SKF

SKF Static Motor Analyzer

AWA-IV 2/4 kVs and 6/12 kVs

SKF

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AWA-IV 2/4 kVs and 6/12 kVs

User manual

Part number: 71-025 EN

Revision: V11

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Baker Instrument Company, an SKF Group Company

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http://www.skf.com/group/products/condition-monitoring/electric-motor-testing/index.html

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>
> Baker Instrument Company—an SKF Group Company—assumes no liability for damages consequent to the use of this product.

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#US04768380 • #US05679900 • #US05845230 • #US05854553 • #US05992237 • #US06006164 • #US06199422 • #US06202491 • #US06275781 • #US06489884 • #US06513386 • #US06633822 • #US6,789,025 • #US6,792,360 • US 5,633,811 • US 5,870,699 • #WO_03_048714A1

⚠ **CAUTION**

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, could 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 radiates radio frequency energy while in the active test mode. Care should be taken to ensure this radio frequency energy causes no harm to individuals or other nearby equipment.

Intended use of instrument

The EXP4000 is intended for detection motor efficiency and physical performance deterioration, and other electrical problems within electric machines 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 the instrument.

Note on software

While the UNIT is a Microsoft Windows® based instrument, it is specially configured and optimized to perform the functions for which it was designed. The loading or operation of unauthorized software may cause the instrument to malfunction or cease functioning and may void the manufacturer's warranty.

CE

Declaration of conformity

Manufacturer's Name & Address:

Baker Electrical Instrument Company, an SKF Group Company

4812 McMurry Ave

Fort Collins, CO 80525 USA

Equipment Description: On-Line Motor Monitor

Equipment Model Designations: EXP4000

Application of Council Directive 72/23/EC 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/EC and Council Directive 2004/108/EC on the approximation of the laws related to Member States relating to the electromagnetic compatibility, as amended by: Council Directive 93/68/EC. 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 61000-4-4

EN 61000-4-5

EN 61000-4-6

EN 61000-4-8

EN 61000-4-11

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

Signature:

 Printed Name: Erik A. Stolz

Title: Electrical Engineer

Software License Agreement

UNIT—test equipment and desktop versions

Carefully read the following terms and conditions before opening the software envelope or operating the UNIT. Either opening the envelope or using the software constitutes your acceptance of these terms and conditions on behalf of any party using the instrument (the "User"). If you or the User do not agree with these terms, promptly return the instrument with the envelope unopened for a full refund.

1. Definitions

(a) Computer Software: A Software program provided with the Instrument on CD or other physical medium for installation and use on the User's desktop computer(s) or servers, and all updates, upgrades, enhancements and modifications provided directly or indirectly to the User from time to time.

(b) Documentation: This User Manual and other manuals and documentation relating to the Instrument and provided directly or indirectly to the User in the original Instrument carton or from time to time thereafter.

(c) Instrument: The unit of test equipment with which this User Manual was provided to the User.

(d) Instrument Software: The software program pre-loaded on the Instrument, and all updates, upgrades, enhancements and modifications provided directly or indirectly to the User from time to time.

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In the event of any conflict or inconsistency between the terms of this Software License and any Documentation, this agreement shall preempt such documentation to the extent inconsistent.

Important notice concerning warranty and repairs

The warranty is void if (i) the UNIT is shipped without shock absorbing packing material, (ii) the UNIT is damaged by improper use, (iii) any party other than SKF modifies the Software or loads or operates unauthorized software programs on the UNIT, or (iv) the User has breached the Software License set forth above. The User assumes all responsibility and expense for removal, reinstallation, freight, or on-site service charges in connection with the foregoing remedies.

SKF CMC-Fort Collins (formerly Baker Instrument 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 any cause, shall be limited exclusively to correcting the product and under the conditions as aforesaid.

If the UNIT fails, whether it is under warranty or not, call the SKF service department before returning the unit for repair. If the unit needs in-house repair, our service staff might direct you to ship the unit to the authorized service center closest to you. This might save both time and money. When calling the Baker service department or one of the service centers, please have the model and serial numbers available. These numbers are located on the rear of the instrument. If the unit is out of warranty, a purchase order will be required if the unit is returned for repair.

Virus alert

The UNIT contains computer software that is vulnerable to damage from computer viruses. Before shipping, SKF scanned all data to ensure the UNIT is virus-free. Before inserting any disks into the disk drive or connecting the UNIT to a computer network, scan all disks for viruses.

Trademarks

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Table of contents

1 About this manual

This manual uses the following conventions in formatting, and informational devices to help you more clearly identify specific elements and information.

Formatting

Interface items are set in **Initial Caps and Bold**.

Page or window names are set in *italics*.

File names are set in `courier` font.

Information devices

Information requiring special attention is set in the following format and structure:

NOTE

Indicates additional information about the related topic that deserves closer attention or provides a tip for using the product.

NOTICE

Indicates information about product usage that can result in difficulty using product, a loss of data, or minor equipment damage if not heeded.

CAUTION

Indicates a hazardous situation with potential for minor to moderate injury or property damage, or moderate to severe damage to the product.

WARNING

Indicates a hazardous situation with risk of serious bodily injury or death.

2 Safety and general operating information

Symbols on equipment

Table1   *Symbols and labels used on equipment.*

Symbol/Label	Description
	Protective conductor terminal. Located beside black ground test lead on front panel of instrument.
	Frame or chassis terminal. Located on rear panel of instrument by ground terminal.
	Warning about hazardous voltage and risk of injury or death from severe electrical shock. Located beside each red test lead on front panel of instrument and on back of unit.

Labels on equipment

The following Danger notice label appears on all four sides of the power pack units used with the Baker AWA-IV and on the top of the Baker AWA-IV unit itself.

Figure 1. High voltage warning label.

The following safety labels are found on the right side of the power packs:

Baker 30/x85   Baker 40
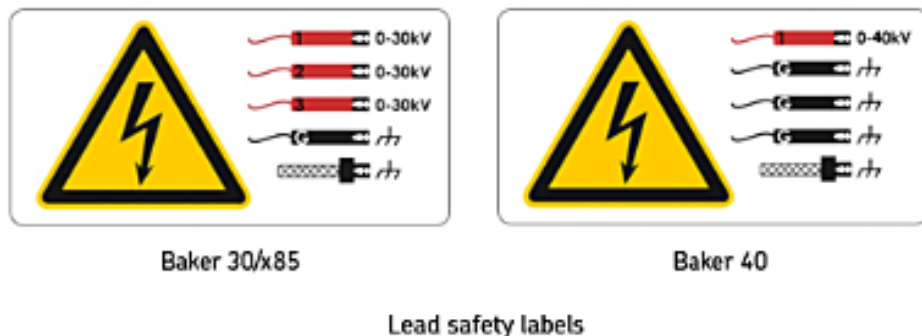
Lead safety labels

Figure 2. Power pack lead safety labels.

Safety precautions

Read and follow all safety precautions and safe operating practices in your manual. Do not exceed maximum operating capabilities of the Baker AWA-IV tester, power packs, or the Baker ZTX accessory.

The general safety information presented here is for both operating and service personnel. You will find specific warnings and cautions throughout this manual where they apply.

If using the equipment in any manner not specified by Baker Instrument Company, an SKF Group Company, the protection provided by the equipment may be impaired.

> **WARNING**
> *Failure to heed the following safety precautions can result in injury or death from severe electrical shock.*

Test related

- Two-party operation is recommended only when using proper equipment (such as the remote E-Stop) and when taking appropriate precautions so both operators are aware of all conditions at all times.

- Always know what test is being performed and when. For example, *do not* adjust test leads when operating a footswitch. Leads will have live voltage and severe electrical shock may result.

- For capacitor-started motors or systems with surge arrestors/power factor capacitors, be sure to *disconnect* all capacitors from the test circuit *before* testing.

- Upon completion of any DC-HiPot, megohm, polarization index (PI), step voltage, or dielectric absorption (DA) tests, be sure to short the winding to ground and allow time for discharge before disconnecting the test leads. If you do not do this, voltage may build up on the winding. Industry practices suggest allowing a winding to discharge four times the total amount of time that DC voltage is applied to the winding.

- If the tester is removed from the windings before complete discharge, short winding leads together and ground them using appropriate jumper cables.

- Make sure to disconnect the tester leads before energizing or powering up the motor.

- Never attempt to test a winding with both host and power pack leads attached to the winding at the same time. Damage to the tester will occur.

General

- *Do not* remove the product covers or panels or operate the tester without the covers and panels properly installed. Components on the inside of the tester carry voltage for operation and can render a shock if touched.

- Use appropriate safety equipment required by your organization, including high-voltage gloves and eye protection.

- The devices covered in this manual are *not* waterproof or sealed against water entry.

- The devices covered in this manual are intended for indoor use. If using outdoors, you must protect the device(s) from rain, snow, and other contaminants.

- **Repair parts warning:** You must replace defective, damaged or broken test leads with factory-authorized parts to ensure safe operation and maintain performance specifications.

- **Ground the product:** The devices covered in this manual are grounded through the power cord's grounding conductor. To avoid electrical shock, plug the power cord into a properly wired/grounded receptacle before connecting the product test leads.

> **WARNING**
>
> **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 cause an electric shock!**

> **NOTICE**
>
> The ground-fault system on the Baker AWA-IV will render it inoperative without a proper ground. When the host Baker AWA-IV tester is connected to a power pack, an inoperable condition will also affect the power pack.

Emergency stop button

The Baker AWA-IV tester and the power packs are equipped with a red Emergency Stop (E-Stop) button on the front panel of the unit. Use it to quickly discontinue a test and to shut off power to the power pack's high-voltage circuitry.

The button will remain locked in position until manually retracted by rotating the Emergency Stop button clockwise.
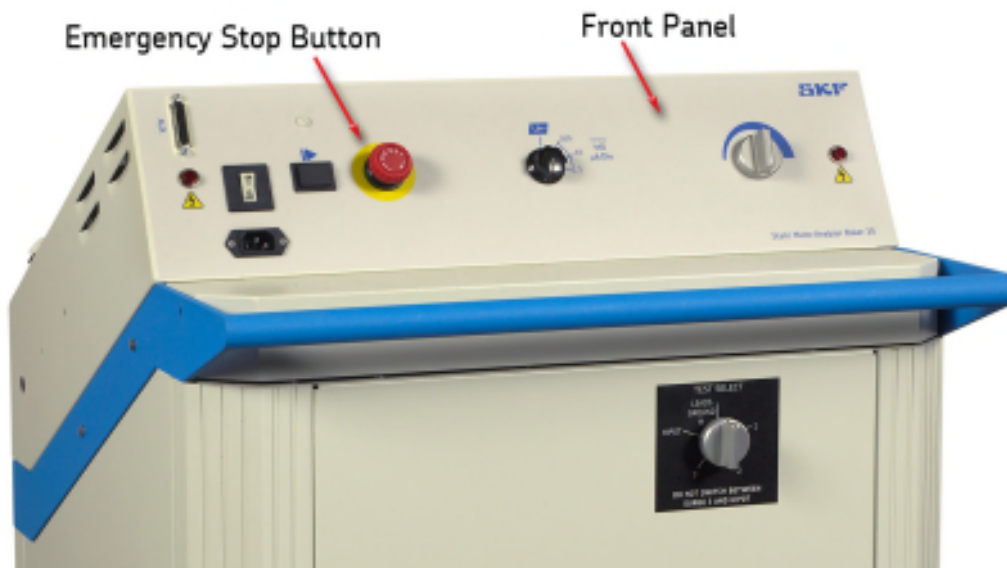
Figure 3. Power pack showing Emergency Stop button.

Baker ZTX E-stop and remote E-stop

The Baker ZTX can be used with the Baker AWA-IV 6/12kV models.

The Baker ZTX unit and the remote E-Stop unit are both equipped with a red Emergency Stop button. The Emergency Stop button is on top of the Baker ZTX unit and it is in the line with the status lights on the remote E-Stop accessory.
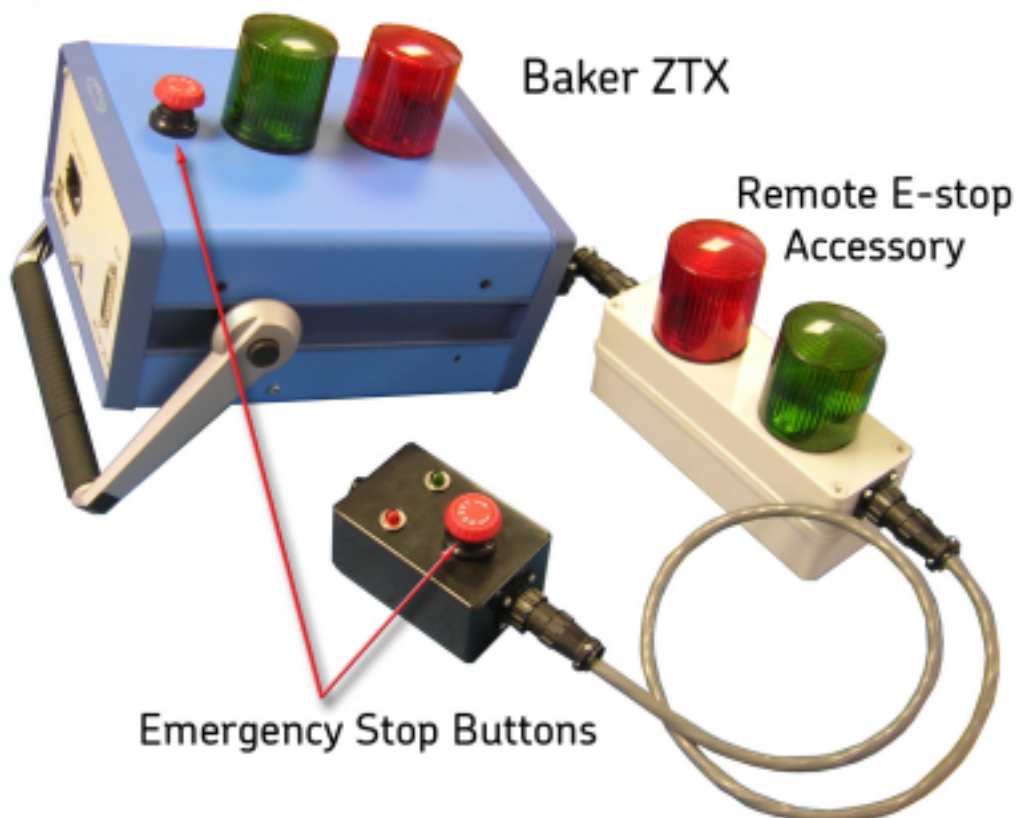
Figure 4. Baker ZTX unit and Remote E-Stop Emergency Stop buttons.

After being pressed, the button will remain locked in position until manually retracted by rotating the Emergency Stop button clockwise. A warning message will appear on the Baker AWA-IV screen.

General operation, maintenance, and service information

Cleaning and decontamination

Keep the unit clean and in a dry environment. To clean the unit, power down and unplug the instrument. 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.

Technical assistance / authorized service centers

See our website at www.bakerinst.com for technical assistance / authorized service center information. This information will be marked with an asterisk.

Unpacking the unit

Carefully remove the following items from the shipping box:

- Baker AWA-IV
- Power cord
- Operation manual (soft copy only)

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 100–240 V AC, 50–60 Hz,

2 amps AC maximum current draw. An auto-reset circuit breaker protects the unit.

Environmental conditions

- The unit has been tested for use up to 2,000 m (6,500 ft.).
- Only operate the tester in temperatures ranging from 5 to 40 °C (41 to 104°F).
- This unit is for use at a maximum relative humidity of 80% for temperatures up to 31 °C (88 °F), decreasing linearly to 50% relative humidity at 40 °C (104 °F). This unit is intended for Installation Category II in a Pollution Degree II environment.

Power pack lifting and shipping

Lifting the instrument

⚠ **CAUTION**

Lift the unit using two 3,6 m (12 ft.) lifting straps placed under the unit, as shown in the photos below. Do not use the handle of the instrument to lift the unit.

Figure 5. Properly lifting the unit using straps.

⚠ **CAUTION**

The power pack is shipped as indicated by the shipping labels. Inspect the units after shipping and notify carrier immediately if damaged is found.

Confirm that the back panel of the power pack lists the Baker AWA-IV serial number before connecting to the power pack.

Operating and shipping positions

The power pack, when equipped with the Test Select switch option, is not rated for operation in any position other than vertically, with all four wheels down on a level service.

If the product must be shipped for any reason, the package containing the power pack must be properly labeled with "this side up" labels to ensure the instrument is shipped in the upright position.

3   Instrument overview and setup

Baker AWA-IV setup (all models)

The Baker AWA-IV requires adequate ventilation. Place the unit where air can circulate freely around it and avoid locations in direct sun or near heat sources. Do not stack objects on or near the Baker AWA-IV. To prevent shock hazard, do not expose the Baker AWA-IV to rain, snow, or moisture. Avoid locations with high levels of dirt or dust.

1) Place the Baker AWA-IV on a large table or bench. Check the Baker AWA-IV power switch and make sure it is in the off position.

2) Plug one end of the Baker AWA-IV power cable to the line connector on the left side of the Baker AWA-IV and plug the other end of the power cable into a grounded wall socket. The unit will operate between 85-264 VAC 50/60Hz.

3) Locate the keyboard/pointer USB unit. Plug into one of the USB ports.

4) If a CD-ROM, disk drive needs to be used, plug it into one of the USB Ports for the Baker AWA-IV.

5) Power up the Baker AWA-IV by turning the power switch to the On position.

6) As the Baker AWA-IV powers up, various BIOS messages will appear on the screen.

7) The Baker AWA-IV will automatically log in to the Baker AWA-IV software with the associated serial number information.

> **NOTE**
>
> An Administrator can change this to log into the Windows Desktop; however, Baker Instrument Company, an SKF Group Company, recommends this be unchanged. If passwords are changed and the instrument is returned for service without the passwords, the instruments hard drive will be reformatted and any data may be lost.

Printer configuration

The Baker AWA-IV comes with a set of printer drivers installed. More printer drivers may be added if necessary. To install a printer, follow the instructions provided in the Windows® manual. In order to print, the Baker AWA-IV must be connected to the printer and the proper printer driver must be selected.

Provided memory key

An external, USB memory key is shipped with the unit for data storage, backup, or transfer.

To enable the CD-ROM driver, have the devices plugged in upon boot-up. The devices will be automatically recognized at this point and ready for use.

Use of footswitch

On the rear of the instrument a four-pin connector is available to plug in the footswitch to operate the instrument for span testing of armatures. The footswitch allows you to continue testing the entire armature easily and quickly.

4 Recommended testing sequence and voltages

Recommended testing sequence

To adequately test motors and to establish effective predictive maintenance programs, we 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. More rigorous testing should only commence after satisfactory diagnosis and/or repair.

The suggested testing sequence is:

1) Resistance,

2) Meg-Ohm, Polarization Index, Dielectric Absorption

3) HiPot, Ramp Voltage, Step Voltage

4) Surge

Balance resistance test or line-to-line resistance

A coil resistance test looks for resistance imbalance between phases. If a large imbalance is found, the motor should be inspected for the cause of the discrepancies. Typical problems that can 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.

Meg-Ohm test

A Meg-Ohm test is performed using a test voltage based on the operating voltage of the motor and the appropriate standards/company guidelines. Look for an unusually low Meg-Ohm value when compared to previous measurements or industry accepted limits for the type of insulation in the motor. If a low Meg-Ohm value is measured, the motor should be inspected for ground wall insulation damage. 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 contaminates.

3) Connections to the actual coils may be damaged.

4) Wrong insulation may have been used to connect the coils to the motor's junction box.

No further testing is necessary until the reason for the low Meg-Ohm reading is found and corrected.

HiPot test

A HiPot test is performed using a test voltage that is substantially higher than the Meg-Ohm test; however, it should be based on the operating voltage of the motor and the appropriate standards/company guidelines.

1) Look for unusually high leakage currents, a leakage current that does not stay constant, or a leakage current that intermittently jumps up and down.

2) Breakdowns or high leakage currents are an indication of damaged ground wall insulation.

3) Inspect the motor's slot liner, wedges, conductors between the junction box and the coils, and so on.

No further testing is necessary until the reason for the unacceptable HiPot reading is found and corrected.

Step voltage test

The Step Voltage test is used for predictive maintenance and field-testing. This DC test is performed to a voltage of what the motor typically sees during starting and stopping. The test voltages are governed by IEEE and other industry accepted organizations (NEMA, EASA, IEC). The DC voltage is applied to all three phases of the winding, raised slowly to a preprogrammed voltage step level, and held for a predetermined time-period. This is continued until the target test voltage is reached. Because the test is the most stable at the end of each step, data is logged at this point. If at this point the leakage current (IμA) doubles, insulation weakness is indicated and the test should be stopped. If the leakage current (IμA) raises consistently less than double, the motor insulation is likely in good condition.

Surge test

A Surge test is performed on each phase of the motor, using a 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. This is the signature of a turn-to-turn short. If a jump is observed, inspect the motor. Look for damaged insulation between adjacent conductors. The insulation might be hard to see, so you might have to disassemble the motor to find the problem. If you do not observe a jump in the wave patterns, the likelihood of motor failure due to turn insulation failure is greatly reduced.

Recommended test voltages – HiPot and Surge tests

Recommended 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).

Examples for 460VAC and 4160VAC motors are as follows:

$2 \times 460V + 1000V = 920 + 1000 = 1920\,V$

$2 \times 4160V + 1000V = 8320 + 1000 = 9320\,V$

For new windings or rewound motors, the test voltage is sometimes increased by a factor of 1.2 or even 1.7. This provides for a higher level of quality control on the work performed. For motors above 460V, the test voltage would be:

1920V * 1.2 = 2304

Or

1920 * 1.7 = 3264

5   Using the Baker AWA-IV software

The Baker AWA-IV software performs pre-configured tests, automatically, on pre-configured motors. Pre-configured tests are identified by Test IDs. Pre-configured motors are identified by Motor IDs.

Motor IDs are stored in the Baker AWA-IV's database along with the Test ID to be used when testing that motor. Additional information about the motor such as manufacturer, serial number, horsepower rating, frame size, speed, operating voltage, and current are also stored in the Motor ID. New motors can be entered into the database or existing motors can be edited, corrected, or updated.

The Test ID consists of all test parameters to be used when performing tests on a motor. Details such as test-voltages, pass or fail criteria, and test times are contained in a Test ID. You name and define Test IDs.

The software includes predefined Test IDs for several different machines. Usually, the most important parts of a Test ID are the test voltages. Therefore, a Test ID is named after the operating voltage of the motor. Several motors can share a single Test ID. For example, all 480-volt motors can use the same Test ID.

Database management

Database management is a highly important feature of a good predictive maintenance-testing program. It facilitates organization of periodic maintenance data. The database section of the Baker AWA-IV software allows the entry of identifiers to help clarify the location of specific motors, along with the use of multiple databases to help organize overall program maintenance. You should develop best practices for keeping the data collected, easily accessible, and meaningful.

Consequences of not organizing data

Because the Baker AWA-IV can be configured to store every test it ever performs, we recommend that you establish a structure that everyone performing tests will follow. Consider the following example: A maintenance program is established to test motors at seven plastics production plants, each in a remote location. Each plant has nearly 1000 motors that are identified as needing periodic testing. All works well for several months until a motor that was previously tested fails. The maintenance manager wants to see all the test data. When the project supervisor looks at the data, he finds nearly 7000 tests, all in one large database, and in a random order. The manager spends about an hour looking for the last test performed and gives up. Upon investigation, the manager finds that each of the technicians using the equipment has been entering the data based upon what made sense to them at the time. Because of the disorganization, important test data has been lost or at best is difficult to locate.

The Baker AWA-IV's database structure is designed to facilitate data organization and to be flexible enough to allow you to uniquely plan for specific needs. The Motor ID, two location fields, and the multi-database abilities are the tools you can use to organize the data so that something like the above scenario does not happen to you.

Starting the software

To start the Baker AWA-IV, locate and double click the Baker AWA-IV icon on the Windows® desktop. The Baker AWA-IV software will start and present a window with two options: create a new database or open an existing database.
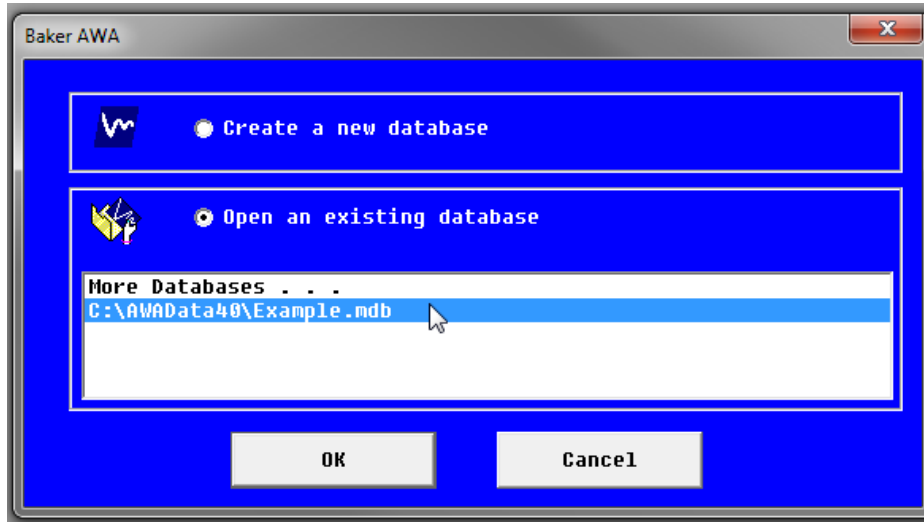
Figure 6. Opening software from the desktop.

Creating a new database

There are two ways to create a new database. Click on the radio button upon entering the Baker AWA-IV software. The second way is after you are already using the software.

1) To create a new database from the first window presented click on the radio button in front of the **Create a New Database**. Type the name of the database and click on **Save**.

