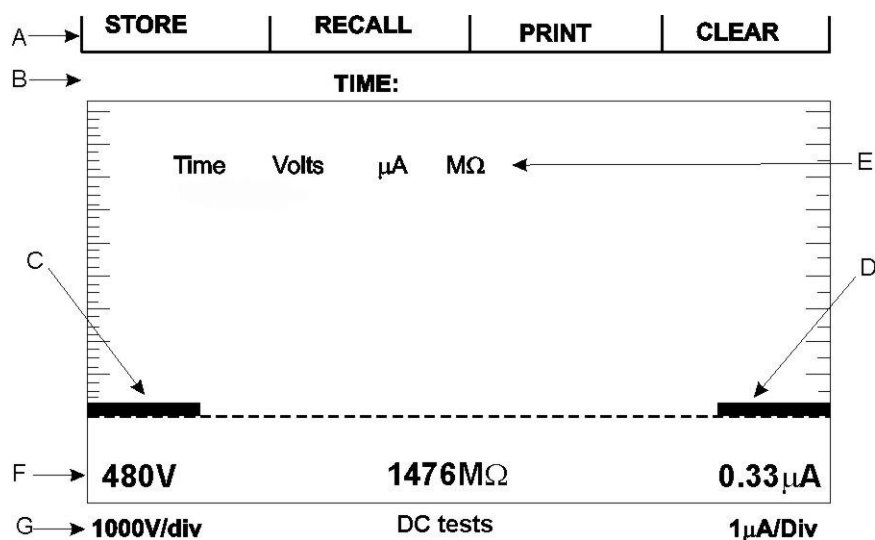


Fig 5-1: Test Display

- Main Menu for Function buttons and Message area.
- Time duration of DC Tests:
- Voltage Bar
- Current Bar
- Results from 30 sec, 1min, 3 min, 10 min, PI, DA Mohm, HiPot,
- Digital Output; Resistance Measurement, Current Measurement
- Volts/Div Setting; Current Test Name; $\mu\text{-Amps}/\text{Div}$ Setting

General User Cautions and Notes

- DO NOT change the TEST LEAD SELECT (TLS) SWITCH while a test is being made. Doing so will cause arcing and damage of the instrument's components.
- Do not switch the FUNCTION CONTROL between Surge and HiPot settings during testing.

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- When increasing the applied voltage during a test, use a higher Volts/Div setting so the entire trace stays visible on the screen. It is acceptable to change this setting while testing. The Volts/Div control has no effect on and does not limit the output voltage of the tester. It only controls the display scale.
- When removing Test Leads ALWAYS unclip the test leads. Do not jerk or pull them from the motor leads.
- Only touch the test leads with the Test Lead Select Switch in the GROUND POSITION.
- Never connect test leads from two or more testers on the same motor. This includes connection of host and power pack unit leads to the same motor. This warning also includes lead connections, even for grounding purposes.
- Do not connect both the resistance test leads and the high voltage test leads to the motor at the same time.
- Please do not hesitate to contact Baker Instrument Company for technical applications assistance at (970) 282-1200, or toll free at (800) 752-8272. Fax your questions, information, printouts, diagrams, or photographs of your tests to (970) 282-1010. E-mail is also available at www.bakerinst.com.

Test Precautions

Before beginning a HiPot test of any kind, insure that the work area is safe. Remove the line voltage from the motor (the motor is off), insure that there are no power factor correction (PFC) capacitors, noise suppression filters, or surge suppressors in the motor test circuit.

It may be noted that PFC capacitors or surge suppressors may be tested in part with the Baker Tester. See the particular component's manufacturer for more information. If capacitors or surge suppressors are left in place, either the tester will over current trip or the leakage current of the capacitor will be measured along with the motor's leakage resulting in an erroneous measurement of the motor's insulation properties.

If the particular motor is a synchronous type or a DC machine, remove brushes, slip rings, etc. before beginning the test. **It is the operator's responsibility to know what is being tested.**

Note: use caution after performing High Voltage DC Tests. Residual charge may still be present on the motor after these tests. **Extreme caution should be taken this charge can render a sizable shock.** Completely discharge the motor under test long enough for any residual charge to flow to ground. The required amount of discharge time should be specified by your organization's testing procedures. A widely accepted discharge time is the same time as the duration of the test just completed. Also a good practice is to short the windings of a motor to the motor's core when a motor is not being used for long periods. See IEEE 43 and 95 Standards for other recommended times.

High Voltage DC Test Checklist

DC Testing

As explained earlier in Chapter 2, the Megohm test gives a quantitative measure of insulation resistance (IR) and is performed at a test voltage similar to operating voltage of the motor (See IEEE 43). The PI test gives a quantitative measure of the ability of insulation to polarize. The PI test is performed at the same time and test voltage as the Megohm test. A DA test is often done if it is evident that the PI test does not provide useful information or is too long. The DA test is often called an abbreviated PI test and is described in industry standards documents that deal with PI testing. The DC Over Voltage Test or "DC HiPot", is done to prove that insulation has the dielectric strength to withstand typical over voltages that a motor can see while in service due to transients, lightening strikes, loss of a phase, etc. The Baker DR Series digital testers are capable of performing all described tests during the same application of voltage to the motor.

Full DC Testing of a Motor

A Full DC Test of a motor consists of a Megohm, DA, PI and DC HiPot test. Follow the procedure below:

1. Connect appropriate high voltage leads to stator windings.



Fig 5-2: Motor Hookup Example

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Do Not Touch Test Leads while test is in Progress!

2. Move Test Lead selector switch to “HiPot” position.



Fig 5-3: Digital Unit Front Panel View

3. Move Function Knob to the 100uA/Div position.
4. Press and hold “Test” button. The “Test” button needs to be pressed for the duration of the 10-minute test. Baker has a footswitch that can be used to replace the “Test” button for easier use.
5. Ramp test voltage up to desired Megohm test voltage and press the “Time=0” button at the top of the screen after reaching required voltage.
6. Adjust “uA/div” knob if required to get machine in the most accurate current range for reading leakage current. The DR Series tester will display a message on the screen if the knob should be moved to a lower current range.
7. After time has elapsed for the Megohm test, usually 60 seconds per IEEE 43, press the “Save Meg” button. The Megohm data will show up in the middle of the screen between the voltage and current slider bars. Data acquired at 30 seconds and 1 minute will also be displayed. These

two values are required for calculation of the DA and PI tests. The tester automatically acquires these values.

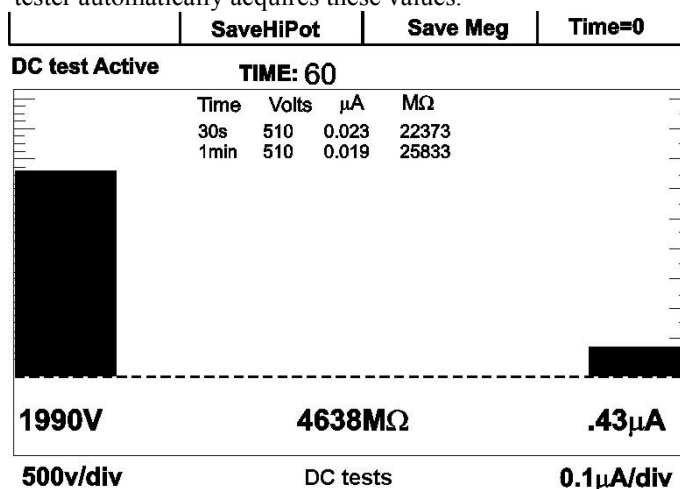


Fig 5-4: Test Active to 60 seconds

8. Continue to press and hold “Test” button. In the screen’s center, the tester will acquire and display a Leakage Current Reading at 3 minutes. This is used for the DA calculation. The DA ratio will also appear.

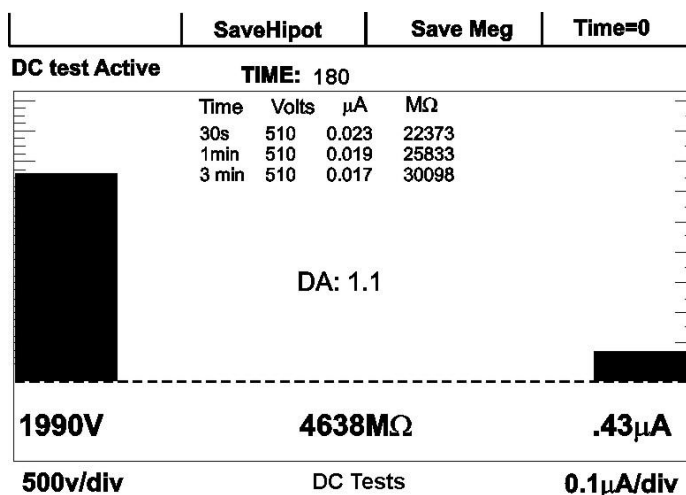


Fig 5-5: Test Active to 3 Minutes

9. After 10 minutes of continual testing, the tester will automatically acquire and display the leakage current. The PI ratio will be automatically calculated and displayed.

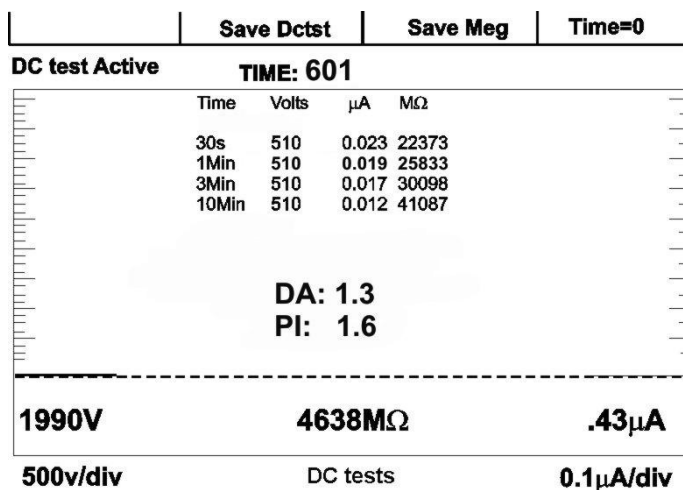


Fig 5-6: Test Active 10 Minutes

10. Continue to press and hold "Test" button, and turn Function knob to 100 μA /div position.
11. Ramp test voltage to desired DC over voltage test value (HiPot test voltage).
12. Change μA /div setting as required to obtain best current readings (follow instructions on screen).
13. After time required to hold HiPot test voltage has elapsed (usually 60 seconds), release "Test" button. The leakage current readings upon button release are displayed in the center of screen.

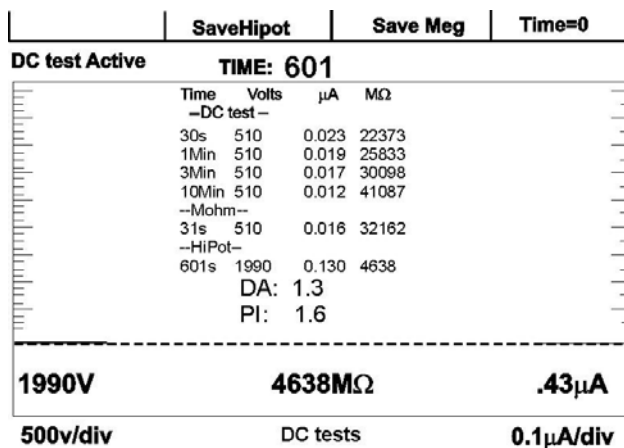


Fig 5-7: DC Tests Complete

14. Save test results by pressing the “Store” button and selecting desired record.

Performing *Only* a Megohm Test

1. Connect appropriate high voltage leads to stator windings.
2. Move Test Lead selector switch to “HiPot” position.



Fig 5-8: Tester Hookup Example

Do Not Touch Test Leads while test is in Progress!

3. Move Function Knob to 100uA/Div position.
4. Press and hold “Test” button. Ramp test voltage to desired Megohm test voltage and press the “Time=0” button at the top of the screen after reaching required voltage.
5. Adjust “uA/div” knob if required to get the machine in the most accurate current range for observed leakage current. The DR Series tester will place a message on the screen if it should be moved to a lower current range.
6. After time has elapsed for the Megohm test, usually 60 seconds per IEEE 43, press the “Save Hipot” button. The Megohm data will be displayed in the middle of the screen between the voltage and current slider bars. Data acquired at 30 seconds and at 1 minute will be displayed. These two values are required for calculation of the DA and PI tests. The tester automatically acquires these values; however, if only a Megohm test is required, these data points will not be used.

Performing Only DC Over Voltage Test (DC HiPot Test)

1. Connect appropriate high voltage leads to stator windings.
2. Move Test Lead selector switch to “HiPot” position.
3. Move Function Knob to 100uA/Div position
4. Press and hold “Test” button. Ramp test voltage to desired Megohm test voltage and press the “Time=0” button at the top of the screen after reaching required voltage.
5. Adjust “uA/div” knob if required to get machine in the most accurate current range for reading leakage current. The DR Series tester will place a message on the screen if it should be moved to a lower current range.



Fig 5-9: Tester Hookup Example

6. After time has elapsed for the DC Over Voltage Test, usually 60 seconds per IEEE 95, press the “Save Meg” button. Megohm data will be displayed in the middle of the screen between the voltage and current slider bars. Data acquired at 30 seconds and at 1 minute will be displayed. These two values are required for calculation of DA and PI tests. The tester automatically acquires these values; however, if only a DC Over Voltage Test (HiPot test) is required, these data points will not be used.

