



## **Users Manual** **Digital Winding Tester**

D12R, D6R, 3R

### **Baker Instrument Company, an SKF Group Company,**

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800-752-8272 (USA Only)

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference with the equipment is operated in its installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the product manual, may cause harmful interference to radio communications. If this equipment does cause harmful interference, the user will be required to correct the interference. Due to the phenomena being observed and the material properties being measured, this equipment does radiate radio frequency energy while in the active test mode. Care should be taken to insure this radio frequency energy causes no harm to individuals or other nearby equipment.

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**Caution:** Do not touch test leads while testing is in progress!



## Hardware Warranty Information

All products manufactured by Baker Instrument Company, an SKF Group Company, are warranted against defective materials and workmanship for a period of one year from the date of delivery to the original purchaser. Any product that is found to be defective within the warranty period will, at the option of Baker Instrument Company, an SKF Group Company, be repaired or replaced. This warranty does not apply to products damaged by improper use. The purchaser shall assume all responsibility and expense for removal, reinstallation, freight, or on-site service charges in connection with the foregoing remedies. Baker Instrument Company, an SKF Group Company's liability to purchaser relating to the product whether in contract or in part arising out of warranties, representations, instructions, installations, or defects from an cause, shall be limited exclusively to correcting the product and under the conditions as aforesaid.

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D12R, D6R, D3R

## Preface

### Inside this chapter

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- Intended use of instrument
- Technical assistance/Authorized service centers
- Positioning of instrument
- Intermittent operation limits
- Safety symbols & precautions
- Symbols on equipment
- Ground the product
- Cleaning & decontamination
- Installation requirements
- Pollution Degree II
- Power requirements
- Environment conditions
- Unpacking the unit
- Storage (indoor/outdoor)
- Shipment

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**Caution:** Do not touch test leads while testing is in progress!



## Declaration of Conformity

**Manufacturer's Name & Address:**

Baker Electrical Instrument Company, an SKF Group Company,  
4812 McMurry Ave  
Fort Collins, CO 80525  
USA

**EC Representative's Name & Address:**

Baker Instrument GmbH  
Hutbergstrasse 21  
D-90475 Nurnberg  
Germany

**Equipment Description:** Testers for Surge, DC Hi-Pot,  
and Winding Resistance of motors.

**Equipment Model Designations:** D12R, D6R, D3R  
Application of Council Directive 72/23/EEC on the  
harmonization of the laws related to Member States  
relating to electrical equipment designed for use within  
certain voltage limits, as amended by: Council Directive  
93/68/EEC and Council Directive 89/336/EEC on the  
approximation of the laws related to Member States  
relating to the electromagnetic compatibility, as  
amended by: Council Directive 93/68/EEC. Note: due to  
the phenomena being observed and the material  
properties being measured, this equipment does  
radiate radio frequency energy while in the active test  
mode.

**Referenced Safety Standards:**

EN 61010-1

**Referenced EMC Standards:**

EN 61326:2001

EN 55011 Class A

EN 61000-3-2

EN 61000-3-3

EN 61000-4-2

EN 61000-4-3

EN 61000-4-5

EN 61000-4-5

EN 61000-4-6

EN 61000-4-11

I, the undersigned, hereby declare that the equipment  
specified above conforms to the above Directives and  
Standards.

**Signature:**

**Printed Name:** John S. Wilson

**Title:** Manager, Standard Products.

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### Intended use of instrument

The D12R, D6R and D3R, is offered by Baker Instrument Company, an SKF Group Company's standard products division. This machine is intended to be used for the detection of weak insulation within electric motors by trained professionals. It is intended to perform only the specified tests that this manual explains in detail. Please refer to chapters in this manual concerning specific operation of instrument.

### Technical assistance / Authorized Service Centers

|               |                                                                                                     |                                              |
|---------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------|
| Europe        | Baker Instrument GmbH<br>Hutbergstrasse 21<br>D-990475 Nurnberg 60<br>GERMANY                       | 49-911-984600<br>49-911-832169               |
| United States | Baker Instrument Company, an<br>SKF Group Company,<br>4812 McMurry Avenue<br>Fort Collins, CO 80525 | 970-282-1200<br>970-282-1010<br>800-752-8272 |
| Canada        | Emsco, Ltd<br>57 Cannifton Road<br>Belleville, ON K8N 4V1<br>CANADA                                 | 613-966-3235<br>613-966-5806                 |
|               | Prime Instrument Inc.<br>4407, rue Charleroi<br>Montreal-Nord PQ H1H 1T6<br>CANADA                  | 514-329-3242<br>514-329-3750                 |
|               | Pulse Engineering, Ltd<br>1137 Keewatin Street<br>Winnipeg, MN R2X 2Z3<br>CANADA                    | 204-633-4321<br>204-697-2264                 |

### Positioning of equipment

**Note:** Do not position equipment in such a way that it is difficult to operate the disconnecting device(s).

### Accessory interconnection and use

The D12R, D6R and D3R can be equipped with a footswitch. Please see details about the footswitch in later chapters in this manual.

### Intermittent operation limits

At this time there is no intermittent operation limits to the use of the AWA unit.

### Safety symbols & 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.

**Note:** If the equipment is used in any manner not specified by Baker Instrument Company, an SKF Group Company, the protection provided by the equipment may be impaired.

### Symbols on equipment



Earth (ground) terminal

Protective conductor terminal

Frame or chassis terminal

Caution statements identify conditions or practices that could result in damage to the equipment or other property.

Warning statements identify conditions or practices that could result in personal injury or loss of life.



This symbol indicates cautionary information.

This symbol indicates: Caution, risk of electric shock.

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**.

**Caution:** Do not touch test leads while testing is in progress!

**Never** attempt to test an energized motor.

For capacitor started motors or systems with surge arrestors/power factor 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 in an explosive environment.

**Do not** remove the product covers or panels or operate the tester without the covers and panels properly installed.

### 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!**

### Cleaning & decontamination

The D12R, D6R or D3R should be kept clean and in a dry environment. To clean the unit, wipe with a clean water dampened cloth. Do not submerge in water or other cleaners or solvents. To clean the screen, take a soft water dampened cloth and *gently* wipe the surface.

### Installation requirements

The unit may be operated

1. Flat on the bottom of the unit,
2. Flat on the back of the unit, or
3. Held at an angle using the rotating handle.

There are no ventilation requirements.

The unit is intended for use in Installation Category II (Portable Equipment) areas and pollution Degree II Environments where occasional non-conducting condensing pollution can be encountered.

### Pollution Degree II

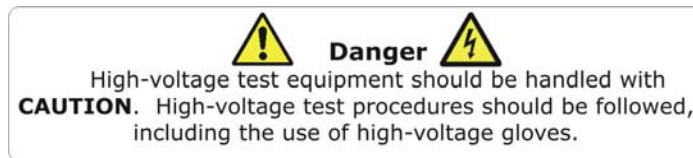
(From IEC 61010-1 3.6.6.2) Only non-conductive pollution occurs. However, temporary conductivity caused by condensation is expected.

### Power requirements

Using the provided AC power cord, connect the unit to a grounded AC power source. The unit's power requirements are 100-240VAC, 50-60 Hz, 2 amps AC maximum current draw. The unit is fused using 2.5A fast blow fuses. Replace fuses with like type and rating.

### Environment conditions

The unit is for indoor use. If used outdoors, the unit



must be protected from rain, snow and other contaminants.

The unit has been tested for use up to 2000m.

The tester should only be operated in temperatures ranging from 41 to 104 degrees Fahrenheit (5° C to 40° C).

This unit is for use at a maximum relative humidity of 80% for temperatures up to 31 °C decreasing linearly

**Caution:** Do not touch test leads while testing is in progress!



to 50% relative humidity at 40°C. This unit is intended for Installation Category II in a Pollution Degree II environment.

This instrument is **NOT** waterproof or sealed against water entry.

This tester is **NOT** approved for use in an explosive environment.

### Repair Parts



Warning: Electric Shock Hazard

During repairs, do not substitute any parts.

Use only factory-supplied parts to minimize

safety hazards.

Do not modify or repair test leads in any way.

Defective, damaged, or broken test leads must be replaced with factory-authorized parts to ensure safe operation and maintain performance specifications.

### Unpacking the unit

Carefully remove the following items from the shipping boxes.

D12R or D6R, D3R

Power Cord

Operator's Manual

**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Instrument Overview

### Inside this chapter

- Front Panel Controls
- On Line Labels
- Initial Tester Power Up & Checkout
- Using the Footswitch

**Caution:** Do not touch test leads while testing is in progress!



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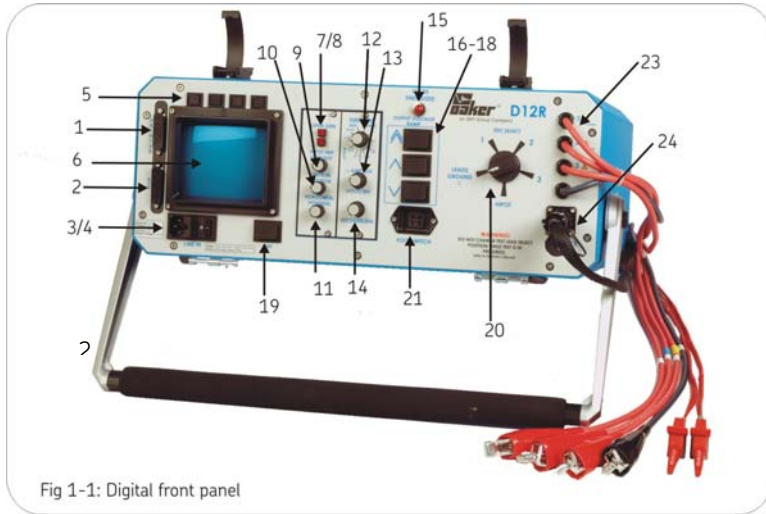


Fig 1-1: Digital front panel

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).

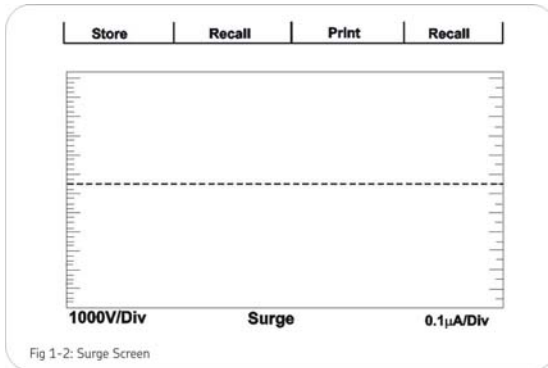
7. Open ground warning light  
When the AC line source is not properly grounded, the red Open Ground light will illuminate. The test set will power up, but high voltage will be withheld by internal electronics.

### 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. Aux port  
Auxiliary port for using the Digital Tester with a 30kV power pack, for high voltage testing. (Refer to Supplement 1: PP130/PP30 Power Pack)
3. Line in  
AC power entry.
4. On/Off  
The on off switch for the unit. On/off switch is combined with the AC power entry and a fuse.
5. Function keys  
Function keys for data collection, recall, clearing and printing of tests.
6. 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
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.
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: Surge Testing, HiPot testing with 4 different current sensitivities, resistance testing for each of the three leads, AT101 testing, and auxiliary/power pack surge/HiPot testing.  
AT101: This position is used when using the Baker Instrument Company, an SKF Group

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Company, Model At101 Bar-to-Bar Armature

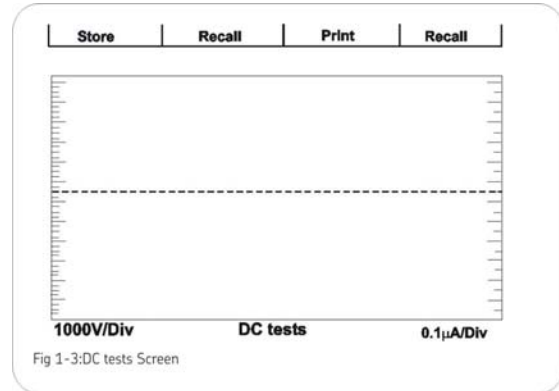


Test Accessory. **Note:** The Zero Start Interlock is disabled when this function is selected and the Footswitch is depressed.

AUX: The auxiliary position is for use with a 30kV Power Pack. The display will also show wave patterns from accessory units in this position.

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-  $\mu\text{A}/\text{div}$ : 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 four positions associated with the HiPot test. The four positions are  $100\mu\text{A}/\text{div}$ ,  $10\mu\text{A}/\text{div}$ ,  $1\mu\text{A}/\text{div}$ , and  $0.1\mu\text{A}/\text{div}$ . The chosen micro-amps per division setting is displayed on the lower right portion of the CRT for reference during testing. The position of the function knob in one of the above current ranges also automatically selects the overcurrent trip point which will be ten



time the settings or  $900\mu\text{A}$ ,  $90\mu\text{A}$ ,  $90\mu\text{A}$ , or  $0.9\mu\text{A}$ , respectively, for each of the sensitivity ranges above.

Resistance Lead 1-2: This position selects the storage location for a resistance test. This does not select the actual leads connected to the D12R/D6R/D3R.

Resistance Lead 2-3: This position selects the storage location for a resistance test. This does not select the actual leads connected to the D12R/D6R/D3R.

Resistance Lead 1-3: This position selects the storage location for a resistance test. This does not select the actual leads connected to the D12R/D6R/D3R.

#### 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 the tester. For example the D12R Volts/Div are 500, 1000, 2000, and 3000 volts. **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, 600, 1000, 2000 micro-seconds per division. The

**Caution:** Do not touch test leads while testing is in progress!

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.

#### 15. Leads energized indicator light

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

#### V fast up



When pressed, this control will increase the applied voltage to a motor at an increasing rate of approximately 1000V/second.

#### V slow up



When pressed, this control will increase the applied voltage to a motor at a slower but still increasing rate of 33.3V/second.

#### V slow down



When pressed, this control will decrease the applied voltage to a motor at a slow rate of approximately 250V/second.

#### 16. Test button

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 and must be held in during the whole length of the test unless the Footswitch is being used.

#### 17. Test lead select switch

#### Test lead connections

| Switch position  | Test lead #1 | Test lead #2 | Test lead #3 | Ground |
|------------------|--------------|--------------|--------------|--------|
| Surge lead 1     | Hot          | Ground       | Ground       | Ground |
| Surge lead 2     | Ground       | Hot          | Ground       | Ground |
| Surge lead 3     | Ground       | Ground       | Hot          | Ground |
| HiPot            | Hot          | Open         | Open         | Ground |
| All leads ground | Ground       | Ground       | Ground       | Ground |

#### 18. Footswitch connector

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 users hand from having to operate the Test button.