2) If the software is already running, you can create a new database by clicking on **New** from the **File** menu or the new database icon on the toolbar. The same *Create New Database* window will appear.
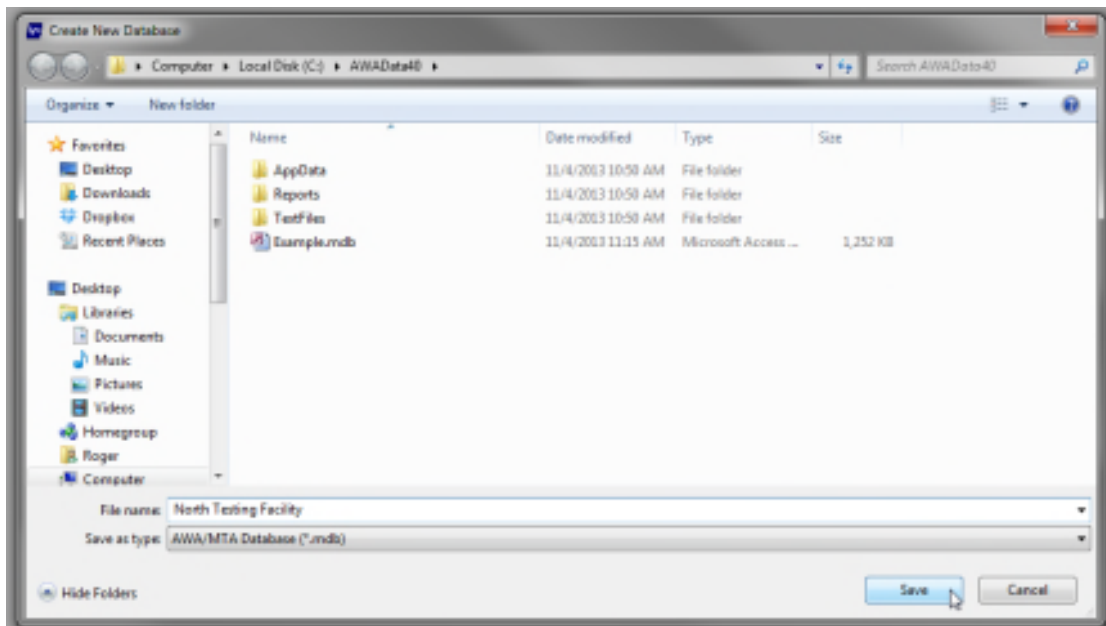
Figure 7. Creating a new database.

3) The **Save as type** folder is the default folder. Navigate to another folder if you prefer and enter the name of the new database in the box next to the file name.

4) Click on the **Save** button. A database will be created and opened that has one default motor and the default Test IDs. At this point begin entering new motors using the **Data**-**Nameplate** tab.

Opening an existing database

There are also two ways to open an existing database: when you start the software, by clicking on the **Open an existing database** radio button, or later as you are running the software.

1) To open a database after the software is running, click on the **Open** option under the **File** menu or click on the open database icon on the toolbar.

2) A Select Baker AWA-IV Database window appears to help you locate and select the desired database. It will default to the folder that has been selected in **View-Options-File Locations** menu item.

3) Select a database (.mdb) then click the **Open** button or double clicking on the desired database.
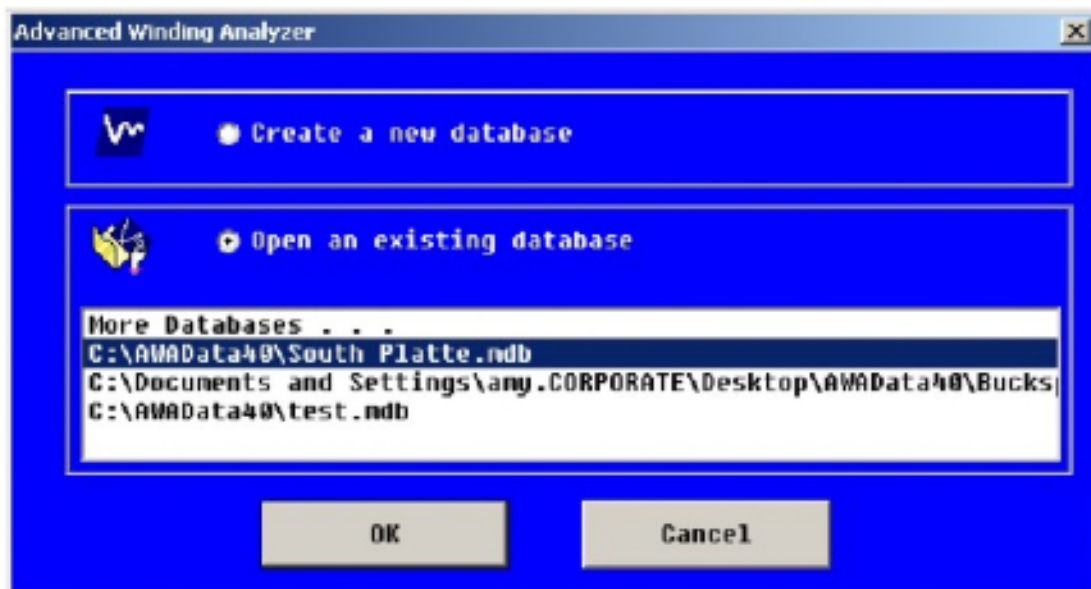
Figure 8. Selecting an existing database.

Using multiple databases

The Baker AWA-IV software allows the use of multiple databases. You can split data between different databases, grouping motors in whatever way that is beneficial to your application. For example, motor shops might want to use different databases for each customer. A preventive maintenance department could use a different database for each part of their plant.

Your application might require that you keep the data in a centrally located database on a network and have databases locally on each Baker AWA-IV, which then update the main database.
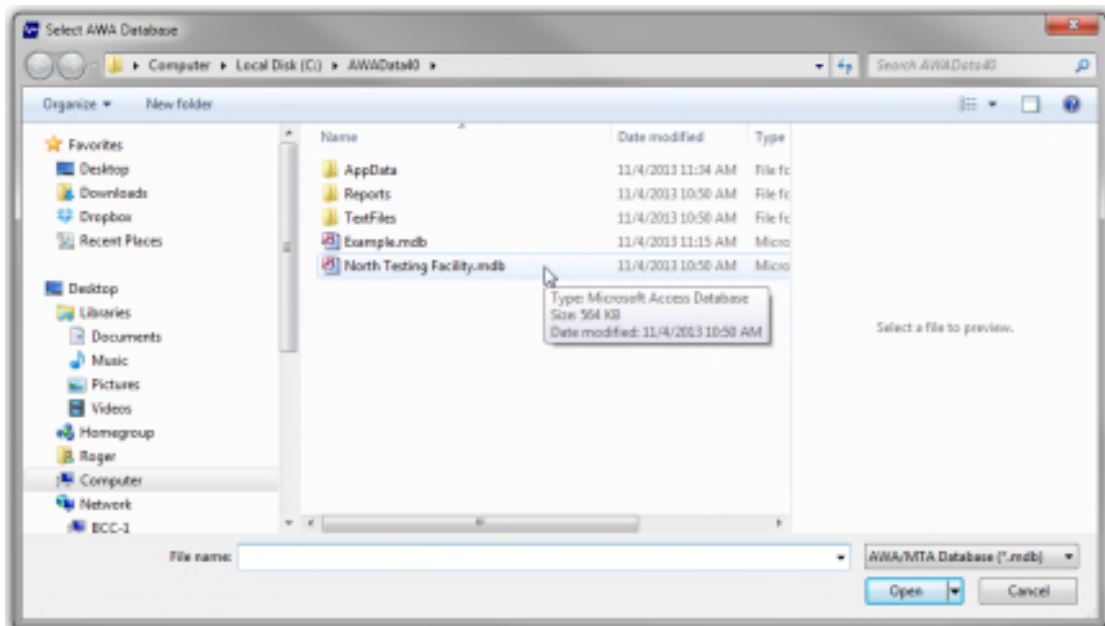
Figure 9. Opening an existing database.

NOTICE

It is important to establish best practices for database organization early and maintain adherence to your practices to avoid loss of data or data duplication.

Manipulation of the database may be useful for management and auditing purposes. Do not delete records associated with Motor IDs. Proceed with caution when manipulating data from the Baker AWA-IV.

Always backup a database before deleting records or manipulating the database in any way.

The first time version 4 software is used

The first time the Baker AWA-IV software is used, the *Enter Test Equipment Information* window will appear. Select the tester type, serial number (found on a sticker on back of unit), and customer's tester ID (can be an asset ID).   If the software is being installed on a desktop computer, all other fields will be gray.

This information will be used to track each data record to identify which Baker AWA-IV tester acquired the given record. The tester information is usually entered at the manufacturer before the Baker AWA-IV is shipped; however, it may be changed though calibration, which can be invoked by checking the **Enable Calibration** box in the **Tests** tab.

Figure 10. Enter Test Equipment Information window.

> **NOTE**
>
> Test results from a converted database (databases from a pre-4.0 version) will not have this information. Converted records will contain the tester type of Baker AWA-IV converted. Subsequent test results will be stamped with machine information, which can be viewed in the application view at the bottom of the pane.

Main window

After selecting or creating a database, the Baker AWA-IV software *Main* window appears:
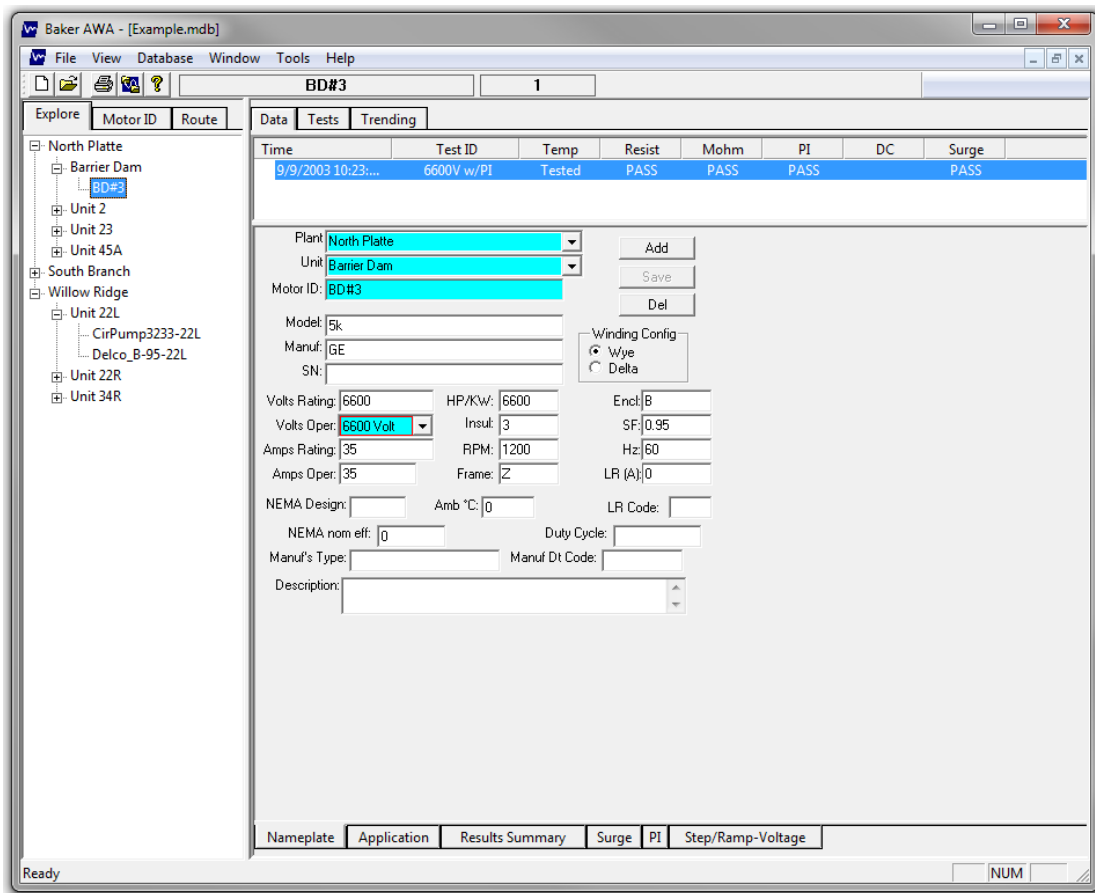
Figure 11. Selected database.

To view test results for a given motor or to perform a test on a motor, you must first select the desired motor from all the other motors in the Baker AWA-IV's database. The Baker AWA-IV software *Main* window is split into two panes. The left pane contains three different tabs—**Explore**, **Motor ID**, and **Route**—that facilitate browsing through the motors in the database. The right pane contains three more tabs—**Data**, **Tests**, and **Trending**—that help you view test data, performance of set tests, and trending mechanisms.

The *Main* window includes several tools to help you navigate the user interface and access the Baker AWA software features and functions. The tools include the **Main menu**, the **Toolbar**, and the **Tabs** mentioned above.
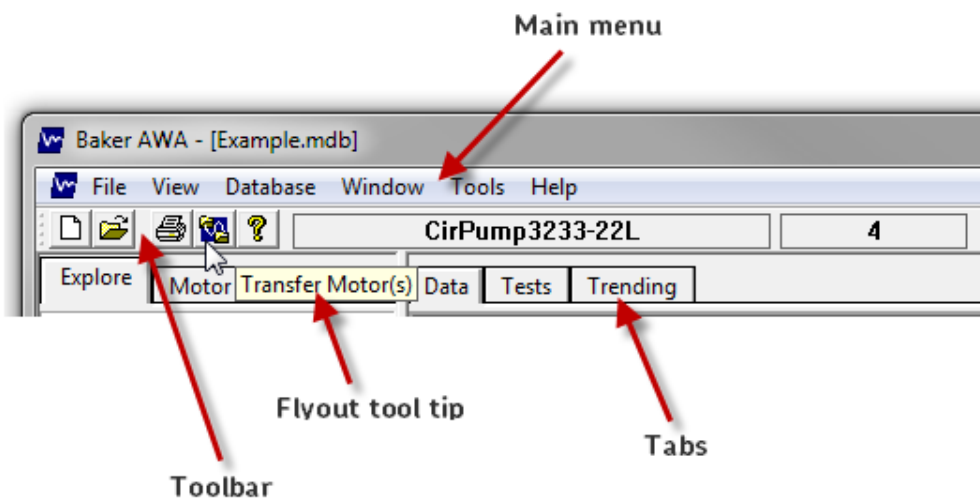
Figure 12. Main window tools.

Main menu

The **Main menu** contains six menus that provide access to features and functions organized by the categories implied by the menu labels. Each menu is described in the following sections.

File menu

Clicking on the **File** menu drops down a list of items that help you choose the database(s) that you want to use during your session. Databases that are open are listed just above the **Exit** item.

Clicking on **Exit** closes the application.

The **Print** menu item provides access to printing features.
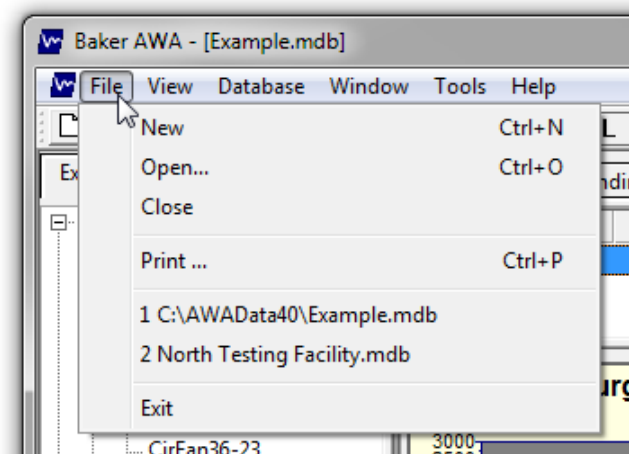
Figure 13. File menu.

View menu

The **View** menu allows you to specify whether the **Toolbar** and **Status Bar** will be displayed in your view of the user interface. A check mark next to an item indicates that the feature will be displayed.

The **Options** item drops down a sub-menu that provides access to additional features.

Clicking on the **File** Locations item opens a dialog box that helps you identify where specific file types used by the system are stored. You can also use this dialog box to modify locations if needed.

Clicking on the **Changable** labels item opens a dialog box that helps you rename the labels for location field one (default is "Location") and location field two (default is "Building").

Clicking on the **Enable Voltage Class** item toggles the setting that requires the use of voltage classes. When this feature is enabled, a check appears next to the item.

Clicking on the **Allow Duplicate Motor ID's** item allows the system to create motor IDs that are identical.
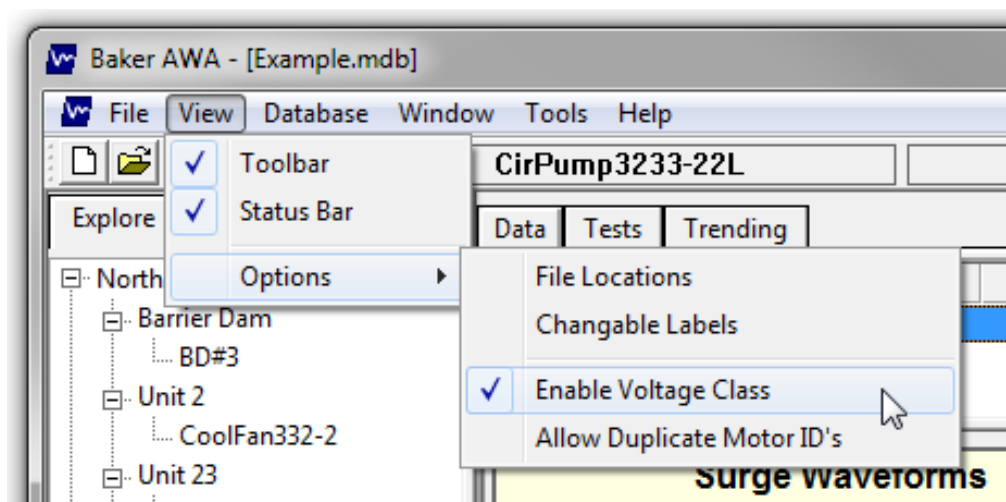
Figure 14. View menu.

Database menu

The **Database** menu provides access to functions used to maintain and manipulate database files. The data transfer, archive, and restore features are described later in sections relevant to their specific context.

Clicking on **Locate on Disk** opens a window that shows you the current location of the database file you are current using.

Clicking on **Load Text File** opens a system window to help you select a text file to load into the system.
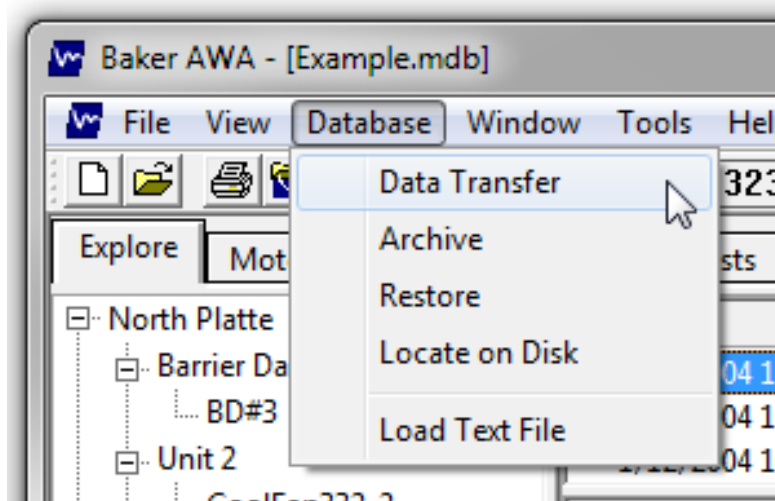
Figure 15. Database menu.

Window menu

The **Windows** menu provides you with functions for selecting which database to use (if several are open) along with options for displaying windows within your screen.
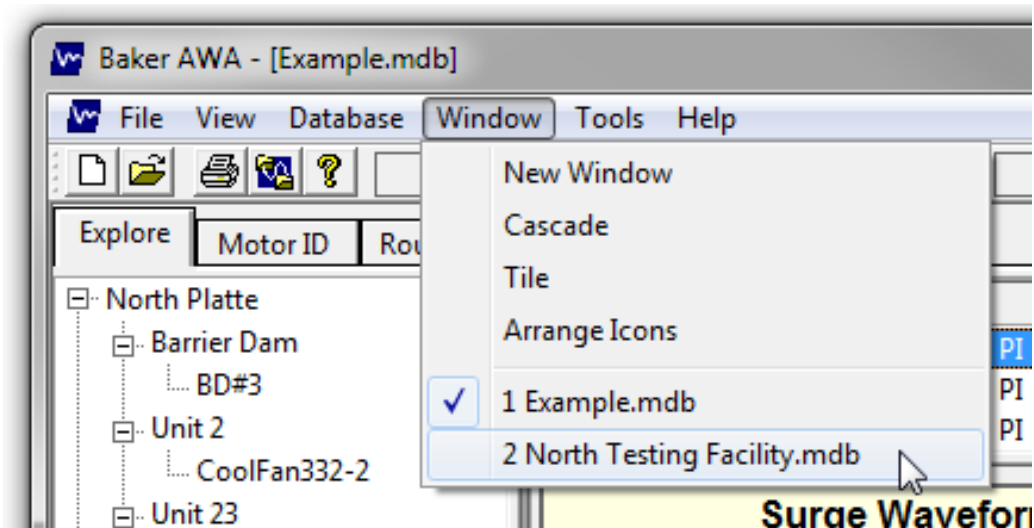
Figure 16. Window menu.

Tools menu

The **Tools** menu provides access to other basic tools including WordPad, MS Paint, and a web archive file viewer.
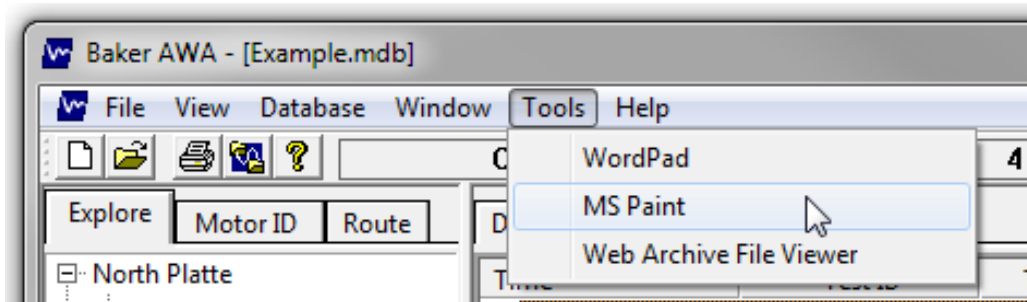
Figure 17. Tools menu.

Help menu

The **Help** menu provides information about the Baker AWA software version and tester. It also provides access to the current user manual, which is available online.
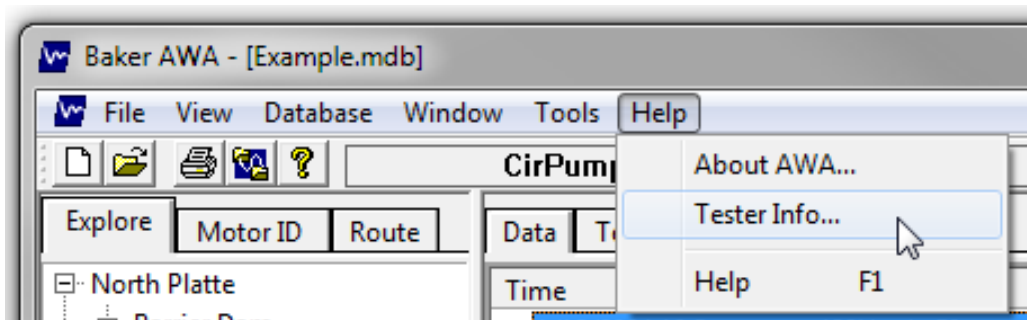
Figure 18. Help menu.

Toolbar

The **Toolbar** contains several icons that provide shortcut access to several features that can also be accessed from the **Main** menu. From left to right the icons (and their features) include **New, Open, Print, Transfer Motors**, and **About**.

Hovering the mouse cursor over an icon provides you with flyout tool tips that identify the icon.

The **Toolbar** also identifies the current motor displayed in the user interface along with the type of Baker AWA used to test that motor.
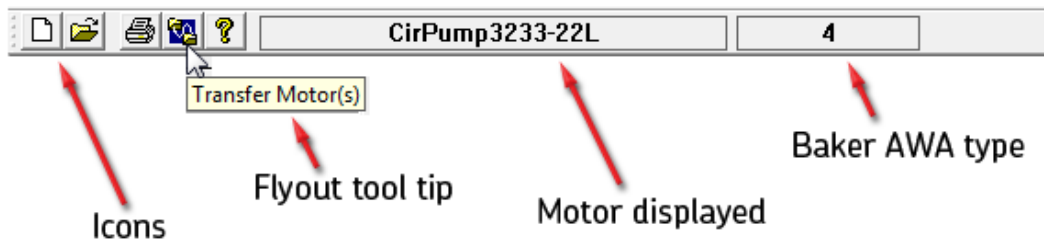
Figure 19. Toolbar.

Tabs

The left side of the *Main* window is used to navigate through the motors within the opened database. Three tabs help you locate and select motors for testing.

The **Explore** tab displays the motor locations in a three-level view called the **Motor Tree**.

The **Motor ID** tab gives you an alphabetical list of Motor IDs. You can type the first few characters of the Motor ID into the blank field above the list to locate a specific motor.

The **Route** tab provides predefined lists of motors used to locate a subject motor. The **Route** tab is similar to a route often used in the predictive maintenance business.

Explore tab

The **Explore** tab uses a tree structure to help you locate and select a particular Motor ID. The two upper levels of the tree correspond to the location and building in which the physical motor is housed.
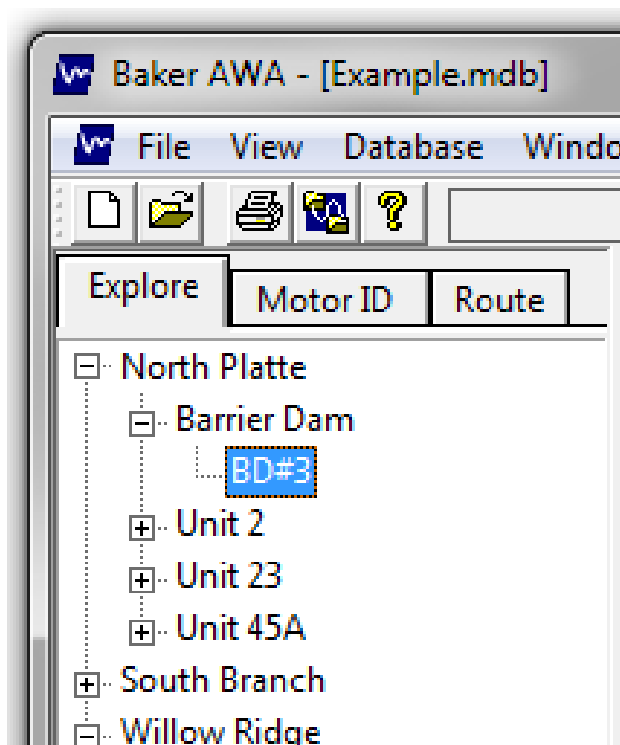
Figure 20. Explore tab.