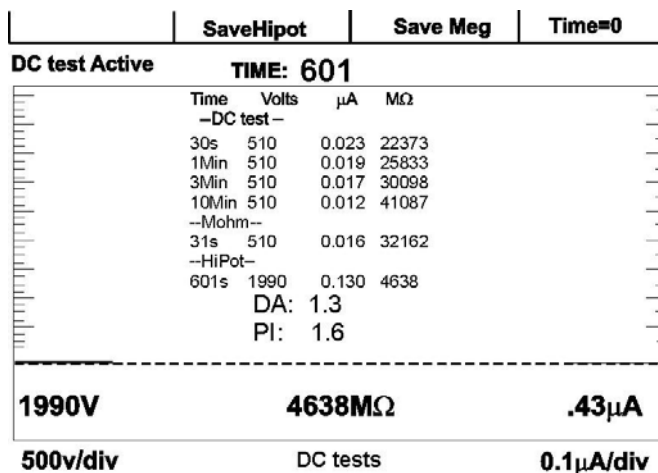


Fig 5-10: Completed Test View

Sample Data showing Good & Poor Insulation

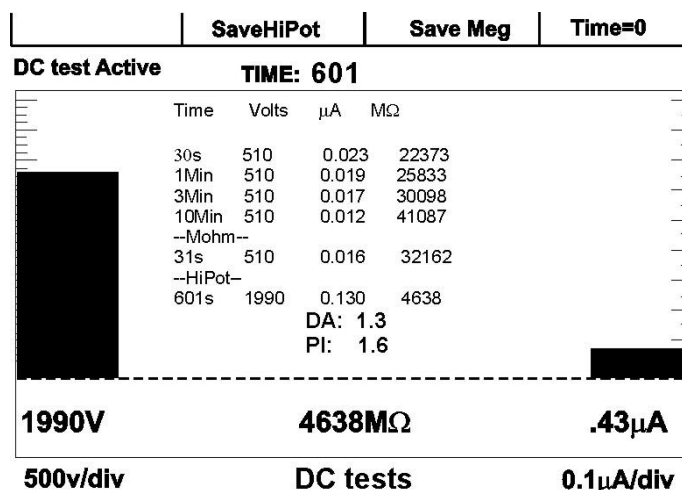


Fig 5-13: Sample Data-Good Insulation with high voltage and low leakage current.

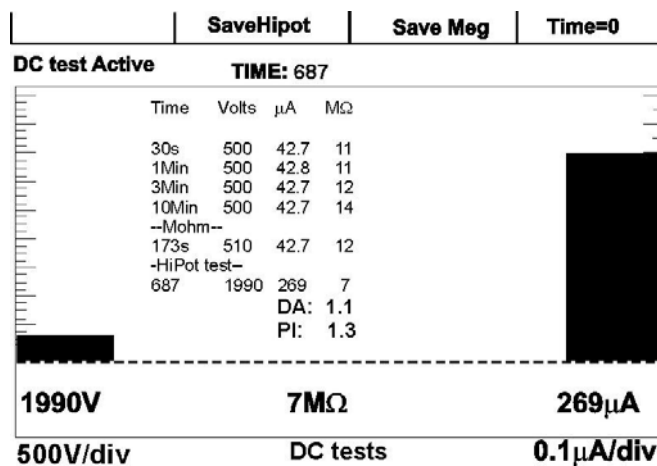


Fig 5-14: Sample Data - Poor Insulation with low voltage and high leakage current.

Storing the Test Results in Memory

1. Press the "STORE" soft key. A list of available Records appears.

2. Select the desired record to store the data by pressing the function keys corresponding to the UP and/or DOWN to bring the cursor to the desired record and pressing "SELECT".
3. Highlight "HiPot" or "PI" on the CRT screen using the "UP" and "DOWN" soft keys and press "SELECT". The leakage current and applied voltage will be saved in the system's internal memory. The main menu will reappear and the next motor may be tested after grounding the motor for the appropriate amount of time.

Using the Foot Switch

Several of the High Voltage DC tests require the Test button be depressed for long periods of time. To enable hands free operation, a foot switch is available for use with the Baker tester. The foot switch plugs in the front panel as shown and may be used in place of the test button.

The HiPot Over Current Trip Indicator

The Digital tester is equipped with an Auto-Ranging HiPot Over-Current safety trip. If the HiPot current levels exceed:

- ~900uA in the 100uA/div range,
- ~90uA in the 10uA/div range,
- ~9uA in the 1uA/div range or
- ~0.9uA in the 0.1uA/div range

The over-current trip will remove the high voltage from the test leads, stop the test and illuminate the red HIPOT TRIP lamp on the front panel. Releasing the TEST button resets the trip circuitry, extinguishes the red HIPOT TRIP lamp, and readies the tester for another test.

Effects of Temperature

Temperature has a very strong effect on megohm readings because insulation resistance varies inversely with temperature on an exponential basis. (IEEE 43 has a very good description of this effect.)

Simply put, the insulation resistance drops in half for every 10°C rise in temperature. Therefore, before any judgments are made regarding the health of a motor's insulation based on a trend of past megohm measurements, all the measurements used in the trend should be "compensated" or "corrected" for temperature. The temperature compensation of the insulation resistance means to convert all the IR measurements used in the analysis to the same temperature. The recommended temperature to use is 40°C. The following formula should be used to make the calculation.

$$R_c = \left[(1/2)^{\left\{ \frac{(40 - T)}{10} \right\}} \right] * R_T$$

For example: An insulation resistance/megohm value is 5000Mohms at 30°C, the compensated IR value at 40°C is 2500Mohms.

Step Voltage Test

Another test that can be performed using the Digital tester is the Step-Voltage test. This test is used to indicate the condition of winding insulation by observing the linearity of leakage current as voltage is increased in steps. The best results can be achieved if historical records are maintained of multiple Step-Voltage tests, beginning with measurements made when the winding is new.

Use the same voltage increments and time intervals for all Step-Voltage tests of a particular winding. Baker Instrument Company recommends that results are plotted on graph paper in order to make comparisons of different tests.

Note: It is important for the insulation to be free of moisture and dirt when this test is made.

Step Voltage Test Procedure

Determine the number of steps to perform, and the voltages and time increments that best suits testing needs.

For example, if the maximum voltage should be 12,000 volts, it may be best to use six steps of 2000 volts. The time interval will depend on the capacitance of the test piece and the type of insulation it uses. Choose an interval that lets a noticeable change in resistance readings occur at each step. One minute step intervals are fairly standard for many windings (See IEEE 95 for more information).

For example, with a 12 kV test instrument:

1. Connect motor as usual for a HiPot test.
2. Move Function Knob to 100uA/div position.
3. Press start button and ramp voltage up to 2000 volts.
4. Move Function Knob to the best uA/div range for the observed leakage current.
5. At one minute, note resistance reading.

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6. Move Function Knob to the 100uA/div setting and increase voltage to 4000 volts.
7. Change uA/div range to best match the observed leakage current.
8. At the end of the next minute (2 min after start of test), note the resistance reading.
9. Again, move Function Knob to the 100uA/div setting and then increase voltage to 6000 volts.
10. Change uA/div knob to best match the observed leakage current.
11. At the end of the minute (three minutes after test start) note the resistance reading.
12. Again, move Function Knob to the 100uA/div setting and then increase voltage to 8000 volts.
13. Change uA/div knob to best match the observed leakage current.
14. At the end of the minute (four minutes after test start) note the resistance reading.
15. Again, move Function Knob to the 100uA/div setting and then increase voltage to 10,000 volts.
16. Change uA/div knob to best match the observed leakage current.
17. At the end of the minute (five minutes after test start) note the resistance reading.
18. Again, move Function Knob to the 100uA/div setting and then increase voltage to 12,000 volts.
19. Change uA/div knob to best match the observed leakage current.
20. At the end of the minute (six minutes after test start) note the resistance reading.

Note: At each step ramp voltage on the tester in single motions to get the most accurate rise from one test voltage to the next.

CHAPTER 6: PRINCIPLES AND THEORY OF SURGE TESTING

Inside.....

- Principles of Surge Testing
 - Surge Testing Theory
 - Determination of a Fault
 - Motivation for Surge Testing
 - Contact Bounce
 - Lightening Strikes
 - Inverter Transients
 - Line Surges
- IGBT Switching Technology



Principles of Surge Testing

Surge testing is performed to detect insulation damage between turns within a motor's winding. This type of insulation problem cannot be found any other way than by surge testing. The surge test consists of applying a short, fast rise time, high current impulse to a winding. This high rise time impulse will induce, via Lenz's Law, a voltage difference between adjacent loops of wire within the winding. If the insulation between the two loops of wire is damaged or somehow weakened, and if the voltage difference between the wires is high enough there will be an arc between the wires. The arc is detected by observing a shift in the surge waveform.

The Surge test is performed with an impulse generator and an oscilloscope type display to observe the "surge waveform" in progress. The surge waveform is a representation of the voltage present across the test leads of the Baker tester during a test. The indication of a turn-to-turn fault is a shift to the left, and/or a decrease in amplitude of the surge test waveform as the test voltage is increased.

Surge Testing Theory

As mentioned above very short high current pulses are applied to the coil during a Surge test to create a voltage gradient (or potential) across the length of the wire in the winding. This gradient produces a momentary voltage stress between turns.

The coil will respond to the surge pulse with a ringing or damped sinusoidal waveform pattern. Each coil has its own unique signature ringing or wave pattern, which can be displayed on a CRT display screen as shown below.



Fig 6.1: Example of a "ringing" wave pattern resulting from Surge Testing

The wave pattern observed during a Surge Test is directly related to the coil's inductance. (There are other factors influencing the wave pattern but inductance

is the primary one.) The coil becomes one of two elements in what is known as a tank circuit – a **LC-type** circuit made up of the coil's inductance (**L**) and the surge testers internal capacitance (**C**).

Inductance (L) of a coil is basically set by the number of turns in a winding and the type of iron core it rests in. The frequency of the wave pattern is determined by the formula:

$$Frequency = \frac{1}{2\pi\sqrt{LC}}$$

This formula implies that when the inductance decreases, the frequency will increase.

A surge test can detect a fault between turns that is due to weak insulation. If the voltage potential is greater than the dielectric strength of the turn insulation, one or more turns may be shorted out of the circuit. In effect, the number of turns in the coil is reduced. Fewer working turns reduce the inductance of the coil and increased the frequency of the ringing pattern from the surge.

The voltage or amplitude of the surge wave pattern is also reduced due to the decrease in inductance of a coil with a fault between turns. It is determined by the formula:

$$Voltage = L \frac{di}{dt}$$

Where the current (i) varies according to time (t)

When the insulation between turns is weak, the result is a low energy arc-over and a change in inductance. When this happens the wave pattern becomes unstable – it may shift rapidly to the left and right, and back to the original position.

A reduction in inductance occurs due to turn-to-turn faults, phase-to-phase faults, miss-connections, open connections, etc. Partial ground wall testing is also performed in a surge test when there is a ground line to the machine frame.

The Surge test is most often used to test turn-to-turn insulation of coils or single windings. Form coils, start and run windings, and multi-tapped windings are a few examples. Surge tests are also used to compare new windings to a standard winding to assure they conform.

Determination of a Fault

If a fault exists in a motor, the wave pattern on the display will collapse in amplitude and a distinct shift to the left will occur, signifying an increase in frequency (a decrease in inductance). When inductance decreases, the frequency of the wave pattern will increase according to the formula above.

This is illustrated in the figure below. This type of fault is generally one that indicates a failure of the turn-to-turn short.

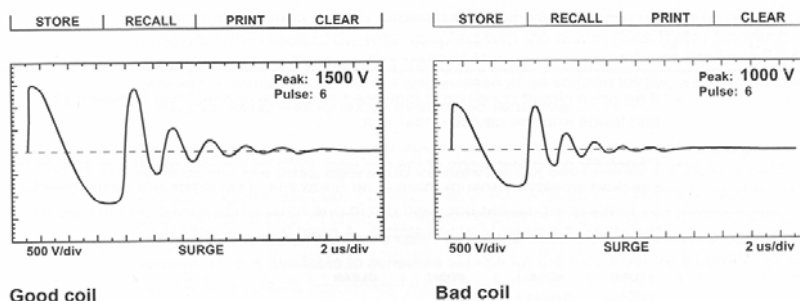


Fig 6-2: Good vs Bad Coil Waveform

If any wave pattern becomes erratic and/or flickers during testing, intermittent shorting or arcing is probably occurring in the windings under the voltage stress. Arcing is often accompanied by audible sounds. It may be desirable to store the wave pattern by this arcing for reference if the operator can release the TEST (this freezes the wave pattern) at the moment when the wave pattern appears the most affected by the fault (reduced amplitude and increased frequency or shift to the left).

Motivation for Surge Testing

Motors are subjected to high energy, high voltage transients in their everyday operating environment. These transient pulses can damage the insulation in the motor and, given enough time, cause a catastrophic failure in the motor. The causes of high energy, high voltage transients are:

- Motor start-up inrush current coupled with **contact bounce** in the MCC.
- **Lightening** strikes in the power system.

- **Inverter drive transients.**
- **Line surges** caused by other motors or transformers tripping in the power system.

One of the primary functions of a Baker Tester is to closely simulate the transient voltages seen by the motor without the high energy that accompanies the normally occurring transients. These spikes are a significant aging factor for the end turn insulation of an electric motor.

Contact Bounce

Oddly enough one of the major sources for the high-energy transients is the MCC, a device that is supposed to protect the motor. When the breaker contacts close in the MCC during startup, they will often “bounce” or chatter, this means that the high inrush current is being made and broken several times. As a result of interrupting the current, an inductive “kick back” voltage spike will be developed. Large inrush currents along with the high inductance of electric motors are what give these “kick back” voltage spikes their high energy.

Lightening Strikes

Lightening strikes can often be present on the power system or grid. Although a great amount of effort is made to protect the grid from the damage caused by lightening, the high voltage transients caused by strikes still get through to motors.

Inverter Transients

Variable speed drives or pulse width modulated drives are based on switching currents very quickly in such a manner that the motor runs at a pre-set speed. The switching of the current combined with the obvious fact that the motor is an inductor result in high-speed transients being generated by the motor drive electronics. These transients are impressed on the motor where they can slowly degrade the insulation in the motor windings.

Line Surges

When a transformer or motor operating on a power system trips off line, the energy stored in the motor or transformer has to go somewhere. The energy is either absorbed by the device or is pushed out onto the power system where other transformers or motors have to absorb the energy. Often, large transient

voltage spikes manifest this energy impressed on the power system. These spikes are again, a source of damage to motors, especially if the motor already has weakened insulation.