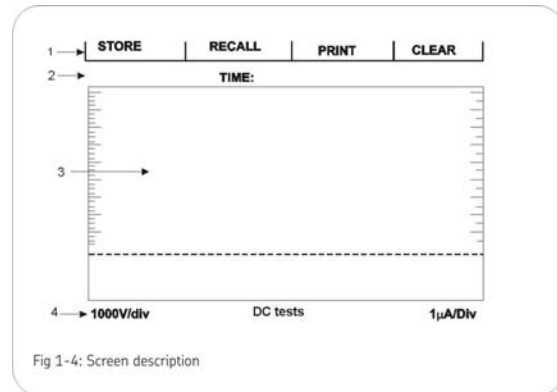
#### 19. Test leads

Test leads #1, #2, and #3 (red) and grounds (black) are provided for contact to the windings. Test leads are insulated to 45kV.

#### 20. Resistance test leads

There are two sets of test leads, two wires each lead, that are provided to make contact to the windings of a motor. Each set of leads contains a current carrying lead and a high impedance sense lead.

#### On-line labels



#### 1. Menu bar

The Menu Bar presents various options for recalling data, storing data, printing data, and clearing the display.

#### 2. Message area

Operation and print message are displayed in this area.

#### 3. Wave pattern display area/record choice area

**Caution:** Do not touch test leads while testing is in progress!

During testing, Surge wave patterns and DC tests potentials are graphically displayed here. Major and minor graticules are provided. During internal memory access, Record and Lead locations are displayed here.

4. Seconds/Div or micro Amps/Div Setting  
Seconds/division is displayed here during Surge Testing. The micro amps/division setting is displayed here during HiPot Testing.

### Initial tester power-up and checkout

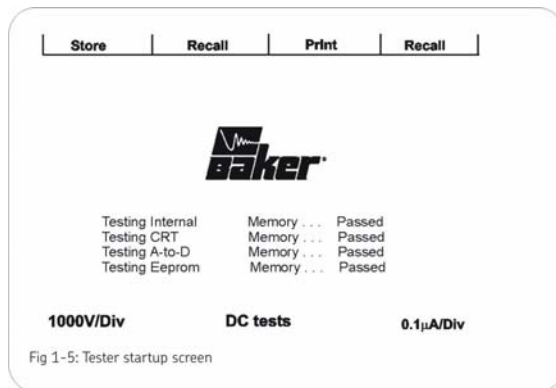
Upon powering up the D3R/D6R/D12R the digital control system begins a self check. Memory is tested, HiPot trips circuits armed, high voltage power supplies disabled, etc. If nothing is visible on the screen, turn the Intensity control to the center of the knob's range. If no image is visible, verify good power is available to the unit and verify the fuses aren't blown.

the tester (broken ground, bad extension cord, excessive ground to neutral voltage) and assure that a low impedance ground is provided to the unit.

If the instrument does not appear to be working properly, contact Baker Instrument Company, an SKF Group Company, 's Service Department. Refer to Warranty Notes and Appendix B: Troubleshooting for more information.

### Using the footswitch

The Digital tester can be equipped with a footswitch that allows hands free operation of the instrument. For example it is used to help eliminate the display effect of rotor loading, by allowing the operator to spin the rotor of the equipment under test.



Each Baker Instrument Company, an SKF Group Company, tester incorporates a supply ground detection circuit. The ground detection circuit is active immediately upon power up on and assures a positive ground is available to the tester. If the instrument is not properly grounded, the Open ground indicator will light and testing cannot proceed. Check the supply to

**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Chapter 2: Test sequence, voltages & applicable standards

### Inside this chapter

- Recommended test sequence
- Coil Resistance
- Megohm test
- Dielectric Absorption (DA)
- Polarization Index (PI)
- DC HiPot
- Surge
- Recommended test voltage DC HiPot & Surge
- Applicable standards

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

## Recommended testing sequence

In order to test motors adequately and to have effective predictive maintenance programs, Baker Instrument Company, an SKF Group 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 meg-ohm 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 – HiPot and Surge tests

Recommended test voltages for HiPot and Surge testing a motor, generator or transformer are 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 tables below for a comparison of IEEE 95, EASA DC HiPot, IEEE522 Surge Testing, IEC 34-15 and Baker recommended testing voltages. Note: Representations of motors are listed. The formulas to calculate voltages are also listed so that test voltage of any size motor can be calculated.



# IEEE 95-1977

| V Line | Per Unit | Min Test<br>Vline*1.25<br>x 1.7 | Max Test<br>Vline * 1.5<br>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<br>+1700 | In Service<br>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<br>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<br>+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, an SKF Group 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
- 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 95-1977 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 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)

**Caution:** Do not touch test leads while testing is in progress!



- 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](http://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](http://www.iec.ch)

**Reprints of IEEE standards are available from:**

IEEE Customer Service  
445 Hoes Lane  
P.O. Box Piscataway, NJ 08855-1331  
Phone: 1-800-678-IEEE  
Fax: 908-981-9667  
[www.ieee.org](http://www.ieee.org)

**Reprints of NEMA standards are available from:**

National Electrical Manufacturers Association  
(NEMA)  
Global Engineering Documents  
Phone: 1-800-854-7179  
International: 303-379-2740



D12R, D6R, D3R

## Chapter 3 Coil Resistance testing

Inside this chapter

- Principles of Coil Resistance testing
- Resistance test display
- Resistance test checklist
- Auto ranging Resistance measurements
- Saving and recalling measurements
- Indications of problems in a motor

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

## 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 D12R/D6R/D3R, 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

## Resistance test checklist

1. Disconnect the high voltage test leads and move them aside. The 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 tester will begin measuring the coil's resistance using an auto-ranging algorithm described below. The test results will be displayed on the screen.

**Caution:** Do not touch test leads while testing is in progress!



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 button to start the resistance test.
9. Once again, the tester 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

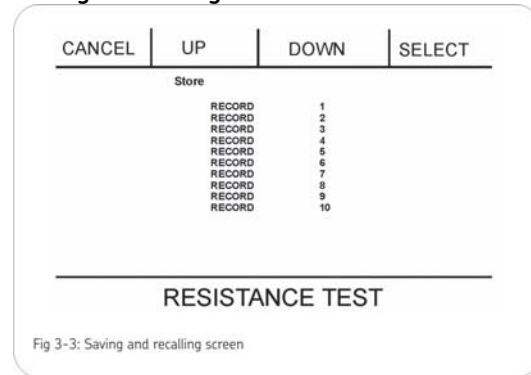


Fig 3-3: Saving and recalling screen

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

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Chapter 4 Principles and theory of DC testing

Inside this chapter

- Principles of DC testing

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

## 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. The test lead selector switch makes all test lead connections. 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 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, an SKF Group 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.

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Chapter 5 Performing high voltage DC tests

### Inside this chapter

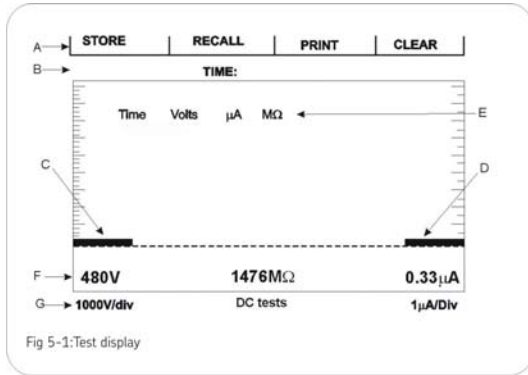
- The test display
- General user cautions and notes
- Test precautions
- High voltage DC test checklist
- DC testing
- Full DC testing of a motor
- Performing only a Megohm test
- Performing only DC over voltage test (DC HiPot test)
- Sample data showing good and poor insulation
- Storing the test results in memory
- Using the footswitch
- The HiPot over current trip indicator
- Effects of temperature
- Step voltage test
- Step voltage test procedure

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

## The 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;  $\mu$ -Amps/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.

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, an SKF Group 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](http://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.
- 2) Move Test Lead selector switch to HiPot position.



Fig 5-2: Motor hookup sample

- 3) Move Function Knob to the 100uA/Div position.

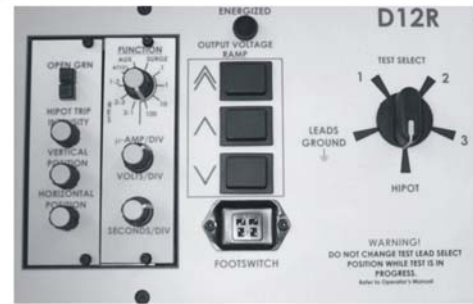


Fig 5-3: Digital unit front panel view

- 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

**Caution:** Do not touch test leads while testing is in progress!

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.

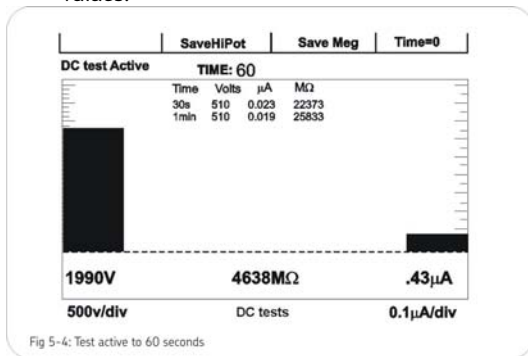


Fig 5-4: Test active to 60 seconds

- 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.

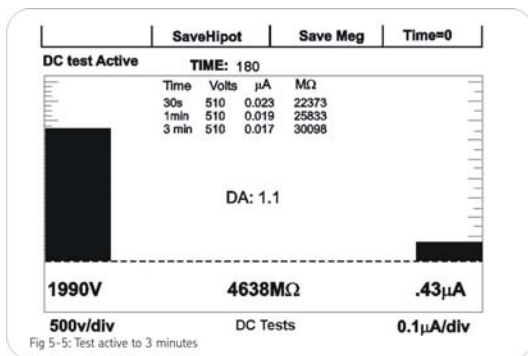


Fig 5-5: Test active to 3 minutes

- 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.

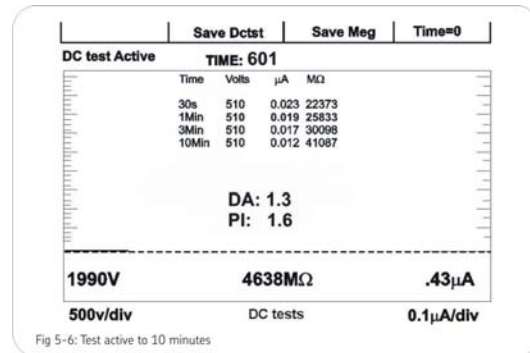


Fig 5-6: Test active to 10 minutes

- 10) Continue to press and hold Test button, and turn Function knob to 100uA/div position.
- 11) Ramp test voltage to desired DC over voltage test value (HiPot test voltage).
- 12) Change uA/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.

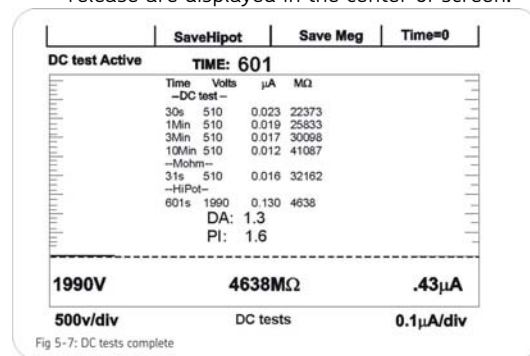


Fig 5-7: DC tests complete

- 14) Save test results by pressing the Store button and selecting desired record.

**Caution:** Do not touch test leads while testing is in progress!

### Performing only a Megohm test

- 1) Connect appropriate high voltage leads to stator windings as seen in Fig 5-2.
- 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 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 as seen in Fig 5-2.
- 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.

- 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.

### Sample data showing good & poor insulation

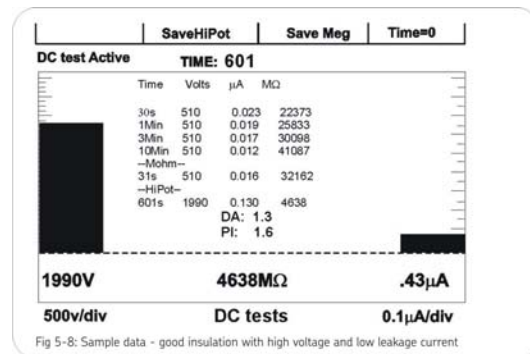


Fig 5-8: Sample data - good insulation with high voltage and low leakage current

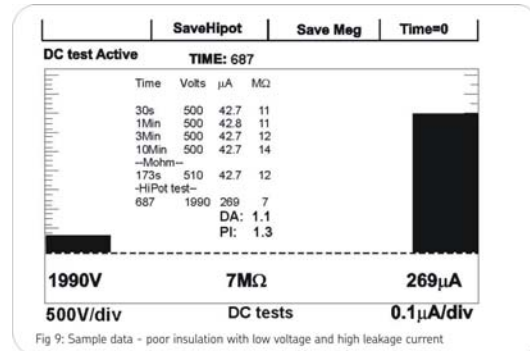


Fig 9: Sample data - poor insulation with low voltage and high leakage current

**Caution:** Do not touch test leads while testing is in progress!

### 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 footswitch

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.

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

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, an SKF Group 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.

**Caution:** Do not touch test leads while testing is in progress!



### 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 or 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.
- 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.

**Caution:** Do not touch test leads while testing is in progress!

D12R, D6R, D3R

## Chapter 6 Principles and theory of Surge testing

Inside this chapter

- Principles of Surge testing
  - o Surge testing theory
  - o Determination of a fault
  - o Motivation for Surge testing
  - o Contact bounce
  - o Lightning strikes
  - o Inverter transients
  - o Line surges
  - o IGBT switching technology

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

## 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.

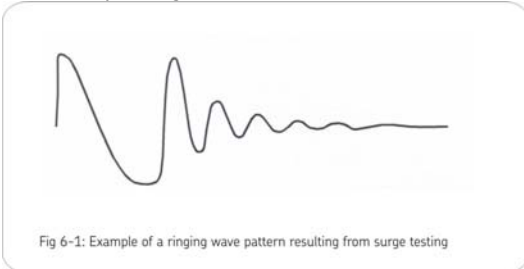


Fig 6-1: Example of a ringing wave pattern resulting from surge testing

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.

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 tester's 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:

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

A surge test can detect a fault between turns that is

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

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.