Location and **Building** are the default tree labels, but these labels can be changed to better suit your situation and best practices.

The lowest level is the Motor ID. In the example above, the selected Motor ID is BD#3. The motor is physically located at the North Platte plant, Barrier Dam. By clicking on Motor ID, a motor and its associated data is loaded from the database into the related tab fields on the right side of the window. It becomes the current motor. Expand a motor location by clicking on the plus sign or contract a location by clicking on the minus sign.

Motor ID tab

The **Motor ID** tab lists all motors currently stored in the database in alphabetical order. When you click on a motor in the list, the list item is highlighted and the Motor ID appears in the field found just above the list.
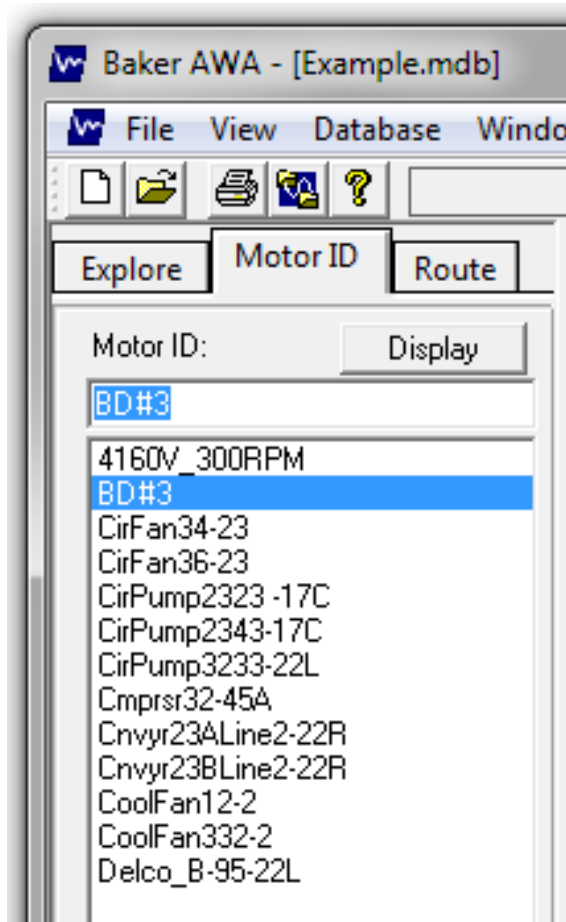
Figure 21. Motor ID tab.

Locate a Motor ID two ways within this tab. Begin typing the Motor ID needed into the field found just above the list. The list will automatically scroll to the nearest Motor ID that begins with those characters and will automatically update as you enter more characters. For example, if the letters Cmp are typed, the Cmprse32–45A Motor ID would be highlighted.

When you find the Motor ID you are looking for, double click on that Motor ID. You can also ensure that the Motor ID you want is highlighted and appears in the field just above the list. Then you can click the **Display** button. Using either method, the Motor ID would become the currently selected motor.

The second method is to simply scroll down in the list until you spot the Motor ID you need, then double click or highlight the Motor ID and click the **Display** button to select the desired Motor ID.

Route tab

The **Route** tab allows you build lists of Motor IDs for routing purposes.
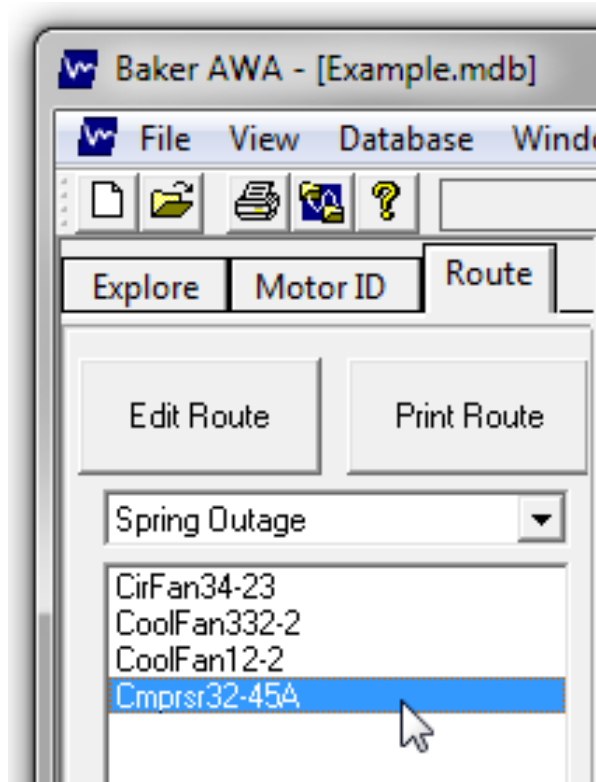
Figure 22. Route tab.

As the example above shows, Spring Outage list is selected. This list has four motors associated with it. The electrical technician does not have to search the entire database for these four motors to be tested during the spring outage.

This tab also allows editing and printing of these routes. Click on the **Edit Route** button to start the editor. The editor allows you to Add, Rename, and Delete routes. It also allows addition, removal, and changing the Motor ID list order.

Adding a route

1) To add a new route, click on the **Add** button at the top of the window. The Route IDs edit box will be blank so you can enter a new Route ID. After entering the new ID, start adding Motor IDs from the Available Motors list box on the right to the Route Motors list box on the left.

2) To add a motor, select the Motor ID on the right and click on the **<<Add** button. The Motor ID will be moved from the **Available Motors** list to the **Route Motors** list. Continue adding motors as needed.

3) When you have finished, click on the **Update** button at the top of the window. The **Update** button appears when you click the **Add** button.

Renaming a route

1) Select the Route in the Route IDs combo box to rename.

2) Click on the **Rename** button.

3) The Route ID will be highlighted. Edit the ID as needed then click the **Update** button. The **Update** button appears when you click the **Rename** button.

Deleting a route

1) Use the **Route ID** combo box to select the route you want to delete.

2) Click on the **Delete** button. The selected route will be deleted.

> *i* **NOTE**
> Deleting a route does not delete the Motor IDs from the database.

Editing motor IDs on an existing route

1) Use the **Route ID** combo box to select the route you want to edit.

2) The Motor IDs associated with that route will appear in the **Route Motor**s list.

3) All Motor IDs not on the route will appear in the **Available Motors** list.

4) To add Motor IDs, select the Motor IDs from the **Available Motors** list that you want to add then click on the **<<Add** button. Select one motor at a time, or use the control/shift keys to select a group of Motor IDs.

5) To remove unwanted Motor IDs from the route, select the Motor IDs from the **Route Motors** list then click on the **Remove>>** button. The Motor IDs will be removed from the **Route Motor** list and be added back to the **Available Motors** list.

6) To change the order of the Motor IDs in the **Route Motors** list, select the motor or group of motors to move and click on the **Move Up** or **Move Down** buttons found just below the list.

7) When you have finished editing a route, click on the **Update List** button to save your changes.

Viewing test data

The right pane of the software has three tabs at the top of the window—**Data**, **Tests**, and **Trending.** Respectively, these tabs help you view results data for a variety of tests; check the status, configure, or execute tests; and display trending graphs that chart acquired data over time.
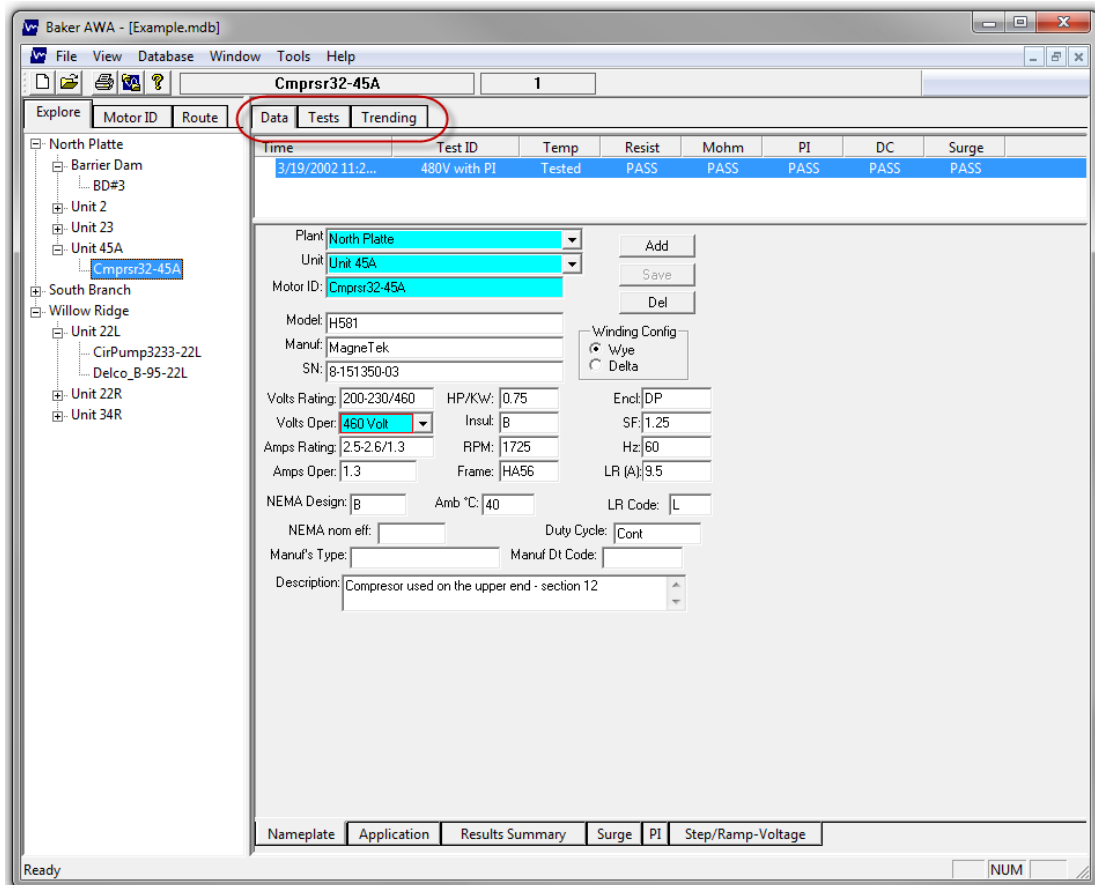
Figure 23. Right pane of *Main* window features **Data**, **Tests**, and **Tending** tabs.

Using the Data tab

The **Data** tab contains two section; one above the other. The top section shows the date and time for the test result data and whether the motor passed the specific test. By clicking on a date/time, you can view test result data for that specific date within the **Application, Surge, PI, or Step/Ramp-Voltage** tabs in the lower section. The view in the lower section changes depending on which bottom tab is selected.
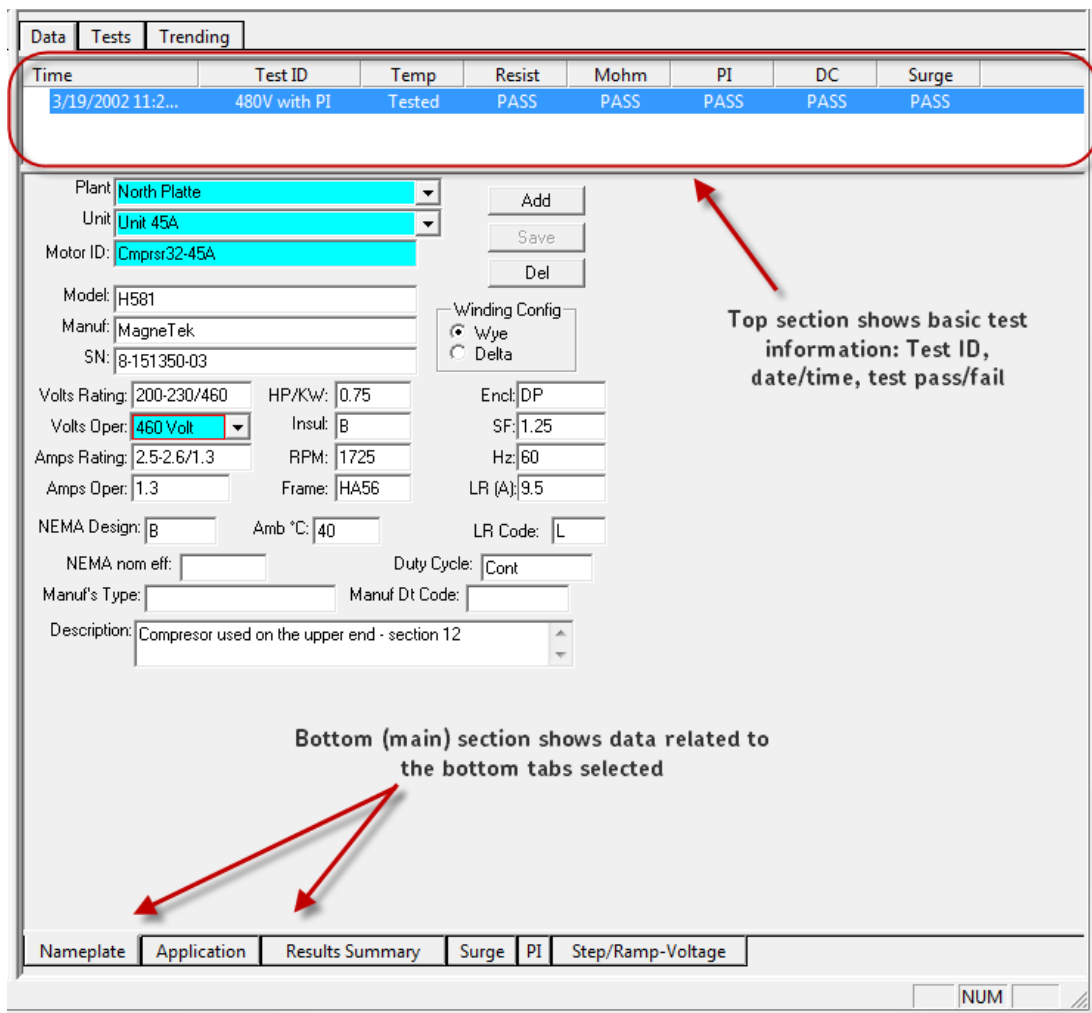
Figure 24. Data tab sections.

Motor ID field

The records stored by the Baker AWA-IV are hierarchically linked to each other. The **Motor ID** field serves as the primary key for linking associated records. The Motor ID is the principal means of locating and interacting with a motor's data. Therefore, it is important to develop a naming scheme that will facilitate locating and retrieving information.

Consider the common case in which a plant has duplicate processes, with identically named motors in each process. This can cause confusion, because the motors have the same Motor ID, but are in different locations. Take steps at the start to ensure that Motor IDs are unique.

For example, two identical intake pumps are present in duplicate processes. It makes database management easier if these two motors can be uniquely identified. One way to solve this problem is to include the process ID in the motor ID. For example, the motor ID for process 1 could be intake pump P1 while the Motor ID for process 2 could be intake pump P2.

Motor location fields

The Motor ID is the primary identifier and locator of a motor. Two other fields are also used to help locate a motor within the database. These fields have the default field names **Location** and **Building**. If these labels do not make sense for the situation, you should change them.

To change location labels, click on the **View** menu then **Options** then **Changeable Labels**.

Consider the example that a plant maintenance program has several plants. The labels of the location fields could be renamed to something like Plant and Unit. The location data is the used with the Motor ID to create the nameplate record and are used to make up the tree structure of the **Explore** tab.

In the example **Explore** tab shown in the next section, motors have been organized by location in Plants and Units: North Platt and South Branch are Plants and Unit 23, Unit45A, Unit 17C are all units.
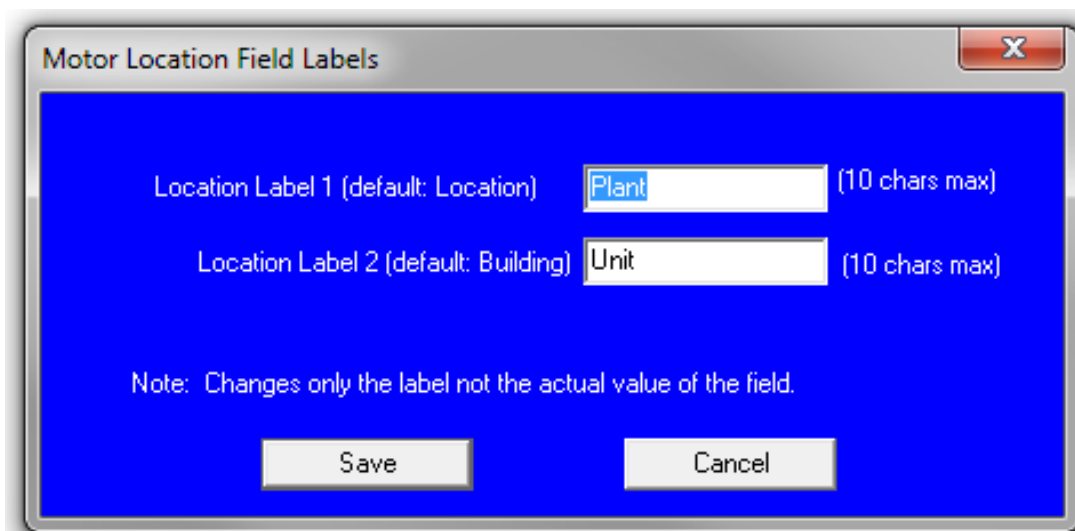
Figure 25. Changeable labels.

Data tab—Nameplate view

The **Nameplate** view contains the nameplate data on each motor in the database. The first field is **Motor ID**, which is used by the Baker AWA–IV program to uniquely identify the motor. *Values must be entered in the Motor ID and the two motor location fields.*

The labels for the location fields are user definable. In the example below, their labels are **Plant** and **Unit**. The default values are **Location** and **Building**.

If you need to change the field labels, click on the **View** menu then **Options** then **Changeable Labels**. The location fields are used in the **Explore** tab to help locate motors. All other fields in the **Nameplate** view are optional.

Figure 26. Data tab, nameplate view.

> **NOTE**
>
> Many industrial customers have found that filling in all nameplate fields greatly helps with preventive maintenance programs by providing one place where their plant's motor data is kept. Likewise, motor shop customers often discover that recording complete nameplate information is required when working with their customers' motors.

The **Nameplate** view is also used to add new motors, update existing motors, and delete unneeded motors from the database.

Adding a new motor

1) Click on the **Add** button. The **Motor ID** and **SN** (serial number) fields will be blanked out.

2) If needed, click on the **Clear** button to clear all fields.

3) The **Location** fields (**Plant** and **Unit** in this example) and **Motor ID** are required. Values entered cannot begin with a space. If more then one location exists, click on the down arrow of the location boxes. You can enter a new **Plant** location simply by typing the new name in the field.

Figure 27. Adding a new motor ID. Required fields appear in blue in this example.

4) If voltage class restriction is enabled (via the **View** menu **Options** and **Enable Voltage Class** is checked), entering a value in the **Volts Oper** field will also be required. Entering information in other fields is recommended for tracking and other purposes, but is not required. When you have finished entering your values, click on the **Save** button.

5) Enter the **Test ID** to be used when testing the new motor.

> *i* **NOTE**
>
> Clicking the **Reset** button will re-display the previously motor and nothing will be added.

Updating an existing motor's nameplate information

1) Select the desired Motor ID then move the cursor to the field(s) you need to update and make your changes. The **Save** button will be enabled as soon as changes are started.

2) When finished, click on the **Save** button and your changes will be committed to the database. If the changes are not needed, click on the **Reset** button instead of the **Save** button. All fields will be reset and no changes will be committed to the database.

Deleting an existing motor from the database

1) Select the desired Motor ID then click on the **Del** (delete) button.

2) A dialog box appears asking if the request is appropriate. If it is, click **Yes.** The motor and all of its test results will be deleted.

Data tab—Application view

The **Application** view provides a place to enter data about a particular test. Information such as who did the test, who the test was done for, which MCC the test was performed from, and a general memo can all be entered in their respective fields when the test is conducted or at a later date. The general memo field is a good place to put information such as humidity, noticeable vibration of the motor before it was tested, and so on.

Figure 28. Data tab, applications view.

> **ℹ NOTE**
>
> The tester type, tester serial number, and calibration date are stamped on this record, to indicate what tester performed the test.

You can use this view to add new application records (which add an empty test record), update existing information, and delete test results.

To change what test result is being displayed, click on the date/time in the top section of the **Data** tab. The **Application** view will then display the selected data/time's information.

Data tab—Results Summary view

The **Results Summary** view displays the test results summarized in a grid or spreadsheet form. Each column represents one test result.

Figure 29. **Data** tab—**Results Summary** view example.

The first two rows are used as the heading for each column, displaying the date and time the test was performed. If all tests performed passed, the date/time will display in a green cell. If one or more tests fail, the date/time will display in a red cell. If no tests were performed, the cell will be gray.

Use the scroll bars to the right and bottom to scroll through the results for each test category. The side-by-side nature of this view allows comparisons to easily be made by allowing all test results for a motor to be seen in one view.

To print a copy of this view, click the right mouse button click anywhere on the grid and a dialog box will appear, allowing you to choose a printer and parameters for printing the grid.

Data tab—Surge view

The **Surge** view shows the surge waveforms for a particular test. The surge waveforms can be viewed in two ways. As a comparison, all waveforms for each lead are superimposed on each other, or in a nested view where waveforms for each lead at the 1/3, 2/3 and full voltage are superimposed. Additionally, if the test failed, the previous to fail and the failed waveform will be displayed with the failed waveform being drawn in red.
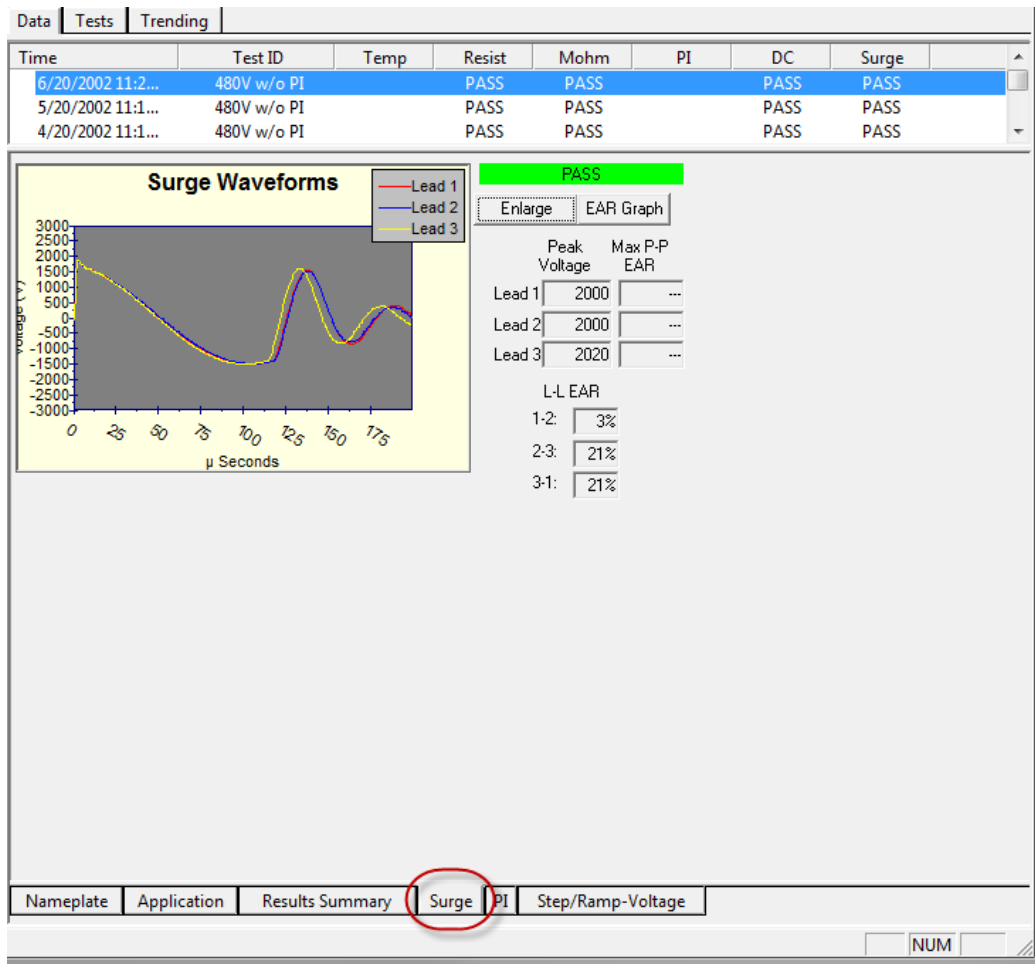
Figure 30. **Data** tab—**Surge** view showing test results.

The **Surge** view not only displays the surge waveforms for all leads, it also renders a view of the pulse-to-pulse Error Area Ratio (EAR).