IGBT Switching Technology

Insulated Gate Bipolar Transistors (IGBTs) are used in the D30R surge testers to make a very fast high voltage switch, which is the heart of the surge impulse generator. These IGBT devices are very fast switching transistors. These are often found in variable speed motor drives and are used in the D30R in much the same manner as in the drives. However, Baker Instrument Company has uniquely configured many IGBT devices in series to form the high voltage switch. With the fast switching characteristics of the IGBT transistors, the rise time of each surge pulse is between 0.1 and 0.2 micro-seconds.

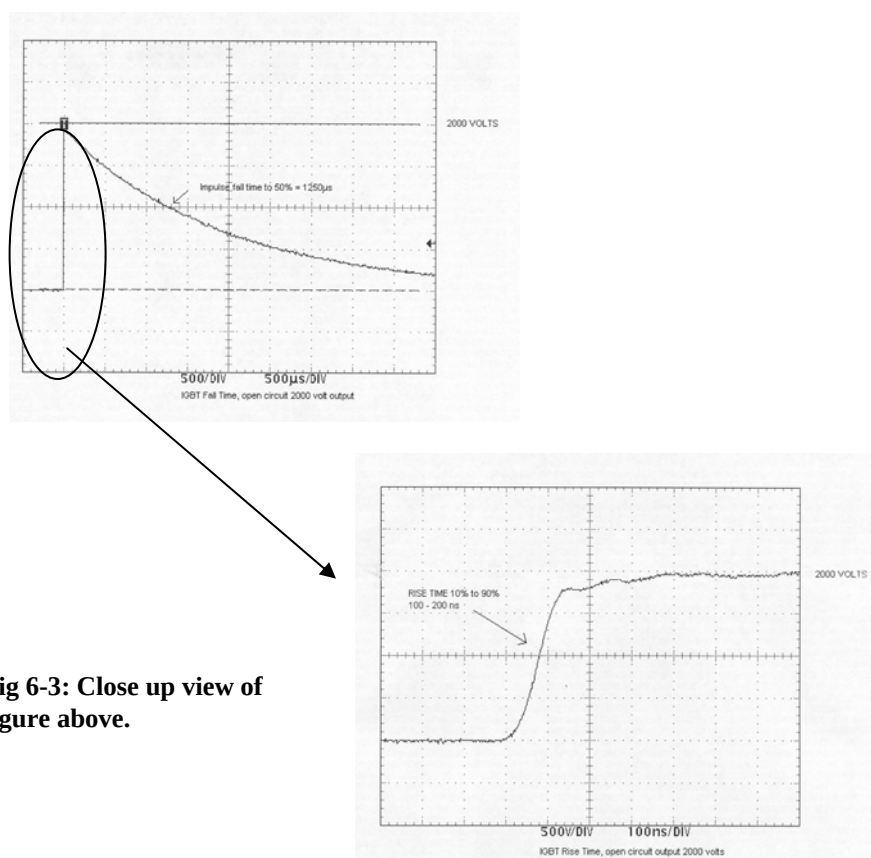


Fig 6-3: Close up view of figure above.

Do Not Touch Test Leads while test is in Progress!

CHAPTER 7: PERFORMING SURGE TESTS

Inside.....

- Surge Test Display
- Surge Test Setup
- 480V 3 Phase Motor Check List
- Single Coil Surge Test and Setup



Surge Test Display

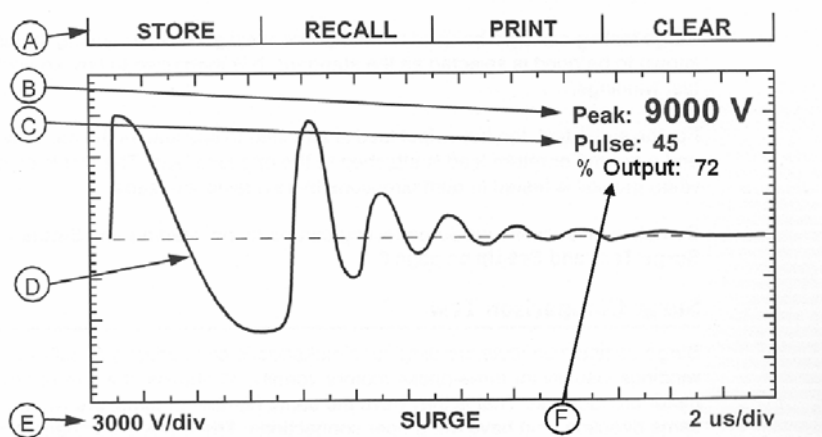


Fig 7-1: Surge Test Display

- Main Menu
- Digital Peak Voltage Readout
- Number of surge pulses applied to the test winding
- Example of a surge wave pattern
- Volts/Div Setting, current Test Name, Seconds/Div setting
- % output

General User Cautions and Notes

- Irregularities, particularly vertical spikes, may be seen the first cycle of the surge wave pattern. These occur most frequently on large, high voltage motors. Do not interpret these as faults in the windings. Any winding fault will be seen throughout the entire wave pattern.
- DO NOT change the TEST LEAD SELECT (TLS) SWITCH while a test is being made. Doing so will cause arcing and damage of the instrument's components.
- Do not switch the FUNCTION CONTROL between Surge and HiPot settings during testing.

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- When increasing the applied voltage during a test, use a higher Volts/Div setting so the entire wave pattern or trace stays visible on the screen. It is acceptable to change this setting while testing. The Volts/Div control has no effect on and does not limit the output voltage of the tester. It only controls the display scale.
- ALWAYS unclip the test leads. Do not jerk or pull them from the motor leads.
- Only touch the test leads with the Test Lead Select Switch in the GROUND POSITION.
- Never connect test leads from two or more testers on the same motor. This includes connection of host and power pack unit leads to the same motor. This warning also includes lead connections, even for grounding purposes.
- Do not connect both the resistance test leads and the high voltage test leads to the motor at the same time.
- Please do not hesitate to contact Baker Instrument Company for technical applications assistance at (970) 282-1200, or toll free at (800) 752-8272. Fax questions, information, printouts, diagrams, or photographs of tests to (970) 282-1010. E-mail is also available at www.bakerinst.com.

Surge Test Setup



Fig 7-2: Tester/Motor Hookup Example

Do Not Touch Test Leads while test is in Progress!

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1. Connect the motor as shown in one of the figures above. Connect phase 1 to Test Lead 1, phase 2 to Test Lead 2, phase 3 to Test Lead 3, and the motor core to the black ground lead.

Note: these connections are the same as for the HiPot tests of Chapter 5. To HiPot and Surge Test a motor, the test leads only need to be connected once. The position of the Test Lead Selector Switch determines which lead is “hot” and which lead is held at ground. The table below details the test lead configuration for each of the positions of the Test Lead Selector Switch:

Switch Position	Test Lead #1	Test Lead #2	Test Lead #3	Ground
Test Select 1	Hot	Ground	Ground	Ground
Test Select 2	Ground	Hot	Ground	Ground
Test Select 3	Ground	Ground	Hot	Ground
HiPot	Hot	Open	Open	Ground
All Leads Ground	Ground	Ground	Ground	Ground

After connecting the motor to the test leads, rotate the Function Knob to the Surge position. The CRT display should look like the one shown below.

Note: the “Surge” message at the bottom of the display indicates a normal surge test is active (and not an AT101 type test or a power pack test).

Before beginning the test, insure that there are no power factor correction capacitors or surge suppressors in parallel with the motor. Power factor correction capacitors will reduce the effectiveness of the surge test while surge suppressors will shunt to ground the surge signal. It is the responsibility for the operator to know what is being tested.

It is the responsibility of the operator to insure that the work area is safe.

Once the area is clear and safe, press the “Test” button to start the test. Press the voltage control buttons to ramp the test voltage up or down. As the voltage increases watch the waveform for sudden jumps to the left which indicates a turn-to-turn short.

The test should conclude once a predetermined test voltage is reached. Consult IEEE 522, NEMA MG-1 for recommended test voltages. A good rule of thumb is to test a coils at $2*V+1000$ where V is the operating voltage of the motor. Examples: a 480 volt motor would be tested at $2*480+1000=1960V$, a 4160 volt motor would be tested at $2*4160+1000=9320V$.

480V Three Phase Motor Check List

Check to ensure there is nothing connected to the coil or winding being tested. This is extremely important when testing installed coils or windings. Test inaccuracies will result and the situation can be hazardous to personnel performing tests.

1. Plug the unit in and insure that there is a good ground connection. The unit will illuminate the Open Ground detect light and inhibit testing if a positive ground is not sensed.
2. Move Test Lead Switch to Ground.
3. Connect the three-phase motor as shown.
4. Calculate final test voltage.
5. Rotate the Function Knob to Surge.
6. Rotate the test selector knob to Lead 1.
7. Press and hold the Test button. The instrument is now generating surge pulses and the waveform is shown on the display. The trace for the waveform may be moved up and down and left and right using the Horizontal and Vertical position controls on the front panel. The display will show the measured maximum voltage across the terminals of the motor, number of applied pulses, and the % output of the tester along with the waveform.
8. Press the Output Control buttons to increase the applied surge voltage.
9. Adjust the Volts/div scale and the Time/div scale to fit the surge waveform on the screen. The Volts/div scale may have to be changed as the test proceeds to higher test voltages.



Fig 7-3: Motor Hookup Example

Example: For a test voltage of 2000V, a Volts/Div setting of 500 will give a wave pattern with 4 divisions of amplitude that does not go off the screen. For a

test voltage of 4000V, a setting of 500 Volts/Div would result in a wave pattern with 8 divisions amplitude which would go off the screen.

10. Watch the surge waveform display while the voltage is increasing looking for flickering display, a drop in amplitude or a jump of the waveform to the left of the display.
11. Once the test voltage of 1960V is reached, stop pressing the output control button and release the Test button.
12. Store the results for Lead 1 in one of the 10 test records with the following procedure:
 - a. Press the store Function Key above the top of the screen.
 - b. Select the record to store the data in by pressing the Up / Down Function Keys to highlight the desired record and pressing Select.
 - c. Highlight Lead 1 on the next screen.
 - d. Again press select to load the data into the tester's memory.

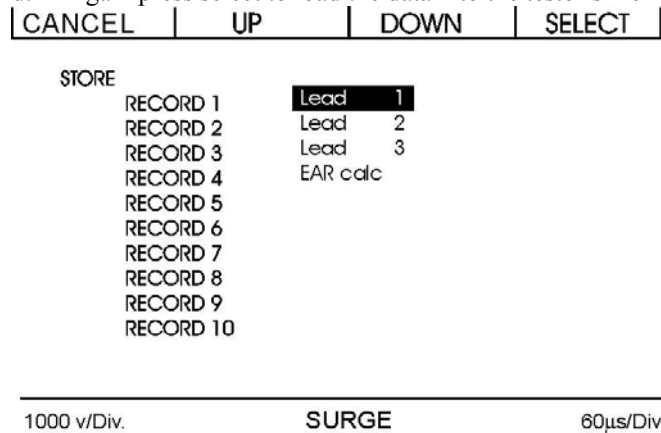


Fig 7-4: Save Surge Data Lead 1

10. Move the Test Lead Selector Switch to Lead 2.
11. Repeat steps 5 through 8 for lead 2, and save the data in the tester's memory as was done in step 12.

12. Move the Test Lead Selector Switch to Lead 3.
13. Repeat Steps 5 through 8 for Lead 3 and again save the data in the testers memory as was done in step 12.

Note: A good way to check the wave patterns after the test is complete is to display all three wave patterns at once. To do so, press the function key that corresponds to Recall. Press the Up and/or Down keys to bring the cursor to the desired Record and press the key that corresponds to Summary. Stored data for all three lead locations appear on the display along with any recorded HiPot data.

Single Coil Surge Test and Set-Up

Note: Check to ensure there is nothing connected to the coil or winding being tested. This is extremely important when testing installed coils or windings. Test inaccuracies will result and can be hazardous to personnel performing tests.

1. With the TEST LEAD SELECT (TLS) switch in the LEADS GROUND position, make the following connections. Refer to the Test Lead Connections table present earlier in this chapter for lead information.
 - a. Connect lead #1 on one side of the coil or winding.
 - b. Connect test lead #2 to the other side of the coil or winding.
 - c. Connect the black Ground lead and test lead #3 to the frame or housing of the coil or winding.
2. Turn the FUNCTION switch to the Surge position.
3. Select TLS position #1. This lead will be HOT.
4. Set the VOLTS/DIV switch at the lowest setting that will allow the maximum pattern to be viewed entirely on the CRT.



Example: For a test voltage of 2000V, a Volts/Div

Fig 7-5: Single Coil Test Hookup

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setting of 500 will give a wave pattern with 4 divisions of amplitude that does not go off the screen. For a test voltage of 4000V, a setting of 500 Volts/Div would result in a wave pattern with 8 divisions amplitude which would go off the screen.

5. Depress and hold the TEST button (or FOOTSWITCH).
6. Press Up or Fast Up switch. Apply voltage to the test windings. Monitor the trace on the display and adjust the Volts/Div and Seconds/Div controls to get the best waveform. Release Up or Fast Up when voltage is reached.
7. Adjust the OUTPUT and VOLTS/DIV controls to the desired voltage level while maintaining a fully visible wave pattern on the CRT display. The voltage is measured from the zero line to the first positive peak (at the far left) of the trace multiplied by the display VOLTS/DIV setting. The peak voltage is numerically displayed in the upper right portion of the Surge Test display.
8. When the test for the lead is complete, the TEST button may be released.
9. If the surge wave pattern appears steady and stable, the winding insulation is sufficient to withstand the applied voltage and the test is successful.

Note: If the wave pattern begins to flicker or rapidly shift to the left and right and/or up and down as the OUTPUT is increased, there is weakness in the winding insulation and intermittent arcing between the windings or phases. The winding or phase contains a fault when the wave pattern shifts to the left and the amplitude drops. The more severe the shift and amplitude drop, the more severe the fault. Faults are often accompanied by an audible arcing sound.

When an obvious fault is present, perform **Step 7** below. End the test by disconnecting the motor from the tester.

10. Store the test results in the tester's memory.
 - a. For testing a single coil or for standards testing, store the pattern using QUICK STORE.
 1. Press the function key corresponding to STORE. A list of available records and leads appears.