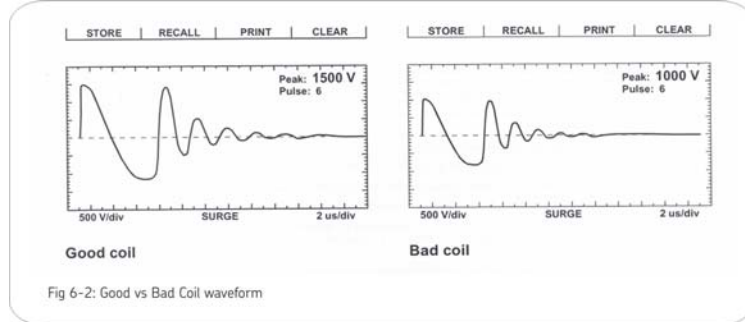


Fig 6-2: Good vs Bad Coil waveform

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.

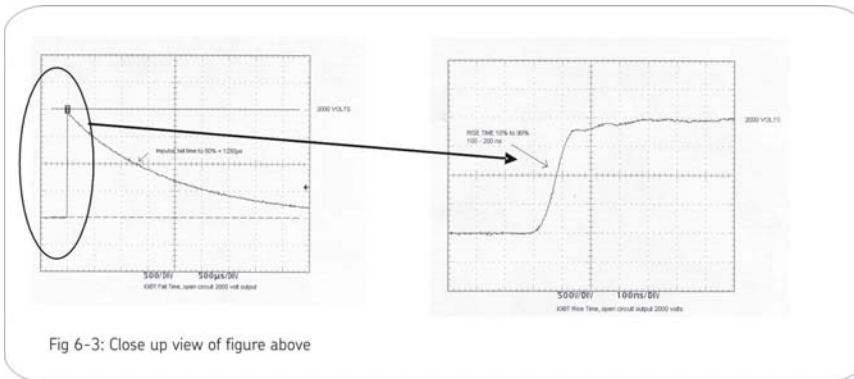
### Inverter transients

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.

### IGBT switching technology

Insulated Gate Bipolar Transistors (IGBTs) are used in the D12R/D6R/D3R 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 D12R/D6R/D3R in much the same manner as in the drives. However, Baker Instrument Company, an SKF Group 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.



### Line surges

The stored energy in a motor or transformer must dissipate when that motor or transformer trips offline from its power system. 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.



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Chapter 7 Performing Surge tests

Inside this chapter

- Surge test display
- Surge test setup
- 480V 3 phase motor checklist

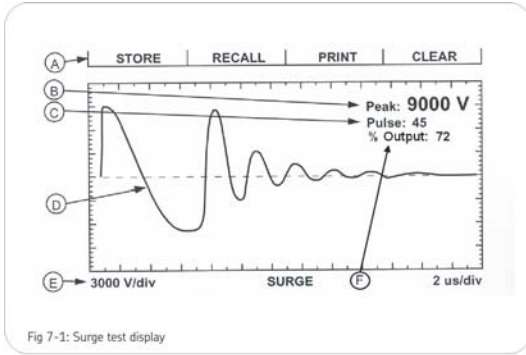
Single coil surge test and setup

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

## Surge test display



- A. Main Menu
- B. Digital Peak Voltage Readout
- C. Number of surge pulses applied to the test winding
- D. Example of a surge wave pattern
- E. Volts/Div Setting, current Test Name, Seconds/Div setting
- F. % 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.

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, an SKF Group 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](http://www.bakerinst.com).

## Surge test setup

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.



Fig 7-2: Tester/motor hookup example

**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

**Caution:** Do not touch test leads while testing is in progress!



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

- 1) 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.
- 2) 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.
- 3) Move Test Lead Switch to Ground.
- 4) Connect the three-phase motor as shown.
- 5) Calculate final test voltage.
- 6) Rotate the Function Knob to Surge.
- 7) Rotate the test selector knob to Lead 1.
- 8) 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.
- 9) Press the Output Control buttons to increase the applied surge voltage.
- 10) 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.

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.

- 11) Watch the surge waveform display while the voltage is increasing looking for flickering display,

**Caution:** Do not touch test leads while testing is in progress!

a drop in amplitude or a jump of the waveform to the left of the display.

- 12) Once the test voltage of 1960V is reached, stop pressing the output control button and release the Test button.
- 13) Store the results for Lead 1 in one of the 10 test records with the following procedure:
- 14) Press the store Function Key above the top of the screen.
- 15) Select the record to store the data in by pressing the Up / Down Function Keys to highlight the desired record and pressing Select.
- 16) Highlight Lead 1 on the next screen.
- 17) Again press select to load the data into the tester's memory.

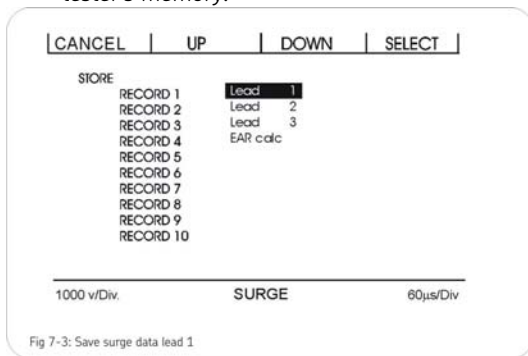


Fig 7-3: Save surge data lead 1

- 18) Move the Test Lead Selector Switch to Lead 2.
- 19) Repeat steps 9 through 12 for lead 2, and save the data in the tester's memory as was done in step 12.
- 20) Move the Test Lead Selector Switch to Lead 3.
- 21) 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.



Fig 7-4: Single coil test hookup

- 2) Connect lead #1 on one side of the coil or winding.
- 3) Connect test lead #2 to the other side of the coil or winding.
- 4) Connect the black Ground lead and test lead #3 to the frame or housing of the coil or winding.
- 5) Turn the Function switch to the Surge position.
- 6) Select TLS position #1. This lead will be HotT.
- 7) 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 setting of 500 will give a wave pattern with 4 divisions

**Caution:** Do not touch test leads while testing is in progress!



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.

- 8) Depress and hold the TEST button (or FOOTSWITCH).
- 9) 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.
- 10) 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.
- 11) When the test for the lead is complete, the TEST button may be released.
- 12) 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.

- 13) When an obvious fault is present, perform **Step 16** below. End the test by disconnecting the motor from the tester.
- 14) Store the test results in the tester's memory.
- 15) For testing a single coil or for standards testing, store the pattern using Quick Store.

- 16) Press the function key corresponding to Store. A list of available records and leads appears.
- 17) 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.
- 18) Store the pattern conventionally if the tests are to be downloaded to a pc for further analysis.
- 19) Press the function key corresponding to Store. A list of available records appears.
- 20) Press the keys corresponding to the UP and/or DOWN to bring the cursor to the desired Record. Press Select.
- 21) 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.

- 22) 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).
- 23) 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***

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. Standard testing demonstrates the coils ability to withstand minimum test voltages and the signature waveform can be compared to the standards single waveform.



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Chapter 8 Surge test applications

Inside this chapter

- Maintenance testing
- Single phase motors and two terminal devices
- Form coils
- Three phase motors
- Two or more single coils
- Wound rotors motors
- Synchronous motor/generator
- DC motor/generator
- Field coils
- Chiller motor testing
- Armatures
- Testing large AC stator/motors
- Rotor loading (coupling) when testing assembled motors
- Testing assembled motors from the switchgear
- Transformers

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

**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, an SKF Group 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 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.

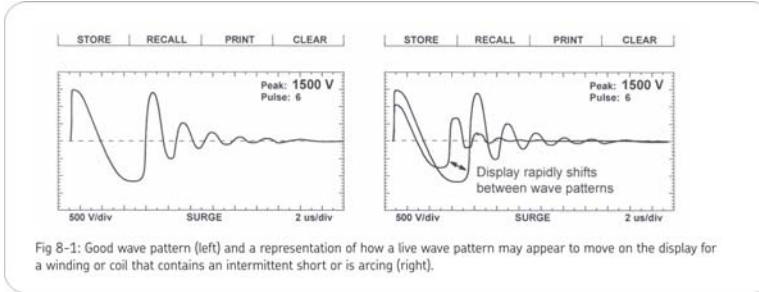
During surge testing, steady separation in the wave pattern comparisons is most often the result of the rotor coupling with the stator. (See Rotor Loading (Coupling) when testing Assembled Motors). In this case, a consistent double wave pattern will be seen at all voltage levels. Separation due to rotor 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 but not above what the motor would withstand during start-up. 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.

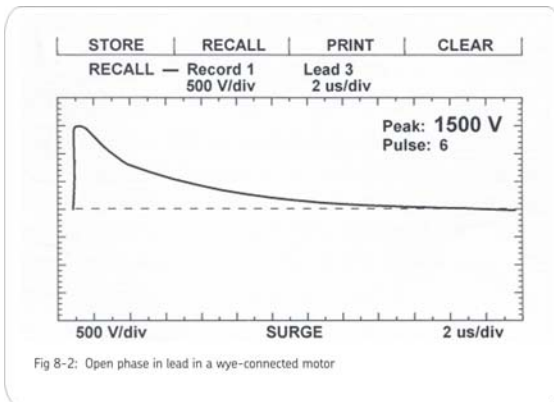
The goal, therefore of the surge test is to detect weakness well above the operating voltage of the motor, as much as twice the operating voltage plus 1000 volts. Refer to Recommended Voltages for a thorough description of how to determine test voltages along with IEEE references that explain the reasons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



### 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.



terminal device. Connect the ground lead and test lead #G 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:

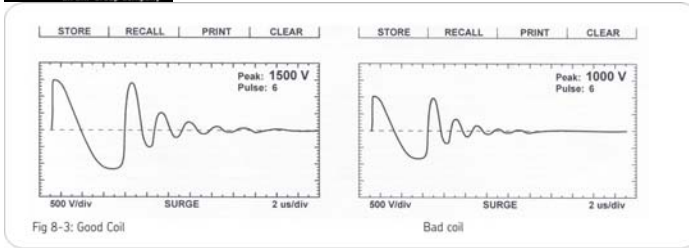
$$Frequency = \frac{1}{2\pi\sqrt{LC}}$$

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

### Single phase motors and two terminal devices

Connect test lead #1 to one side of the device.  
Connect test lead #G to the opposite side of the two

**Caution:** Do not touch test leads while testing is in progress!



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:

$$\begin{aligned}\text{Minimum} &= \text{Number of turns} \times 500 \text{ Volts} \\ \text{Maximum} &= \text{Winding operating voltage} \times 1.5\end{aligned}$$

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 motors

Wave patterns for three phase windings are compared in pairs. The storage capabilities of the Digital Tester allow all three phases to be compared after reconnecting the test leads. The operator simply recalls any one of the previously tested leads. Baker Instrument Company, an SKF Group Company recommends the following procedure:

- 1) Connect the lead number 1 test lead to the terminal lead 1. Connect leads #G to terminals 2 and 3.
- 2) Connect the BLK G lead to the frame or core of the winding.

**Caution:** Do not touch test leads while testing is in progress!

- 3) Begin with terminal 1. This indicates lead #1 will be hot while G leads connected to terminals #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 the wave patterns for the motor for comparison. If three good wave comparisons are seen, there is every indication to believe the motor is good. If anything other than good patterns is seen, 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 #G to the other side.
- 2) Surge test the first coil. Store the results in memory.

Note: Use Quick Store for a fast determination of the results of the test.

- 3) Surge test the second coil or any number of identical coils. Comparing the display to pattern obtained in step 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: i.e.: 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 Motors 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.

**Caution:** Do not touch test leads while testing is in progress!

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 Motors.
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. The bar-to-bar, low impedance test accessory from Baker Instrument Company, an SKF Group 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

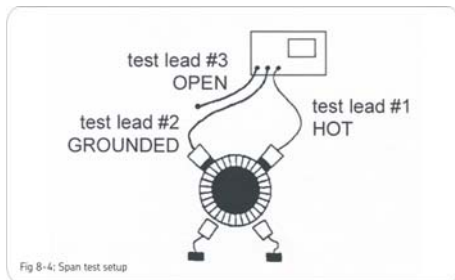
There are two methods of surge testing armatures: the Bar-to-Bar surge test and the Span surge test. The use of a Footswitch is highly recommended to ease the operation of these tests.

#### 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.

#### 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).



### Span Test using the Motor's Brushes

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.

**Caution:** Do not touch test leads while testing is in progress!

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 AT101 accessory (D12R). It also will allow successive testing using this method. (See Supplement #: Model AT101D) and the Footswitch is depressed. When using the internal AT101, the output will not need to be turned back to zero and then brought back up to the peak voltage value Noted above in Step 6. The same test voltage is 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.

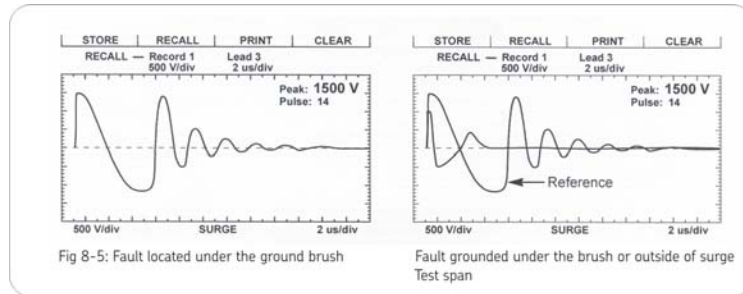
Note: It is recommended to release the Test button (or Footswitch) each time the armature is turned, but it is not necessary. Doing so minimizes the chance of marking the commutator.

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.



### 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.

**Caution:** Do not touch test leads while testing is in progress!

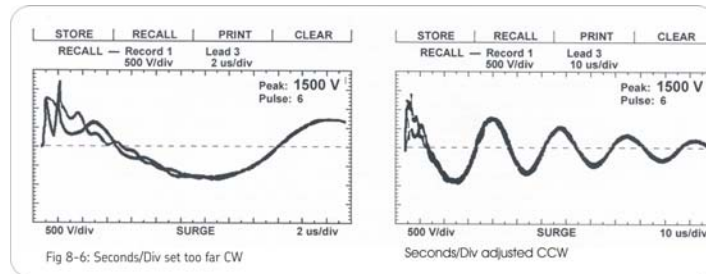
- The greater the span surge test voltage is, the more adequate the stress between bars is (ideally, 335 volts according to Paschen's Law). Voltage stress is measured by the differential or drop between each bar. For example, a 10 bar span with 1000 volts applied to it will result in a 100 volt stress 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. 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.



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

**Caution:** Do not touch test leads while testing is in progress!

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 the Baker milli-ohmmeter or a third party 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

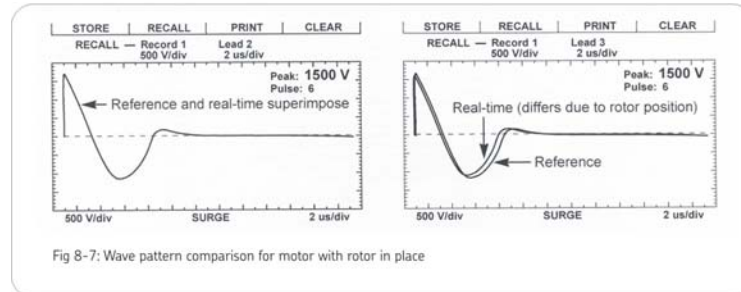
When testing assembled motors, the rotor can influence the shape of the surge wave pattern. These influences are as follows.