Click on the **pp-EAR** button to view the pulse–to–pulse EAR graph. The graph displays the EAR percentage between successive pulses per test lead and the tolerance used during the test.
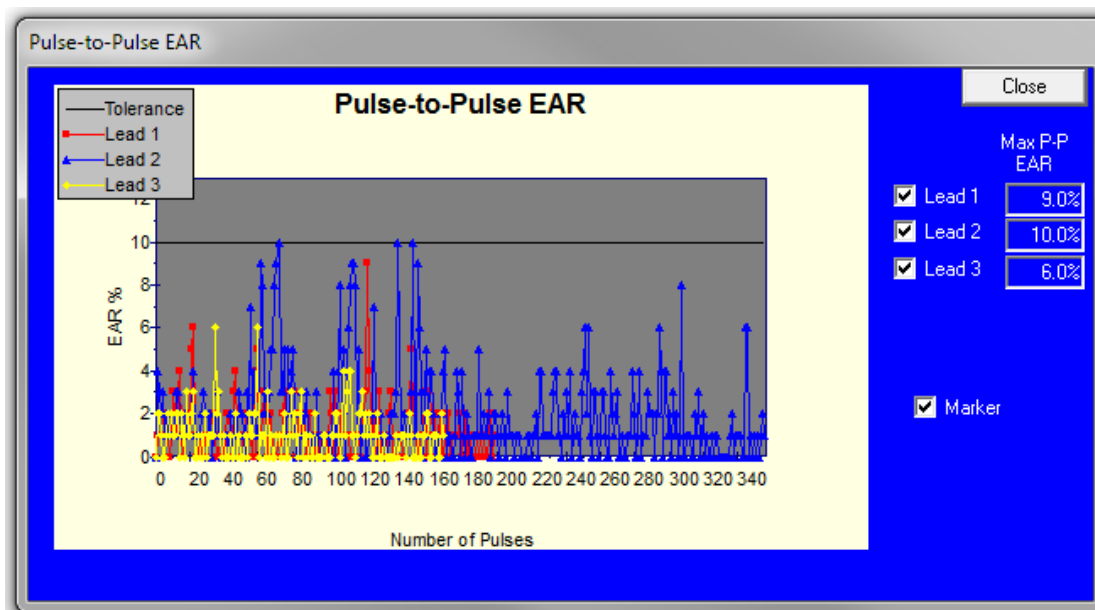
Figure 31. Pulse–to–pulse EAR example.

Data tab—PI view

Clicking on the **PI** (Polarization Index) tab displays the **PI** view, which contains the PI/DA graph and the data table.
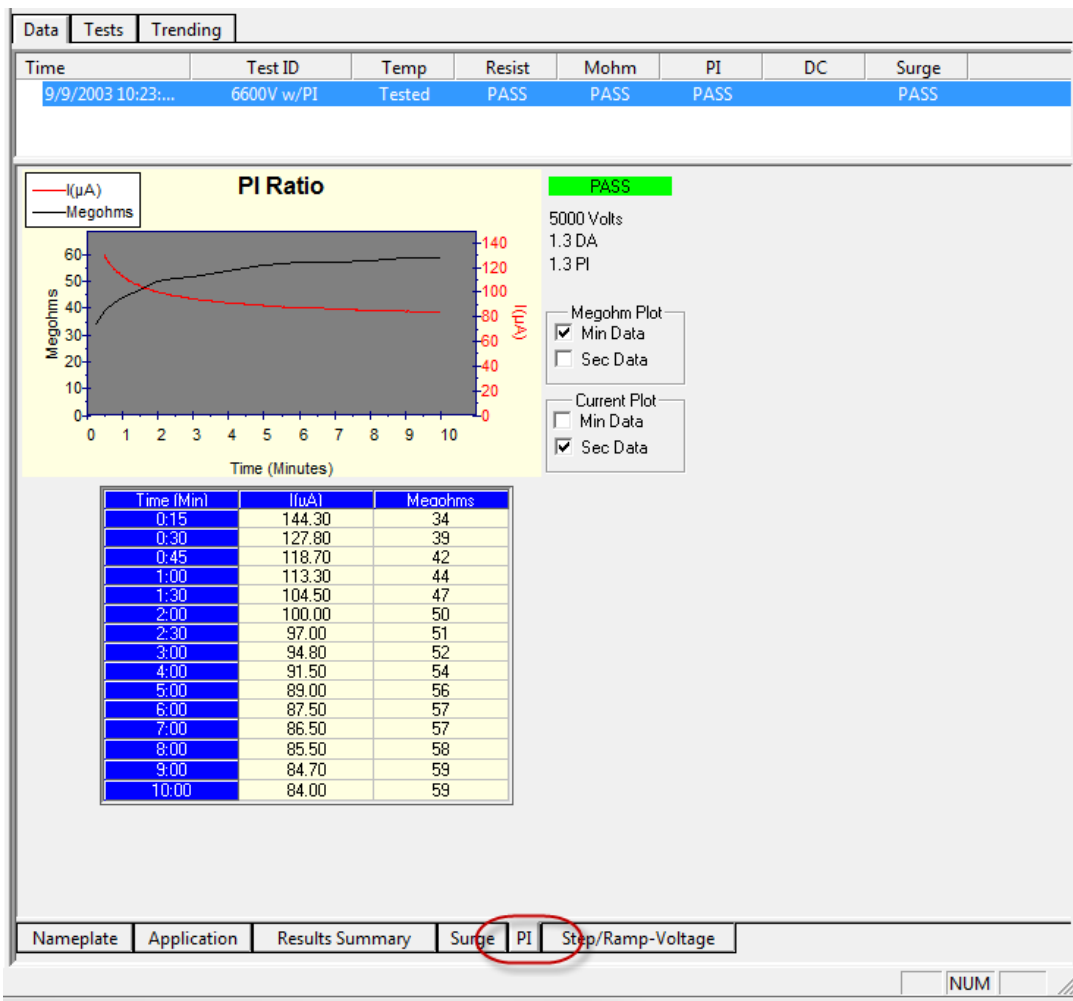
Figure 32. Data tab, PI view.

The PI graph charts the current vs. time and the Meg-Ohm reading vs. time. Under the PI graph are selected data points used in the graph. On the right side of the graph you will see data for PASS/FAIL, Test Voltage, DA/PI ratios, and four check boxes.

You can use the check boxes to select the graph plot Meg-Ohm and/or Current data in one second or one-minute increments.

Data tab—Step/Ramp-Voltage view

Clicking on the **Step/Ramp-Voltage** tab displays the Step Voltage test data in both graphical and tabular form. The graph defaults to plotting current vs. voltage.

The red triangles indicate the current level at the end of each step.

Clicking on the **Current vs. Voltage** or **Current/Voltage vs. Time** radio buttons determines what will be plotted on the graph and in the table.

Voltage is displayed in blue and real-time current in red. The green line with triangle markers indicate the current at the end of each step.
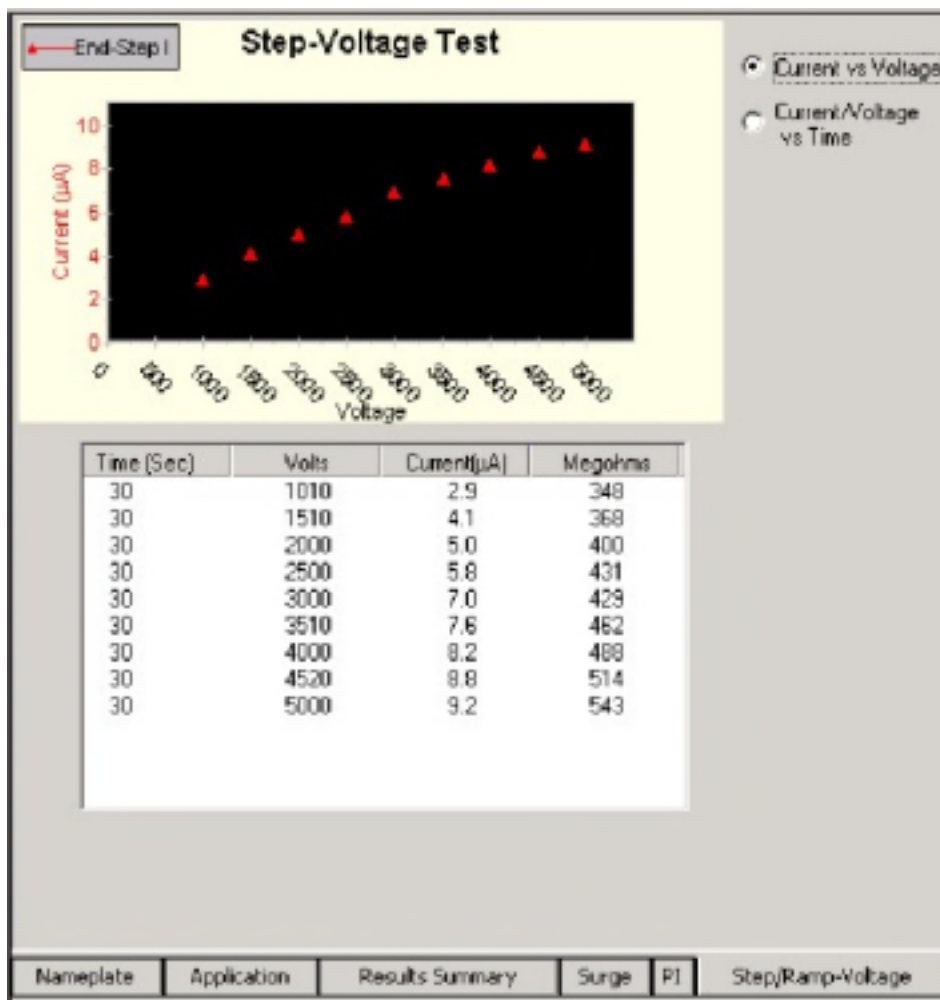
Figure 33. **Step/ramp Voltage** view showing current vs. voltage.

> ℹ **NOTE**
>
> The large excursion of the red real-time current line shows the motor's charging current while ramping up voltage. The large swings of this value do not indicate an insulation problem

Most concern is typically given to the current at the end of the voltage step. End-of-step currents should be linear. If they are not, an insulation problem is often indicated. The data in the table below the graph shows the test time per step, the voltage of each step, the measured end-point current and the Meg-Ohm value at each end point.
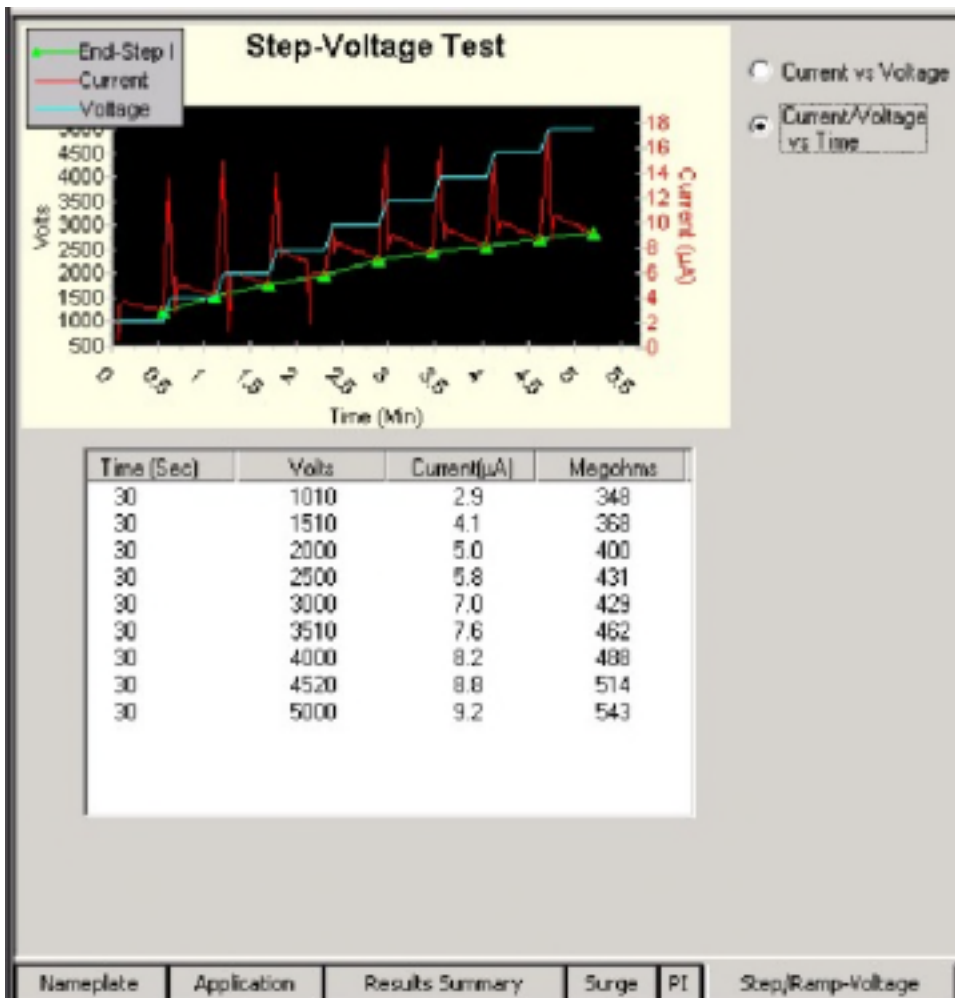
Figure 34. **Step/Ramp Voltage** view showing current vs. time.

Using the Tests tab

Clicking on the **Tests** tab changes the display area in the right side of the *Main* window as shown in the example below. This is the main testing window of the Baker AWA-IV. Each of the tests the unit performs is indicated by several columns of buttons that show the status of each test.

In the left-most column are **On/Off** buttons that show if the test is active. Click on the related button to turn each test on or off.

Click the buttons in the center column to execute the particular test. This is considered semi-automatic testing.
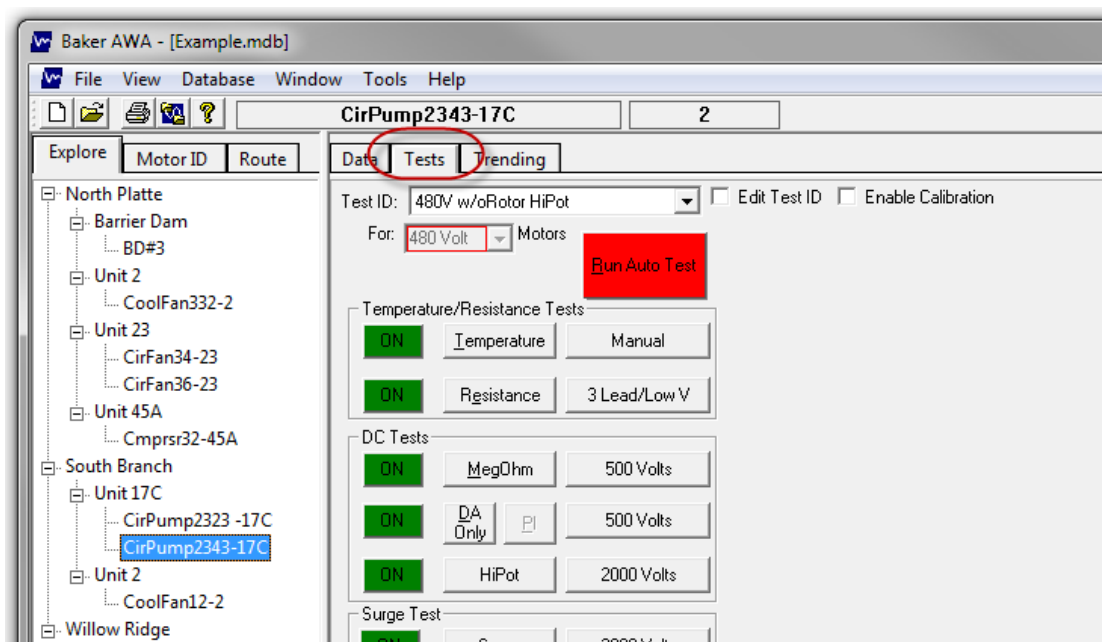
Figure 35. Test view.

Use the buttons in the right column to open a new window used to configure each test. The button labels indicate how each test is set up, how many leads will be used, the test voltage, and so on. Each test's configuration window is described below.

A fourth shaded column appears at the end of testing. Green indicates that the test passed; red that it failed. A red indicator also displays the reason the test failed.

To run an automatic test, click the **Run Auto Test** button. Each test that is turned on will be performed in the sequence as it appears in the **Tests** tab view.

To edit Test IDs, click on the **Edit Test ID** check box. You will be prompted for a password. If this is the first time you are editing a Test ID since the Baker AWA-IV software's installation, click on the **Change Password** button and enter the password in its field.

Click on the **Set Password** button.

If this is not the first time you are editing a Test ID, simply enter the password and click **OK.** Three new buttons will appear below the Test ID. Use the **Save** button to save changes you make to the selected Test ID. Use the **Add** button to add a new blank Test ID or to copy the a selected Test ID. Use the **Delete** button to delete the selected Test ID. When you are finished editing Test IDs, click on the **Edit Test ID** check box to disable Test ID editing.

NOTE

Leaving the **Tests** view will also disable the editing of test ID's and all changes will be lost if they have not been saved.

Test configuration

The three major setup windows for configuring Baker AWA-IV tests are described below. The specific choices made in the test setup windows define the Test ID. Before editing test parameters, check the **Edit Test ID** box and enter your password to allow updates to the test parameters and to enable saving your changes when finished.

Temperature/Resistance test window

When one of the temperature or resistance test configuration buttons is clicked, the *Temperature/Resistance Test* window pops up. The resistance and temperature test windows are combined into one and are shown below. This window is also used during testing. The resistance test and the temperature test can also be turned on or off using the check boxes on the left side of the window.
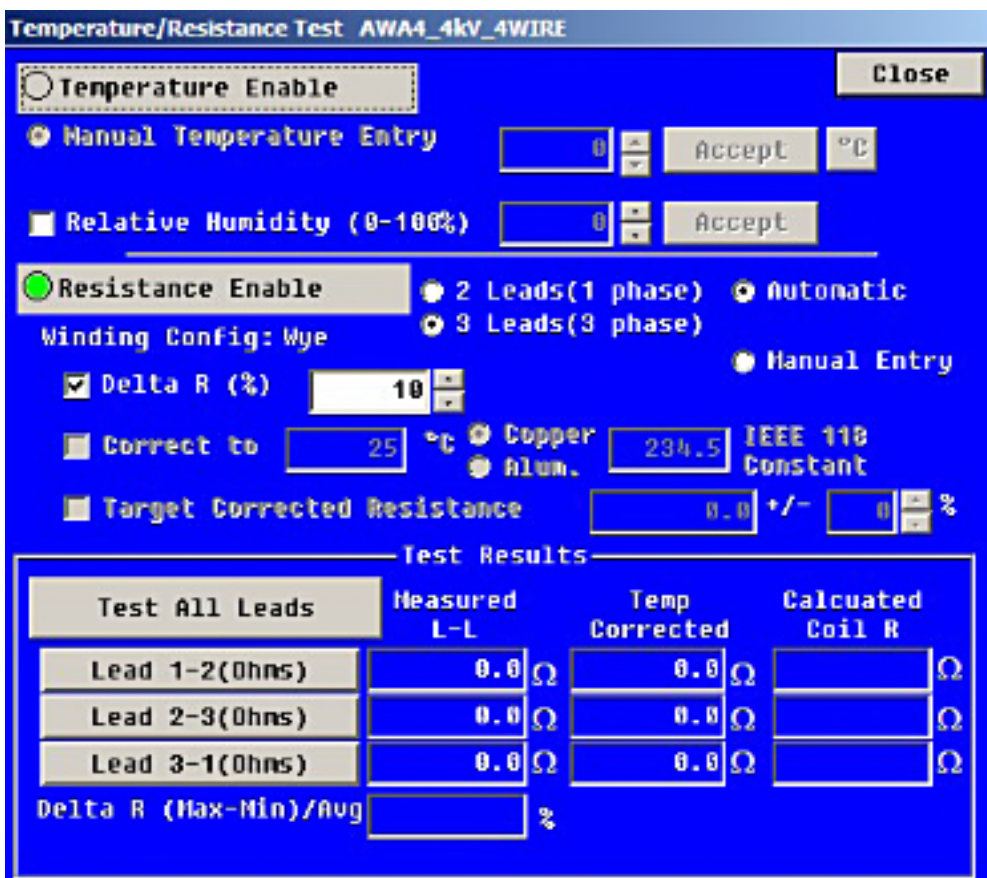
Figure 36. Temperature/Resistance test window.

The temperature test is used to acquire the temperature of the motor. The temperature is entered manually. Temperature can be entered in either ºC (Celsius) or ºF (Fahrenheit).

The temperature acquired at test time is used later on to temperature correct coil resistance values per IEEE 118 and insulation resistance values per IEEE 43/95.

The resistance test has several options. The test can be performed on a two-lead device such as a single coil or a three-lead device such as a three-phase motor. The motor may have Wye or Delta winding configurations. The Wye or Delta configuration is entered in the nameplate window.
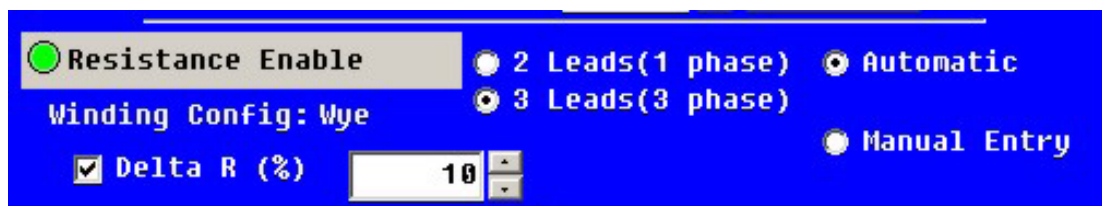
Figure 37. Resistance enabled.

The resistance values may be automatically acquired by the tester, or acquired by some other means and manually entered into the Baker AWA-IV software. The method for entering or obtaining resistance data is described later.

Figure 38. Max delta R (%).

By checking the **Delta R (%)** box, the resistance values will have their percent spread calculated at the end of the test. If the percent spread is outside the number entered in the edit box, the Baker AWA-IV will fail the resistance test.

Resistance measurements can be influenced by humidity. To enable setting the relative humidity, check the **Relative Humidity** box then enter the humidity present. Click on **Accept** to commit the settings.

The acquired resistance values may be temperature corrected by checking the T**emperature Enable** box.

Figure 39. Relative humidity.

The temperature the resistance value is corrected to is set to 25⁰ C or can be changed to another value. IEEE 118 recommends 25⁰ C. The constant used to convert resistances at one temperature to another is known as the IEEE 118 constant and is 235.4 for copper or 224.1 for aluminum.

Click on the **Temperature** radio button to enter temperature into the software so that corrected resistances are obtained.

Figure 40. Temperature correction.

A motor that does not have a resistance reading within a target resistance range may also be failed by checking the **Target Corrected Resistance** box and entering the appropriate resistances.
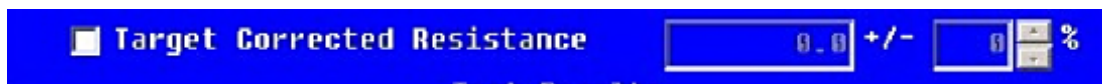
Figure 41. Target corrected resistance.

> *i* **NOTE**
>
> Only temperature corrected values will be used in determining if values are within tolerance

At the end of the test, the Baker AWA-IV compares corrected resistance readings to the target corrected resistance to determine if the motor passes.

The lower portion of the *Temperature/ Resistance Test* window contains the test radio buttons, measured resistance values, and the temperature corrected resistance values. The fourth column displays the calculated coil resistance.

As mentioned previously, there are two ways to obtain resistance data. In automatic mode, the Baker AWA-IV will measure the resistance when you click on the **Automatic** radio button. The second way to determine resistance data is to enter it by hand using measurements made with a precision resistance bridge.

Figure 42. Temperature correction.

There is another key difference between the automatic and manual modes. The automatic mode will make a resistance measurement per your specifications between a lead with the other two leads held at ground. A balance test can be done or the low-voltage leads can be used for a more precise test.

A resistance value that is manually entered will be different: a measurement made with a bridge will be between two leads with a third lead allowed to float. Due to this difference, the winding configuration becomes even more important. The Baker AWA-IV software assumes that manually entered data will be made with a two-lead precision bridge and that the third lead is allowed to float. Clearly, a Wye motor's lead-to-lead measurement will be different from a Delta lead-to-lead measurement.

Regardless of how the resistance measurements are acquired, after they are obtained the software will calculate the temperature corrected resistances and display them. Additionally, if possible, the Baker AWA-IV will calculate the individual coil resistances. If not, the software will display a message indicating that a solution to the coil resistance that could not be found.

While the *Temperature / Resistance* window is open, there are several ways to start an automatic measurement:

1) Click the **Test All Leads** button. The Baker AWA-IV then measures each lead's resistance sequentially.

2) Click one of the **Lead** buttons on the front panel of the Baker AWA-IV. The Baker AWA-IV then measures the resistance of the clicked lead only and displays the results.

Manually entered resistance measurements

Resistance measurements from high-precision resistance bridges can be manually entered instead of having the Baker AWA-IV run an automatic resistance test. Manually entered data should be line-to-line type measurements. To enable manual data entry, click the **Manual Entry** radio button; then the results section of the *Resistance test* window shows measured L-L above the **Lead Resistance** column. In this column of three edit boxes, the lead resistances for the manual measurement should be entered as described below for the either the wye-wound motor or the delta-wound motor. When you have finished entering data, click the **Accept** button.

Wye-wound resistance measurement

Using the NEMA nomenclature for a Wye wound motor, the resistance measurement for lead 1 should be made between terminals 1 and 2 with terminal 3 left floating. This measurement will consist of coils 1–4 in series with coils 2–5. Likewise, the lead 2 measurement should be made between terminals 2 and 3 with terminal 1 left floating. The lead 3 measurement should be made between terminals 3 and 1 with terminal 2 left floating.

Delta-wound resistance measurement

Using the NEMA nomenclature for a Delta wound motor, the lead resistance measurement should be made between terminals 1–6 and 2-4. This measurement will be of coils 1–4 in parallel with the series combination of coils 2–5 and 3–6. The lead 2 measurement should be from terminals 2–4 and terminals 3–5. Likewise, the lead 3 measurement should be made between terminals 3–5 and terminals 1–6.

After entering all data and clicking the **Accept** button, the measurements will be temperature corrected and displayed in the **Temp Corrected** column. The coil resistances will also be calculated for the individual coils and displayed in the **Calculated Coil R** column.

Coil resistances

As discussed above, the resistance measurements made by the Baker AWA-IV are a user-configured series or a parallel combination of coils. At the end of a resistance test, the Baker AWA-IV will calculate and display the coil resistances; if a temperature has been entered, it will also report those values. These values are found in the right-hand column of numbers in the *Resistance* window. The calculation involves numerically solving for the coil resistances given the type of winding (Wye or Delta) and the measured balance values.

Under some circumstances, the algorithm fails. In such cases, the Baker AWA-IV will indicate that it cannot find a solution given the balance resistance values.