2. Press the key corresponding to QUICK STORE. The wave pattern is now stored in Record #1, Lead #1 and is immediately recalled on the screen.
- b. Store the pattern conventionally if the tests are to be downloaded to a pc for further analysis.
 1. Press the function key corresponding to STORE. A list of available records appears.
 2. Press the keys corresponding to the UP and/or DOWN to bring the cursor to the desired Record. Press SELECT.
 3. Repeat step 2 above for the desired lead.

Note: The flicker in wave patterns that is observed when there is arcing between the windings or phases cannot be stored in the Digital tester. As soon as the TEST button is released, the wave pattern freezes. This is the only wave pattern that can be stored.

It is desirable to store the wave pattern production by this arcing for reference. The operator must attempt to release the TEST (thus freezing the wave pattern for storage) at the moment when the wave pattern appears the most affected by the fault (reduced amplitude and higher frequency).

11. Change the TLS to position #2 and test again.

Note: It is convenient to store the results of a single motor into a single Record. Store the two wave patterns for the coil into two Lead locations for the desired Record. The results of up to ten motors can be stored on the Digital tester.

In summary, for each direction the coil is tested, check the display for the wave pattern produced in each test. If there are two good stable patterns, the winding is good. If anything other than good patterns is seen, there is a possible fault. Refer to the chapter on Determination of a Fault for explanations of wave patterns indicating good or faulty windings. For determination of wave patterns for a variety of devices refer to Surge Test Applications. Keep in mind, fault determination is often a result of experience.

Example: Comparison to a Master Coil

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Occasionally, a manufacturer may want to test against a standard. The selected standard coil is surge tested, results are stored in memory and recalled to the screen. QUICK STORE is useful for this situation. All unknown coils would be tested and compared to the standard coil's wave pattern. Standards testing demonstrates the coils ability to withstand minimum test voltages and the signature waveform can be compared to the standards single waveform.

CHAPTER 8: SURGE TEST APPLICATIONS

Inside.....

- Maintenance Testing
- Single Phase Motors and Two Terminal Divices
- Form Coils
- Three Phase Motors
- Two or More Single Coils
- Wound Rotor Motors
- Synchronous Motor/Generator
- DC Motor/Generators
- Field coils
- Chiller Motor Testing
- Armatures
- Testing Large AC Stators/Motors
- Rotor Loading (coupling) when Testing Assembled Motors
- Testing Assembled Motors from the Switchgear
- Transformers



Note: For additional reference for fault determination see Typical Winding Faults.

Note: If all three wave pattern comparisons in surge testing show considerable separation when testing three phase windings, the motor has a Phase-to-Phase short.

Maintenance Testing

Baker Instrument Company Surge Testers have become extremely popular for industrial maintenance programs, troubleshooting, and to ensure that replacement motors (spares, reconditioned motors, or rewinds) are thoroughly tested. The following are guidelines for performing surge tests on assembled motors in the field as part of maintenance testing.

Hard-shortened winding faults are rarely found in motors during maintenance testing. Solid turn-to-turn winding faults happen when the insulation on adjacent copper wires has failed to the point that adjacent wires are welded together. It is a rare condition in maintenance testing because of a transformer action, which occurs within the shorted windings which induces very high current in a hard turn-to-turn short. The high current causes heating and deterioration of the surrounding insulation systems. The single turn-to-turn short rapidly compounds until the damage causes a failure in the ground wall insulation. The high current will trip the circuit breaker and stop the motor. A solid turn-to-turn, or hard-shortened winding fault is not the type of fault to expect to see during maintenance testing. This condition is usually only found after the motor has failed.

During surge testing, steady separation in the wave pattern comparisons is most often the result of the rotor coupling with the stator. (See Rotor Loading (Coupling) when testing Assembled Motors). In this case, a consistent double wave pattern will be seen at all voltage levels. Separation due to rotor coupling should **not** be interpreted as a fault.

The key to the surge test for maintenance is to detect a fault at a voltage level above the peak operating voltage. For example, a 460V motor that shows a good trace at 500V but shows an unstable, flickering pattern, (regardless of rotor coupling) at 1500V definitely contains a fault. When the fault is detected above operating voltage, time is available to schedule service for the motor before a hard short and rapid failure occurs.

Consider a 460V AC motor. The operating voltage is the root mean square, a kind of average, of the AC power supply. For this motor, multiply 460V by 1.4 to determine the maximum voltage level that the coil undergoes during normal operation. It is approximately 650 volts. Suppose the motor has an insulation fault at 500 volts. This motor will probably fail while in service well before it can be surge tested because the peak of the AC voltage will continuously stress the fault under normal conditions.

The goal, therefore of the surge test is to detect weakness well above the operating voltage of the motor, as much as twice the operating voltage plus 1000 volts. Refer to Recommended Voltages for a thorough description of how to determine test voltages along with IEEE references that explain the reasons for these recommendations.

As shown in the figures below, a good winding will produce stable wave patterns from zero volts up to the recommended test voltage. Faults will be detected during surges tests are unstable, flickering wave patterns that appear as the voltage is increased.

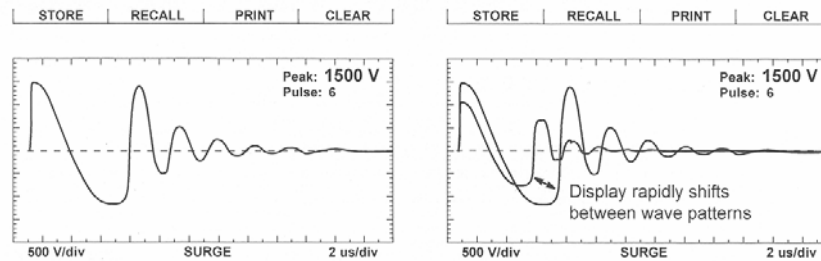


Fig 8-1: Good wave pattern (left) and a representation of how a “live” wave pattern may appear to move on the display for a winding or coil that contains an intermittent short or is arcing (right).

Application Notes

- If an open circuit is indicated, check the connections between all three test leads and the device under test.
- Check for open test leads at the clip end. With heavy use test leads should be checked weekly to ensure there is no breakage. Test leads are easily

checked by firmly grasping the boot and clip in one hand while pulling on the lead with the other. A broken lead will stretch. A good lead will not stretch.

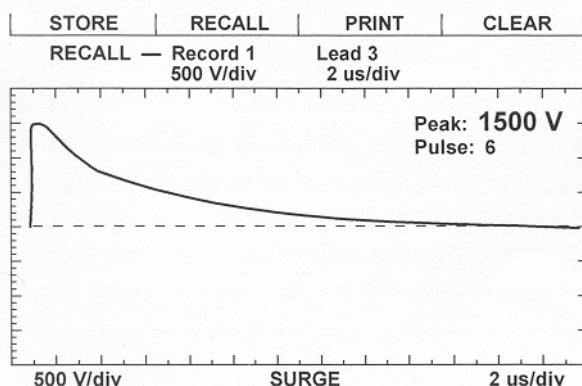


Fig 8-2: Open phase in lead in a wye-connector motor.

Single Phase Motors and Two Terminal Devices

Select TLS #1 and connect the corresponding test lead #1 to one side of the device. Connect test lead #2 to the opposite side of the two terminal device. Connect the ground lead and test lead #3 of the tester to the frame or metal core material.

Determination of a Fault

If a fault exists in a single phase motor or two terminal device, the wave pattern on the display will collapse in amplitude and a distinct shift to the left will occur, signifying an increase in frequency (a decrease in inductance). When inductance decreases, the frequency of the wave pattern will increase according to the formula:

$$Frequency = \frac{1}{2\pi\sqrt{LC}}$$

This is illustrated in the figure below. This type of fault is generally one that indicates a failure of turn-to-turn insulation.

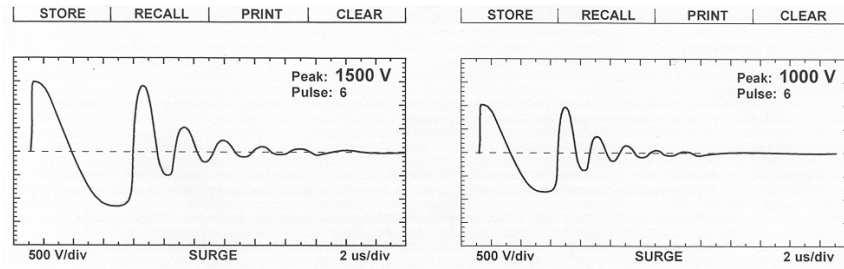


Fig 8-3: Good Coil & Bad Coil

If any wave pattern becomes erratic and/or flickers during testing, intermittent shorting or arcing is probably occurring in the windings under the voltage stress. Arcing is often accompanied by audible sounds. It may be desirable to store the wave pattern produced by this arcing for reference if the operator can release the TEST (this freezes the wave pattern.) at the moment when the wave pattern appears the most affected by the fault (reduced amplitude and increased frequency or shift to the left).

Form Coils

Form coils should be tested similarly to a two terminal device (see Single Phase Motors and Two Terminal Devices). The Surge test is recommended for form coil testing because it alone can generate the turn-to-turn voltage that is required in these low impedance coils.

Determination of a Fault

Refer to the previous section on Single Phase and Two Terminal Devices to determine if a fault is present.

Notes and Tips for Form Coils

- IEEE-522-1992 recommends a test voltage for Vacuum Pressure Impregnation coils, before they are cured, of 60-80 percent of the test voltage of fully cured coils.

- Currents required to test form coils often limit the maximum surge voltage. Placement of the coils into the stator iron or spare laminations has the effect of enabling the tester to produce a higher voltage drop across the coil for a given current level.
- CAUTION should be exercised since the laminations or stator core have induced voltage on them, and can provide a path to ground.
- Many formulas are used in calculating a test voltage for AC form-wound coils. These are generally based on experience and theoretical arguments about the distribution of voltage in a coil and the entire winding. Some of these formulas are difficult to apply because of the great diversity of coil specifications and characteristics. One popular formula (based on Paschen's Law) states a minimum and maximum test voltage range:

Minimum = Number of turns x 500 Volts

Maximum = Winding operating voltage x 1.5

The minimum voltage would be necessary to show a void in the turn insulation that would result in arcing. The maximum voltage value is based on the worst case distribution of a surge in the winding. Studies (IEEE-522-1992 and IEEE-587-1980) have shown that a very rapid surge from a lightning strike or contactor closing/opening may be distributed across the first coil of a winding.

Three Phase Stators

Wave patterns for three phase stator windings are compared in pairs. The storage capabilities of the Digital Tester allow all three phases to be compared without removing and reconnecting the test leads. The operator simply recalls any one of the previously tested leads. Baker Instrument Company recommends the following procedure:

1. Connect the three numbered RED test leads to the three winding legs.
2. Connect the BLK GRD lead to the frame or core of the winding.
3. Begin with the TLS in position #1. This indicates lead #1 will be hot while leads #2 and #3 provide a ground path for the surge impulse.

4. Perform the test as described in Three Phase Motor Surge Test and Set-Up.

For each test, check the display for a wave pattern. Recall a SUMMARY from the digital tester's memory for wave patterns for the motor to compare. If three good wave comparisons are seen, there is every indication to believe the motor is good. If anything other than good patterns are visible, there is a possible fault.

Determination of a Fault

If any wave pattern becomes erratic and/or flickers during testing, intermittent shorting or arcing is probably occurring in the windings under the voltage stress. Arcing is often accompanied by audible sounds. It may be desirable to store the wave pattern produced by this arcing for reference if the operator can release the Test (this freezes the wave pattern) at the moment when the wave pattern appears the most affected (reduced amplitude and increased frequency or shift to the left).

Separation in two of three wave pattern comparisons indicates incorrect turns count. The fault will be in the phase connected to the test lead in common between the two comparisons which show the separation for wye-connected windings.

In the Repair Shop: separation of compared wave patterns on Stators indicates a hard fault, such as a solid turn-to-turn or group-to-group short, an incorrect turns count, or misconnections.

In the Field: In assembled motors, separation of the wave patterns is often the effect of rotor coupling, also known as rotor loading (see Rotor Loading (Coupling) when Testing Assembled Motors).

Two or More Single Coils

Surge testing can be used to test two or more identical single coils separately and then compare their wave patterns against each other.

1. Connect test lead #1 to one side of coil #1 and connect the ground test lead to the other side.

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2. Connect test lead #2 to the second coil or identical coils and connect test lead #3 to that coil's other side.
3. Surge test the first coil with the TLS in position #1. Store the results in memory.

Note: Use QUICK STORE for a fast determination of the results of the test.

4. Surge test the second coil or any number of identical coils with the TLS in position #2. (Store the results if desired).

If the wave patterns are stable and they superimpose on the display, the two windings are identical. They have no faults and the insulation of both coils is good.

Determination of a Fault

If any wave pattern becomes erratic and/or flickers during testing, intermittent shorting or arcing is probably occurring in the windings under the voltage stress. Arcing is often accompanied by audible sounds. It may be desirable to store the wave pattern produced by this arcing for reference if the operator can release the Test (this freezes the wave pattern) at the moment when the wave pattern appears the most affected (reduced amplitude and increased frequency or shift to the left).

Separation of the wave patterns when compared indicates incorrect turns count. The fault will be in the coil connected to the test lead which produces the wave form most shifted to the left and collapsed in amplitude.

Notes and Precautions for Two Single Coils

- All windings or magnetic material (iron or ferrite) close to the coils under test **MUST BE THE SAME** for both coils. For example, if DC fields coils are being tested, both should have the pole pieces inserted or both removed. A coil on a table when compared to an identical coil in the frame will show separation of the wave patterns because inductance differs in iron and air.
- Slight variations in magnetics of the tested device can result in similar coils not comparing identically. An example of this is synchronous

pole pieces, one of which is making better magnetic contact with the rotor than the comparing pole. For this reason it is recommended that devices like pole pieces be evaluated individually and Not compared.