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 surges 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).



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.

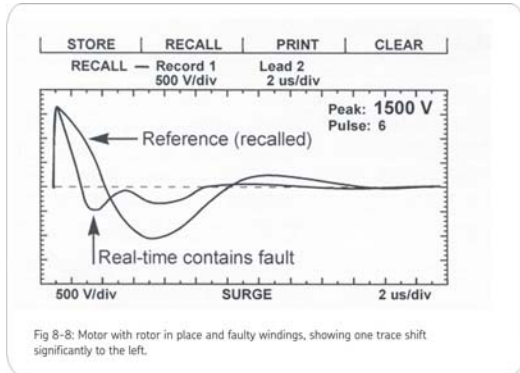
1. Surge test phase #1 of the motor. Store and recall the wave pattern by using the quick store function.
2. Surge test phase #2 of the motor. During the test carefully turn the rotor until the wave pattern superimposes that of phase #1 on the display. Store the results in Lead 2 in memory.
3. Repeat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

**Caution:** Do not touch test leads while testing is in progress!

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.



## 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.

**Caution:** Do not touch test leads while testing is in progress!

## 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, an SKF Group 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 test lead #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 #G go to the frame.
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

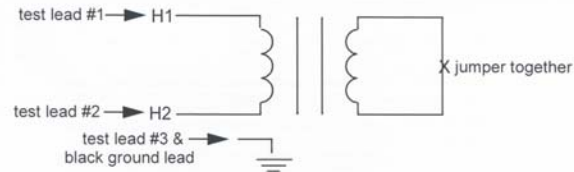


Fig 8-9: Single phase transformer connections

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 test lead #1.
2. Connect the black ground test (GND) 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).

**Caution:** Do not touch test leads while testing is in progress!



## Wye-Wye Transformers

| Test Lead #1 | Test Lead #2 | Jumper   |
|--------------|--------------|----------|
| H1           | H0           | X0 to X1 |
| H2           | H0           | X0 to X2 |
| H3           | H0           | X0 to X3 |

## Delta-Wye Transformers

| Test Lead #1 | Test Lead #2 | Jumper   |
|--------------|--------------|----------|
| H1           | H2           | X0 to X2 |
| H1           | H3           | X0 to X1 |
| H2           | H1           | X0 to X2 |
| H2           | H3           | X0 to X3 |
| H3           | H2           | X0 to X3 |
| H3           | H1           | X0 to X1 |

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Chapter 9 Documenting tests

### Inside this chapter

- Test data storage
- Recalling test data
- Printing reports
- Compatible printers

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



The Digital Tester comes equipped with a micro-controller 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, an SKF Group 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

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

Up moves the cursor up the Record list.

#### Down

Down moves the cursor down the Record list.

#### Select

Press Select to choose the Record that the cursor is presently on.

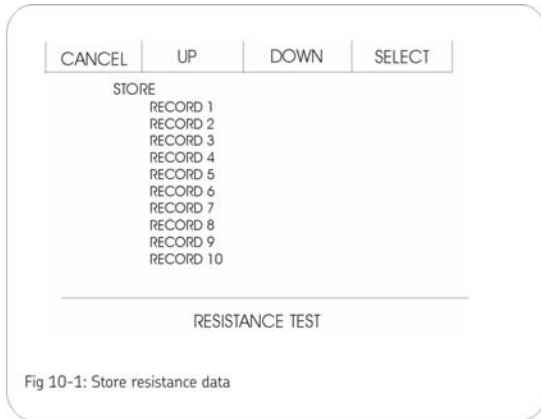
In Surge Mode: Press select to reveal the next menu for Lead selection or to cancel a selection (see next page).

In HiPot Mode: Press select to store HiPot and/or PI data into the Record and return to the main menu.

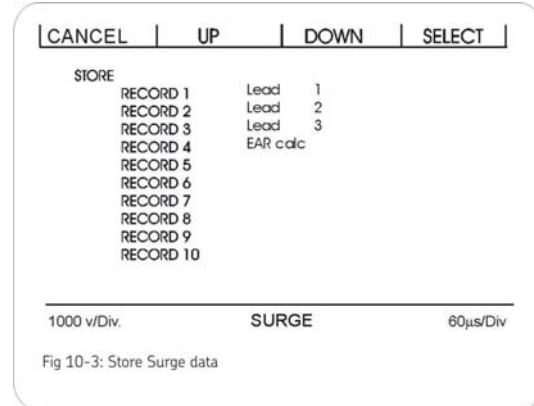
**Caution:** Do not touch test leads while testing is in progress!

### 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.

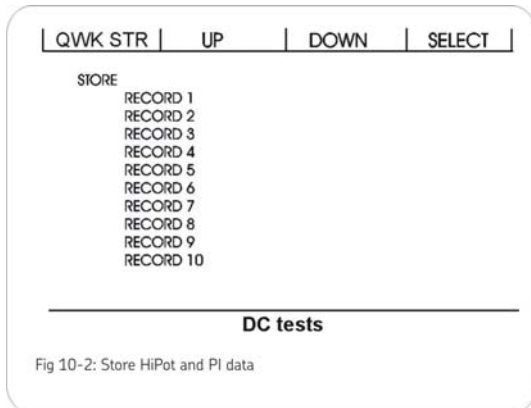


memory for Surge tests. Three Lead locations are available for each Record.



### 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.



### Store Surge data

If the tester is currently in the Surge mode, the display will allow the user to choose the Lead location in

**Caution:** Do not touch test leads while testing is in progress!

| 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.<br>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.<br>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.<br>In Surge Mode: Press select to reveal the next menu for lead selection or to cancel a selection (see next page).<br>In HiPot Mode: Press select to recall HiPot and/or PI data from the Record and return to the main menu. |

**Caution:** Do not touch test leads while testing is in progress!

### Recall Resistance data

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

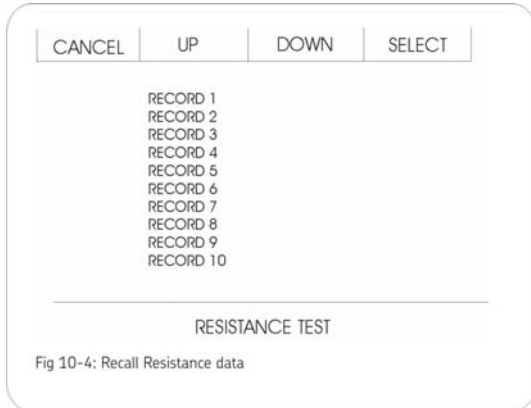


Fig 10-4: Recall Resistance data

### 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.

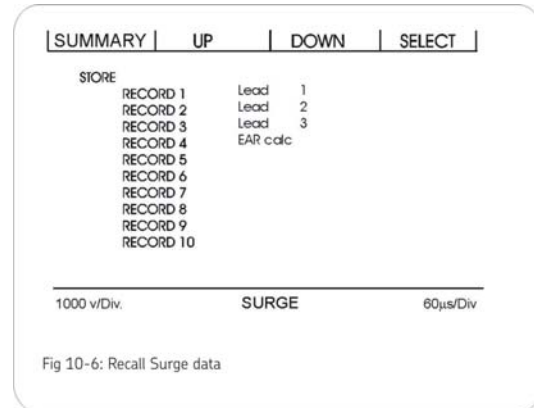


Fig 10-6: Recall Surge data

### 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.

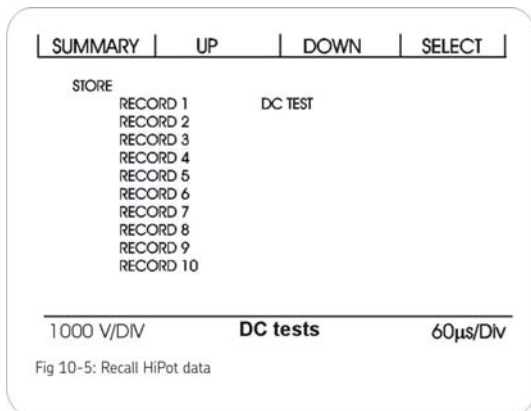


Fig 10-5: Recall HiPot data

**Caution:** Do not touch test leads while testing is in progress!

| 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.

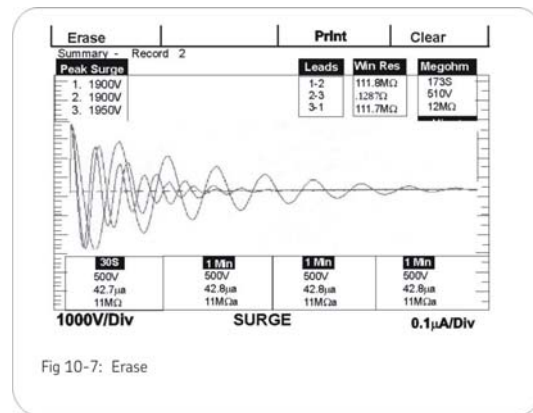


Fig 10-7: Erase

### 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

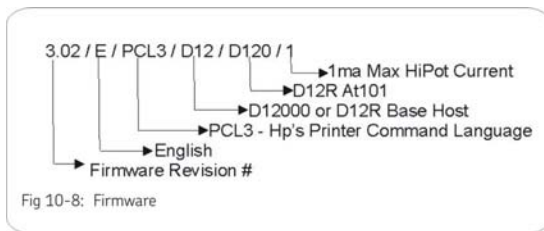
**Caution:** Do not touch test leads while testing is in progress!



- 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



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Appendix A Winding Faults

### Inside this chapter

- Typical winding faults

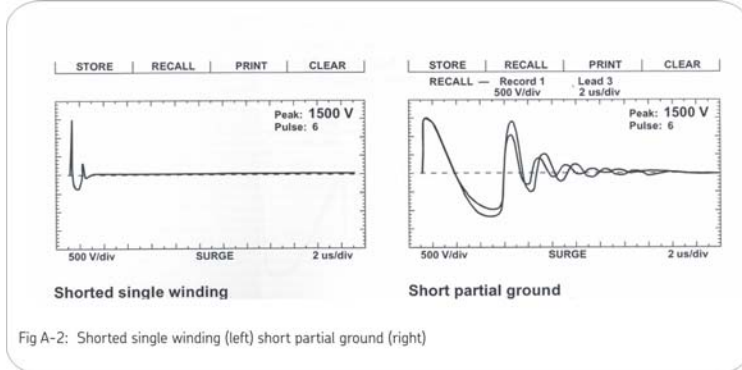
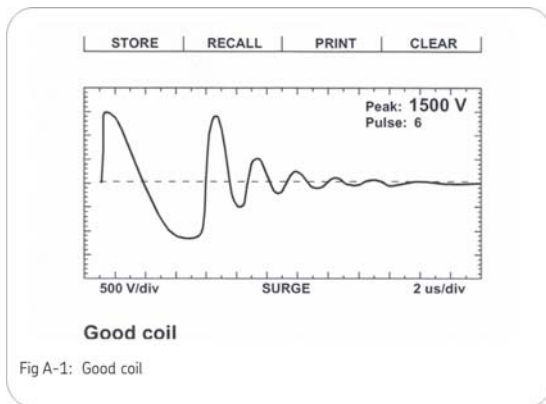
**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

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.



**Caution:** Do not touch test leads while testing is in progress!

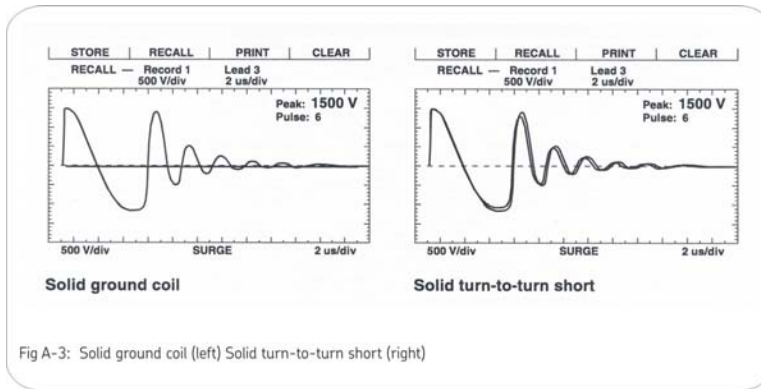


Fig A-3: Solid ground coil (left) Solid turn-to-turn short (right)

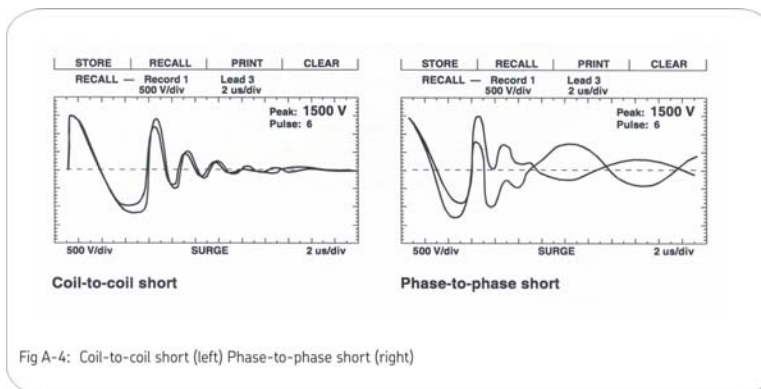
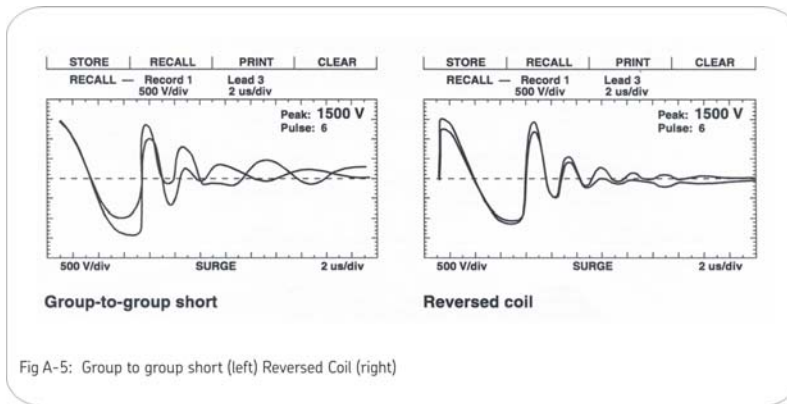


Fig A-4: Coil-to-coil short (left) Phase-to-phase short (right)

**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.

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Appendix B Troubleshooting

### Inside this chapter

- Self help & diagnosis
- Applications – What to do first
- Common application problems
- Service – What to do first
  - o HiPot display check
  - o HiPot over current trip check
  - o Open ground check
  - o Limited output surge waveform
- Precautions for proper operation
- Warranty return
- Warranty return form

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



Please review this section before calling Baker Instrument Company, an SKF Group 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, an SKF Group 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, an SKF Group 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.**

**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 Note: *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, an SKF Group 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, an SKF Group 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, an SKF Group Company Applications Department.