DC Tests: Meg-Ohm/PI/DA/ HiPot/Step or Ramp Voltage test window

The *DC Tests* window is displayed when the **Meg-Ohm, PI, DA,** or **HiPot** voltage buttons are clicked on in the **Tests** view.
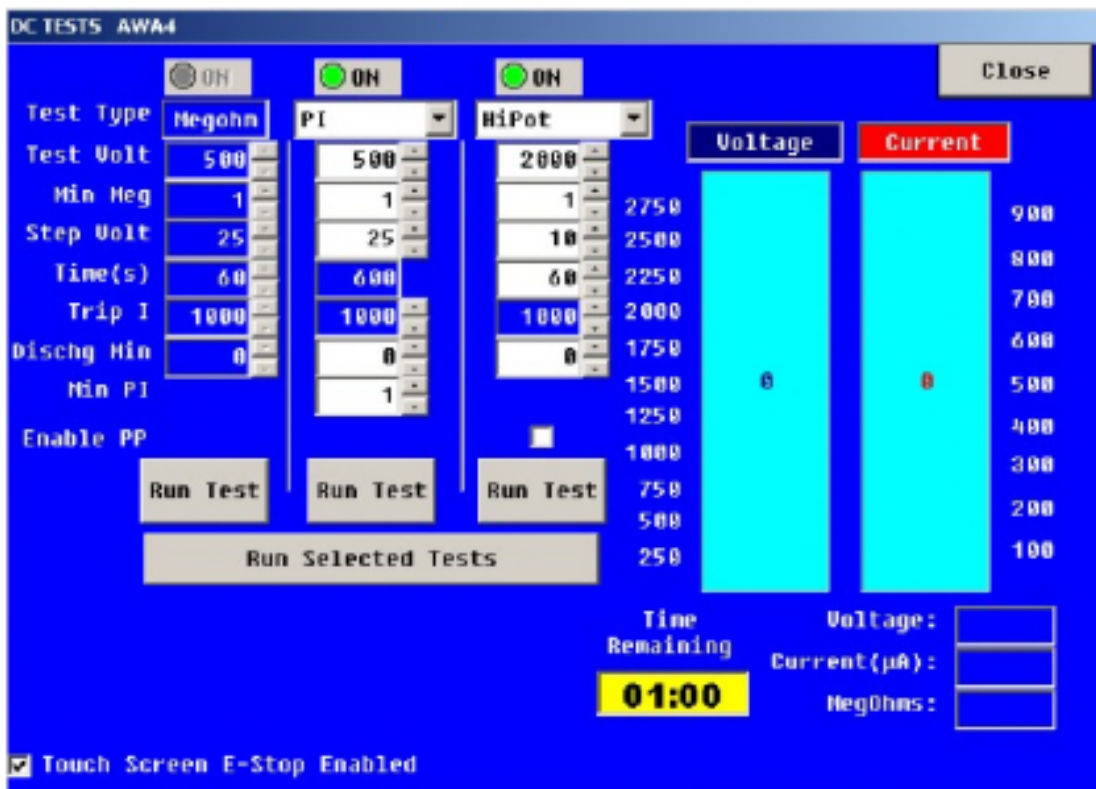
Figure 43. DC tests.

Think of all these tests as a single type of test. The Meg-Ohm test is the first test to be run, followed immediately by a PI test, and then a HiPot test. There are two dropdown lists for PI and HiPot. This is where the DA only, Revert DA, Ramp-Voltage and Step-Voltage tests are located. Therefore, a single setup window for these three tests is used to configure each test.

The left half of the window is where test voltages, minimum Meg-Ohm readings, voltage ramp rate, test times, current trip settings, discharge times, and minimum PI values are all entered. The PI has two extra options: 1) default to the Dielectric Absorption if the IR=5000MΩ at 1 minute and 2) the Dielectric Absorption test only. The PI test has many subtleties; these two options let you set up the tests so that no unnecessary time is spent on the PI test.

Each test may be run individually by clicking the appropriate **Run Test** button. Alternatively, all selected tests can be run by clicking the **Run Selected Tests** button.

The right side of the window displays the real-time voltage, current, and the insulation resistance readings collected during the Meg-Ohm and HiPot tests. The voltage and current are displayed as slider bars. Below the slider bars are real-time voltage and current numerical outputs.

Ramp voltage test

The ramp voltage test is used mostly for generators. it gives information on the contamination level with the winding. The ramp voltage test is performed for a predetermined length of time at a specific voltage level. The voltage increases linearly on a specific time scale. As the test is operating, the key is to watch the current. If it remains linear with the voltage, the winding is in good condition; however, if the current waves up and down the winding may be contaminated. The figure below provides a graphical representation of this test. In the illustration, the unstable line suddenly increases in voltage and current. If this occurs, it could indicate an imminent overcurrent trip and a problem within the winding.
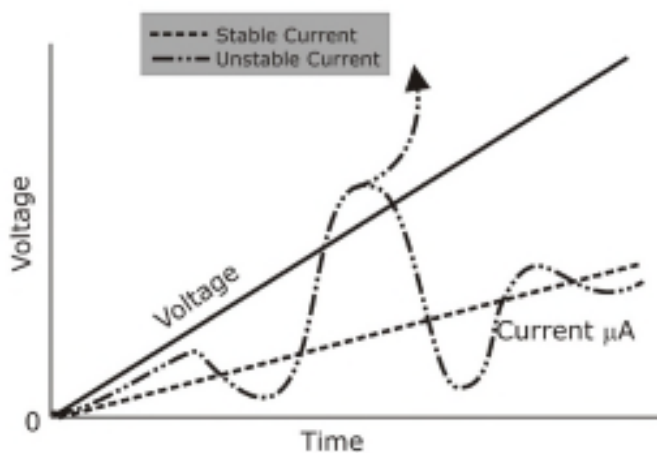
Figure 44. Temperature correction.

Step Voltage test window

The third type of HiPot test is the step voltage test. This test is also called a step test and is described in detail in IEEE 95. Clicking on the dropdown arrow on HiPot reveals the Step Voltage test. Clicking on the **Step Voltage** test will start the wizard for setting up the test.
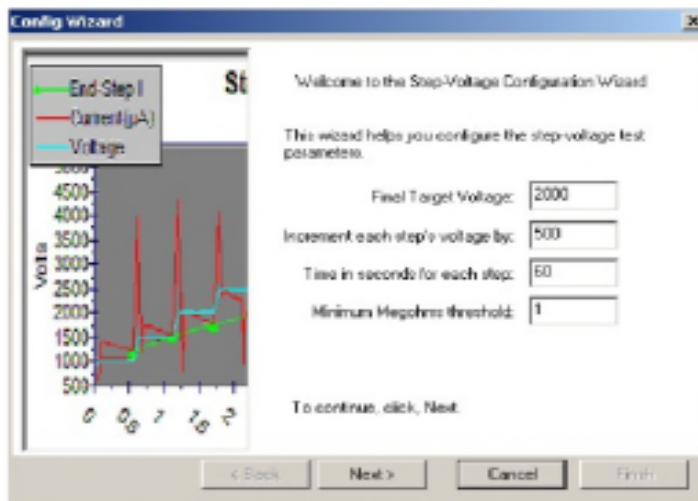
Figure 45. Step voltage wizard—step 1.

Fill in the appropriate information for the steps needed. Make sure the steps are appropriate for the application being tested.

The *Seconds* window is used to enter up to 30 voltage steps or test intervals for each step. This window will also appear when the step voltage test runs and will display a real-time graph of the voltage and current collected during the test. After this test has been set up, it can be edited prior to running the test. Click on **Config** in the test window and the second or step page appears.
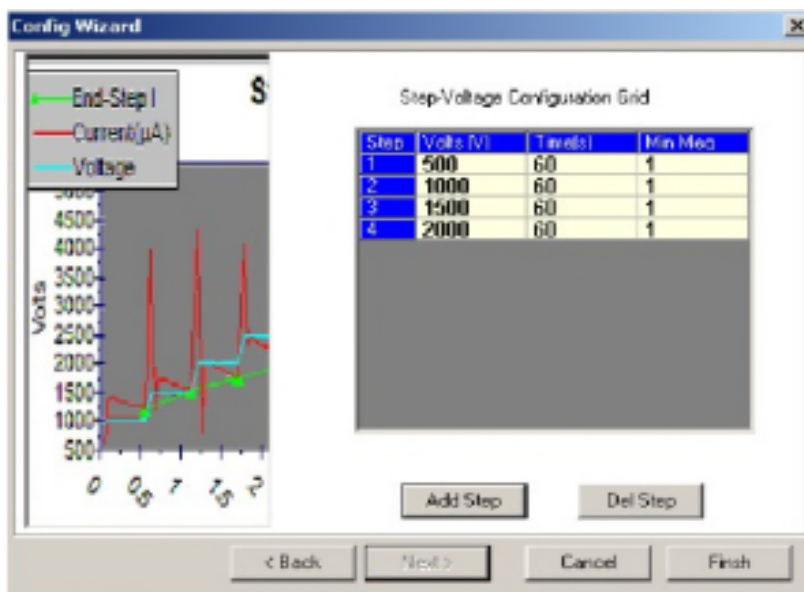
Figure 46. Step voltage wizard—step 2.

Surge Test window

The *Surge Test* window, shown in the example below, appears when you click on the surge voltage button, which is located in the **Surge Test** section of the **Tests** tab—just to the right of the S**urge** button.
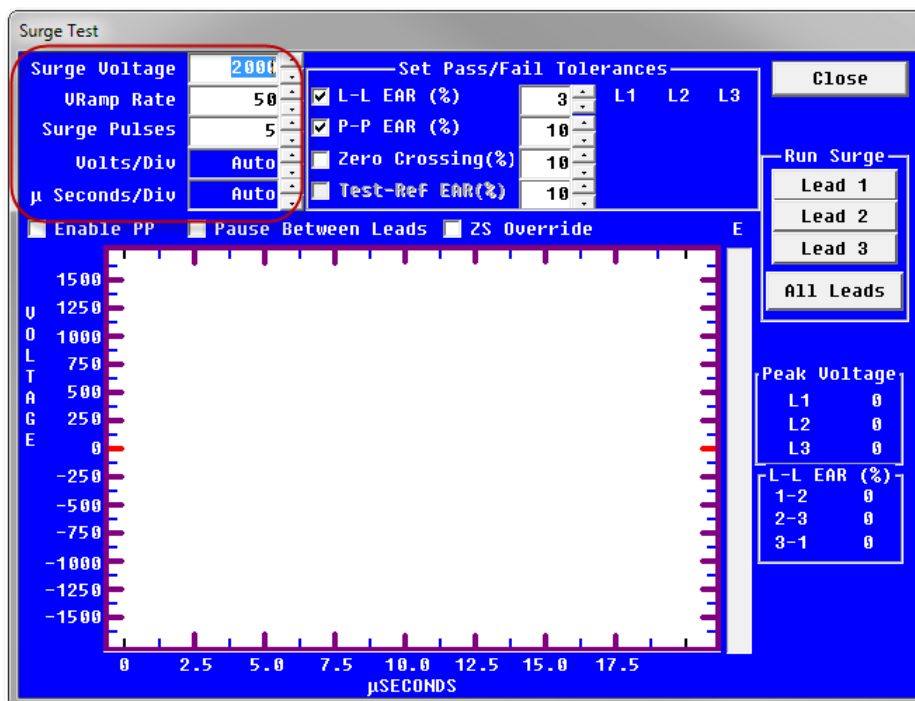
Figure 47. Surge Test window.

In the upper left corner of the window the surge voltage, step voltage, and the number of surge pulses are entered in their respective fields.

We recommend that the surge voltage be 2V+1000. The step voltage controls the rate at which the voltage increases during the test and is set to a default rate of 25 volts per step.

Use the **Surge Pulses** field to define the number of pulses applied to the winding after the full test voltage is reached.

The other two fields—**Volts/Div** and **μS(Seconds)/Div**—are related to the x- and y-axis of the surge waveform graph located in the middle of the window. The **Volts/Div** field is typically set automatically by the Baker AWA-IV, but it may be overridden by the user. This field determines the y-axis scale on the surge waveform graph. The **μS/Div x-axis** field can also be set to automatically capture the waveform in time. It can also be manually overridden in a specific setting.

The top center of the window shows a series of check boxes that determine Pass/Fail criteria for the surge test. The **L-L EAR (%)** check box sets the maximum Lead-to-Lead Error Area Ratio (EAR) allowed between the different leads. This is usually set to 10%; however, some people have found settings as low as 4% to be useful.

> **NOTE**
>
> This option should not be set if testing a motor with a rotor installed. If it is absolutely necessary to use the L-L EAR with the rotor installed, increase the tolerance to avoid nuisance trips. The increase in EAR tolerance with installed rotors makes the use of this feature a poor detector of a turn-to-turn insulation problem.

Use the **P-P EAR (%)** field to set the maximum Pulse-to-Pulse Error Area Ratio allowed for the test.

Figure 48. Pass/Fail tolerances.

The **Zero Crossing (%)** option determines how much a waveform must shift to the left (compared to the width of the window) during the surge test before the Baker AWA-IV fails the test. Recall from previous chapters, a turn-to-turn fault is identified by a sudden jump to the left of the surge waveform. If a waveform jumps more that the percentage indicated, the Baker AWA-IV will fail the surge test. The remaining three columns (L1, L2, and L3) show real-time numbers for the specific lead while the test is running. These numbers will become visible during the test.

Check the **Test-Ref EAR (%)** box to enable setting pass/fail criteria when comparing the surge waveforms from the test to a previously stored reference test.

The four buttons on the right side of the window will run a surge test when clicked. Clicking on the **Lead 1** button starts a manual surge test on lead 1 only; likewise for the **Lead 2** and **Lead 3** buttons.

Clicking on the **All Leads** button starts a manual three-lead surge test. A surge test can also be started by clicking one of the test buttons on the front panel of the Baker AWA-IV.
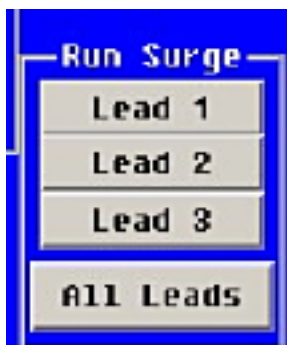
Figure 49. Run surge buttons.

The final voltage reached for each lead tested is displayed in the text boxes in the middle right of the window. The EAR values shown correspond to the measured L-L EAR between the three leads during the test.
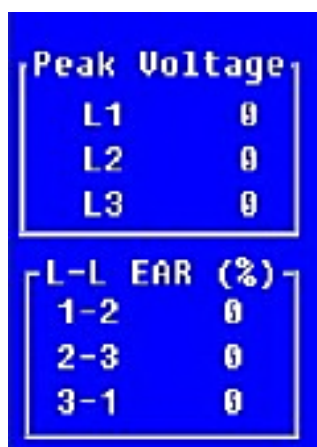
Figure 50. Final voltages and EAR values.

E bar graph

The surge waveform graph is shown in the graphic below. The vertical (y-axis) displays the voltage while the horizontal (x-axis) displays time. The surge waveform is a plot of the voltage across a coil versus time. On the right side of the graph is a slider bar with an **E** label at the top. This slider bar will rise as the energy is increased by the tester to create the displayed waveform.
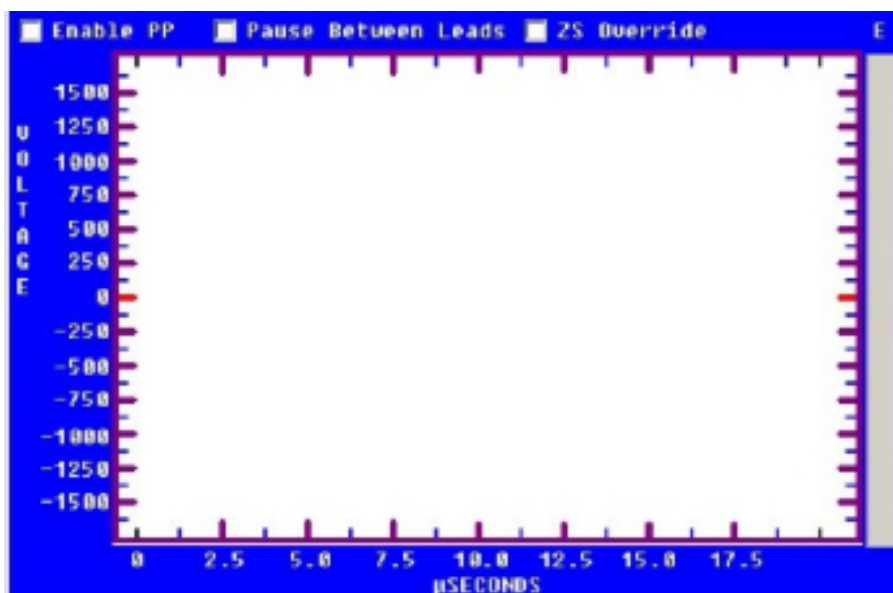
Figure 51. Surge waveform window.

Effectively, this slider bar shows how far down the pedal must be clicked to obtain the surge waveform. Low impedance coils (those with few turns) require more energy in the surge pulse to develop a given voltage than a higher turn count coil. The energy slider bar gives you an idea of how hard the Baker AWA–IV is working.

Setting up test parameters for a reference waveform

To acquire a reference waveform, check the **Edit Test ID** box in the *Main* window. Turn on the Surge test and set the desired voltage, Zero Crossing, and both L–L EAR and P–P EAR tolerances. The **Micro sec/div** parameter defaults to auto. If this setting is known, it is better to enter that setting than leave it at auto. However, if the setting is unknown, leave it at auto and run a test then select that setting to run further tests. After the test parameters have been modified, click the **Update** button to save the parameter changes.

> ### NOTE
> It is important when comparing waveforms that all settings are the same. If the scales are different then a comparison cannot be made.
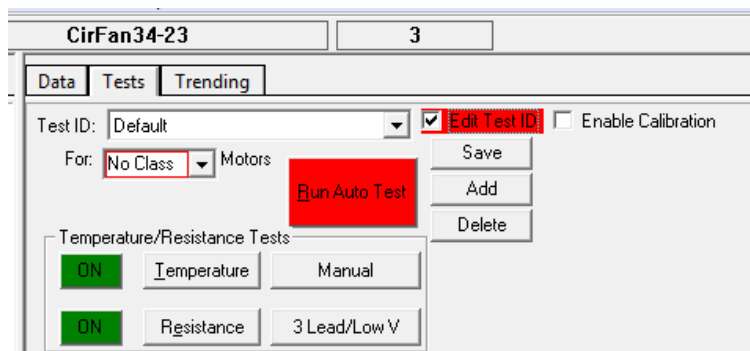
Figure 52. Edit test ID.

Testing a reference motor

While in edit mode, the **Edit Test ID** check box is checked. Directly after setting up the test parameters, hook the Baker AWA-IV to the reference motor and confirm that the Motor ID displayed on the toolbar is the reference Motor ID.

Click the **Run Auto Test** button. Upon completion of the test, the tester will prompt to save the results as a reference.
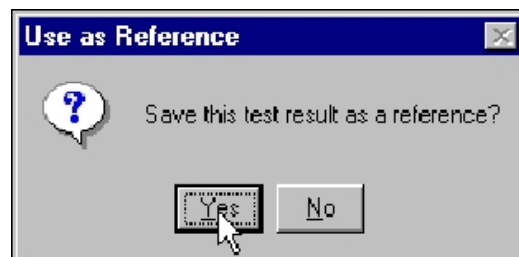
Figure 53. Confirmation dialog to use waveform as a reference.

If the results are good, click **Yes**. If the test needs to be run again, click **No**. Multiple tests can be run in order to obtain the necessary standard. In automatic mode, test results are always saved. Reference waveforms will only be part of the Test ID when **Yes** is clicked in the **Use as Reference** dialog box.

Continue to add or update Test IDs. When you have finished editing, uncheck the **Edit Test ID** box to turn off the edit mode.

Testing a production motor by comparing with a standard motor

If a specific motor has not yet been entered into the database, add it via the **Nameplate** tab. From the **Test** tabs, select the Test ID to be used. Determine if the selected Test ID has a waveform attached by viewing the *Surge Configuration* window. The **Test-Ref EAR (%)** box will be checked and a **Display Ref** button will be visible.

Click on the **Display Ref** button and the reference waveform will be displayed.

> ### NOTE
>
> If the reference waveform is no longer needed or if by accident the reference waveform has been made, uncheck the Test-Ref EAR(%) and click the **Done** button, then update the Test ID and it will detach the reference waveform from the selected Test ID.
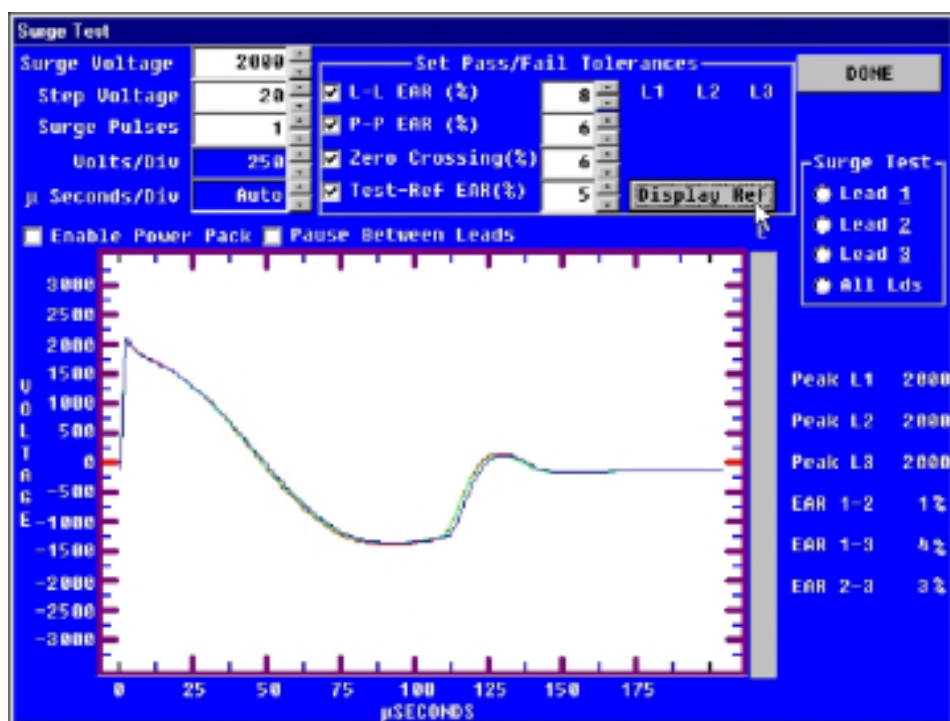
Figure 54. Display reference button.

Click **Done** to return to the *Tests* window.

Click the **Run Auto Test** button to begin the test. If the motors have passed all other tests and there is a reference waveform, the Baker AWA-IV software will calculate the Error Area Ratio (EAR) at the end of the surge test. The EAR is calculated between leads of the motor under test and the reference motor. (Reference motor's lead 1 and motor under test lead 1; reference lead 2 and lead 2; and reference lead 3 and lead 3.) The software will then compare the EAR values with the tolerance entered as part of the surge test parameters. If the EAR values are within tolerance, the motor passes. Conversely, if an EAR value is outside the tolerance, the motor fails. After the test has been performed and saved, surge waveforms can be examined using the **Data** and **Surge** tabs.

Viewing surge results

To examine surge results go to Surge view. If the Test ID used has a reference motor attached to it, the Baker AWA-IV software displays the selected motor's surge waveform (solid lines) and the overlaid reference motor's surge waveforms (dashed lines).
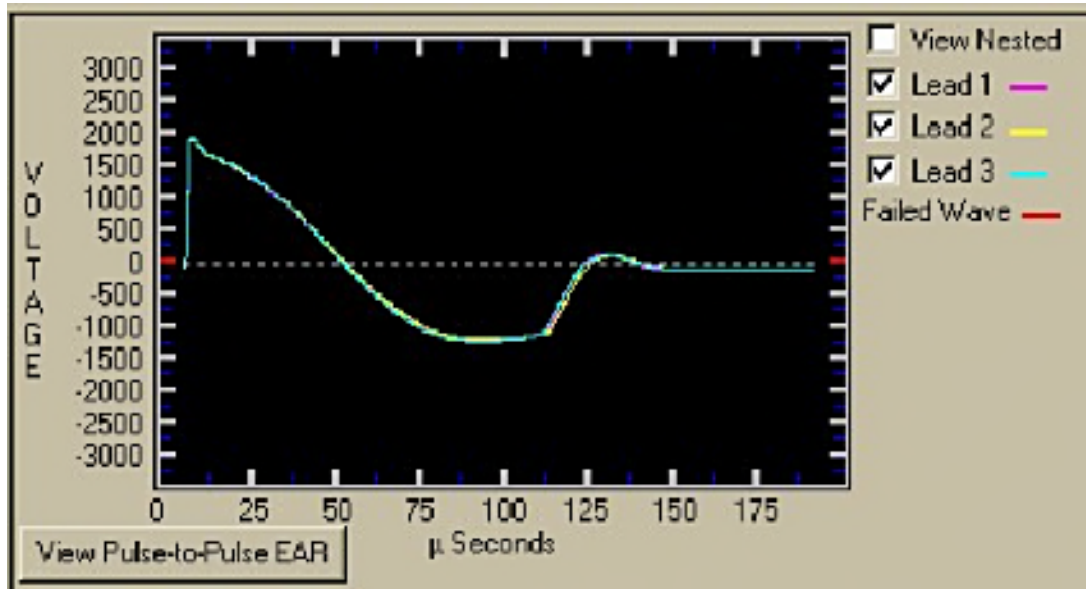
Figure 55. Surge results display.

> ***i*** **NOTE**
>
> If the reference waveform is very close to the selected motor's waveform, it will hide the dashed waveform so only the solid lines are viewed. To see one lead at a time, check or uncheck the desired lead's check box.