- Paschen's Law states that a voltage greater than 334 volts is required to initiate an arc between two conductors in air. This would suggest a minimum voltage for surge testing to be greater than 334 volts. Because of the sometimes non-linear distribution of the surge pulse, it is recommended that a minimum surge potential of 500 volts be used when testing a two terminal device.
- Shunt coils often have a small error in turns count. Some mismatch or separation of patterns should be acceptable. If the wave patterns are very close in shape and remain stable during the test, the coils generally are acceptable. In addition, winding tolerances on single coils may allow for differences in turns count which causes a slight, steady separation. The operator should investigate whether this condition is acceptable or not.
- A slight imbalance (separation) may be noticed if the windings are not correctly phased: ie: the winding configuration of one compared to another is clockwise verses counterclockwise. Try reversing one set of test leads connections and repeating the test before rejecting the winding.
- Many two terminal devices have very high turns count. The waveform displayed is similar to that of an OPEN circuit. In this case, the impedance of the coil is too high to be tested. Double check for poor connections and test lead breakage to see if these conditions may be causing the apparent open condition.

Wound Rotor Motors

Wound rotor motors are tested as though they are two separate three phase windings where one is the stator and the other is the rotor. Procedures to successfully test the wound rotor motor are as follows.

1. Remove the brushes touching the slip rings.
2. Short together the slip rings with jumpers. The jumpers minimize the coupling effect between rotor and stator.

3. Surge test the stator as would be done on a three phase induction motor. See Three Phase Stators or follow the directions in Three Phase Motor Surge Test and Setup.

Note: Since the rotor is shorted out there will be no chance for a high induced voltage transformed from the stator to damage the rotor.

4. To surge test the rotor, disconnect the jumpers from the slip rings. Connect the tester test leads to the rotor slip rings.
5. Short together the stator leads with jumpers, as done for the rotor.
6. Repeat Step 3 for the rotor.

Note: Check the motor name plate for rotor voltage to calculate the rotor test voltage level. Rotor Voltage is **not the same** as the stator voltage.

If the wave patterns are stable and they superimpose on the display, the windings are identical. They have no faults and the insulation of both coils is good.

Determination of a Fault

If any wave pattern become erratic and/or flickers during testing, intermittent shorting or arcing is probably occurring in the windings under the voltage stress. Arcing is often accompanied by audible sounds. It may be desirable to store the wave pattern produced by these arcing for reference if the operator can release the Test (this freezes the wave pattern) at the moment when the wave pattern appears the most affected (reduced amplitude and increased frequency or shift to the left).

Separation of the wave patterns when compared indicates incorrect turns count. Interpret the separations as for three phase motors.

Synchronous Motor/Generator

The synchronous stator is tested as a three phase induction motor. The rotating fields should be tested individually.

1. Before surge testing the stator.
 - a. Remove the DC Leads to the brush boxes or lift all of the brushes off the slip rings.
 - b. Short the slip rings for the rotating fields together.
2. Surge test the stator following the procedures and steps for Three Phase Stators.
3. Individual poles are surge tested as outlined in the procedures for testing Single Phase Motors and Two Terminal Devices. The recommended test voltage is 600 volts per pole. It is not necessary to disconnect the pole piece leads before testing.
4. The Hot and Ground leads are then reversed and the test repeated on each coil.

If the wave patterns are stable and they superimpose on the display, the windings are identical. They have no faults and the insulation of both coils is good.

NOTE: One field can be tested and its surge wave pattern can be stored for reference. The other fields can then be compared to this reference pattern in a procedure that is similar to that of Two or More Single Coils.

Determination of a Fault

Two types of faults may exist in synchronous motors and generators.

Pole Piece Fault

Do not expect coils to compare exactly. Rotating fields or pole pieces are often not wound to identical, exacting standards. If a fault does exist in the pole pieces of the test, the wave pattern on the display will collapse in amplitude and a distinct shift to the left will occur, signifying an increase in

frequency (a decrease in inductance). This type of fault is usually failure of the turn-to-turn insulation.

Stator Winding Fault

For a stator winding fault, if the wave pattern changes and becomes erratic during the test, then intermittent shorting or arcing is occurring in the winding under test. Steady separation of the wave patterns of the phases when recalled and compared indicates solid shorts. (See Three Phase Motors).

Chiller Motor Testing

Before applying any test potential to a chiller motor, please review the manufacturer's instructions. These instructions usually recommend bleeding the vessel to atmospheric pressure before applying a test potential.

Surge test procedures for chiller motors follow those outlined for Three Phase Motors.

Field Coils

When testing field coils follow the procedures outlined for testing Single Phase Motors and Two Terminal Devices and Synchronous Motor/Generator. The recommended surge test voltage for DC fields is 600 volts.

If the impedance of the coils is very low (few turns count, generally form coils with very low resistance) the surge tester stand-alone may not adequately test the coils. A bar-to-bar, low impedance test accessory from Baker Instrument Company will be necessary.

DC Motor/Generators

While the series or shunt fields of the DC motor/generator are tested as a two terminal device, the armature may be tested by three different methods.

Armatures

There are two methods of surge testing armatures: the Bar-to-Bar surge test and the Span surge test. The use of a Footswitch is highly recommended to ease the operation of these tests.

Bar-to-Bar Surge Test

Bar-to-Bar armature surge testing is the most effective method to test DC armatures and detect winding insulation weaknesses and faults. In many cases, where the impedance of the coils in the armature is very low, it may be the only method possible to test the armature.

To perform bar-to-bar Surge testing, the Model AT101D Bar-to-Bar testing accessory is necessary. Bar-to-Bar testing instructions accompany the AT101D and can be found in Supplement 3: Model AT101D Bar-to-Bar Armature Test Accessory in this manual.

Span Testing

This method uses the brushes of the assembled DC motor to make the connections with the commutator for testing of the armature. Any number of bars can be used in this test. Either adjacent bars can be surge tested or a specific number, or “span” of bars can be tested. The number of bars tested in each span for an individual motor must be the same during the entire test. In the repair shop, a fixture can be used in place of the motor’s brushes (refer to Notes and Tips for Span testing an armature).

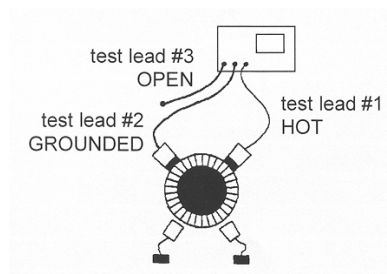


Fig 8-4: Span Test using the Motors Brushes

Do Not Touch Test Leads while test is in Progress!

The wave pattern produced in this test represents the voltage oscillation between the tester and the coils for the specific number of commutator bars spanned. For example, any 10 bars spanned in series on the armature should give the same pattern as any other 10 bars spanned. As the armature is rotated, all the commutator segments and therefore their respective coils, pass into the “test area” between the Hot surge test lead and the GRD lead.

Note: It is important that the same number of bars (and therefore coils) always be in the “test area”. The test wave pattern for each span should match a reference wave pattern on the display for the complete armature if the coils are all good.

1. Remove all brush pig tail connections from the leads at the brush rigging for all sets of brushes to isolate the armature from the power source.
2. With the TLS switch in the LEADS GROUND position, connect test lead #1 to one of the brush assembly pigtails. Connect the GRD test lead to the shaft or other good ground on the frame.

Note: When testing armatures that have bars that are wired in series, it is very important to ground at least two bars of the armature a few bars away from those that are being surged. If this is not done, very high potential voltages to ground can develop in the armature due to a transformer effect in the coil.

3. Select the adjacent set of brushes or the brushes of the bar corresponding to the desired span. Connect test lead #2 and #3 to the pigtail of that brush assembly.
4. Select the TLS position #1. Be sure the Function switch is set to Surge.
5. Begin the test by pressing the test button or footswitch and slowly raising the Output control to the desired test voltage level. Carefully observe the wave pattern for its reference shape.
6. Store this wave pattern as the “reference” wave pattern for this span on this particular armature. Recall the reference wave pattern to the display (Use Quick Store if desired). Note the Peak Voltage displayed on the screen.
7. Begin testing again using the same Output voltage until the test wave pattern matches the reference wave pattern.

Note: The Zero Start Interlock is disabled only when the Function switch is set to AT101 for the AT101D accessory (See Supplement #: Model AT101D) and the Footswitch is depressed. Without the accessory and a footswitch, the Output must be turned back to zero or Min and then brought back up to the peak voltage value noted above in Step 6. The same test voltage must be used for each span tested.

8. Rotate the armature slowly through 360 degrees so that all commutator segments are tested while observing the reference wave pattern.

Note: It is recommended to release the Test button (or Footswitch) each time the armature is turned, but it is not necessary. Doing so minimizes the chance of marking the commutator.

If the test button or footswitch is not released each time the armature is turned, the wave pattern will show regular shifts and flickers as the brushes move across one commutator bar to the next. This wave pattern movements should be ignored as long as the trace returns to the reference wave pattern and remains stable when the brushes are again centered on top of the bars.

Determination of a Fault

If the insulation is weak or failing on a particular bar or coil of the armature, the test wave pattern will become unstable and Shift Left when the section that contains the fault passes through the “test area”. The test wave pattern will no longer match the reference wave pattern. This indicates shorted windings within the span.

Usually, as soon as the bad bar is placed under the hot brush, the wave pattern will show the shift to the left as noted above. Thus the bar directly below the hot brush is the faulty bar. An example of a fault found surge testing using the motor’s brushes is illustrated below.

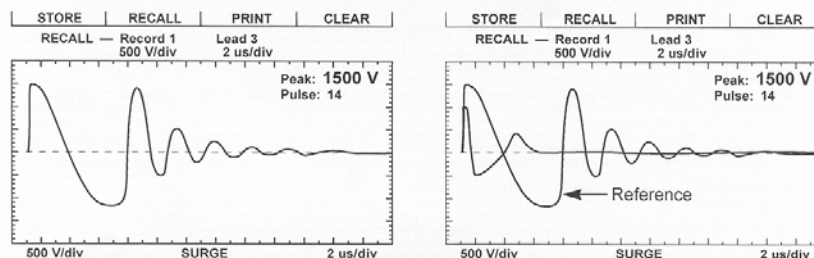


Fig 8-5: Fault located under the ground brush Fault grounded under the hot brush or outside of the surge test span

Notes and Tips for Span Testing Armatures

- A test fixture can be used in place of using the motor's brushes to make contact with the armature.

Set the span between the fixture's brushes to the desired number of commutator bars. Either the fixture can be moved around the commutator during testing, or the armature can be rotated. Procedures for testing and fault determination are the same.

- Always HiPot the armature to ground first. This gives an upper limit for the maximum voltage to apply when surge testing.
- The greater the span surge test voltage is, the more adequate the stress between bars is (ideally, 335 volts according to Pashen's Law). Voltage stress is measured by the differential or drop between each bar. For example, a 10 bar span with 1000 volts applied to it will result in a 100 volt stress between bars. If the span is lowered to 5 bars, 1000 volt applied to the span will result in 200 volts between bars.

Consider, however, that a ten bar span at 335 volts between bars would require a span test voltage of 3350 volts. This potential to ground at the first coil may be too high for the ground insulation system. A lower span test voltage is recommended if, for instance, the HiPot test was only to 2200 volts.

- It is advantageous to keep the span as low as possible to still get a reasonably good ringing wave on the display. However, lowering the span reduces the resistance and inductance of the load under test. The

low inductive load may cause difficulty achieving the desired test voltage and a good ringing wave pattern on the screen.

- To simulate a fault, use an insulated screwdriver to temporarily short two commutator bars together that are in the “test area”. This shows the response of the wave pattern when a fault exists. It gives an indication of what the user should expect to see.
- Equalizer windings can separate the test wave pattern from the reference pattern seen during span tests. Thus, a good armature winding can appear to be bad. For example, a wave pattern for 7 bars spanned may sometimes match that for 11 bars spanned. In addition, the patterns may show a rhythmic shift consistently throughout the 360 degrees of rotation, (for instance, as the armature or fixture is rotated, every third bar shifts left a little), which is not a fault. This is due to the equalizers and does not indicate faulty windings.
- Releasing the Test button or the Footswitch before moving to the next bar during the test minimizes the chance of marking the commutator.

Testing Large AC Stators/Motors

Due to the physical non-symmetry of the input area, high capacitance, and inductance on some large AC high voltage machines, care must be exercised when evaluating the waveforms.

The screens below show wave pattern comparisons for a typical 4160V stator. The first wave pattern is produced when the Seconds/Div control (sweep rate) has been turned clockwise too far, expanding the display of the wave pattern. The sweep rate is set too fast. This wave pattern is actually the first half cycle of the full wave. Distortion is caused by the non-symmetrical, distributed capacitance in the input portion of the winding.

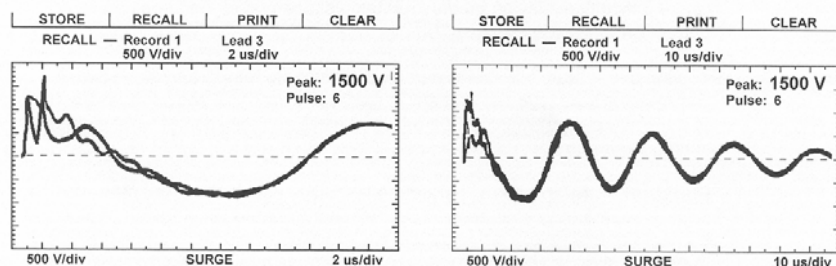


Fig 8-6: Seconds/Div set too far CW

Seconds/Div adjusted CCW

To correct for this display condition turn the Seconds/Div control counter-clockwise, slowing the sweep rate. The correct surge wave pattern will always extend below the zero line. Observe the natural ringing to the right of the point where the wave pattern crosses the zero line in a positive (upward) direction.

Good practice is to start with the Seconds/Div control turned to its counter-clockwise limit to begin when testing high voltage AC machines.

Notes and Tips for Large AC Stator/Motors

- Large AC motors with parallel windings may show little, if any separation of wave patterns when shorted or open windings are present. The inductance change caused by these faults is often not detectable. Instances have been noted where an end turn of a winding “has a hole blown in it,” and yet surge wave pattern comparisons show no separation.

As a result, it is critical to perform a winding resistance test with a milli-ohmmeter or micro-ohmmeter whenever evaluating the condition of a motor winding.

- The surge test must be done on each of the parallel windings individually for the highest degree of fault sensitivity.

Rotor Loading (Coupling) when Testing Assembled Motors

When testing assembled motors, the rotor can influence the shape of the surge wave pattern. These influences are as follows.