**Caution:** Do not touch test leads while testing is in progress!



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 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.

**Caution:** Do not touch test leads while testing is in progress!

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, an SKF Group 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.

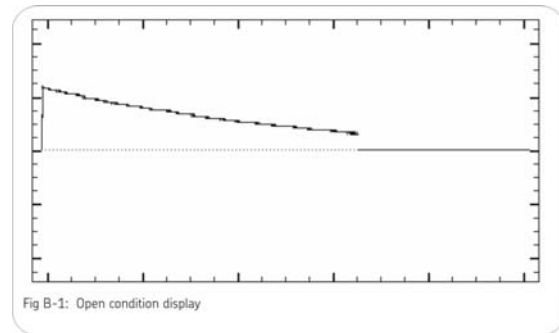
The AC power source needs to supply at least 200 watts with minimal sag. If the AC supply is extremely weak, the CRT may show some wavy appearing lines. Use a power supply rated at least to 500 watts for reliable, trouble-free performance.

## 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.

Verify this by pulling on the book/clip assembly of the lead. A broken test lead will stretch. If the lead does not stretch, 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.

**Caution:** Do not touch test leads while testing is in progress!



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, an SKF Group 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, an SKF Group 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, an SKF Group 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  
**Note:** 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!**

**Caution:** Do not touch test leads while testing is in progress!



- **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 Note and Shipment sections at the beginning of this manual before sending the tester to Baker Instrument Company, an SKF Group 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, an SKF Group 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, an SKF Group Company.

**Note:** Be sure to follow the guidelines for shipping when sending the tester to Baker Instrument Company, an SKF Group 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, an SKF Group Company by phone. Use the back of this form if necessary.

Person Contacted at Baker: \_\_\_\_\_

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

**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Appendix C Technical specifications and calibration

### Inside this chapter

- D12R/D6R/D3R technical specifications
- Accuracy of measurements – coil resistance test
- Testing accuracy – HiPot measurements
- Voltage measurement accuracy – Surge (D12R)
- Voltage measurement accuracy – Surge (D6R/D3R)
- Calibration information

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



## Technical specifications

|                                                     | Model D3R                    | Model D6R                    | Model D12R                   |
|-----------------------------------------------------|------------------------------|------------------------------|------------------------------|
| <b>Surge test</b>                                   |                              |                              |                              |
| Output voltage                                      | 0-3000 Volts                 | 0-6000 Volts                 | 0-12000 Volts                |
| Max output current                                  | 190 amps                     | 350 amps                     | 400 amps                     |
| Pulse energy                                        | 0.18 joules                  | 0.72 joules                  | 2.88 joules                  |
| Sweep range                                         | 2-2000i seconds              | 2-2000 μ seconds             | 2-2000 μ seconds             |
| Volts/division                                      | 250/500/1000/1500            | 250/500/1000/1500            | 500/1000/2000/3000           |
| Repetition rate                                     | 5 Hz                         | 5 Hz                         | 5 Hz                         |
| Voltage measurement & accuracy                      | +/- 12%                      | +/- 12%                      | +/- 12%                      |
| DC High Potential (HiPot) test                      |                              |                              |                              |
| Output voltage                                      | 0-3000 Volts                 | 0-6000 Volts                 | 0-12000 Volts                |
| Max output current                                  | 1000i amps                   | 1000 μ amps                  | 1000 μ amps                  |
| Current resolution                                  | 0.1/1/10/100 i amps division | 0.1/1/10/100 μ amps division | 0.1/1/10/100 μ amps division |
| Over-current trip settings                          | 1/10/100/1000 i amps         | 1/10/100/1000 μ amps         | 1/10/100/1000 μ amps         |
| Full scale voltage & current measurement & accuracy | +/- 5%                       | +/- 5%                       | +/- 5%                       |
| Meg-ohm Accuracy                                    | +/- 10%                      | +/- 10%                      | +/- 10%                      |
| Max Meg-ohm reading                                 | 50,400 MΩ                    | 50,400 MΩ                    | 50,400 MΩ                    |
| Physical characteristics                            |                              |                              |                              |
| Weight                                              | 40 lbs                       | 40 lbs                       | 40 lbs                       |
| Dimensions                                          | 19 x 8 x 23 in.              | 19 x 8 x 23 in.              | 19 x 8 x 23 in.              |
| <b>Power requirements</b>                           | 85-264 VAC 50/60 Hz          | 85-264 VAC 50/60 Hz          | 85-264 VAC 50/60 Hz          |
| <b>Resistance measurement display</b>               | .0008 ohms – 216 ohms        | .0008 ohms – 216 ohms        | .0008 ohms – 216 ohms        |

**Caution:** Do not touch test leads while testing is in progress!



### 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%              |

### 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%               |
| 0.1μA/Div Range | .9μA +/- .045μA                        | +/-5% from .1μA - .9μA | +/-10%              |

### Voltage measurement accuracy – Surge (D12R)

| Range     | Resolution                   |
|-----------|------------------------------|
| 500V/Div  | +/- 12% from 500V – 1960 V   |
| 1000V/Div | +/- 12% from 500V – 3930 V   |
| 2000V/Div | +/- 12% from 1000V – 7870 V  |
| 3000V/Div | +/- 12% from 2000V – 11900 V |

### Voltage measurement accuracy – Surge (D6R/D3R)

| Range     | Resolution                  |
|-----------|-----------------------------|
| 250V/Div  | +/- 12% from 250V – 980 V   |
| 500V/Div  | +/- 12% from 500V – 1960 V  |
| 1000V/Div | +/- 12% from 1000V – 3930 V |
| 1500V/Div | +/- 12% from 1500V – 5950V  |

### Calibration information

Please contact Baker Instrument Company for current calibration information. Contact the service department at (970) 282-1200, or (800) 752-8272.

**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Supplement 1 PP130/PP230 power pack (D12R only)

### Inside this chapter

- Initial set-up
- Power pack operation
- Surge testing
- DC HiPot testing
- Lead connection
- Single phase lead connection
- Three phase lead connection
- Note regarding 220/240 VAC units
- Output configuration
- Output during testing
- Operation position
- Lifting instructions\
- Shipping

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



The use of the PP130/PP230 Power Pack incorporates a system of two separate units; a 12 kV host unit (the Digital Tester) and a 30 kV power pack. The 12 kV portion of the system is capable of stand alone operation for Surge or DC HiPot test functions. The power pack relies on the 12 kV host unit to provide triggering and readout functions and cannot operate alone.

Instructions for stand alone operation of the 12 kV host unit should be reviewed in the main portion of this manual before attempting operation with the 30kV power pack. This supplemental manual will provide instruction on how to correctly set up, connect, and operate the power pack, and other important safety information.

**Caution**

Never attempt testing a load with both 12 kV and Power Pack test leads attached to the load at the same time!

Note: The ground fault system on the 12 kV host tester will render it inoperative without a proper ground. When the host tester is connected to the PP130/230, any inoperable condition will also affect the power pack due to loss of the surge enable signal.

These instruments should never be used without a grounded supply.

**Caution notes**

User safety demands that the tester output never be activated without connection to a winding load of some type. Please refer to the host tester instructions in the main portion of this manual for connection procedures to various windings.

Remember: The host testers Volts/Div switch affects only the display amplitude on the CRT. It does not control or limit the output voltage of the host unit or power pack in any way.

**Emergency shut off button**

The 30kV power pack is equipped with a large, red Emergency Shut-Off button on the front panel of the unit. It is located to the right of the TEST button. Use it to quickly discontinue a test and to shut off all power to both the power pack and the Digital Tester.

The emergency shut-off button is a two position switch. While in the IN position, power is supplied to both the power pack and the Digital tester and testing can proceed as normal. When put into the OUT position by pressing it once, any test that is in progress will immediately stop and the power to both units will turn off.

To resume testing with the power pack and/or the Digital tester, depress the emergency shut-off button again (it must be in the IN position). The On/Off switch lights of both units will turn on. Follow the procedure for Power Pack Operation to follow.

**Initial set-up**

These instructions refer to the PP130/230 VAC Power Pack. Instructions are identical for the PP230/240 VAC power pack.

Connect the power pack to the tester. Use the short AC line cord on the power pack front panel to connect to the 12 kV host tester power entry receptacle (Line In).

Connect the 25-pin interconnect cable between the front of the two units. The cable is marked on each end. Be sure to plug in the end marked HOST into the Auxiliary port (AUX) on the front of the Digital Tester panel and the end marked 30KV into the Auxiliary port (AUX) on the front of the Power Pack.

Connect the long AC power cord to the power pack front panel receptacle and then to an appropriate AC power source. For 220/240 Volt Power Packs, please see note regarding 220/240VAC UNITS concerning AC line cord connectors.

Both units are now ready for operation.

The host tester is equipped with a ground fault monitor and indicator. This circuitry should not hinder operation of GFI protected AC power circuits.

**Caution:** Do not touch test leads while testing is in progress!



If a problem exists, the internal ground monitoring circuit may be disabled. Please call Baker Instrument Company, an SKF Group Company's Service Department at 800-752-8272 for assistance. The ground fault monitor must also be disabled in the event that the unit is to be operated on a transformer isolated AC circuit. Failure to do so will cause a loss of ground indication, disabling the high voltage power section of the unit. Please assure safe operating practices whenever disabling the ground monitor circuit! It is advised that some type of external grounding strap be used.

## Power pack operation

### Surge testing

Power-up the 30 kV power pack and host tester. Follow the host tester set-up procedures in this manual (refer to Single Coil Surge Test and Set Up or Three Phase Motor Surge Test and Set Up).

**Note:** The PP130/230 requires a one to two minute warm up prior to operation.

Set the 12 kV host tester FUNCTION control switch to AUX (auxiliary) position.

**Note:** The volts per division setting when the AUX is selected will change the Volts/Division setting from 500, 1000, 2000, 3000 Volts/Div to 1250, 2500, 5000, and 7500 Volts/Div. The 1250 Volts/Div setting is not available with the PP130/230 and an error message will appear on the display when this setting is selected. Use 2500, 5000, and 7500 Volts/Div only.

Assure the power pack OUTPUT control is at MIN, (full counter-clockwise).

Connect the power pack leads to the appropriate load. See Lead Connection for proper test lead connection.

**Note:** It is important to connect the safety ground (the smaller diameter black ground lead) to the frame of the test winding and NOT to the coil ground lead. Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.



### CAUTION

High Voltage ACTIVATION is next! Ensure that all personnel are away from the device under test and are not in contact with either load or test leads!



### WARNING

Some test leads will be open during the test and can be at the same voltage potential as the winding! All precautions should be made to avoid touching these leads.

Start test by depressing the power pack Test switch (or footswitch) and slowly raise the power pack output control. A pattern should immediately be visible on the display screen of the host tester. If not, recheck the connections and all the switch settings. Also assure that the interconnect cables have been attached and are secure.

The display may require adjustment for optimum clarity, sweep and positioning. Make any adjustments required prior to continuing the test.

Determine test voltages and adjust the VOLTS/DIV setting so that the waveform is fully displayed without going off the screen.

When the test is complete, release the test switch of the power pack and return the output control to its minimum setting.

Store the wave patter into the internal memory of the host unit, or onto a computer connected to it. See Storage and Print Capabilities.

Reposition the red (Hot) and black (Ground) test lead, previously connected to the leads of the windings. Refer to Lead Connections. Compare all phases against each other: #1 vs. #2, #2 vs. #3, and #3 vs. #1. By switching one hot and the ground lead each time, the operator can make all the measurements necessary for these comparisons. The operator may find it advisable to mark or identify the stator leads at the time of or prior to the first test.

**Caution:** Do not touch test leads while testing is in progress!



| Lead 1 | Lead 2 | Lead 3 |
|--------|--------|--------|
| Hot    | Ground | Ground |
| Ground | Hot    | Ground |
| Ground | Ground | Hot    |

### DC HiPot testing

Power-up the 30 kV power pack and host unit. Follow host tester set-up procedures in this manual (Refer to DC HiPot Test and Set-Up)

Set the host units function-switch to the Aux setting. Set the 30 kV Power Packs function-switch to the HiPot setting.

**Note:** As the Power Pack function switch is changed to the HIPOT setting, a loud relay noise will be heard. This is normal for the Power Pack.

Connect the red (Hot) lead from the power pack to the winding to be tested, and the black (Ground) leads to the iron or core material.

Begin testing by depressing the power pack test switch and slowly increase the output control.

As the output is increased, the Voltage Bar rises up slowly and the Current Bar rises rapidly on the right side showing the charging current. When the output is held at a given voltage setting, the Current Bar will fall and remain at a constant level to indicate the leakage current.

**Note:** This test should be interrupted any time a fast, sharp rise in the current is observed.

**Note:** The over-current HiPot trip levels that activates the HIPOT TRIP light are ten times the micro-amps/division settings on the tester. The trip levels are 10,100, 1000 micro-amps. Releasing the TEST button will reset the over-current trip to begin testing again.

Adjust Volts/Div and  $\mu$ Amp/Div to best monitor the voltage and current levels. Note the voltage, resistance in mega-ohms, and leakage current levels displayed on the screen.

When the desired test voltage has been achieved, press the Time=0 function button (the right most button above the CRT display). The elapsed time

displayed in the upper left corner of the screen will reset to zero.

**Note:** Use Time=0 function to be sure the full DC voltage potential is applied for the required test time. In this way, the time required for voltage ramp-up will be discounted for both HiPot and Polarization Index tests.

Upon completion of the test, return the output control to min and release the test button. If desired, store the HiPot data into the internal memory of the host unit. See Storage and Print Capabilities.

**Note:** Always allow a sufficient time for the winding under test to completely discharge before disconnecting the test leads. The recommended practice is to discharge the winding for duration of at least five times the duration of the DC HiPot test for high voltage windings.



#### CAUTION

Disconnect the units test leads not being used from the load.

Never use the host units ground leads for grounding during the 30kV power pack test!

**Note:** For HiPot operation of the 12 kV host tester alone, the host tester and the power pack must be disconnected from each other.

For Surge operation of the 15kV host tester alone, the operator need not disconnect the two units. Simply place the 12 kV host unit function back to the Surge position. The host unit is now ready to Surge test alone.