Using the Trending tab

Clicking on the **Trending** tab brings up a graph that charts acquired data. Trending information such as Max Delta R%, Balance Resistance, L–L Resistance, Coil Resistance, Meg-Ohm (correct or not corrected), PI, and HiPot leakage currents can be graphed over time so you can get an idea of the long–term status of a motor's insulation. These graphs can be reset, are selectable by date, and have several printing options.
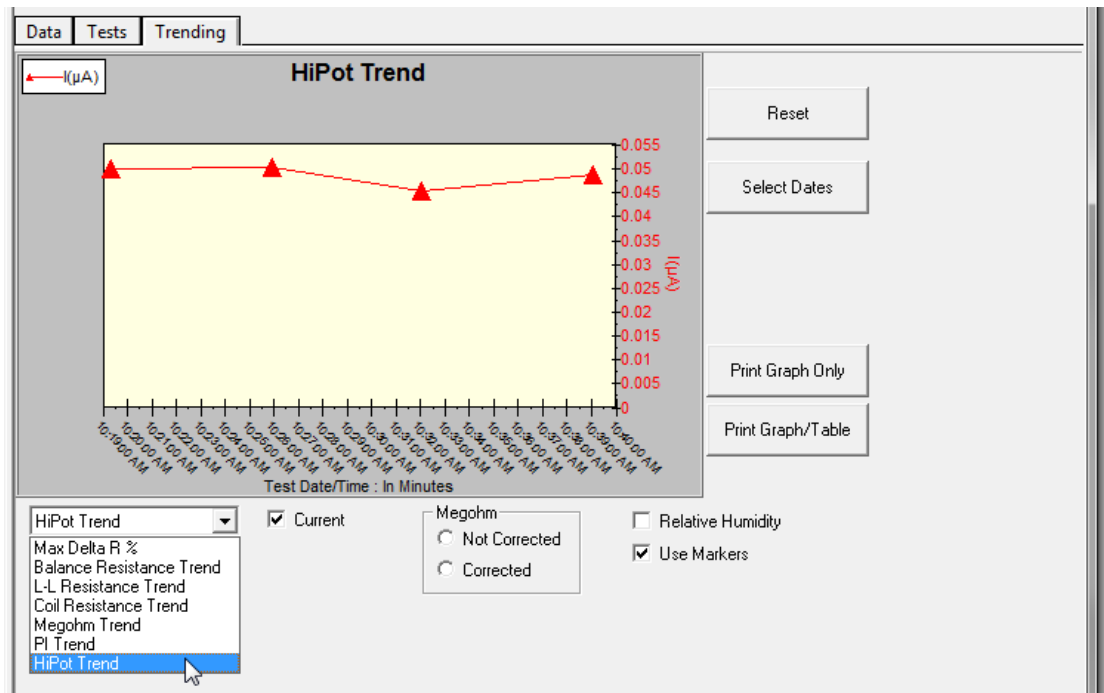
Figure 56. Trending graph.

Max Delta R% Resistance

There are two different types of resistance data that can be trended: line-to-line and coil. Selecting one will bring up a graph similar to the main trending graph. Resistance measurements are taken against time and show very little variation over the test interval.

Each of the three leads is shown in its own color. Each data point is indicated by a square, diamond, or triangle marker. Hovering over a data point will show a date/time stamp and give the value of the test. This feature allows for easy identification of the test record for that point. Clicking the **Reset** box returns the markers to the first trending window.
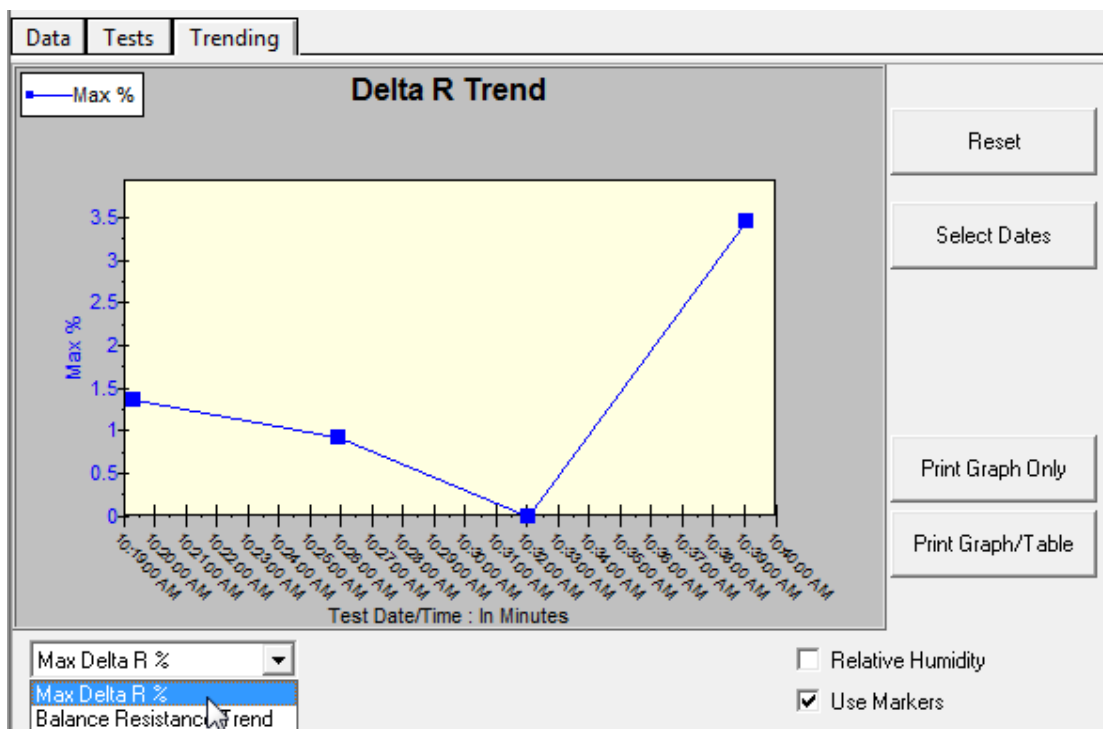
Figure 57. Resistance trending graph.

Insulation Resistance/Meg-Ohm
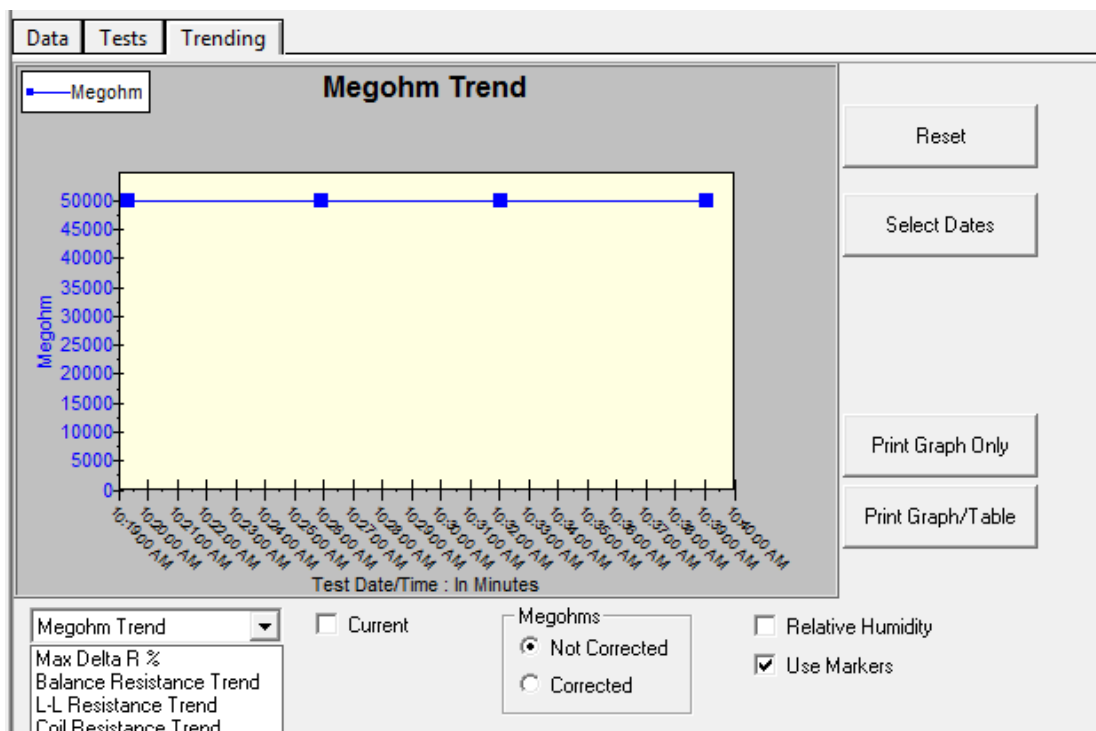
Figure 58. Meg-Ohm trending graph.

Meg-ohm data is graphed by checking the **Meg-Ohm** button. Hovering over a data point shows a date/time stamp and gives the value of the test.

> **NOTE**
>
> When trending Meg-Ohm values, the temperature corrected values should be used and not the uncorrected values. Both values are available in the software. Sometimes it is not possible to acquire the temperature of a motor when testing due to inaccessibility of the motor.

PI

Clicking the **PI** button displays the graph trending the PI ratio versus time, and has similar features to the other trending graphs.
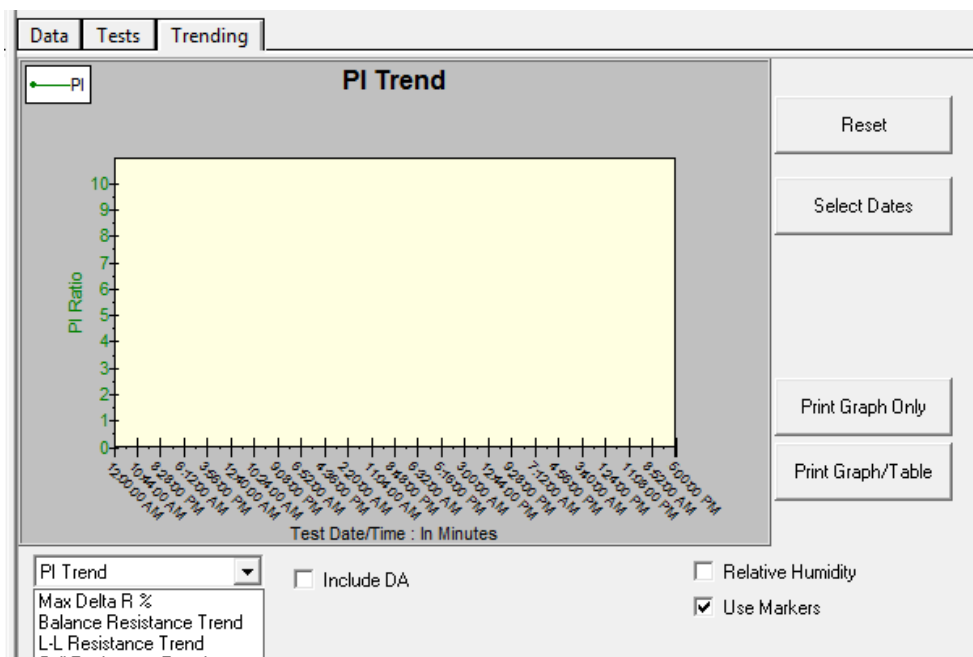
Figure 59. PI trending graph.

HiPot

Clicking on **HiPot** in the dropdown box brings up a graph of the HiPot leakage current data. This has the same features as the Meg-Ohm trending graph.
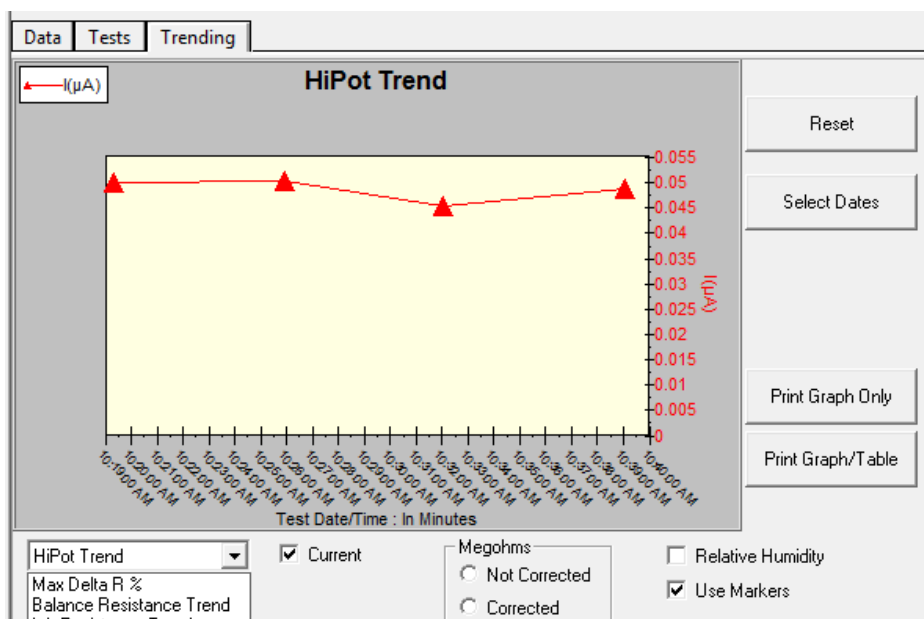
Figure 60. HiPot trending graph.

Relative humidity

Checking **Relative Humidity (RH%)** causes the tool tips to display the RH% entered at test time. Hovering over a data point causes the related tool tip to display the Time/Date stamp value of the point and the RH%.

Special software trending features

On occasion, only a certain time period of data is desired or some invalid points need to be excluded. You can select specific data points using one of two methods. The first is when the trending graph is displayed. Hold the left mouse button then drag and draw a box around the points you want to display. When you release the left mouse button, the graph will automatically re-scale and display the points inside the box you drew.

To reset the graph, click on the **Reset** button then all points will be displayed.
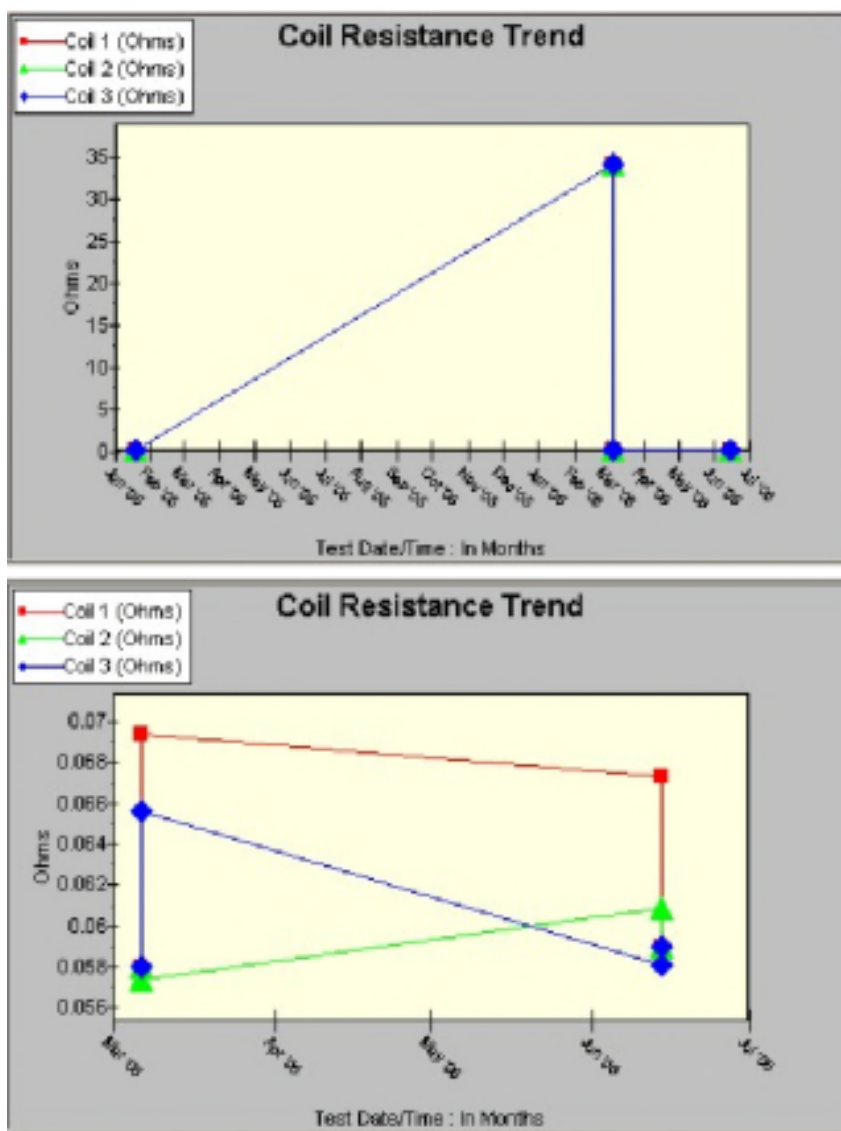
Figure 61. Special trending features

The second method is to choose points from a list of all test dates/times.

Click the **Select Dates** button and a window pops up showing all test dates and times along with a spreadsheet style view of the data. All of the data can be selected or just specific tests. Most often, this feature will be used to exclude a test that contains known bad data that, for example, might be acquired in a test that was aborted.

To select or deselect dates, use the same type of selection techniques used to select files in Windows Explorer.

1) Click the left mouse button to select a single record.

2) Click on the first record.

3) Click the **Shift** key on your keyboard and click on the last record to select a range.

4) Within a selected range, click the **Ctrl** key on your keyboard and click to remove an unwanted record from the selection.

Figure 62. Dates to trend spreadsheet.

Additionally, all of the records on this window can be exported to a comma-delimited file for later importing into a spreadsheet. In this manner, data can be analyzed using your preferred tools in any way desired.

1) To create the comma delimited file, select the test date/time to export or select **None** and all data will be exported.

2) Click on the **Create Text File** button and enter a file name.

3) The application will create a comma-delimited file. This dialog will also allow printing of all the data see in the list box. Click on **Print List** to print all selected data.

6   Performing an example test

The following chapter walks you through an example setup just as an operator would if a motor was to be tested for the first time.

- The first thing to do is create a Motor ID that uniquely identifies the motor. This example uses a 460V Delco motor.

- Next, a Test ID must be created for this motor and assigned to the Motor ID.

- Then tests will be run and the results reviewed.

- Finally, reports will be printed.

The motor for this example is a Delco 460V, three phase, wye wound, induction motor and has the following data on the nameplate:

Model: 2G2104

Frame: 213

SN B-95

Insulation: B

Amb oC: 65degC

V: 460V

A: 4.2A

HP: 3

RPM: 1765

Hz: 60

LR Code: J

SF: 1.0

Des: B

NEMA nom eff: 84

Duty Cycle: Cont

Using this information, we will fill out the Motor ID Nameplate form.

Creating a motor ID

1) Select the motor using the **Explore** tab.

2) From the **Data** tab—**Nameplate** view, the Motor ID information is displayed for the selected motor. In this example, the AC17343 is chosen.

3) Clicking on the **Add** button clears the **Motor ID** and **SN** fields. In these data fields, enter the nameplate information for the motor. If needed, click on the **Clear** button to clear the rest of the nameplate form.

4) The **Reset** button restores the previous motor's information to the form.
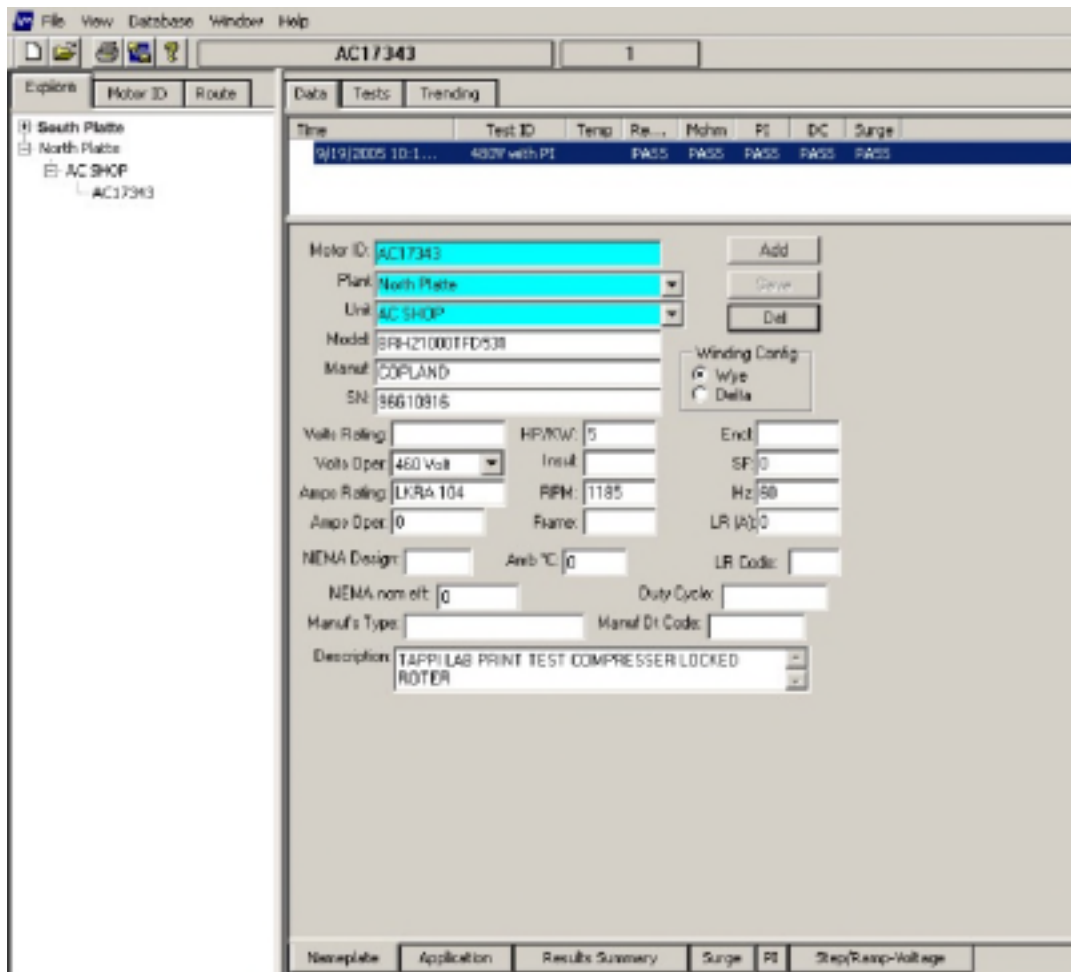
Figure 63. Motor IDs.

> ℹ️ **NOTE**
>
> There are more data fields available than are contained on the nameplate. Only those items that are on the nameplate are filled in.

5) Enter a unique identifier for the Motor ID. For this example, use Delco_B-95-ACS as the Motor ID.

6) **Plant** location is North Platte and **Unit** location is AC shop. Fill in the rest of the fields from the nameplate data previously given. After all data is entered click on the **Save** button to add the new Motor ID to the database.

7) After the **Save** button is clicked, a *Select Test ID* dialog box appears.
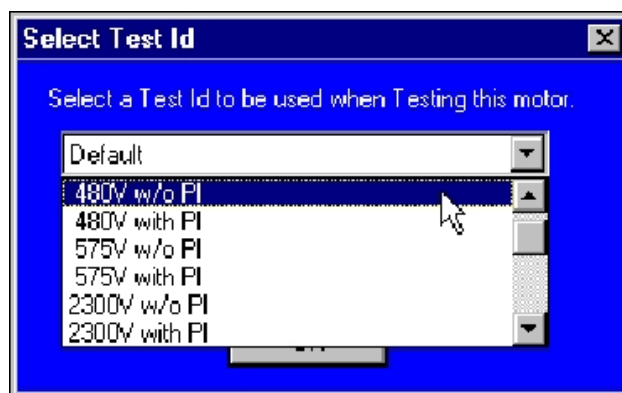
Figure 64. Test ID.

8) Assign a Test ID to the newly-created motor. In this example, select the 480Vw/o PI Test ID.

9) Create a new Test ID and assign the new Test ID to this Motor ID.   For this example, we use Delco_B-95-22L.

10) After the Test ID is selected, click on the **OK** button. The new Motor ID (Delco_B-95-22L) is now added to the **Motor Tree** along with all the other motors.

Now that the Motor ID has been created, the next step is to create a Test ID and assign it to this motor.

Creating a test ID
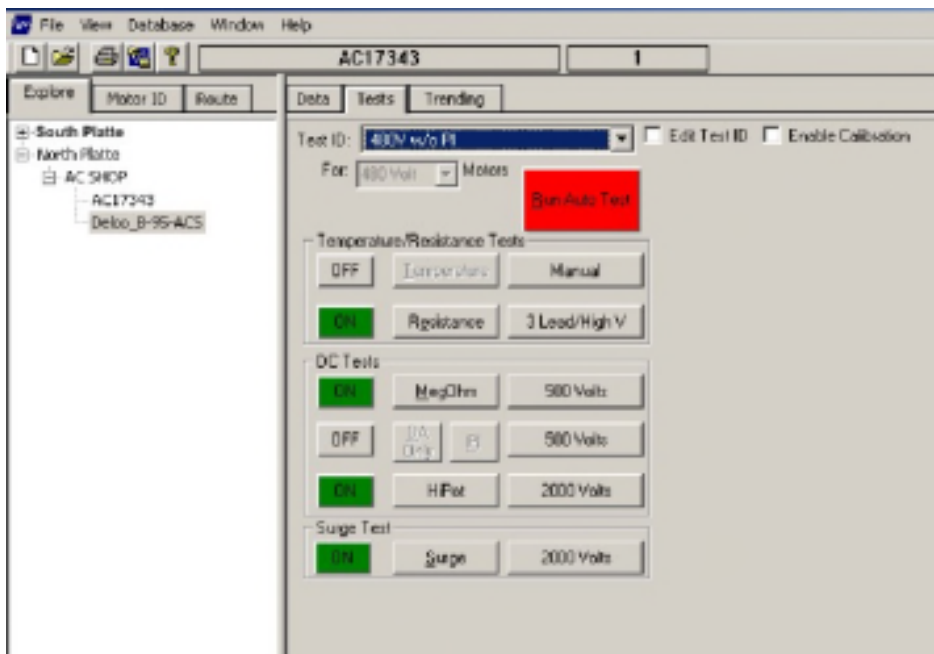
Figure 65. Creating a test ID.

1) Click on the **Tests** tab. Notice that the Test ID that was assigned via the Test ID dropdown box when the Motor ID was created appears in the **TestID** field. However, for this example, we will add a new Test ID.

2) Add a blank test ID. From the **Tests** tab, check the **Edit Test ID** box.

3) Enter the password.