1. Loss of wave pattern amplitude: The inductive loading of the rotor causes rapid dampening (little to no cycles of the ringing pattern) of the wave pattern.
2. Separated wave pattern comparisons for good windings: Imbalance in the inductive coupling between the rotor and stator winding causes the wave patterns of two good phases to appear separated when they are compared. By turning the rotor, this coupling effect can be balanced out so the wave patterns superimpose.

Rotor loading can be understood when the rotor is considered as a secondary of a transformer. When one phase being surged has a different number of rotor bars under its stator windings than the other phase being surged and compared, there is a different transformer action existing for each phase. The wave patterns on the display indicate this difference by displaying separated wave patterns when they are compared.

Not all motors exhibit this characteristic. It is most prevalent in smaller, high efficiency motors with small tolerance air gaps. Separation of wave patterns that are due to rotor coupling can be determined when the wave patterns separate from the first positive peak downward, cross one another at the bottom (first most negative point) and separate again as they go upward (positive).

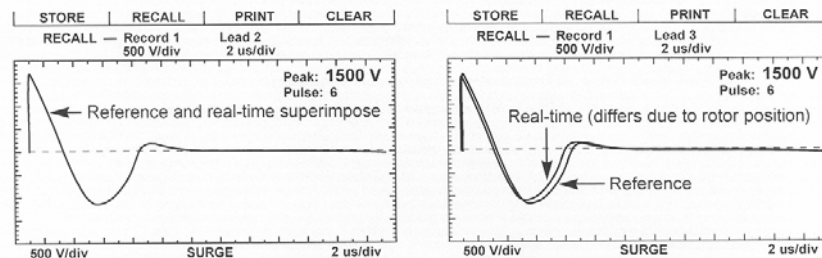


Fig 8-7: Wave pattern comparisons for motor with rotor in place.

The recommended procedure for testing assembled motors where rotor coupling may occur is as follows. Refer to Three Phase Motor Surge Test and Setup for

detailed instructions for surge testing and Storage and Print capabilities for discussions of the storage and recall functions.

1. Surge test phase #1 of the motor. Store and recall the wave pattern by using the quick store function.
2. Surge test phase #2 of the motor. During the test carefully turn the rotor until the wave pattern superimposes that of phase #1 on the display. Store the results in Lead 2 in memory.
3. Repeat step for phase #3.

If the rotor cannot be turned, carefully observe the wave pattern as the test voltage is slowly raised. Watch for a sudden shift to the left, instability, or flickering which could indicate a winding fault. Many winding insulation failures will not be visible at low voltages but become apparent at a higher voltage.

Note: Rotor coupling does not impede the surge impulse from stressing the turn-to-turn or phase-to-phase insulation. It only causes the rapid damping of the wave pattern. This rapid damping decreases sensitivity in interpretation of solid faults. Unstable, flickering wave patterns clearly indicate a fault in assembled motors whether rotor coupling is present or not.

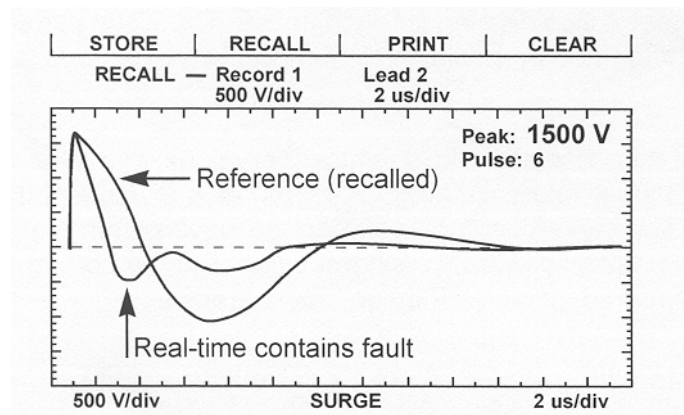


Fig 8-8: Motor with rotor in place and with faulty windings. One trace shift significantly to the left.

Testing Assembled Motors from the Switchgear

The Surge and HiPot tests are valid tests when testing from the switchgear at the motor control center. Not only are the windings of the motor tested, but the insulation on the connections and feeder cables phase-to-phase and phase-to-ground are tested.

Follow all the procedures for surge testing (also refer to Surge Testing). Keep in mind that different types and sizes of motors will give different traces, but the principle of testing assembled motors is still the same. When interpreting the wave patterns for good or bad windings, stability and symmetry are the most important factors.

WARNING!

The motor must be de-energized before testing!
Connect the test leads to only the load side of the open disconnect

Notes and Tips for Testing from the Switchgear

- The test motor should be properly tagged during the test as a safety precaution.
- All of the limitations and guidelines covered for testing assembled motors apply here (see Rotor Loading (Coupling) when Testing Assembled Motors).
- Any power factor capacitors in the circuit must be disconnected. If power factor capacitors are present, no waveform will be observed when the voltage is raised. This will also happen if the motor was not connected to the cable. Only a rise in the trace on the far left will be noted.

- The surge test circuit will be loaded by the feeder cable capacitance as well as the motor. Significantly higher Output settings will be needed to reach the required test voltage. If the surge tester is too small to handle both the cable and the motor load, a trace will be observed but the proper test voltage will not be reached. A higher output surge tester model will be required or the motor may have to be tested while disconnected from the feeder cable.

There is no precise science to determine what size motor, with what size and length feeder cable a particular surge test model can adequately test. In general, the closer the size of the motor is to the recommended maximum motor size for a given model surge tester, the shorter the cables can be and still allow testing at the required voltage. Conversely, the smaller the motor size, the longer the cable can be.

Transformers

Transformers contain similar insulation systems as motors: ground, turn-to-turn and phase insulation. However, the spectrum of winding characteristics for transformers is much broader than for motors.

The Surge test is only one of many tests that should be performed to properly test a transformer. If the transformer has thousands of turns, the surge tester may not be sensitive enough to detect a single shorted winding. It may also sense the high inductance of a transformer as an open.

The following procedures for single phase and three phase transformers provide the basics necessary to surge test transformers. Please call Baker Instrument Company at 800-752-8272 for further assistance or if difficulties are encountered when testing transformers.

Single Phase Transformers

1. Jumper (or short out) the secondary side (low side) of the transformer.
2. Select TLS #1. Follow the diagram below to connect test lead #1 to H1 and to H2 of the transformer. The black GRD lead and test lead #3 go to the frame.

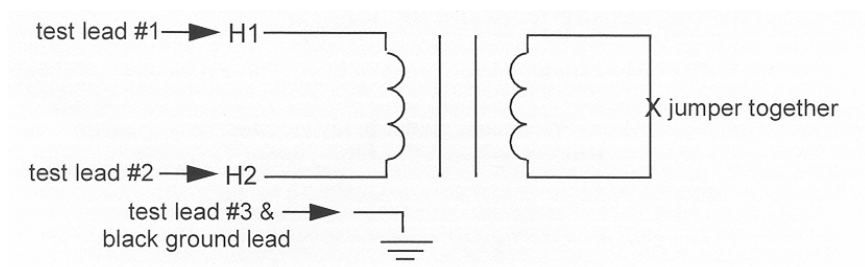


Fig 8-9: Single Phase Transformer Connections

3. Surge test the winding following the procedures outline for Single Phase Motors and Two Terminal Devices. The discussion of determining a fault applies.

NOTE: Secondary winding insulation problems are reflected into the primary winding, and will be observed on the display.

4. After completing the test, reverse the test leads (connect test lead #2 to H1 and test lead #1 to H2) and repeat the surge test. This is commonly referred to as “shooting in the other direction”.
5. Repeat this test process for each TAP position.

Three Phase Transformers

It is beyond the scope of this manual to cover all possible transformer connections. It is important to remember that each line high side connection point must be surge tested to the other end of its own coil, and that the secondary side of the coil being surged must be shorted out (jumpered together and to ground).

Note: A wye-wye transformer with the star point internally tied can be surge tested without opening the tie point.

1. Use TLS position #1.
2. Connect the black ground test lead to the frame (ground) of the transformer.

3. Follow one of the charts below for connections for wye-wye or delta-wye transformers. The transformer windings should be surge tested for all the configurations shown.
4. Test procedures follow identically as for Single Phase transformer testing (refer to Single Phase Motors and Two Terminal Devices)

Determination of a Fault

The determination of a fault when surge testing a transformer winding follows that of the Two Terminal Device (refer to Single Phase Motors and Two Terminal Devices).

Wye-Wye Transformers

Test Lead #1	Test Lead #2	Jumper
H1	HO	XO to X1
H2	HO	XO to X2
H3	HO	XO to X3

Delta-Wye Transformers

Test Lead #1	Test Lead #2	Jumper
H1	H2	XO to X2
H1	H3	XO to X1
H2	H1	XO to X2
H2	H3	XO to X3
H3	H2	XO to X3
H3	H1	XO to X1

CHAPTER 9 DOCUMENTING TESTS

Inside.....

- Test Data Storage
- Recalling Test Data
- Printing Reports
- Compatible Printers



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The Digital Tester comes equipped with a microcontroller based hardware that allows the user to digitize, store, recall and print test data for up to 10 motors or windings. This applies to Surge and DC HiPot testing. The data can also be uploaded to a computer using Baker Instrument Company's MTA for Windows software for further analysis.

There are ten Records available in memory. For each Record there are three Lead memory locations for recording three phase surge testing results. Each record can also record the results of HiPot tests.

The four FUNCTION KEYS above the display correspond to the four functions displayed beneath them. The main functions are STORE, RECALL, PRINT, and CLEAR and are listed across the top of the display. Subsequent submenus also correspond to the four function keys.

Store

Store is used to record measurements to internal memory on the testers.

Choosing Store reveals a list of memory locations available for surge and HiPot tests. Ten available Record memory locations are then listed on the display.

Choosing STORE also reveals a submenu, with choices that correspond to the four function keys above the display.

Store Record Submenu Options

QWK STR	UP	DOWN	SELECT
QWK STR represents QUICK STORE. The wave pattern or HiPot/PI data that is currently on the display is automatically stored in memory of the selected record. The wave pattern will be stored in the Lead #1 location and will immediately display on the CRT. Operation will be returned to the main menu.	UP moves the cursor up the Record list.	DOWN moves the cursor down the Record list.	Press SELECT to choose the Record that the cursor is presently on. In Surge Mode: Press SELECT to reveal the next menu for Lead selection or to cancel a selection (see next page). In HiPot Mode: Press SELECT to store HiPot and/or PI data into the Record and return to the main menu.

Store Resistance Data

If the tester is currently in the resistance test mode and store is selected, the display will allow the user to choose from 10 memory locations that are listed on the display.

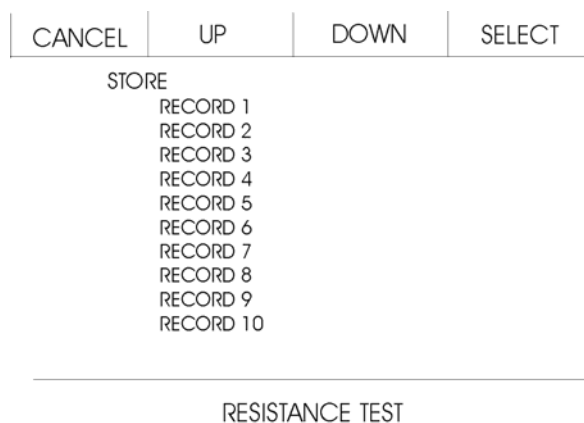


Fig 9-1: Store Resistance Data

Store HiPot and PI Data

If the tester is currently in the HiPot mode, the next display will allow the user to choose whether to store HiPot or Polarization Index data into memory.

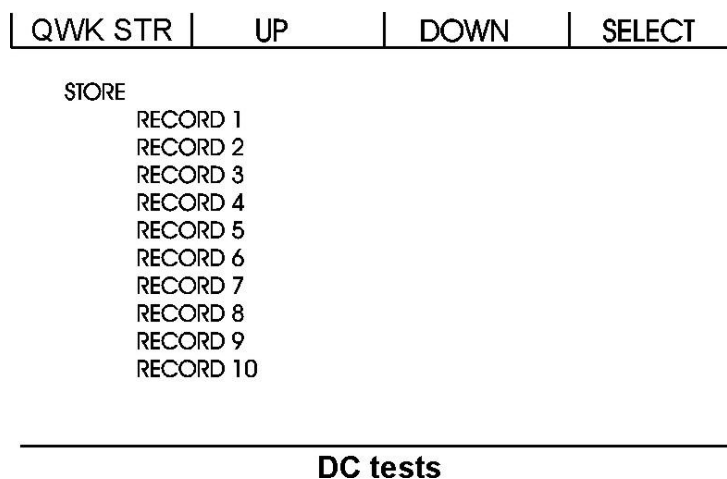


Fig 9-2: Store HiPot & PI Data

Store Surge Data

If the tester is currently in the Surge mode, the display will allow the user to choose the Lead location in memory for Surge tests. Three Lead locations are available for each Record.

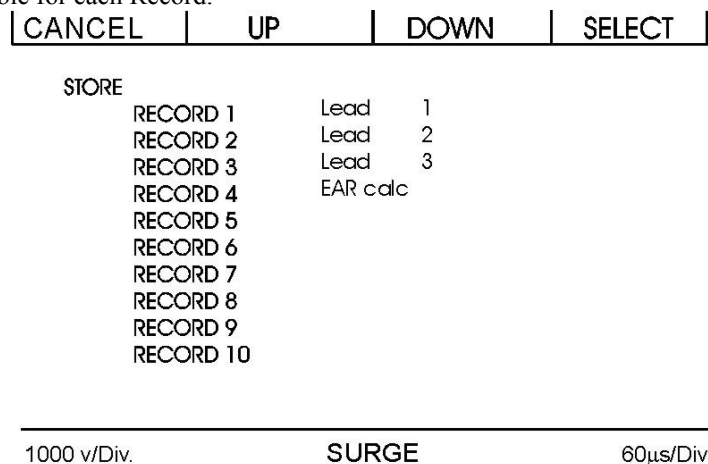


Fig 9-3: Store Surge Data

STORE Lead Submenu Options

CANCEL	UP	DOWN	SELECT
Press CANCEL to return to the main menu without storing any data.	UP moves the cursor up the Lead list.	DOWN moves the cursor down the Lead list.	Press SELECT to choose the Lead of HiPot data type that the cursor is on. Data will be loaded into memory. The user will be returned to the main menu.