### Lead connection

RED = Hot lead

BLK/BLU = larger diameter black ground lead with blue braided cover

SM BLK = smaller diameter black ground lead

**Note:** It is important to connect the safety ground (the smaller diameter black ground lead) to the frame of the test winding and NOT to the coil ground lead.

**Caution:** Do not touch test leads while testing is in progress!



Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.

**Note:** Some test leads will be open during the test and can be at the same voltage potential as the winding! All precautions should be made to avoid touching these leads.

### Single phase lead connections

|              | Lead 1  | Lead 2  | Lead 3  | Frame  |
|--------------|---------|---------|---------|--------|
| Test Phase 1 | Red     | Blk/Blu | Open    | Sm Blk |
| Test Phase 2 | Open    | Red     | Blk/Blu | Sm Blk |
| Test Phase 3 | Blk/Blu | Open    | Red     | Sm Blk |

|              | Lead 1  | Lead 2  | Lead 3  | Frame  |
|--------------|---------|---------|---------|--------|
| Test Phase A | Red     | Blk/Blu | Open    | Sm Blk |
| Test Phase B | Open    | Red     | Blk/Blu | Sm Blk |
| Test Phase C | Blk/Blu | Open    | Red     | Sm Blk |

\*(Phase A = L1 – L2; Phase B = L2 – L3, Phase C = L3 – L1)

### Three phase lead connection

| Motor Leads  | Lead 1 | Lead 2 | Lead 3 | Ground |
|--------------|--------|--------|--------|--------|
| Surge Lead 1 | Hot    | Grd    | Grd    | Blk    |
| Surge Lead 2 | Grd    | Hot    | Grd    | Blk    |
| Surge Lead 3 | Grd    | Grd    | Hot    | Blk    |

Connect the safety ground (the smaller diameter black ground lead0 to the frame of the test winding and NOT to the coil ground lead. Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.

Manually connecting the winding to test is required once. At this point, apply the different tests to all of the phases of the test object remotely, negating the need for manually-switched test operations.

### Note regarding 220/240 VAC units

220/240 VAC input units may require the user to supply an appropriate AC connector for mating to the power source. These units are designed for use on a single (1) phase, 220/240 VAC power source. Split phase AC power sources will not work. Color codes for the AC line cord supplied are as follows:

|              |                        |
|--------------|------------------------|
| Brown        | AC Line Hot            |
| Blue         | AC line Neutral        |
| Green/Yellow | AC line Ground (earth) |

### Output configuration

Three Red output cables, with insulating jacket rated at 60 KVDC, appropriately marked.

One Black ground cable, also with insulating jacket rated at 60 KVDC, appropriately marked.

### Output during testing

HiPot: Test lead 1 energized, leads 2 and 3 open connections.

Surge Lead 1: Test lead 1 energized, leads 2 and 3 grounded.

Surge Lead 2: Test lead 2 energized, leads 1 and 3 grounded.

Surge Lead 3: Test lead 3 energized, leads 1 and 2 grounded.

**Note:** The Power Pack control panel function switch must be placed into the HiPot position when performing a HiPot Test. Be sure to switch the Power Pack test lead selector switch into the HiPot position.

Be sure not to switch the Test Lead Selector switch while a test is in progress. The useful life of the switching element may be substantially reduced.

### Operating position

The Power Pack, when equipped with the Three Phase Selector Switch option, is not rated for operation in any position other than vertically, with all four wheels, down, on a level surface.

### Lifting instructions

This unit may be lifted using two 12 foot lifting straps placed under the unit as shown in the photos below. Do not use the handle of the instrument to lift the instrument.

**Caution:** Do not touch test leads while testing is in progress!



Fig Sup 1-1: Lifting instructions

### Shipping

The Power Pack, when equipped with the Three Phase Selector Switch option, is not rated for shipment in any other position than vertical, with all four wheels, down, in a suitable shipping crate.

When shipped, the Power Pack must be properly labeled with this side up warning labels.

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Supplement 2 PP185 power pack (D12R only)

### Inside this chapter

- Emergency shut-off button
- Initial setup
- Power pack operation
- Surge testing
- Lead position
- DC HiPot testing
- Storing the test results in memory
- Using the footswitch
- The HiPot overcurrent trip indicator
- Effects of temperature
- Determination of a bar-to-bar fault
- Armature application recommendation
- Lead connection
- Single phase lead connection
- Three phase lead connection
- Note regarding 220/240 units
- Output configuration
- Operating position
- Lifting instrument
- Shipping

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



The use of the PP130/PP230 Power Pack incorporates a system of two separate units; a 12 kV host unit (the Digital Tester) and a 30 kV power pack. The 12 kV portion of the system is capable of stand alone operation for Surge or DC HiPot test functions. The power pack relies on the 12 kV host unit to provide triggering and readout functions and cannot operate alone.

Instructions for stand alone operation of the 12 kV host unit should be reviewed in the main portion of this manual before attempting operation with the 30kV power pack. This supplemental manual will provide instruction on how to correctly set up, connect, and operate the power pack, and other important safety information.

**Caution**

Never attempt testing a load with both 12 kV and Power Pack test leads attached to the load at the same time!

**Note:** The ground fault system on the 12 kV host tester will render it inoperative without a proper ground. When the host tester is connected to the PP130/230, any inoperable condition will also affect the power pack due to loss of the surge enable signal.

These instruments should never be used without a grounded supply.

**Caution notes**

User safety demands that the tester output NEVER be activated without connection to a winding load of some type. Please refer to the host tester instructions in the main portion of this manual for connection procedures to various windings.

Remember: The host testers Volts/Div switch affects only the display amplitude on the CRT. It does not control or limit the output voltage of the host unit or power pack in any way.

**Emergency shut off button**

The 30kV power pack is equipped with a large, red Emergency Shut-Off button on the front panel of the unit. It is located to the right of the test button. Use it to quickly discontinue a test and to shut off all power to both the power pack and the Digital Tester.

The emergency shut-off button is a two position switch. While in the IN position, power is supplied to both the power pack and the Digital tester and testing can proceed as normal. When put into the out position by pressing it once, any test that is in progress will immediately stop and the power to both units will turn off.

To resume testing with the power pack and/or the Digital tester, depress the emergency shut-off button again (it must be in the In position). The on/off switch lights of both units will turn on. Follow the procedure for Power Pack Operation to follow.

**Initial set-up**

These instructions refer to the PP130/230 VAC Power Pack. Instructions are identical for the PP230/240 VAC power pack.

Connect the power pack to the tester. Use the short AC line cord on the power pack front panel to connect to the 12 kV host tester power entry receptacle (line in).

Connect the 25-pin interconnect cable between the front of the two units. The cable is marked on each end. Be sure to plug in the end marked Host into the Auxiliary port (Aux) on the front of the Digital Tester panel and the end marked 30KV into the Auxiliary port (Aux) on the front of the Power Pack.

Connect the long AC power cord to the power pack front panel receptacle and then to an appropriate AC power source. For 220/240 Volt Power Packs, please see note regarding 220/240VAC UNITS concerning AC line cord connectors.

Both units are now ready for operation.

The host tester is equipped with a ground fault monitor and indicator. This circuitry should not hinder operation of GFI protected AC power circuits.

**Caution:** Do not touch test leads while testing is in progress!

If a problem exists, the internal ground monitoring circuit may be disabled. Please call Baker Instrument Company, an SKF Group Company's Service Department at 800-752-8272 for assistance. The ground fault monitor must also be disabled in the event that the unit is to be operated on a transformer isolated AC circuit. Failure to do so will cause a loss of ground indication, disabling the high voltage power section of the unit. Please assure safe operating practices whenever disabling the ground monitor circuit! It is advised that some type of external grounding strap be used.

## Power pack operation

### Surge testing

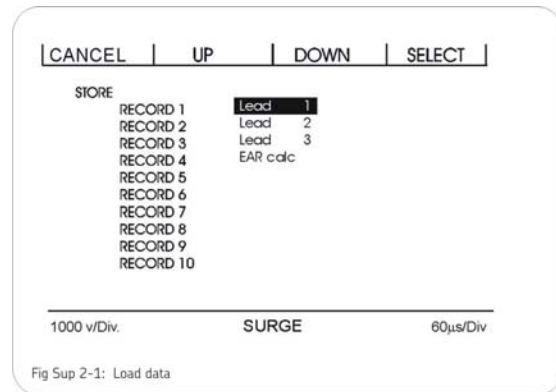
Check to ensure there is nothing connected to the coil or winding being tested. This is extremely important when testing installed coils or windings. Test inaccuracies will result and the situation can be hazardous to personnel performing tests.

- 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.
- 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.

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:
- 13) Press the store Function Key above the top of the screen.
- 14) Select the record to store the data in by pressing the Up / Down Function Keys to highlight the desired record and pressing select.
- 15) Highlight Lead 1 on the next screen.
- 16) Again press select to load the data into the tester's memory.



**Caution:** Do not touch test leads while testing is in progress!

- 17) Move the Test Lead Selector Switch to Lead 2.
- 18) Repeat steps 5 through 8 for lead 2, and save the data in the tester's memory as was done in step 12.
- 19) Move the Test Lead Selector Switch to Lead 3.
- 20) 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.

#### Lead position

| 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 |

#### DC HiPot Testing

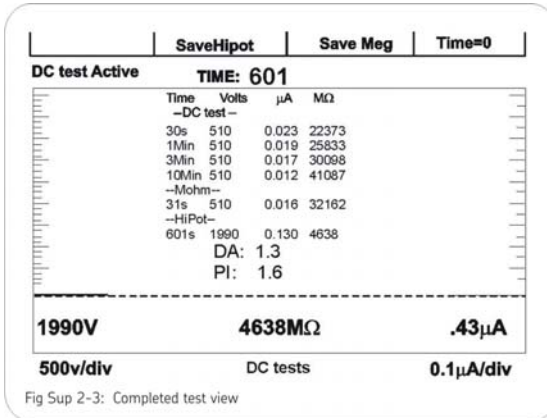
- 1) Connect appropriate high voltage leads to stator windings.
- 2) Move Test Lead selector switch to HiPot position.



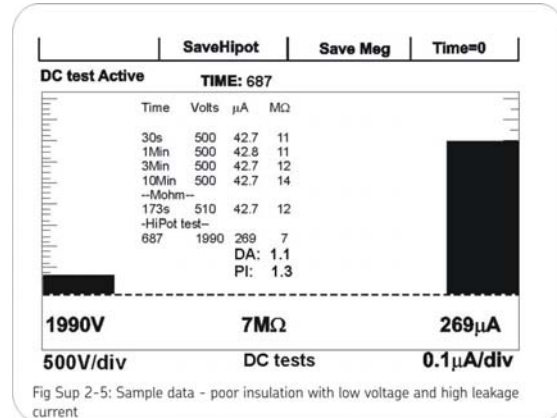
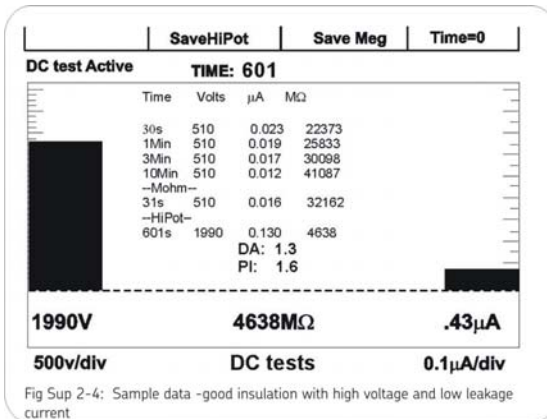
Fig Sup 2-2: Digital tester front panel view

- 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.
- 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.

**Caution:** Do not touch test leads while testing is in progress!



Sample data showing good & poor insulation



### 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 footswitch

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 footswitch plugs in the front panel as shown and may be used in place of the test button.

## The HiPot overcurrent 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.

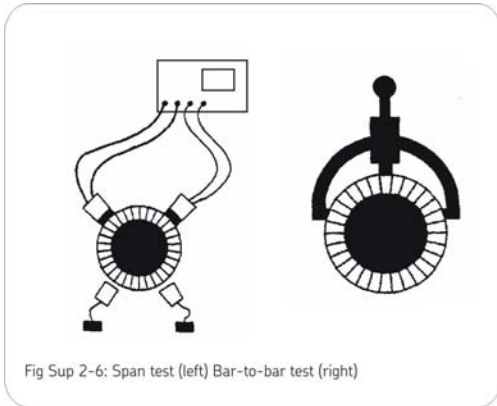
The bar-to-bar armature test feature that comes with your tester converts the surge tester into a low impedance, high current, bar-to-bar armature tester. The bar-to-bar test method is recognized as superior to the span test method for testing armatures.

To illustrate the difference between the bar-to-bar and span tests, consider this example. A manufacturer of lap wound elevator motor armatures determines that, to thoroughly test the turn-to-turn and coil-to-coil insulation, a test voltage of 400 volts across each coil is required. However, the impedance of a single coil in the armature is so low that it appears as a dead short to a conventional surge tester designed for testing AC stators. Even with the hefty current of a 12 kV surge tester, only a few hundred volts may be generated into such a load. Most of this voltage is actually lost in the test leads of the surge tester. Consequently, the span test was developed. (See figure below).

In the span test, the test contacts are placed several bars apart, so that the impedance of several coils in series is large enough to be tested with the surge tester. For example, to generate 400 volts across each coil of a 10 bar span, the test voltage must be increased to 4000 volts. However, 4000 volts at the high voltage contacts delivering the sure test will over-stress and probably damage the ground insulation at the first coil in series. Therefore, the maximum test voltage must be decreased to the same level as the safe DC HiPot voltage for that motor, or about 2000 volts. Now the coils are not adequately being tested, since the bar-to-bar voltage is only 200 volts.

## Bar-to-bar testing/armature testing

In a bar-to-bar surge test, 400 volts is applied directly to each coil without over stressing the ground insulation. The bar-to-bar test feature provides a specially designed high current, low-voltage output surge tester with low impedance test leads to make this test possible.



The bar-to-bar armature test mode converts the surge tester output from high voltage to lower voltage with high current. This is necessary for bar-to-bar armature tests of low impedance coil windings. The armature test mode uses a high energy pulse transformer which steps down the surge tester voltage by a factor of 10 and increases the current by a factor of 10.

The basic procedure involves internally switching the surge tester output to the input of the armature test harness. The output travels through a low impedance cable assembly and armature contactor. The bar-to-bar output voltage is monitored and the bar-to-bar surge test wave pattern is displayed on the surge tester CRT screen. Test voltage is measured directly at the contactor, so there is no measurement error from test lead losses.

When a faulty coil is detected, the output voltage will drop dramatically. A corresponding collapse in the amplitude and left shift of the surge test wave pattern will be evident. This is easily simulated by shorting the two bars under test with a screwdriver. In fact, the bar-to-bar armature test feature often detects shorted bars that are four or five bars away from the bars under test.