> **_i_** **NOTE**
>
> If this is the first time you edit a Test ID on the tester, you will need to set up the password. To do this, click on the **Change Password** button and enter a password. Then click on **Set Password**.
>
> Click **OK**. When the application has accepted the password, the **Update, Add,** and **Delete** buttons will appear and the voltage class dropdown list will be enabled.
>
> The Edit Test ID area will be red when in edit mode

4) Click on the **Add** button. The *Create New Test ID* dialog box appears.

5) Click on the **Add Blank Test ID** radio button.

6) Enter the Test ID. For this example, enter Delco_460/wPI.
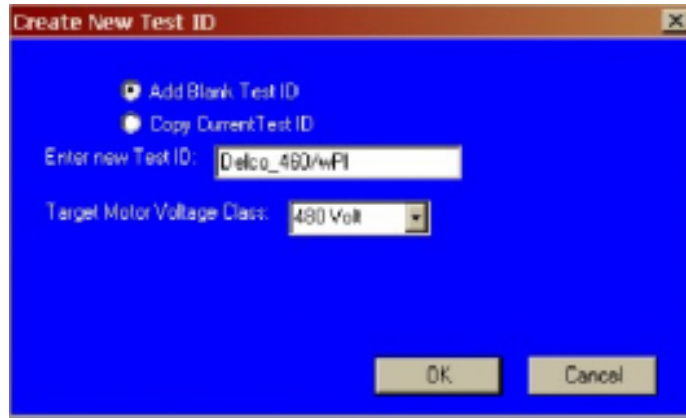
Figure 66. Test ID input.

7) Using the dropdown box, select a **Target Motor Voltage Class.** For this example, choose the existing voltage class of 460. If it does not exist, you can create a new one by typing 460 in the edit box of the dropdown list.

8) If a new voltage class type has been entered, enter a description and click on the **Add Voltage Class** button. A dialog box will appear asking if this action is correct. If it is, click **OK**. This will close the *Create New Test ID* dialog box.

9) The new Test ID will be displayed and all tests are turned off. The **Tests** tab will resemble the example shown below.

10) Turn on all required tests by clicking the **ON/OFF** buttons in the left-most column. The buttons turn green when they are on.
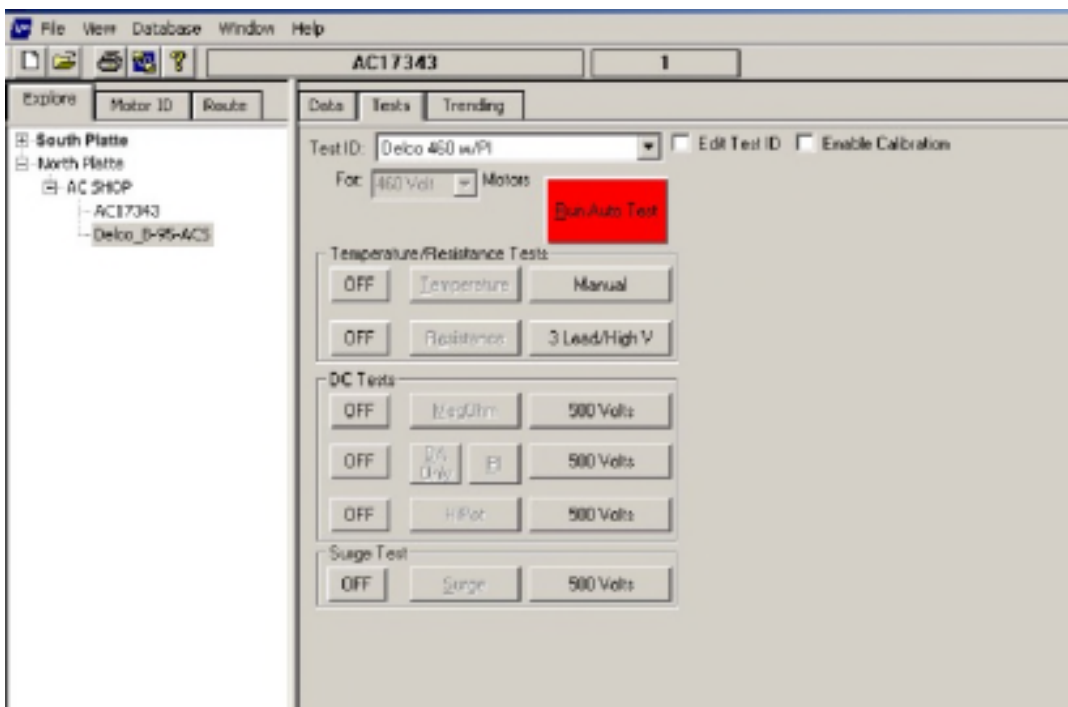
Figure 67. New test window.

Configure Temperature/ Resistance test

1) The temperature and resistance tests share the same setup window. Click on either of the two buttons to the right of the **Temperature** or **Resistance** buttons; by default, they are labelled **Manual** or **3 Lead/High V**. The T*emperature/ Resistance Test* window will appear next.

2) If the test has been selected, the **Temperature Enable** radio button will be green.

3) Click on the **Manual Temperature Entry** radio button.

> ℹ️ **NOTE**
>
> The Baker AWA-IV will accept both °C(Celsius) or °F(Fahrenheit) temperatures and a temperature range of -32°C to 250°C. To unselect the test, click on the radio button and it will gray out.

4) If the resistance test was chosen, the **Resistance Enable** radio button will also be green. The Delco motor in this example is Wye wound, which is indicated on the window and can be changed on the motor's **Nameplate** tab.

Figure 68. Temperature/Resistance test parameters.

5) The **3 Leads** and **Automatic** radio buttons will be selected by the software for the 3-phase motor. The Baker AWA-IV will automatically acquire the resistance readings.

6) Leave the **Res Leads** box unchecked. The Baker AWA-IV is equipped with a separate set of resistance test leads to perform a lead-to-lead low-voltage resistance test. Resistance values must be greater than 0.500 ohms for high-voltage leads. If the high-voltage leads are used on a motor with resistances less than 0.500 ohms, the Baker AWA-IV will prompt the operator to switch to low-voltage leads.

7) Check the **Max Delta R (%)** box and ensure it is set to 10%. If the spread of resistance readings are more then 10%, the Baker AWA-IV will fail the motor.

8) Because temperature is enabled, the **Correct to** box is checked and defaults to 25°C and the copper's IEEE 118 constant.

9) Target Corrected Resistance is another tool that further refines the pass/fail criteria. If checked, the Baker AWA-IV will fail a motor if the readings are not within tolerances. For the example motor, the resistance reading taken using a DVM is 3.1 ohms. Therefore, we can check the **Target Corrected Resistance** box and enter the value of 3.1 +/- 10%. Enabling target corrected resistance makes this Test ID specific to the example motor. If resistance data is not available, do not enable this feature.

10) Click on the **Done** button.

Configure Meg-Ohm/PI/HiPot tests

1) To configure the Meg-Ohm/PI/HiPot tests, click on one of the three buttons to the right of the Meg-Ohm/PI/HIPOT buttons to bring up the *DC Tests* window. For this motor, the Meg-Ohm and PI tests will be run at 500V while the HiPot test will be run at 2000V. Consult IEEE 43/95 or another appropriate standard to determine test voltages.

2) Because this is a small motor, the PI test will run as a DA test only by checking the **DA Only** box. Doing a full PI test would not likely yield useful information.

The other option—**DA If IR>5000 @1m**—sets up the Baker AWA-IV to automatically skip the PI test in favor of the DA test at three minutes if the insulation resistance (IR) is greater than 5000 Meg-Ohms at the one-minute mark. Insulation resistance readings 5000 Meg-Ohms or greater at one minute is the generally accepted criteria for aborting the PI test.

Figure 69. DC Test parameters.

After the DC Tests are configured as shown above, click the **Done** button to return to the main test window.

Configure Surge test

1) Press the **500V** button next to the **Surge** button to open the *Surge Test* setup window.

2) Configure the surge test as shown. Set the **Surge Voltage** to 2000V, which is approximately 2*V + 1000.

3) Set **Step Voltage** to a typical 25V/step ramp rate. If the test should run faster, increase this number to 50V or 100V.

4) Set the **Surge Pulses** number to 1, which means just one pulse will be applied to the windings after the tester reaches its maximum test voltage of 2000V.

5) Set the **Volts/Div** and the **µSeconds/Div** to Auto. The Baker AWA-IV will automatically scale the waveform to fit the graph.

Figure 70. Surge test parameters.

6) **L-L EAR (%)** (Line-to-Line EAR) is turned off because this motor will be tested with the rotor installed. If this option is selected, a nuisance trip could occur because the rotor coupling is different for each phase winding unless the pass/fail value is set to a high number such as 50%.

7) The **P-P EAR (%)** (Pulse-to-Pulse EAR) is set to 10%. This means that a pulse-to-pulse EAR value greater than 10% will cause the Baker AWA-IV to stop testing and fail the test. This number can be reduced provided the step voltage is also reduced.

8) The **Test-Ref EAR(%)** is set to 10%, which means that if a test is run and a reference test exists, the acquired waveforms will be compared to the reference waveform. Should the EAR values between reference waveforms and acquired waveforms be greater than the value shown, the Baker AWA-IV will fail the motor. If this option is not checked and is grayed out, no reference waveform is associated with the test.

9) Click on the **Close** button in the upper right corner of the *Surge Test* window to return to the **Tests** tab.

10) From the **Tests** tab, click on the **Update** button to update the database with the new test information. From this point, the Test ID called Delco_460V/wPI will be used to test the Delco motor or any other motor that has this Test ID assigned to it.

Generic test IDs versus specific test IDs

The Test ID just created is specific to the Delco 460 V motor used in this example. This Test ID should not be used for another 460 V motor such as a 100 hp/460 V motor. The reason is that a Target Resistance value of 3.1 ohms—which is specific to this 3 hp Delco motor—was entered. If this Test ID were used to test a 100 hp motor, the resistance test would fail because the 100 hp motor will have a much lower winding resistance than 3.1 ohms. Therefore, if a Test ID is to be used for many motors, the Target Corrected Resistance option should not be used. Without a Target Corrected Resistance, there is no specific or unique information that ties the Test ID to a specific motor.

Several generic Test IDs based on machine voltage are included the database. Target Corrected Resistance checking is disabled for all of them.

Running an automatic test

After a new Motor ID has been created, and a new Test ID for the motor has been created, a fully automatic test can be run. An automatic test will test the motor in the following sequence:

1) Temperature

2) Resistance

3) Meg-Ohm

4) PI/DA

5) HiPot/Step Voltage

6) Surge

At the end of the sequence, the test data will automatically be saved to the database.

For completeness, it must be mentioned that tests can also be run from the test windows themselves—a process called semiautomatic testing. Additionally, tests can be run manually using the controls on the front panel of the tester. A semi-automatic test can be run by pressing the desired test's button on the tests view.

1) To start an automatic test, make sure the motor is selected within the **Explore** tab.

2) Click on the **Tests** tab to get to the main testing window. If the Motor ID setup and the Test ID setup procedures were followed as described, the Baker AWA-IV should be at the correct place to begin the automatic test.

3) To start the test, click on the red **Run Auto Test** button in the **Tests** tab and follow the directions.

4) The *Safe to Turn On* dialog box appears, instructing you to verify that the correct set of leads is properly connected. If the resistance test is turned on and the **Res Leads** box is not checked, this dialog box will direct you to attached the high-voltage leads. If the **Res Leads** box is checked, the displayed dialog will request that low-voltage leads be attached.

The following sequence of tests will run automatically:

- Temperature—This test dialog will be displayed ready for the temperature reading to be entered from a third-party temperature device. Enter the temperature reading, click the **Accept** button to acknowledge the temperature being entered, and inform the software to proceed with the next test. Automatically, the Baker AWA-IV will proceed with the remainder of the tests.

- Resistance—If the readings pass per the requirements of the Test ID, the Temperature/Resistance dialog box will close. If low-voltage leads were used, a dialog box appears to instruct you to switch to the high-voltage leads.
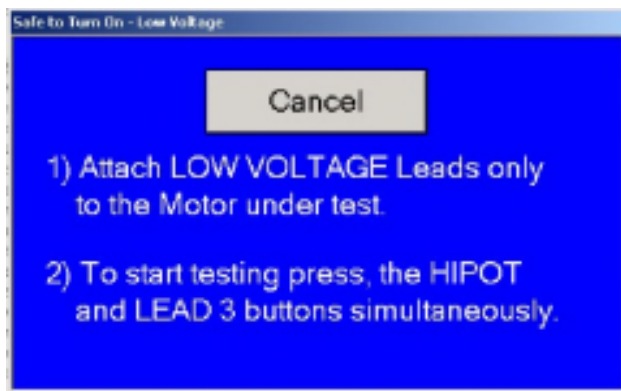
Figure 71. Test verification.

- Meg-Ohm —Starts by ramping up all test leads to 500V. This voltage will be held for 60 seconds during which the Baker AWA-IV watches for HiPot trips or insulation resistance values below the minimum Meg-Ohm setting. Should a failure be detected, all testing will stop; leads will be discharged and grounded. You will be given the choice to repeat the test, stop all testing, or continue to the next test.
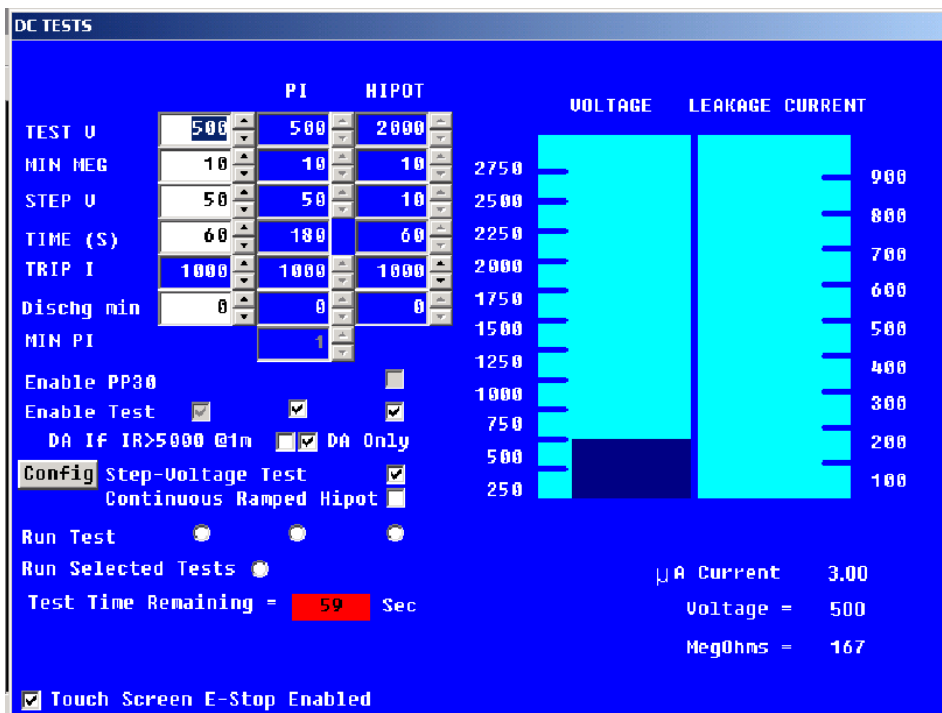
Figure 72. Meg-Ohm test window.

- PI/DA —The test window will appear.   Because the Test ID was set up for a Dielectric Absorption (DA) test, the duration of the test is three minutes (180 seconds). At end of the PI test, if no failures occur, the PI/DA test window will close.

- HiPot—The test will begin automatically.   Preset by the example Test ID, the voltage is ramped up to 2000 V and held for 60 seconds. If the Baker AWA-IV detects a low Meg-Ohm reading or a HiPot trip, the testing will immediately stop, and the leads will be discharged and grounded. You will be given the choice to repeat the test, stop all testing, or continue to the next test. If no failures have been found during the HiPot test, the Baker AWA-IV will continue to the next test.

- Surge—The test will begin automatically.   The *Surge Test* window appears and the test voltage slowly ramps up on lead 1 to 2000 V as specified by the Test ID. If no pulse-to-pulse EAR failures are been detected, lead 2 and lead 3 will be tested in turn. If no failures occur, the data from all tests will be saved to the database and the main test window will re-appear.
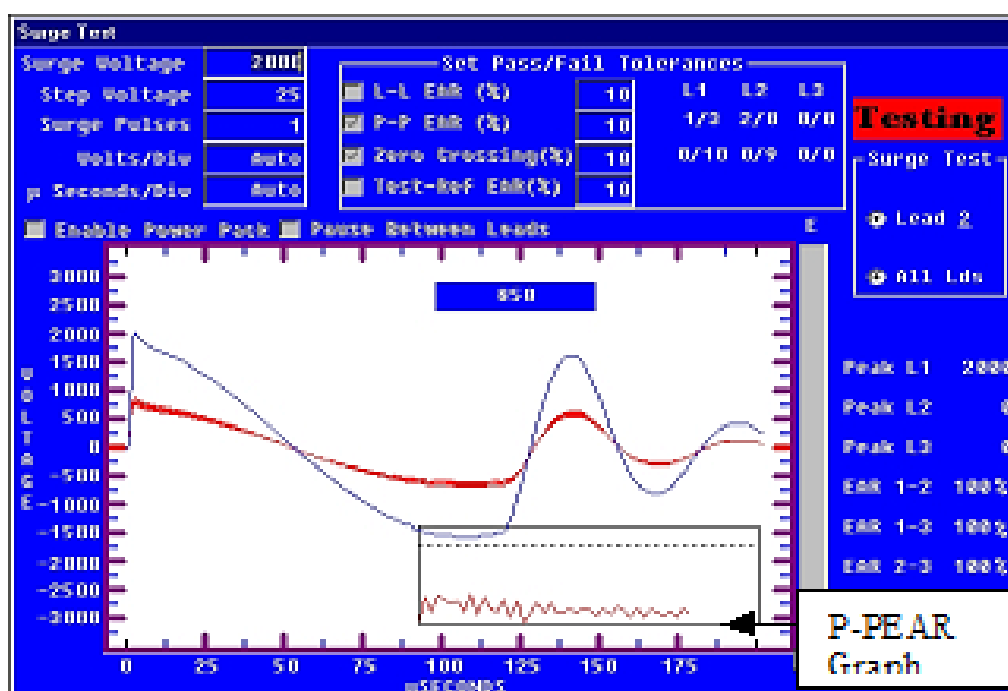
Figure 73. Surge test window.

Reviewing test results/data

After the test results have been saved to the database, they can be reviewed using the **Data** tab in the right pane of the Baker AWA-IV *Main* window. The **Results Summary** tab has a **Date/Time** area on the top part of the window and a spreadsheet style view of the data on the bottom.
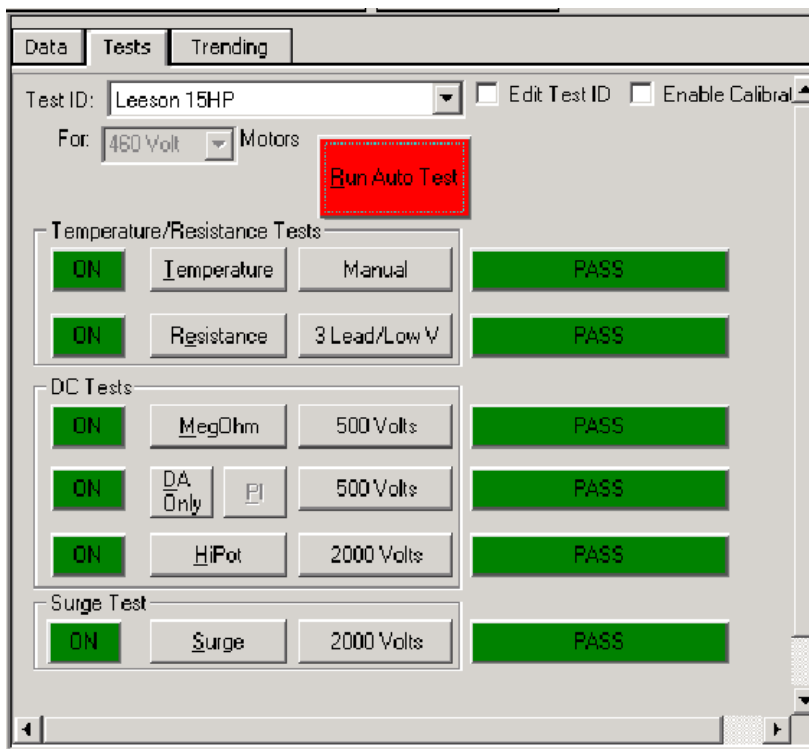
Figure 74. Main test window with passed results.

Figure 75. Date/time results summary.

The **Date/Time** area shows a quick summary of the time and date of tests, and whether the tests passed or failed. Double click on a test date and time to move to a new record.

The results view presents the test data acquired in a spreadsheet style. The test date and time are shown across the top of the window with specific measurement results shown in each column.

Test Date	03/28/02	03/19/02
Test Time	14:51:34	14:21:52
Temp Status	PASS	No Test
Winding Te...	46.0	
Resist Status	PASS	PASS
Bal L1	6.107	3.175
Bal L2	6.093	3.210
Bal L3	6.096	3.150
L1-L2		
L2-L3		
L3-L1		
Coil 1	4.079	2.116
Coil 2	4.061	2.162
Coil 3	4.065	2.082
Delta R Max	0.200%	1.900%

Figure 76. Test results spreadsheet.

The PI test can be reviewed by pressing the **PI** tab. PI view will display the PI/DA graph along with a table of the current and Meg-Ohm readings gathered at specific times.   The PI voltage, DA ratio, and PI ratio are displayed on the right side.   Because this test was a DA, only the PI ratio has I=0 No PI indicating there is no PI value because the current was zero.
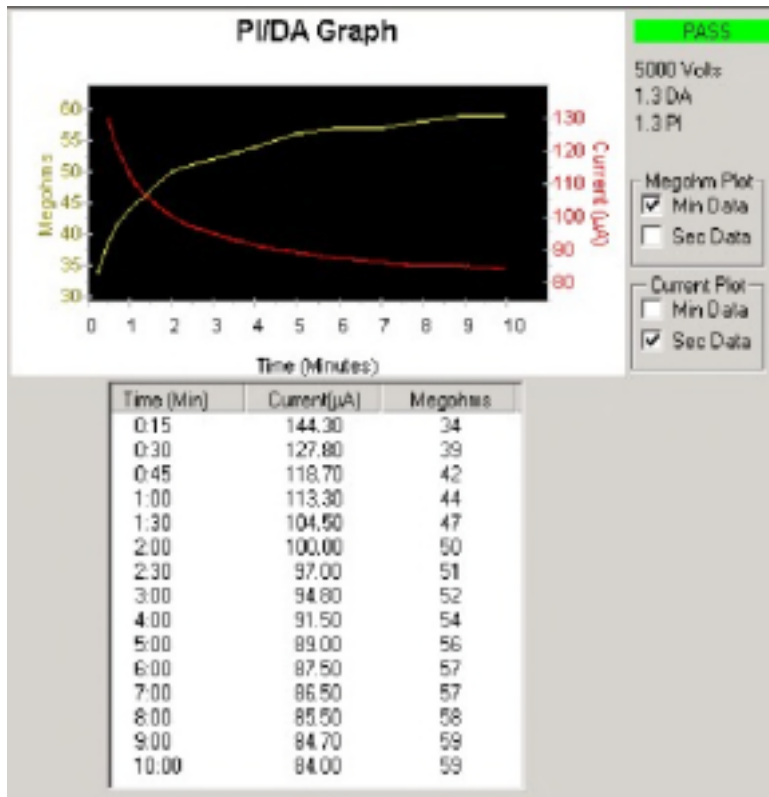
Figure 77. Reviewing PI test data.

Click on the **Surge** tab to view surge test data.
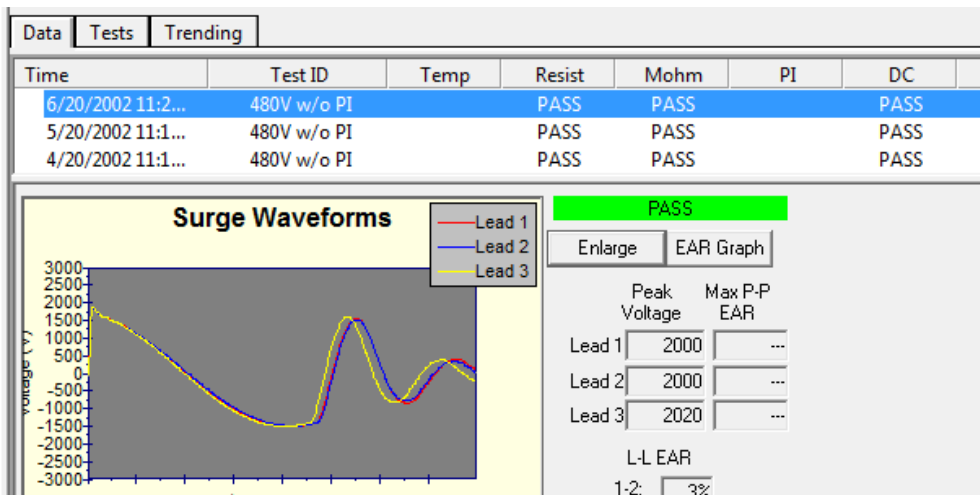
Figure 78. Surge waveform view.

Printing reports

The Baker AWA-IV software includes report generation features so you can provide test results to managers, customers, and repair personnel as required. Reports containing test data, nameplate data, application data, and more can be sent to a printer, or they can be printed to a Microsoft® Word® file or other file formats as needed or preferred. For convenience, we recommend that you print reports from a desktop computer rather than the tester itself.

Figure 79. Report generator.

Start the *Report Generator* by:

• Clicking on **File** then **Print**

• Holding down the **Ctrl** key on your keyboard and pressing the **P** key

• Clicking on the printer icon in the upper left section of the *Main* window.

The top section of the *Report Generator*—called **Select Filter(s)**—contains filters you can use to select which tests results you want to print. Select the current motor and test result, or use any combination of the other filters as needed. For example, you can select a date range and all motors that failed any test during the selected test range.