Recall

RECALL is used to retrieve measurements from internal memory to the display.

Choosing RECALL reveals a list of memory locations available for resistance, HiPot and surge tests. Ten available Record memory locations are then listed on the display.

Choosing RECALL also reveals a submenu, with choices that correspond to the four function keys above the display.

Recall Record Submenu Options

SUMMARY	UP	DOWN	SELECT
Press SUMMARY to display the Resistance data, Surge data in all three leads, the Meg-ohm, HiPot, and the PI data stored in the Record the cursor is presently on. Resistance, all three surge wave patterns, HiPot, and PI results will be displayed simultaneously and operation will be returned to the main menu.	Up moves the cursor up the Record list.	Down moves the cursor down the Record list.	Press SELECT to choose the Record that the cursor is presently on. In Surge Mode: Press SELECT to reveal the next menu for lead selection or to cancel a selection (see next page). In HiPot Mode: Press SELECT to recall HiPot and/or PI data from the Record and return to the main menu.

Recall Resistance Data

If the tester is currently in Resistance mode, the tester will display the recorded Resistance data for the selected record.

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CANCEL	UP	DOWN	SELECT
RECORD 1			
RECORD 2			
RECORD 3			
RECORD 4			
RECORD 5			
RECORD 6			
RECORD 7			
RECORD 8			
RECORD 9			
RECORD 10			
RESISTANCE TEST			

Fig 9-4: Recall Resistance Data

Recall HiPot Data

If the tester is currently in HiPot mode, the tester will display the recorded HiPot and Polarization Index data for the selected Record.

SUMMARY	UP	DOWN	SELECT
STORE			
RECORD 1			
RECORD 2			
RECORD 3			
RECORD 4			
RECORD 5			
RECORD 6			
RECORD 7			
RECORD 8			
RECORD 9			
RECORD 10			
DC TEST			
1000 V/DIV			
DC tests			
60μs/DIV			

Fig 9-5: Recall HiPot Data

Recall Surge Data

If the tester is currently in Surge mode, the next display allows the user to choose the Lead location from which to recall a wave pattern. Three Lead locations are available for each Record.

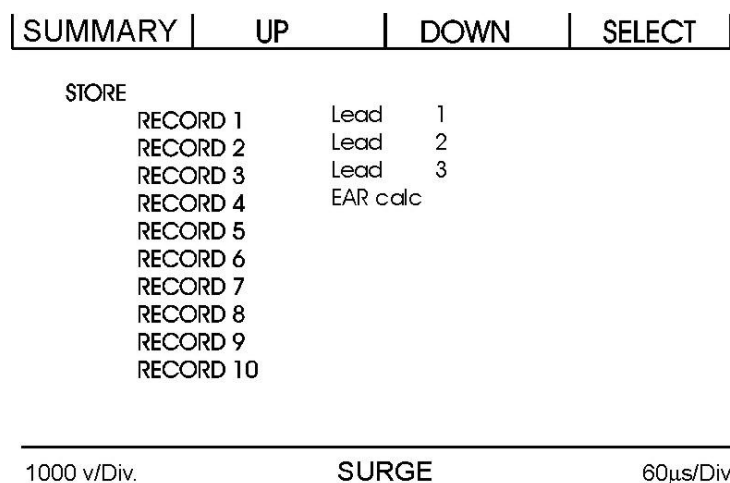


Fig 9-6: Recall Surge Data

Recall Lead Submenu Options

CANCEL	UP	DOWN	SELECT
Press CANCEL to return to the main menu without recalling any data.	UP moves the cursor up the Lead list.	DOW moves the cursor down the Lead list.	Press SELECT to choose the Lead that the cursor is presently on.
Press ERASE to delete the record			Surge data is recalled from memory to the display and the user is returned to the main menu.

Note: RECALL displays only one wave pattern from memory and clears any wave pattern that has been previously recalled to the screen. See Three Phase

Motor Surge Test and Set-up, step 9 for procedures to compare two surge wave patterns simultaneously.

Print

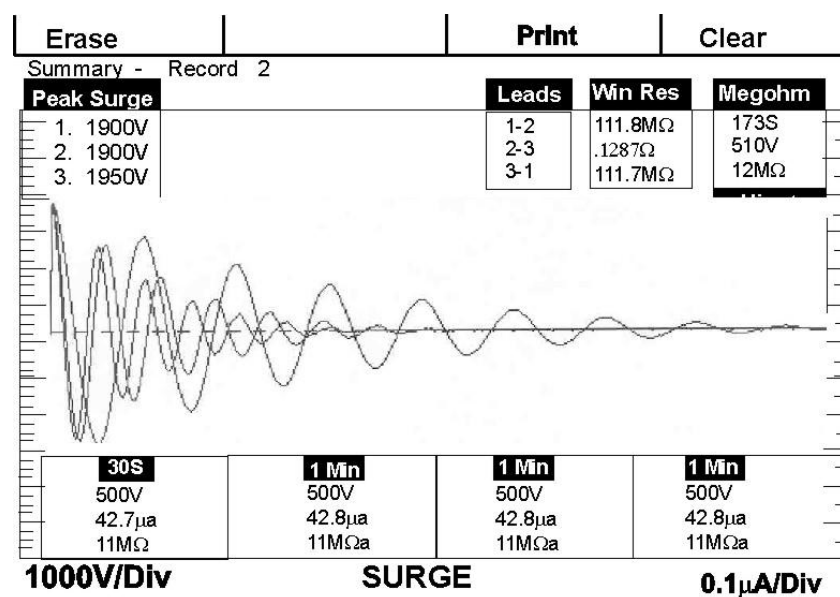
Print will print the record currently on the display.

Clear

Clear will remove or blank out the wave pattern and message area of the display. It has no affect on memory locations or the data stored there.

Erase

The whole record erase feature allows the user to erase all of the Resistance , Meg-ohm, HiPot, PI and Surge data of a particular record after that record's data has been recalled with the Recall Summary feature.



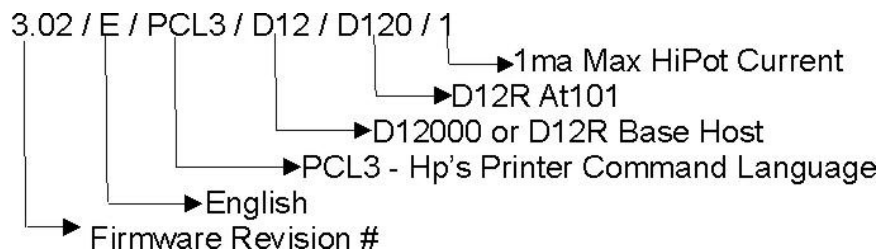
Compatible Printer Information

The HP printer support includes those HP printers that use the Hewlett-Packard PCL 3 printer language/command set. A non-inclusive list of compatible printers follows:

- 500C
- 550C
- 600C
- 610C
- 612C
- 695C
- 697C
- 832C
- 895C
- 970C

The 895C and 970C are unique in that they have universal input power supplies and will work worldwide, regardless of available line power voltage. Any printers purchased for export should be purchased as an export printer which will include HP's international warranty.

Version 3 Firmware



APPENDIX A: TYPICAL WINDING FAULTS

Inside....

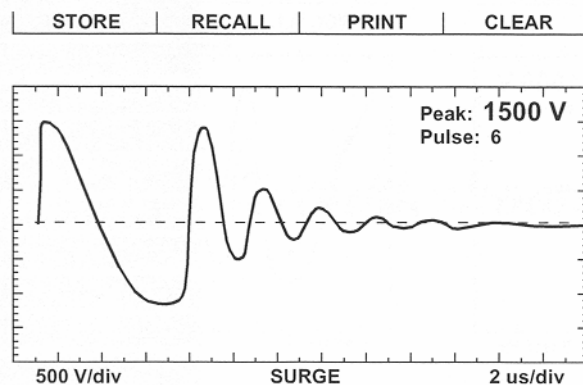
- Typical Winding Faults



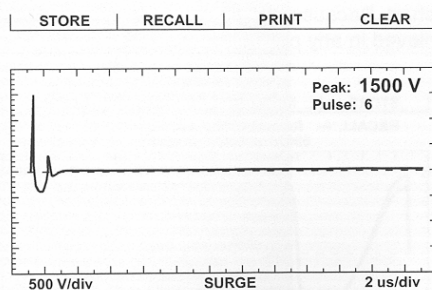
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For initial determination of winding faults, refer to the following figures. These wave patterns are typically seen for three phase, wye-connected, lap-wound induction stators. They provide a reference for associating a characteristic wave pattern with a fault type.

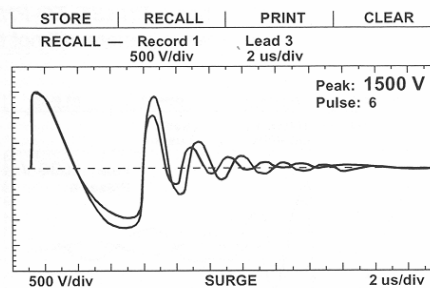
Note: Variation from these wave patterns is to be expected. Do not consider these wave patterns as absolute. Remember, that due to the variety of motor windings and connections that exist, each motor winding will have its own signature wave pattern. Memorization or exact matches to the following patterns is not necessary when testing.



Good coil

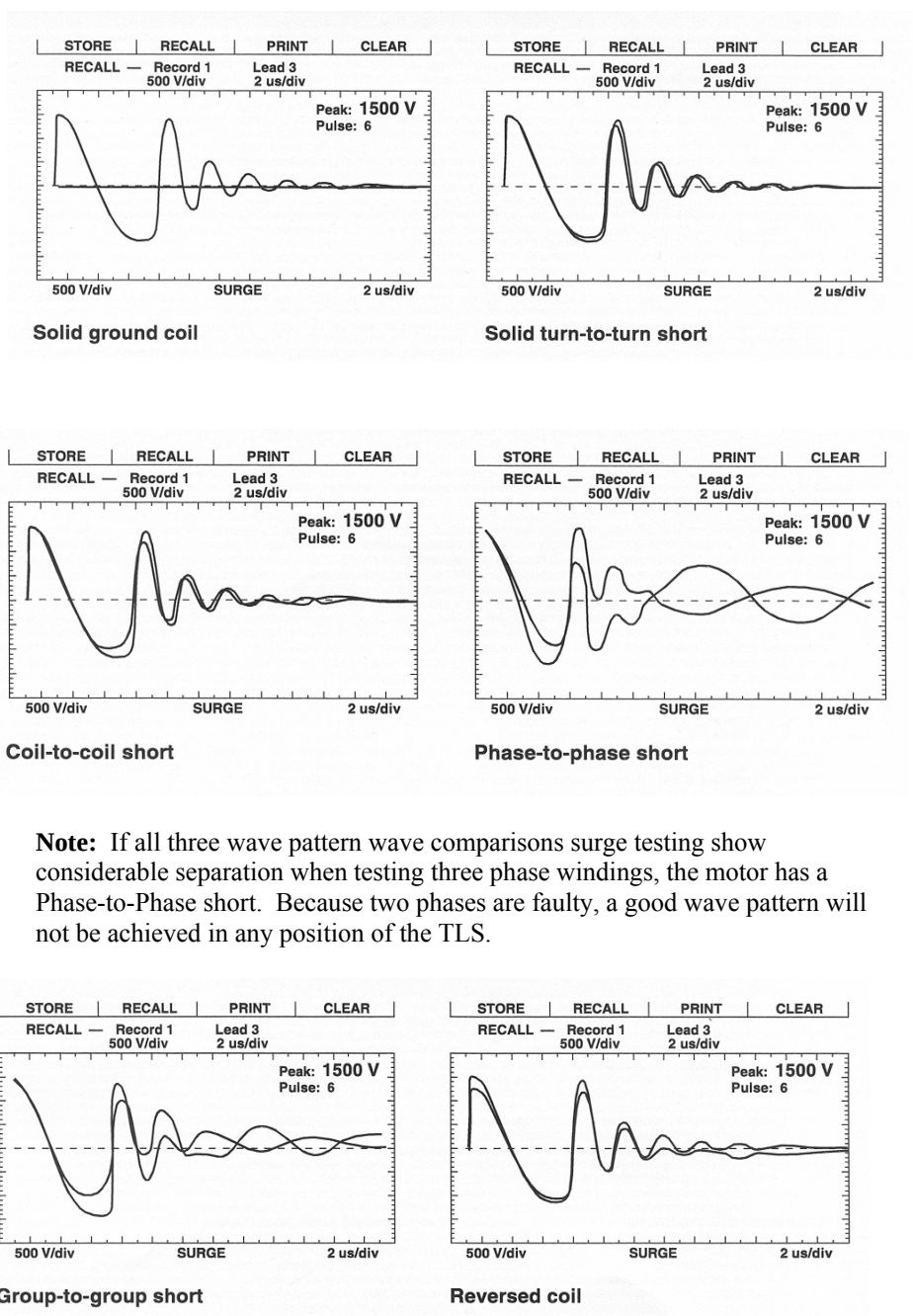


Shorted single winding



Short partial ground

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Note: If all three wave pattern wave comparisons surge testing show considerable separation when testing three phase windings, the motor has a Phase-to-Phase short. Because two phases are faulty, a good wave pattern will not be achieved in any position of the TLS.

Do Not Touch Test Leads while test is in Progress!

APPENDIX B: TROUBLESHOOTING

Inside...

- Self Help & Diagnosis
- Applications – What to do First
- Common Application Problems
- Service: What to do first
 - HiPot Display Checks
 - HiPot Over Current Trip Check
 - Open Ground Check
 - Limited Output Surge Waveform
- Precautions for Proper Operation
- Warranty Return
- Warranty Return Form



Please review this section before calling Baker Instrument Company or returning the unit.

Self Help and Diagnostics

Problems in testing often crop up. If a problem is being experienced and the problem might be with the Baker Instrument Company Digital Tester, please take the following steps before calling or returning the unit.