### Bar-to-bar testing

- 1) Make the appropriate connections between the blue bar-to-bar armature test harness, the text

fixture, and the surge tester. Be sure to completely twist the connectors into place.

**Note:** The black surge tester ground leads must be connected to the armature iron. If testing single low impedance coils using ATP02 alligator clips, connect the surge tester ground to the core metal.

- 2) Turn the Function switches of the unit to AT101. (Both the D12R host and test unit have function switches.
- 3) Turn the surge test Output control to Min.
- 4) Place the test accessory on the armature commutator, making sure the contact brushes are on adjacent bars, not the same bar.

**Note:** The black cover may be removed from the test fixture to access the brushes and shape them as necessary for best contact.

**Note:** When using alligator clips or test probes on 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 coils.

- 5) Press the surge tester Test button (or depress the Footswitch) and raise the Output control slowly. A wave pattern should be visible on the surge tester screen. Adjust the Output control until the desired bar-to-bar voltage is reached.

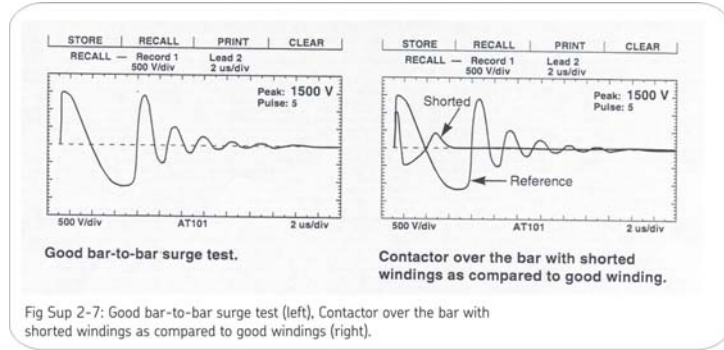
**Note:** The Zero Start Interlock (ZSI) will be automatically disabled when a Footswitch is depressed to conveniently perform this test.

- 6) Release the Test button.
- 7) For testing a single armature, store the pattern using Quick Store.
- 8) Press the function key corresponding to Store. A list of available Records will appear. The menu bar at the top of the screen also changes.
- 9) Press the keys corresponding to the Up and/or down to bring the cursor to the desired Record. Press Select.
- 10) Press the key corresponding to Qwk Str. The wave pattern is now stored in the selected

**Caution:** Do not touch test leads while testing is in progress!

- Record, Lead #1 and is immediately recalled on the screen.
- 11) When surge testing several armatures or for tests that are to be downloaded to a computer for further analysis, store the pattern conventionally.
  - 12) Press the function key corresponding to Store. A list of available Records appears. The menu bar at the top of the screen also changes.
  - 13) Press the keys corresponding to the Up and/or down to bring the cursor to the desired Record. Press Select.
  - 14) Repeat the above step for the desired Lead.
  - 15) Rotate the fixture on the armature commutator to test all of the bars at the same voltage.

and with lower amplitude. The test brushes are over the faulty, shorted bars when the waveform amplitude is lowest. Faulty bars are read through the equalizers but the amplitude of the waveform will not be as low as when the test brushes are directly contacting the actual bad bars. Refer to Armatures for more information.



**Note:** The Test button (or Footswitch) should be released 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 bars to the next. This wave pattern movement 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.

If the first wave pattern was stored using Quick Store, simply compare the two wave patterns on the screen and make an analysis of the condition of the winding.

If the first wave pattern was stored conventionally and subsequent wave patterns are to be stored for further analysis repeat Step b. under Step 7.

#### **Determination of a bar-to-bar fault**

As the contactor approaches a shorted pair of bars, the waveform becomes increasingly distorted, shifting left

**Note:** A slight, regular rhythmic shift may be observed when testing an armature. This is generally due to the equalizer windings and can be ignored. Hard shorted turns or insulation breakdown will be evident by an obvious change in the surge wave pattern.

When testing coils with ATP02 alligator clips, a fault should be interpreted in one of two ways.

A single coil should be tested by observing the wave pattern from zero volts up to the desired test voltage level. A coil with good insulation will show the same wave pattern at increasing voltage levels. A fault will show by the collapse of the amplitude and a shift to the left of the wave pattern.

A group of single coils may be tested by examining and recording a known good coil first.

Using the good coil, adjust the display controls to obtain the desired wave pattern on the display to be used as the reference wave pattern.

**Caution:** Do not touch test leads while testing is in progress!



Leave all surge tester controls unchanged or record these reference settings. Release the Test button and move the test leads to the next coil and depress the Test button again. The other coils surge test wave patterns should fit very closely to that of the first coil if they are in good condition. A shorted coils patten will be collapsed and shifted left of the pattern of the reference coil.

### Armature application recommendations

Most armatures requiring the use of an armature bar-to-bar test will be tested to at least 350 volts bar-to-bar.

Very large armatures, such as diesel locomotive traction motor armatures, require testing up to 750 volts bar-to-bar.

### Lead connection

RED = Hot lead

BLK/BLU = larger diameter black ground lead with blue braided cover

SM BLK = smaller diameter black ground lead

**Note:** It is important to connect the safety ground (the smaller diameter black ground lead) to the frame of the test winding and NOT to the coil ground lead. Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.

**Note:** Some test leads will be open during the test and can be at the same voltage potential as the winding! All precautions should be made to avoid touching these leads.

### Single phase lead connections

|              | Lead 1  | Lead 2  | Lead 3  | Frame  |
|--------------|---------|---------|---------|--------|
| Test Phase 1 | Red     | Blk/Blu | Open    | Sm Blk |
| Test Phase 2 | Open    | Red     | Blk/Blu | Sm Blk |
| Test Phase 3 | Blk/Blu | Open    | Red     | Sm Blk |

|              | Lead 1  | Lead 2  | Lead 3  | Frame  |
|--------------|---------|---------|---------|--------|
| Test Phase A | Red     | Blk/Blu | Open    | Sm Blk |
| Test Phase B | Open    | Red     | Blk/Blu | Sm Blk |
| Test Phase C | Blk/Blu | Open    | Red     | Sm Blk |

\*(Phase A = L1 – L2; Phase B = L2 – L3, Phase C = L3 – L1)

### Three phase lead connection

| Motor Leads  | Lead 1 | Lead 2 | Lead 3 | Ground |
|--------------|--------|--------|--------|--------|
| Surge Lead 1 | Hot    | Grd    | Grd    | Blk    |
| Surge Lead 2 | Grd    | Hot    | Grd    | Blk    |
| Surge Lead 3 | Grd    | Grd    | Hot    | Blk    |

Connect the safety ground (the smaller diameter black ground lead) to the frame of the test winding and NOT to the coil ground lead. Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.

Manually connecting the winding to test is required once. At this point, apply the different tests to all of the phases of the test object remotely, negating the need for manually-switched test operations.

### Note regarding 220/240 VAC units

220/240 VAC input units may require the user to supply an appropriate AC connector for mating to the power source. These units are designed for use on a single (1) phase, 220/240 VAC power source. Split phase AC power sources will not work. Color codes for the AC line cord supplied are as follows:

### Three phase

|              |                        |
|--------------|------------------------|
| Brown        | AC Line Hot            |
| Blue         | AC line Neutral        |
| Green/Yellow | AC line Ground (earth) |

**Caution:** Do not touch test leads while testing is in progress!

**Output configuration**

Three Red output cables, with insulating jacket rated at 60 KVDC, appropriately marked.

One Black ground cable, also with insulating jacket rated at 60 KVDC, appropriately marked.

When shipped, the Power Pack must be properly labeled with this side up warning labels.

**Operating position**

The Power Pack, when equipped with the Three Phase Selector Switch option, is NOT rated for operation in any position other than vertically, with all four wheels, down, on a level surface.

**Lifting Instrument**

This unit may be lifted using two 12 foot lifting straps placed under the unit as shown in the photos below. Do not use the handle of the instrument to lift the instrument.



Fig Sup 2-8: Lifting instructions

**Shipping**

The Power Pack, when equipped with the Three Phase Selector Switch option, is not rated for shipment in any other position than vertical, with all four wheels, down, in a suitable shipping crate.

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Supplement 3 PP40 power pack (D12R only)

### Inside this chapter

- Initial setup
  - Power pack operation
  - Surge testing
  - DC HiPot testing
  - Lead connection
  - Single phase lead connection
  - Three phase lead connection
  - Note regarding 220/240 units
  - Output configuration
  - Output during testing
  - Lifting instrument
- Shipping

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



The instrument works only with the 12kV instrument. The use of the PP40 Power Pack incorporates a system of two separate units; a 12 kV host unit (the Digital Tester) and a 40 kV power pack. The 12 kV portion of the system is capable of stand alone operation for Surge or DC HiPot test functions. The power pack relies on the 12 kV host unit to provide triggering and readout functions and cannot operate alone.

Instructions for stand alone operation of the 12 kV host unit should be reviewed in the main portion of this manual before attempting operation with the 40 kV power pack. This supplemental manual will provide instruction on how to correctly set up, connect, and operate the power pack, and other important safety information.

**Caution**

**Never attempt testing a load with both 12 kV and Power Pack test leads attached to the load at the same time!**

**Note:** The ground fault system on the 12 kV host tester will render it inoperative without a proper ground. When the host tester is connected to the PP40, any inoperable condition will also affect the power pack due to loss of the surge enable signal.

These instruments should never be used without a grounded supply.

**Caution notes**

User safety demands that the tester output NEVER be activated without connection to a winding load of some type. Please refer to the host tester instructions in the main portion of this manual for connection procedures to various windings.

Remember: The host testers VOLTS/DIV switch affects only the display amplitude on the CRT. It does not control or limit the output voltage of the host unit or power pack in any way.

**Emergency shut off button**

The 40 kV power pack is equipped with a large, red Emergency Shut-Off button on the front panel of the unit. It is located to the right of the TEST button. Use it to quickly discontinue a test and to shut off all power to both the power pack and the Digital Tester.

The emergency shut-off button is a two position switch. While in the IN position, power is supplied to both the power pack and the Digital tester and testing can proceed as normal. When put into the OUT position by pressing it once, any test that is in progress will immediately stop and the power to both units will turn off.

To resume testing with the power pack and/or the Digital tester, depress the emergency shut-off button again (it must be in the IN position). The ON/OFF switch lights of both units will turn on. Follow the procedure for Power Pack Operation to follow.

**Initial set-up**

- 1) Connect the power pack to the tester. Use the short AC line cord on the power pack front panel to connect to the 12 kV host tester power entry receptacle (LINE IN).
- 2) Connect the 25-pin interconnect cable between the front of the two units. The cable is marked on each end. Be sure to plug in the end marked HOST into the Auxiliary port (AUX) on the front of the Digital Tester panel and the end marked 40KV into the Auxiliary port (AUX) on the front of the Power Pack.
- 3) Connect the long AC power cord to the power pack front panel receptacle and then to an appropriate AC power source. For 220/240 Volt Power Packs, please see NOTE REGARDING 220/240VAC UNITS concerning AC line cord connectors.
- 4) Both units are now ready for operation.

The host tester is equipped with a ground fault monitor and indicator. This circuitry should not hinder operation of GFI protected AC power circuits.



If a problem exists, the internal ground monitoring circuit may be disabled. Please call Baker Instrument Company, an SKF Group Company, 's Service Department at 800-752-8272 for assistance. The ground fault monitor must also be disabled in the event that the unit is to be operated on a transformer isolated AC circuit. Failure to do so will cause a loss of ground indication, disabling the high voltage power section of the unit. Please assure safe operating practices whenever disabling the ground monitor circuit! It is advised that some type of external grounding strap be used.

## Power pack operation

### Surge testing

Power-up the 40 kV power pack and host tester. Follow the host tester set-up procedures in this manual (refer to Single Coil Surge Test and Set Up or Three Phase Motor Surge Test and Set Up)

**Note:** The PP140/240 requires a one to two minute warm up prior to operation.

Set the 12 kV host tester function control switch to AUX (auxiliary) position.

**Note:** The volts per division setting when the AUX is selected will change the Volts/Division setting from 500, 1000, 2000, 3000 Volts/Div to 1650, 3300, 6600, and 10000 Volts/Div. The 1250 Volts/Div setting is not available with the PP40 and an error message will appear on the display when this setting is selected. Use 1650, 3300, 6600, and 10000 Volts/Div only.

Assure the power pack output control is at MIN, (full counter-clockwise).

Connect the power pack leads to the appropriate load. See Lead Connection for proper test lead connection.

**Note:** It is important to connect the safety ground (the smaller diameter black ground lead) to the frame of the test winding and NOT to the coil ground lead. Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.



### CAUTION

**High Voltage ACTIVATION is next! Ensure that all personnel are away from the device under test and are not in contact with either load or test leads!**



### WARNING

**Some test leads will be open during the test and can be at the same voltage potential as the winding! All precautions should be made to avoid touching these leads.**

Start test by depressing the power pack test switch (and footswitch) and slowly raise the power pack output control. A pattern should immediately be visible on the display screen of the host tester. If not, recheck the connections and all the switch settings. Also assure that the interconnect cables have been attached and are secure.

The display may require adjustment for optimum clarity, sweep and positioning. Make any adjustments required prior to continuing the test.

Determine test voltages and adjust the volts/div setting so that the waveform is fully displayed without going off the screen.

When the test is complete, release the test switch of the power pack, the footswitch and return the output control to its minimum setting.

Store the wave patten into the internal memory of the host unit, or onto a computer connected to it. See Storage and Print Capabilities.

Reposition the red (HOT) and black (GROUND) test lead, previously connected to the leads of the windings. Refer to Lead Connections. Compare all phases against each other: #1 vs. #2, #2 vs. #3, and #3 vs. #1. By switching one hot and the ground lead each time, the operator can make all the measurements necessary for these comparisons. The operator may find it advisable to mark or identify the stator leads at the time of, or prior to the first test.

**Caution:** Do not touch test leads while testing is in progress!



### DC HiPot testing

Power-up the 40 kV power pack and host unit. Follow host tester set-up procedures in this manual (Refer to DC HiPot Test and Set-Up)

Set the host units function switch to the AUX setting. Set the 40 kV Power Packs function switch to the HIPOT setting.

**Note:** As the Power Pack function switch is changed to the HiPot setting, a loud relay noise will be heard. This is normal for the Power Pack.

Connect the red (HOT) lead from the power pack to the winding to be tested, and the black (GROUND) leads to the iron or core material.

Begin testing by depressing the power pack test switch and the footswitch and slowly increase the output control.

As the output is increased, the Voltage Bar rises up slowly and the Current Bar rises rapidly on the right side showing the charging current. When the output is held at a given voltage setting, the Current Bar will fall and remain at a constant level to indicate the leakage current.