By performing these procedures and having the requested information available, Baker Instrument Company's Service or Applications Departments will be able to better analyze the situation and provide a appropriate response. Either department may be reached toll-free at 800-752-8272 or 970-282-1200 for assistance.

Step #1: Basic Information

Take down all basic instrument information, including the following:

Product

Model No.

Serial No.

Ex-Service

Note: All information above is located on the rear panel product label. If the tester has special options installed, please note these. Any information concerning the instrument is helpful. A great tool would be a printout or sketch of the waveforms displayed on the tester.

Step #2: Applications or Service Problem?

Generally, if a problem is noted *Only* when testing a specific motor/generator or other coil type, then Applications would be involved. See **Applications: What to do First!** Please call Baker Instrument Company, Sales Department for Applications assistance.

If you can *Not* say the problem is associated with any *One* type of motor/generator, or other coil type, then Service would be involved. See **Service: What to do First!**

Applications: What to do First!

Review the section below on Common Application Problems. Please have Basic Information about the tester and specific information about the motor being tested should be available when calling or faxing to assist Baker Instrument Company personnel in determining a solution to the problem.

Examples:	Hp rating
	kW rating
	RPM rating
	Operating voltage & current
	How the item being tested is wound and/or number and type of coils
	Application of motor/generator

In short, any information that can be provided from the motor nameplate is helpful. A great tool is a printout or sketch of the waveforms displayed on the tester. If a FAX is available, send a draft to 970-282-1010, attn: Applications.

Common Application Problems

Following are the common application-related problems. Please review the following cases.

1. The surge tester will not give the desired output test voltage or the apparatus under test.

The Test motor may be too large for the instrument being used. The impedance of the windings may be too low.

The Digital tester may be at fault in this case. **DO NOT** continue testing until contacting Baker Instrument Company Applications Department.

2. Separation of compared wave patterns is seen when surge testing on coils that are assumed to be good, even on brand new motors or windings. Often, separation is seen in all three comparisons for three phase motors, but to

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varying degrees. There may not be separation throughout the whole wave pattern.

This situation can be seen in DC fields or rotating poles. Be sure the coils being compared are being tested in identical configurations; i.e. both coils are wound clockwise beginning to end.

On very large equipment, slight differences in capacitance to ground may be the cause. At low voltage levels, begin the test again with the black GRD lead removed from the motor frame. If the separation is now gone, capacitance to ground was effecting the test.

3. There is no dampened sinusoidal wave pattern on the display when testing a coil. The wave pattern rises on the left and then slowly drops as it trails off to the right of the screen. It may or may not cross the zero/base line.

The coil under test is probably too high of an impedance to get a good working pattern. The coil may be very high in resistance and turn counts. The inability to surge test this coil, or group of coils in series, will remain unless they can be broken down to smaller units of lower impedance.

A broken test lead may be the cause. Under heavy use, test leads should be checked weekly to ensure that there is no breakage. Grasp the boot and clip in one hand while pulling on the lead with the other hand. A broken lead will stretch, whereas a good lead will not.

4. The instrument has the "Open Ground" light lit.

The instrument has an earth ground safety detect circuit. In certain situations, such as about ship, the detector may think there is no safety ground present. The detector can be disabled internally by removing the jumper wire present at J8-motherboard connector. To remove the jumper, remove the I/O, A/D and Controller boards from the center front panel of the tester. Look inside the card cage for the J8 jumper, clip it out with a small diagonal cutter, replace the cards in the order taken out.

5. How to test using the Baker Instrument with a generator to supply AC power at a remote site.

The instrument will require a driven or earth ground to operate at a remote site, and will need to have the safety ground detector disabled (#4 above).

6. Test lead clips need replacement.

Slide the rubber test lead boots back, remove the old clip and replace the clips with the new ones.

7. How and why to test from the motor's star point.

When testing very large, high capacity motors, it may be impossible to reach the desired test voltage. Delta wound machines usually have an externally connected star point. It is often possible to apply 25-50% more voltage to a single phase of a winding, if it is disconnected at the star point, and tested end to end. The downside is the fact that the connection needs to be broken, and re-taped after the test, which can take several hours. The upside is a smaller, lighter, less expensive tester can be performed on a larger selection of equipment.

8. Cleaning a dirty display.

Use a standard household cleaner such as Windex with a soft clean cloth, since the screen is plastic. Steel wool or sandpaper will destroy the monitor screen.

9. Doing high voltage testing with a printer attached to the printer port.

The surge pattern seen may show distortion from the interference. Additionally, it is possible to damage the printer port with the PP30D 30kV power pack. Quite high levels of RFI/EMI may be generated when the PP30D is doing a surge test. Print the results after testing is done, it will prolong the service life of the Baker Instrument and any peripheral devices such as printers or laptop personal computers.

10. Why the printer port is not specified for operation with cables longer than 10 meters.

The printer port on the D6/12R is a IEEE 1284 compliant parallel port. Electrical standards for parallel ports do not specify correct operation with cable lengths over 10 meters. Data can become scrambled and cause printer or computer problems. Baker Instrument Company suggests the use of a 2 meter cable.

11. How to check/replace blown power entry module fuses.

The power entry module of the D6/12R contains 2 fuses, one for AC Line and one for AC Neutral. If the unit does not appear to have a display, the first thing to check is the fuses. The fuse block is easily removed with a pair of needle

nose pliers. Baker specifies the following fuse rating: 5x20mm 250V 2.5A Slow-Blow.

12. The screen shows a wavy appearance when the unit is at or near maximum output surge test voltage.

The AC power source needs to supply at least 200 watts with minimal sag. If the AC supply is extremely weak, the CRT may show some wavy appearing lines. Use a power supply rated at least to 500 watts for reliable, trouble-free performance.

Service: What to do First?

Because history has shown that several simple solutions which do not require return of an unit may arise, please perform the following checks.

Open Condition Display

Note the figures below. Is the surge waveform like this?

If yes, the unit may have at least one broken test lead causing an Open condition. In most cases, the test lead in common with the two TLS positions that produces these types of wave patterns is the lead which is broken.

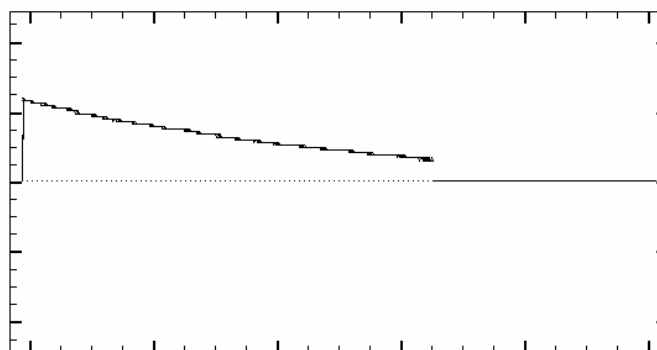


Fig B-1: Open Condition Display

Verify this by pulling on the book/clip assembly of the lead. A broken test lead will stretch. If it does not repeat this procedure at one foot intervals for the length of the lead. If the leads of the tester are good, check the connections and continuity of the test winding.

HiPot Display Checks

The HiPot display shows only the VOLTAGE or CURRENT bar. One of three problems might exist.

- The item being tested is in fact faulty and has either low insulation resistance or open connections.
- The tester has an internal problem.
- The tester has a test lead problem as shown above for an Open Condition.

Disconnect the test leads from the motor and isolate the tester from any grounded surface. Reduce the Output to minimum and attempt a HiPot test with an open lead condition. The display should indicate a rising voltage bar. The current bar may rise slightly but fall back to zero when the output increase is stopped.

Note: It is not necessary to run the output control at a high level to determine if the analyzer is working properly.

If the display still shows **NO** voltage bar call Baker Instrument Company Service Department. Use a meter to confirm the insulation resistance of the device being tested.

Current bar operation can be tested by shorting test lead #1 and the ground lead together. Under this condition, the voltage bar will NOT move off the zero line and the current bar should rise **very rapidly** and activate the HiPot Overcurrent Trip warning light (**HiPot Trip**). If the HiPot Trip light does **not** light, check for open test leads at either test lead #1 or the ground lead (see **Open Condition Check**). If the problem persists, contact Baker Instrument Company Service Department.

HiPot Over Current Trip Check

The HiPot Trip lamp either does not activate (under known shorted conditions) or it will not go out when test is discontinued.

Call the Service Department immediately for assistance. Please record information off the unit and the specific problem prior to calling.

Open Ground Check

The Open Ground warning prevents testing.

Answer these questions:

1. Has the unit recently been moved to a new location with possibly an ungrounded outlet?
2. Is the unit being operated in a field where the AC power source is unknown?
3. Is the unit being operated on a scope cart that has its own outlet or power source?
4. Is the unit being operated using a two-wire extension cord?
5. Is the unit being operated on a transformer isolated circuit?

If any of these questions were answered yes, the unit is probably operational and indicates an open AC line ground connection.

In the case of numbers 1 through 3 above, use an outlet tester to assure proper wiring connections to the outlet. For number 4, replace the two-wire extension cord with a two-wire/with ground extension cord. For number 5, or any of the conditions noted above, use a grounding strap to a good earth ground.

In the case of number 5, call Baker Instrument Company Service for assistance. There is an override available but precautions should be taken.

Limited Output Surge Waveform

The display shows a limited output (amplitude) surge waveform. The display rises normally but stops at some point. Alternatively, continually increase the output control for successive tests to achieve the same output test amplitude.

Call the Service Department immediately for assistance on this or any other abnormal condition noted. Please record basic information from the tester and the specific problem prior to calling.

Precautions for Proper Operation

- **Never raise the output control to attain a display from a blank screen!**
- **Never attempt “simulated” problems by disconnecting the leads and positioning them to arc against each other!**
- **Never come in contact with the item being tested and the test leads or with the tester and the item being tested!**
- **Never attempt a two-party operation. Always know what test is being performed and WHEN!**
- **Never attempt a “Burn-Out” of a detected fault with the tester!**

Warranty Return

Please review the Warranty Notes and Shipment sections at the beginning of this manual before sending the tester to Baker Instrument Company for Warranty repair.

The Warranty Return Form on the following page **MUST BE FILLED OUT** and **RETURNED** with the tester to obtain warranty service. This form will help to ensure that Baker Instrument Company will identify the problem, quickly repair our unit, and return it.

Warranty Return Form

Please fill out all the following information and return this form with the tester.
Make a copy for your records before sending this to Baker Instrument Company.

Note: Be sure to follow the guidelines for shipping when sending the tester to Baker Instrument Company.

Company Name: _____

Your Name: _____

Mailing Address: _____

Shipping Address: _____

Phone Number: _____ Fax: _____

From the Name Plate on the back of the Tester:

Baker Product Number: _____

Model Number: _____

Serial Number: _____

Description of the Problem:

Please give as much information as possible (what is not working, when it happened, what was being tested, any unusual noises, etc.) even if you already talked to someone at Baker Instrument Company by phone. Use the back of this form if necessary.

Person Contacted at Baker: _____

Ship the Tester to: Baker Instrument Company, 4812 McMurry Avenue, Fort Collins, CO 80525, Attn: Service Manager.

APPENDIX C: TECHNICAL SPECIFICATIONS AND CALIBRATION PROCEDURE

Inside.....

- D12R/D6R Technical Specifications
- Accuracy of Measurements – Coil Resistance Test
- Testing Accuracy – HiPot Measurements
- Voltage Measurement Accuracy – Surge (D12R)
- Voltage Measurement Accuracy – Surge (D6R/D3R)
- Quality Control/Calibration Procedure D30R Document



Technical Specifications

Model D3R		
Surge Test	Output Voltage	0-30000 Volts
	Max Output Current	1800-2000 amps
	Pulse Energy	45 joules
	Discharge Capacitance	.1 micro-farad
	Sweep Range	2-2000 μ seconds
	Volts/Division	1250/2500/5000/7500
	Repetition Rate	5 Hz
	Voltage Measurement & Accuracy	+/- 12%
DC Tests	Output Voltage	0-30000 Volts
	Max Output Current	1000 μ amps
	Current Resolution	1/10/100 μ amps division
	Over-Current Trip Settings	10/100/1000 μ amps
	Full Scale Voltage & Current Measurement & Accuracy	+/- 5%
	Meg-ohm Accuracy	+/- 10%
	Max Meg-ohm reading	50,400 M Ω
Physical Characteristics	Weight	305 lbs
	Dimensions	24 x 55 x 26 in.
Power Requirements		120VAC 50/60Hz 230VAC 50/60Hz(Optional)
Resistance Measurement		.0008 ohms – 216 ohms

Accuracy of Measurements - Coil Resistance Test

Approximate Range Resistance	Resolution	Full Scale Accuracy
140Ω - 20Ω	1Ω	+/- 5%
20Ω - 2Ω	100mΩ	+/- 5%
2Ω - .2Ω	2 mΩ	+/- 5%
.2Ω - .020Ω	2 mΩ	+/- 5%
.020 - .0008Ω	1 mΩ	+/- 5%

HiPot Measurement Accuracy – HiPot Voltage

Range	Resolution
1250V/Div	+/- 5% from 1250V – 7000V
2500V/Div	+/- 5% from 2500V – 10000V
5000V/Div	+/- 5% from 5000V – 20000V
7500V/Div	+/- 5% from 7500 – 30000V

Testing Accuracy - HiPot Measurements

Range	Approximate Maximum Measurable Current	Resolution	Full Scale Accuracy
100μA/Div Range	900μA +/- 5% or 45 μA	+/-5% from 90μA-900μA	+/-5%
10μA/Div Range	90μA +/- 4.5 μA	+/-5% from 9μA - 90μA	+/-5%
1μA/Div Range	9μA +/- .45μA	+/-5% from .9μA - 9μA	+/-5%

Voltage Measurement Accuracy – Surge

Range	Resolution
1250V/Div	+/- 12% from 1250V – 5000 V
2500V/Div	+/- 12% from 2500V – 10000 V
5000V/Div	+/- 12% from 5000V – 20000V
7500V/Div	+/- 12% from 7500V – 30000 V

NOTE: PLEASE CONTACT BAKER INSTRUMENT COMPANY PRIOR TO CALIBRATION TO ENSURE THAT THE ENCLOSED CALIBRATION PROCEDURE IS THE MOST CURRENT.

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