**Note:** This test should be interrupted any time a fast, sharp rise in the current is observed.

**Note:** The over-current HiPot trip levels that activates the HIPOT TRIP light are ten times the micro-amps/division settings on the tester. The trip levels are 10,100, 1000 micro-amps. Releasing the TEST button or footswitch will reset the over-current trip to begin testing again.

Adjust VOLTS/DIV and  $\mu$ AMP/DIV to best monitor the voltage and current levels. Note the voltage, resistance in mega-ohms, and leakage current levels displayed on the screen.

When the desired test voltage has been achieved, press the TIME=0 FUNCTION button (the right most button above the CRT display). The elapsed time displayed in the upper left corner of the screen will reset to zero.

**Note:** Use TIME=0 function to be sure the full DC voltage potential is applied for the required test time. In this way, the time required for voltage ramp-up will be discounted for both HiPot and Polarization Index tests.

Upon completion of the test, return the OUTPUT control to MIN and release the TEST button and footswitch. If desired, store the HiPot data into the internal memory of the host unit. See Storage and Print Capabilities.

**Note:** Always allow a sufficient time for the winding under test to completely discharge before disconnecting the test leads. The recommended practice is to discharge the winding for a duration of at least five times the duration of the DC HiPot test for high voltage windings.



#### CAUTION

**Disconnect the units test lead not being used from the load.**

**Never use the host units ground leads for grounding during the 40kV power pack test.**

**Note:** For HiPot operation of the 12 kV host tester alone, the host tester and the power pack must be disconnected from each other.

For Surge operation of the 12 kV host tester alone, the operator need not disconnect the two units. Simply place the 12 kV host unit function switch back to the Surge position. The host unit is now ready to Surge test alone.

### Lead connection

RED = Hot lead

BLK = larger diameter black ground lead with braided cover

SM BLK = smaller diameter black ground lead

**Note:** It is important to connect the safety ground (the smaller diameter black ground lead) to the frame of the test winding and NOT to the coil ground lead. Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.

**Caution:** Do not touch test leads while testing is in progress!



**Note:** Some test leads will be open during the test and can be at the same voltage potential as the winding! All precautions should be made to avoid touching these leads.

### Single phase lead connections

|              | Lead 1 | Lead 2 | Lead 3 | Frame  |
|--------------|--------|--------|--------|--------|
| Test Phase 1 | Red    | Blk    | Open   | Sm Blk |
| Test Phase 2 | Open   | Red    | Blk    | Sm Blk |
| Test Phase 3 | Blk    | Open   | Red    | Sm Blk |

|              | Lead 1  | Lead 2  | Lead 3  | Frame  |
|--------------|---------|---------|---------|--------|
| Test Phase A | Red     | Blk/Blu | Open    | Sm Blk |
| Test Phase B | Open    | Red     | Blk/Blu | Sm Blk |
| Test Phase C | Blk/Blu | Open    | Red     | Sm Blk |

\*(Phase A = L1 – L2; Phase B = L2 – L3, Phase C = L3 – L1)

### Three phase lead connection

| Motor Leads  | Lead 1 | Lead 2 | Lead 3 | Ground |
|--------------|--------|--------|--------|--------|
| Surge Lead 1 | Hot    | Grd    | Grd    | Blk    |
| Surge Lead 2 | Grd    | Hot    | Grd    | Blk    |
| Surge Lead 3 | Grd    | Grd    | Hot    | Blk    |

Connect the safety ground (the smaller diameter black ground lead0 to the frame of the test winding and NOT to the coil ground lead. Results of the surge test will be erroneous if the coil ground lead is used instead of the frame for grounding.

Manually connecting the winding to test is required once. At this point, apply the different tests to all of the phases of the test object remotely, negating the need for manually-switched test operations.

#### Note regarding 220/240 VAC units

220/240 VAC input units may require the user to supply an appropriate AC connector for mating to the power source. These units are designed for use on a single (1) phase, 220/240 VAC power source. Split phase AC power sources will not work. Color codes for the AC line cord supplied are as follows:

|              |                        |
|--------------|------------------------|
| Brown        | AC Line Hot            |
| Blue         | AC line Neutral        |
| Green/Yellow | AC line Ground (earth) |

#### Output configuration

One Red output cable, with insulating jacket rated at 60 KVDC, appropriately marked.

Three Black ground cable, also with insulating jacket rated at 60 KVDC, appropriately marked.

**Note:** The Power Pack control panel FUNCTION switch must be placed into the HiPot position when performing a HiPot Test. Be sure to switch the Power Pack test lead selector switch into the HiPot position.

#### Lifting instrument

This unit may be lifted using two 12 foot lifting straps placed under the unit as shown in the photos below.

**Caution:** Do not touch test leads while testing is in progress!

Do not use the handle of the instrument to lift the instrument.

## Shipping



Fig Sup 3-1: Lifting instructions

When shipped, the Power Pack must be properly labeled with THIS SIDE UP warning labels.

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Supplement 4 AT101D Bar-to-bar armature testing

### Inside this chapter

- Operation
- Determination of a fault
- Application recommendations
- Specifications

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!

The model AT101D Bar-to-Bar Armature Test Accessory is an adapter which converts any Baker Instrument Company, an SKF Group Company surge tester with an output of up to 12 kV into a low impedance, high current, bar-to-bar armature tester. The bar-to-bar test method is recognized as superior to the span test method for testing armatures. The D12R requires use of the external AT101D module.

To illustrate the difference between the bar-to-bar and span tests, consider this example. A manufacturer of lap wound elevator motor armatures determines that, to thoroughly test the turn-to-turn and coil-to-coil insulation, a test voltage of 400 volts across each coil is required. However, the impedance of a single coil in the armature is so low that it appears as a dead short to a conventional surge tester designed for testing AC stators. Even with the hefty current of a 12 kV surge tester, only a few hundred volts may be generated into such a load. Most of this voltage is actually lost in the test leads of the surge tester. Consequently, the span test was developed (see figure below).

In the span test, the test contacts are placed several bars apart, so that the impedance of several coils is large enough to be tested with the surge tester. For example, to generate 400 volts across each coil of a 10 bar span, the test voltage must be increased to 4000 volts. However, 4000 volts at the high voltage contacts delivering the surge test will over-stress and probably damage the ground insulation at the first coil in series. Therefore, the maximum test voltage must be decreased to the same level as the safe DC HiPot voltage for that motor, or about 2000 volts. Now the coils are not adequately being tested, since the bar-to-bar voltage is only 200 volts.

In a bar-to-bar surge test, 400 volts is applied to each coil without over-stressing the ground insulation (see Fig Sup3-1). The AT101D bar-to-bar testing accessory provides a specially designed low output impedance surge tester with low impedance test leads to make this possible.

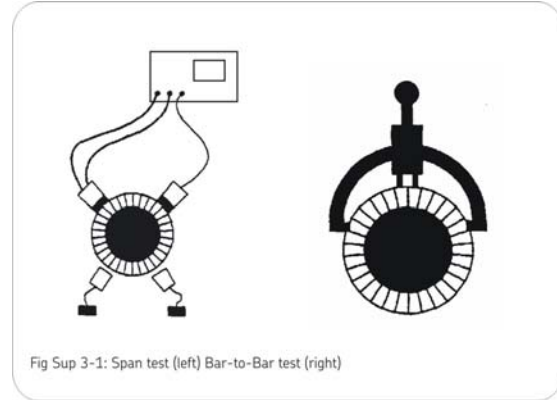


Fig Sup 3-1: Span test (left) Bar-to-Bar test (right)

The AT101D, when connected between a surge tester and an armature, converts the surge tester output from high voltage to lower voltage with high current. This is necessary for bar-to-bar armature testing of low impedance coil windings. The AT101D contains a high energy pulse transformer which steps down the surge tester voltage by a factor of 10 and increases the current by a factor of 10.

The basic procedure involves connecting the surge tester output leads to the input of the AT101D (D12R only). The output of the AT101D travels through a low impedance cable assembly and armature contactor. The bar-to-bar output voltage is monitored by a peak-hold voltmeter in the AT101D. The surge test wave pattern and test voltage are displayed concurrently on the surge tester CRT screen. Test voltage is measured directly at the contactor, so there is no measurement error from test lead losses.

When a faulty coil is detected, the output voltage on the peak voltmeter will drop dramatically. A corresponding collapse in the amplitude and left shift of the surge test wave pattern will be evident. This is easily simulated by shorting the two bars under test with a screwdriver. In fact, the AT101D will detect shorted bars that are four or five bars away from the bars under test.

## Operation

For D12R:

**Caution:** Do not touch test leads while testing is in progress!



**Note:** The AT101D must show on its rear panel that it has been set up and calibrated for the specific surge tester being used.

For D12R all connections are made internally by design. The user has to select AT101 on the Function Switch. The test lead #1 will then be disconnected from internal high voltage by a relay matrix.

1. For the D12R make the appropriate connections between the AT101D and the surge tester.
  - a. The interconnect cable between the AT101D and surge tester is a 25-pin RS232 D-type connector. Connect this cable to the front panel of the AT101D and to the port on the surge tester (D12R), each marked AUX.
  - b. Connect test lead #1 to the recessed bar on the back of the AT101D labeled Hot Lead.
  - c. Connect lead #G to the recessed bar on the back of the AT101D labeled Ground Lead
  - d. Lay the remaining surge tester Ground (#G) leads aside.
  - e. The black surge tester Ground lead must be connected to the armature iron. If testing single low impedance coils using ATP02 alligator clips or test probes, connect the surge tester Ground lead to the core material.

**Note:** When using alligator clips or test probes on 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 coils.

3. Turn the Function knob of the surge tester to AT101D.
4. Connect the armature test fixture to be used (the hand-held contactor, test probes, or test alligator

clip) to the blue braided harness. (Instructions that follow will be for the hand held contactor.) The black cover may be removed to access the brushes and shape them as necessary for best contact.

5. Place the AT101D contactor on the armature commutator, making sure the contact brushes are on adjacent bars, not the same bar.
6. Press the surge tester Test (or depress the Footswitch) and raise the Output control slowly. A wave pattern and its corresponding peak voltage should be visible on the surge tester screen. Adjust the Output control until the desired bar-to-bar voltage is reached.

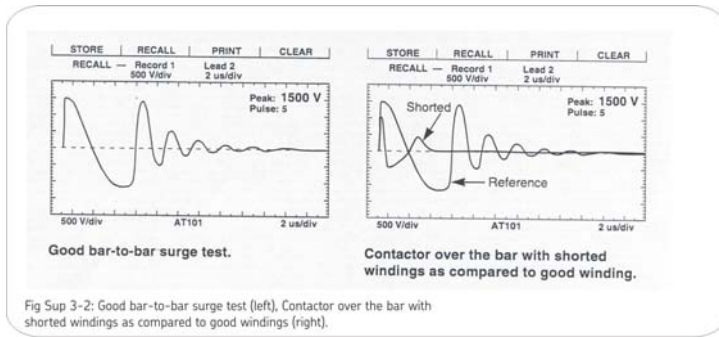
**Note:** The Zero Start Interlock (ZSI) can be disabled to more conveniently perform this test. On the Digital Surge Tester, position the Function switch to AT101D and depress the Footswitch to automatically disable the ZSI.

7. The true test peak voltage is correctly measured from the surge tester display as the contactor head is moved around the commutator. As each bar is tested, the result may be stored in internal memory (refer to Storage and Print Capabilities).

### Determination of a fault

As the contactor approaches a shorted pair of bars, the waveform becomes increasingly distorted, shifting left and with lower amplitude. The test brushes are over the faulty, shorted bars when the waveform amplitude is lowest. Faulty bars are read through the equalizers but the amplitude of the waveform will not be as low as when the test brushes are directly contacting the actual bad bars.

**Caution:** Do not touch test leads while testing is in progress!



Note: A slight, regular rhythmic shift may be observed when testing an armature. This is generally due to the equalizer windings and can be ignored. Hard shorted turns or insulation breakdown will be evident by an obvious change in the surge test wave pattern.

When testing coils with ATP02 alligator clips, a fault should be interpreted in one of two ways.

1. A single coil should be tested by observing the wave pattern from zero volts up to the desired test voltage level. A coil with good insulation will show the same wave pattern at increasing voltage levels. A fault will show by the collapse of the amplitude and a shift to the left of the wave pattern.
2. A group of single coils may be tested by examining and recording a known good coil first.
  - a. Using the good coil, adjust the display controls to obtain the desired wave pattern on the display to be used as the reference wave pattern. Store the pattern in memory if using a digital tester. Use Quick Store to immediately recall this reference wave pattern back to the screen.
  - b. Leave all surge tester controls unchanged or record these reference settings. Begin testing on the other coils. The other coils surge test wave patterns should fit very closely to that of the first coil if they are in good condition. A shorted coils patter will be

collapsed and shifted left of the pattern of the reference coil.

### Application recommendations

- Most armatures requiring the use of an AT101D will be tested to at least 350 volts bar-to-bar.
- It is recommended that Baker Instrument Company, an SKF Group Company 6 kV model surge tester be used with the AT101D only for special applications which do not exceed 300 volts. This is quite common for lift truck armatures.
- Armatures which require bar-to-bar test voltages up to 600 volts should use Baker Instrument Company, an SKF Group Company 12 kV model surge testers with the AT101D.
- Very large armatures, such as diesel locomotive traction motor armatures, require testing up to 750 volts bar-to-bar. These necessitate at least a 15 kV Baker Instrument Company, an SKF Group Company surge tester used in conjunction with the AT101D. Alternatively, a Multiple Tester from Baker Instrument Company, an SKF Group Company may be required. Please contact us for information regarding stand alone high power armature surge and HiPot testers for large AC and DC motor work, especial heavy rail tractions motors.
- A 24 kV tester may be used with the AT101D. Its output should be limited so that the peak voltage measurement on the AT101D never exceeds 950 volts.

**Caution:** Do not touch test leads while testing is in progress!



**Specifications for the AT101D Bar-to-bar  
armature testing accessory**

|                                |                                                                |
|--------------------------------|----------------------------------------------------------------|
| Surge Input-Max Voltage        | 15,0000 V Peak                                                 |
| Testable Inductance range      | 0.4 to 20 $\mu$ H                                              |
| Cable and test head inductance | 1.0 $\mu$ H                                                    |
| Transformer turns ratio        | 10:1                                                           |
| Observed voltage step down     | 10:1 for test load of 5H or greater<br>20:1 for 1 $\mu$ H load |

**Caution:** Do not touch test leads while testing is in progress!



D12R, D6R, D3R

## Index

**Caution:** Do not touch test leads while testing is in progress!



**Caution:** Do not touch test leads while testing is in progress!



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