When you need to print data for several motors, you can select and print them one at a time, or you can select all records that match specified criteria using the report filters. Different combinations of the motor's location fields, date range, and/or pass/fail criteria help you select specific groups of reports.
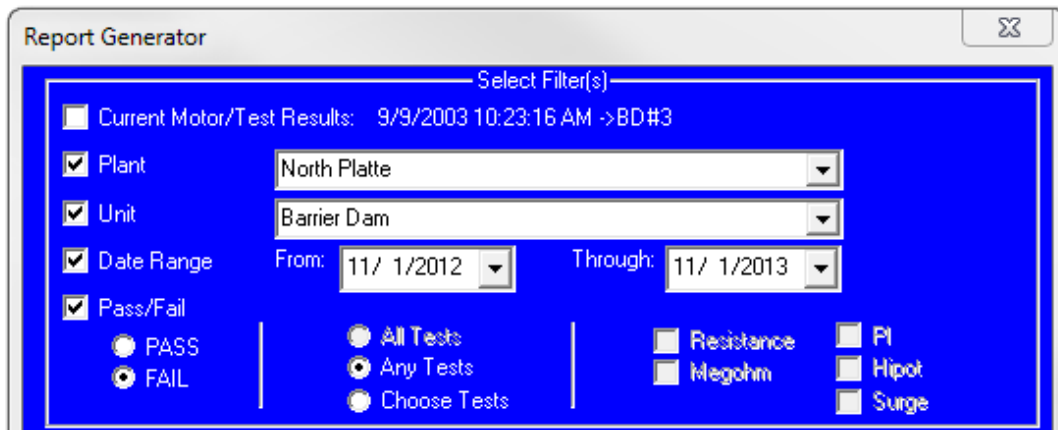
Figure 80. **Select Filters** section of the *Report Generator* window.

After you select your test results, you will use the bottom section of the *Report Generator* window—called **Select Reports**—to select the report type that you want to print. You have several choices including Nameplate, Application, Summary, Surge, PI, and Step Ramp Voltage to name a few. You can also add a report title, which will appear in the final report.

After selecting the report type you need, click on the **Output Report To** dropdown list to select the report format needed. Your options include: MHTML (web archive), MS Word, Printer, Comma Delimited Text File, and Ref to Bar EAR CSV File.
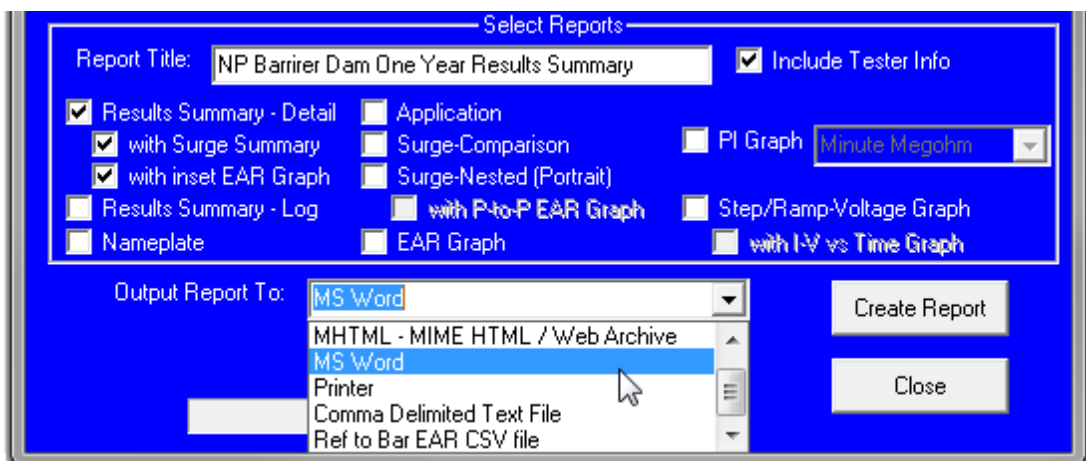
Figure 81. Print selected reports.

In the simplest case, you will want to print the test result being reviewed. The motor and test result selected in the main program will appear to the right of the **Current motor/test** checkbox in the **Select Filter(s)** section.   Ensure that box is checked then check the box(es) in the **Select Reports** section for the type of report you need. Select Printer from the **Output Report To** dropdown list then click on the **Create Report** button.

In other cases, you will want to print a more specific set of reports and/or data for a collection of motors tested. Just be sure to carefully consider what you need so you can generate the results required.

Using an example where an electrician tests many different motors during the day and needs to print reports for failed motors before going home. In this case, the *Report Generator window* should be configured as shown below.

1) The **Select Filter(s)** section has the **Date Range** selected and both dates are set to 11/6/2013 so the software will only include test results for that day.

2) The **Pass/Fail** filter is selected along with the **FAIL** radio button so that results for motors that have failed one or more tests will be included. Passed tests will not be included because that radio button is not selected.

3) In the **Select Reports** section, the **Results Summary** with **Surge Summary** is selected. The **Printer** is selected as the output.

4) When the **Create Report** button is clicked, the *Report Generator* will go through the entire database looking for failed tests that occurred on 11/6/2013.

5) When the software completes its search, a dialog box appears showing how many records were selected. Clicking on **Cancel** stops the process; clicking on **Continue** completes the report generation and printing process.
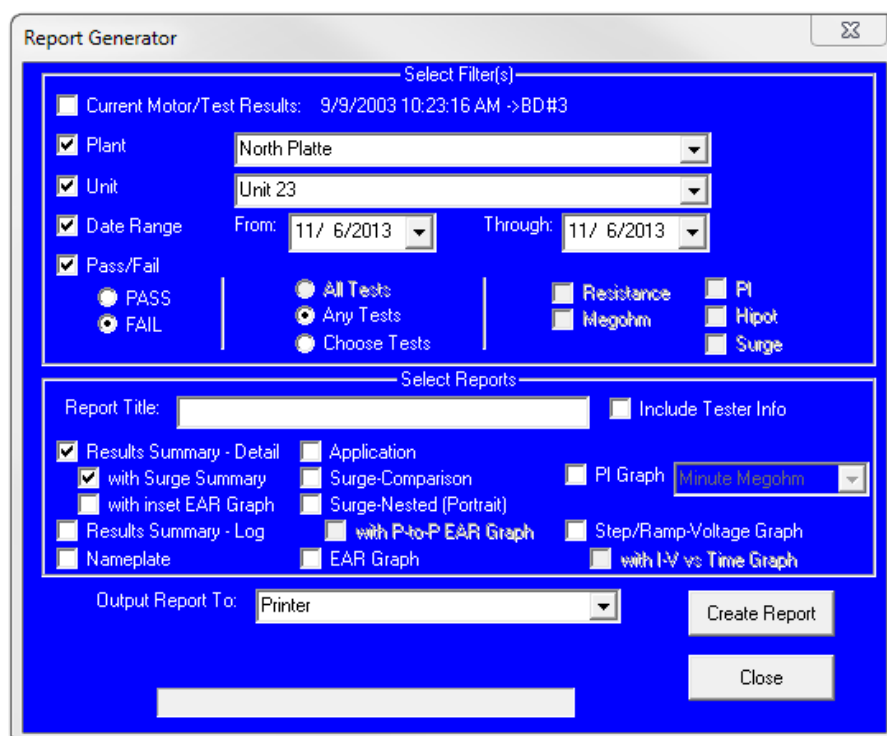
Figure 82. Fig 8-20: Report generation example

ℹ **NOTE**

The Report Generator can be set up so that a large number of reports are created. Printing out a large number of reports can be very time consuming, especially when going to Microsoft Word. The Report Generator will show how many test results are chosen; however, this is not the number of pages that will be printed. That depends on the number of reports chosen.

The program can also print reports to Microsoft Word—if it is installed on the tester—or on a desktop computer running the software. This feature provides a way to annotate reports by adding text to the Word® document as required. For example, a comment regarding the vibration level of the motor before it was turned off can be added to the Word® document. This feature should also be used with discretion because printing reports to MS Word® takes some time; selecting a lot of records to print means the system would be tied up until all records can be transferred to the Word® document.

A example Word® report is shown below. Each section is a Word® table; except the surge waveform, which is a bitmap. The reports can be modified by adding text between the tables or the data tables can be cut and pasted into other documents.
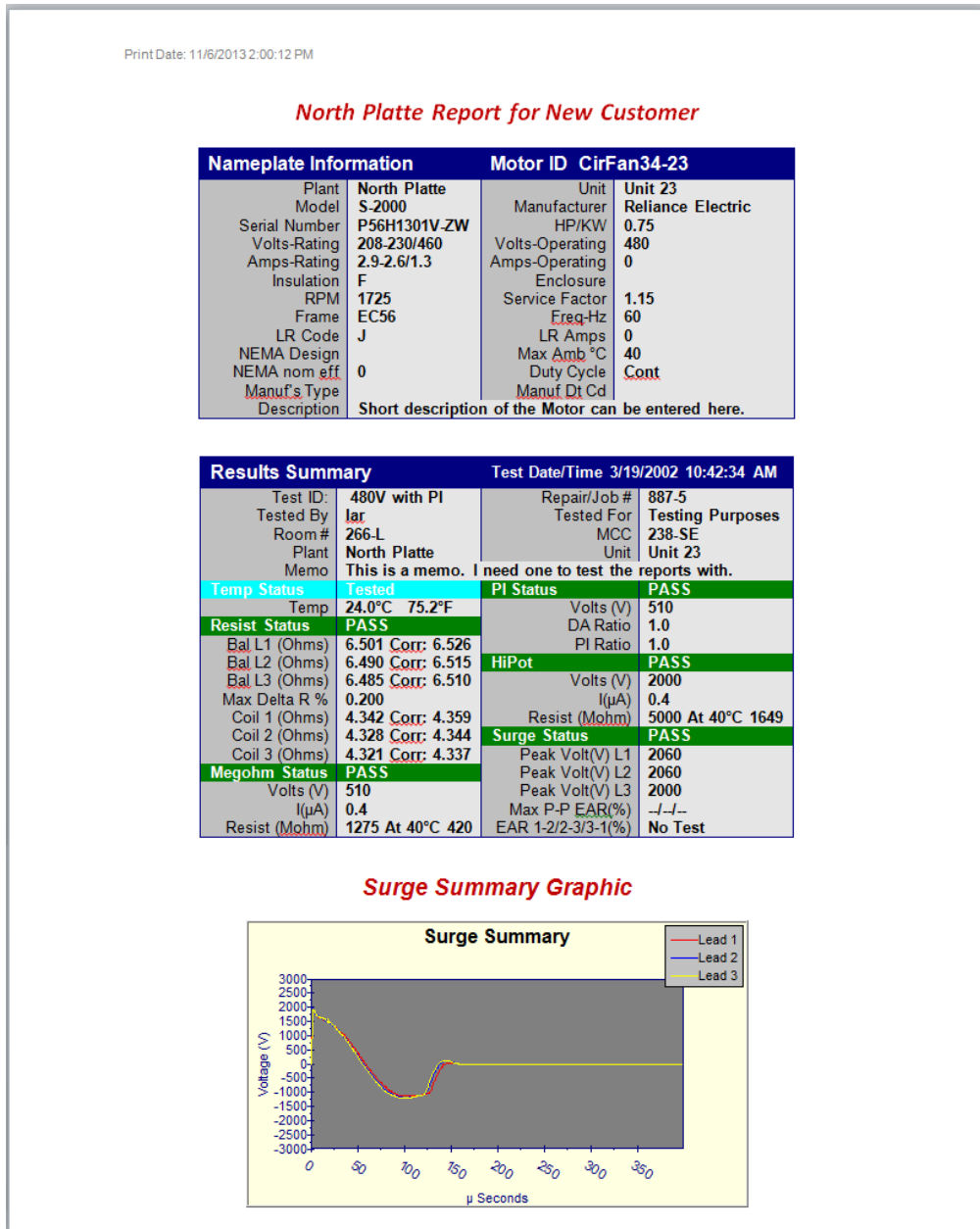
Figure 83. Example MS Word report with nameplate, summary, and surge graphic.

In the following example, we see a report that includes Results Summary and Surge Summary.
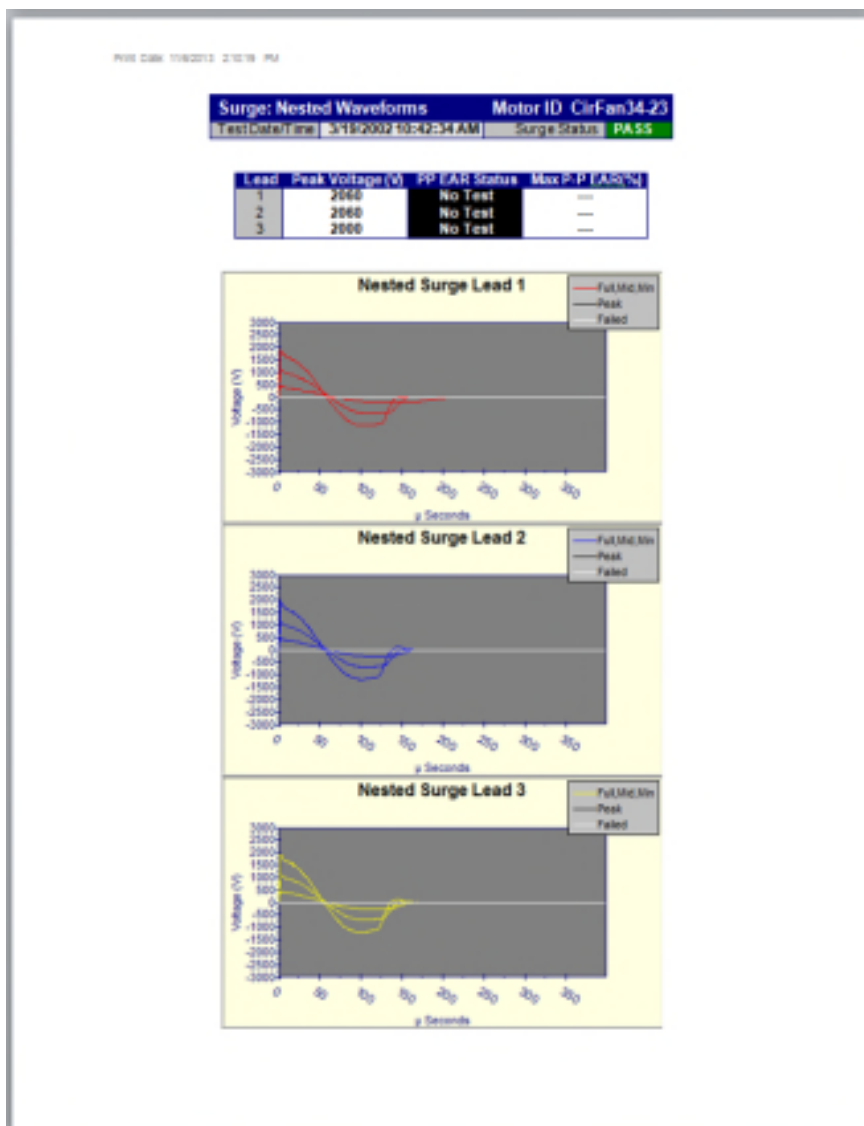
Figure 84. Example MS Word Report with nested surge results and graphics.

Remember that you can output files in other formats including MHTML (MIME HMTL / web archive), a comma delimited text file, and Ref to Bar EAR CSV File.

SKF

7   Applying the Baker AWA-IV

Predictive maintenance

A program of predictive maintenance testing requires that motors be periodically taken off-line and tested with the same parameters each time. This provides a picture of motor condition. Predictive maintenance allows spare parts to be stocked, rewinds or other refurbishments to be scheduled, and minimizes the likelihood of unscheduled down time.
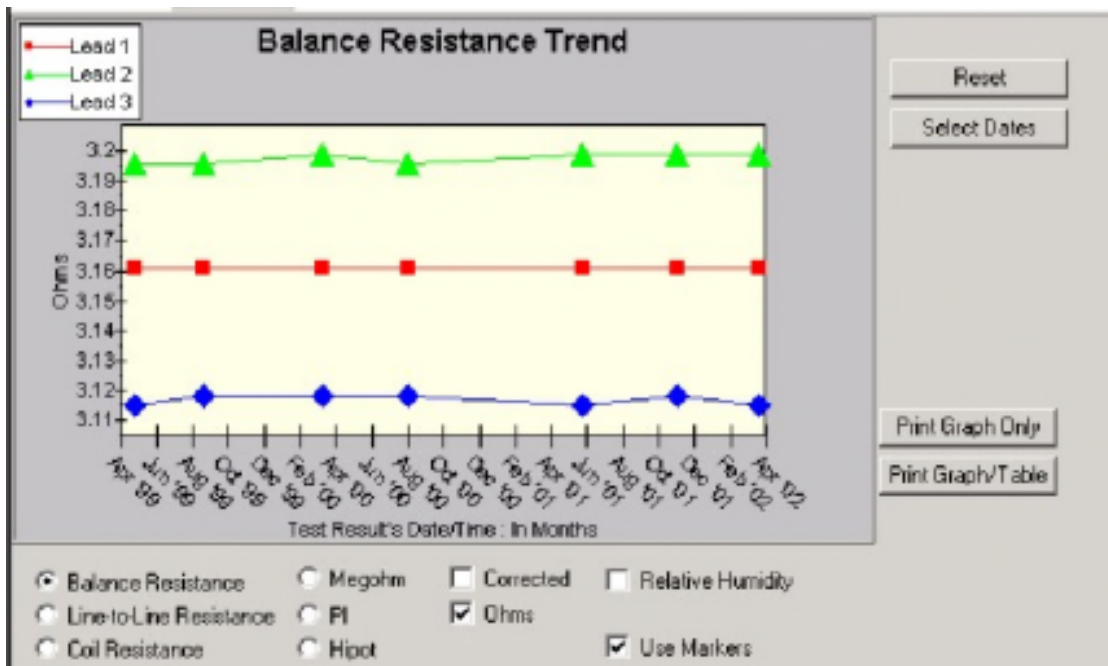
Figure 85. Resistance trending screen.

Particularly useful for predictive maintenance is trending data collected and stored by the Baker AWA-IV. Test parameters must be identical for data trending to be meaningful. Tests at different voltages will render data less useful for trending. If Test IDs are programmed and used properly, and tests are conducted precisely, trending can help monitor the rate of insulation decay. Observing data over time can also help establish a schedule for motor testing.

During maintenance testing, failure of a test indicates possible motor problems. Additional testing—for example, visual inspection—might be warranted. The combination of tests should be determined by experienced operators. If the source of the problem is electrical, the Baker AWA-IV's manual mode can be employed to conduct further testing.

As an example, consider the case of wet windings. The motor is likely to pass resistance tests, fail Meg-Ohm tests, fail HiPot tests, and pass surge tests. After the failed Meg-Ohm test, no further automatic testing will be done by the Baker AWA-IV unless you use the continue option. Knowledge of motor behavior will help an experienced operator conduct visual tests or further electrical tests with the Baker AWA-IV in manual mode to isolate the source of the problem.

Quality control

Quality control testing done in a motor shop or production facility could use relatively higher voltages compared to maintenance testing of the same motor. In a quality control testing situation, the test results are either pass or fail. Data is not trended and diagnosis is not a goal. Rather, the insulation system of the newly-rewound motor must be able to withstand test levels in accordance with IEEE and NEMA standards.

When conducting quality control tests, failures must be analyzed. For example, some winding configurations will fail a winding resistance test with seemingly reasonable test parameters even when the winding resistance is good. Knowledge of special windings is important and can only be provided by those responsible for the winding.

Motor troubleshooting

In the case of a motor failing during service, the Baker AWA-IV can help determine the reason for failing and provide data that assists in making decisions about refurbishment vs. replacement. Isolating the site of a phase-to-phase short, for example, can be done by surge testing the windings. The shorted winding will give a waveform substantially different from the two good windings.

Motor shops can use the Baker AWA-IV to indicate where a problem has occurred, pinpointing what needs to be repaired. Baker AWA-IV test results provide a tool for recommendations to the customer.

Maintenance testing

Baker Instrument Company, SKF Group Company 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 tests on assembled motors in the field as part of maintenance testing.

Hard-shorted 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. This is a rare condition in maintenance testing because of transformer action, which occurs within the windings and 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-shorted winding fault is not the type of fault expected 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 surge testing 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 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 following figures, a good winding will produce stable wave patterns from zero volts up to the recommended test voltage. Faults detected during surge tests are unstable, flickering wave patterns that appear as the voltage is increased.
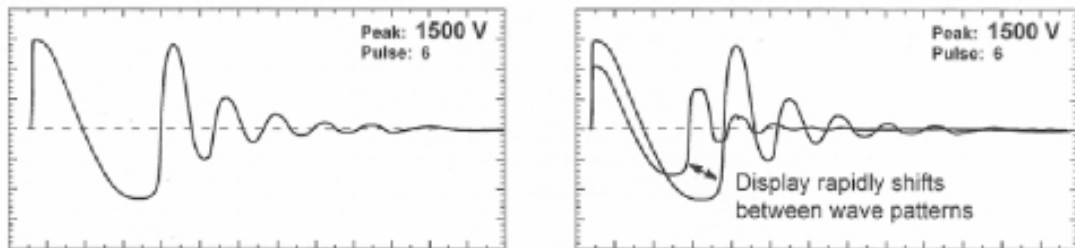
Figure 86. Good waveform vs. faulty waveform

The preceding graphic shows how a good wave pattern (left) and a representation of how a live wave pattern might appear to move on the display for a winding or coil that contains an intermittent short or is arcing (right).

Single-phase motors and two-terminal devices

1) Select lead 1 and connect the corresponding test lead #1 to one side of the device.

2) Connect test lead 2 to the opposite side of the two-terminal device.

3) Connect the ground lead and test lead 3 of the tester to the frame or metal core material.

4) In the Temperature/Resistance window, locate an item called 2 leads (1 phase). Select it for testing single phase or two terminal coils.

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 required in these low-impedance coils.

Determining 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 testing form coils

- IEEE-522-1992 recommends a test voltage for vacuum pressure impregnation coils—before they are cured—at 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 enables the tester to produce a higher voltage drop across the coil for a given current level.

> **CAUTION**
>
> *The laminations or stator core have induced voltage on them, and can provide a path or ground*

- Many formulas are used in calculating a test voltage for AC form-wound coils. These are generally based on experience and theoretical arguments about the distribution of voltage in a coil and the entire winding. Some of these formulas are difficult to apply because of the great diversity of coil specifications and characteristics. One popular formula based on Paschen's Law, states a minimum and maximum test voltage range:

    Minimum = Number of turns x 500 Volts

    Maximum = Winding operating voltage x 1.5

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

Three-phase motors

Wave patterns for three-phase windings are compared in pairs. The storage capability of the Baker AWA-IV allows all three phases to be compared without removing and reconnecting the test leads. We recommend the following procedure:

1) Connect the three numbered red test leads to the three winding legs.

2) Connect the black ground lead to the frame or core of the winding.

3) Within the software, go to the **Tests** tab.

4) Click on the third button in the **Surge Test** section. This button displays the specified test voltage.

5) Make any necessary changes prior to running the manual test.

6) A manual test can be run from here by clicking on the buttons under **Run Surge**.

7) Test each lead separately or test all leads together. Refer to the chapter "Performing an Example Test" for more information on setting up the tester.

8) For each test, check the display for a wave pattern. View the results from the Baker AWA-IV's screen for the wave patterns of the motor for comparison. If three good wave comparisons are seen, the motor is likely good. If anything other than a good pattern is seen, there is a possible fault. The Baker AWA-IV will also prompt if results are out of set tolerances.

Determining 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.

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

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

In the field: In assembled motors, separation of the wave patterns is often the effect of rotor coupling, also known as rotor loading (see "Rotor loading (coupling) when testing assembled motors").

Two or more single coils

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

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

2) Connect test lead #2 to the second coil or identical coils and connect test lead #3 to that coil's other side.

3) Conduct the surge test.

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.

Determining 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 crackling sounds.

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 waveform that shifted to the left and collapsed in amplitude.

Notes and precautions for testing 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 field 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 we recommend that devices such as 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, we recommend 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 can allow for differences in turns count, which causes a slight, steady separation. You should investigate whether this condition is acceptable.

- A slight imbalance (separation) might be noticed if the windings are not correctly phased: (that is, the winding configuration of one compared to another is clockwise verses counterclockwise). Try reversing one set of test lead connections and repeating the test before rejecting the winding.

- Many two-terminal devices have very high turn counts. 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 might 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 follow:

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.")

> ℹ **NOTE**
>
> Because 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.

> ℹ **NOTE**
>
> Check the motor nameplate 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.

Determining 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 crackling sounds.

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.

Determining a fault

Two types of faults can exist in synchronous motors and generators: pole piece or stator winding faults.

Pole piece fault

Do not expect coils to compare exactly. Rotating fields or pole pieces are often not wound to identical 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, 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, two-terminal devices, and synchronous motors/generators. The recommended surge test voltage for DC fields is 600 volts.

If the impedance of the coils is very low, (fewer turns, generally form coils with very low resistance) the surge tester standalone might not adequately test the coils. A bar-to-bar, low-impedance test accessory from Baker Instrument Company, an SKF Group Company, might be needed.

Hi L in Baker AWA-IV-2 and Baker AWA-IV-4

Hi L is a technique that extends the range of use of the Baker AWA-IV-2 and Baker AWA-IV-4 tester's original surge test circuitry. This circuitry, like all electric circuits, has design and operational characteristics that can be enhanced or fine tuned to meet specific additional requirements. In a nutshell, Hi L technique is an example of this.

In essence, the useful range of electric coils that can be tested by the Baker AWA-IV is dictated by the capacitance (C) supplied by the test set, and the inductance (L) of the coil under test. The "Q" factor—or loss of the test object—also has a direct influence.

Per the data specifications, the Baker AWA-IV-2 and Baker AWA-IV-4 testers are supplied with a .1 microfarad energy storage capacitor. To illustrate the phenomena at work, this value (0.1) shall be the basis of the following discussion:

The sample, or data acquisition window of the Baker AWA-IV-2 and Baker AWA-IV-4 is dictated by its analog to digital converter, and the memory size assigned to it. Without going into detail about these signals, or memory depth, suffice it to say that the maximum sample time of the Baker AWA-IV-2 and -4 is approximately 2 milli-seconds.

This illustrates the transient nature of the surge pulse. It is applied, measured, analyzed, and displayed in a fraction of a second.

The Baker AWA-IV-2 tester has a capacitor with a value of 0.1 micro-farad. The frequency (f) generated—and therefore, the sample width needed—when a 100 micro-henry coil is tested with the standard surge test is calculated using the following formula:

$$f = \frac{1}{2\pi\sqrt{C}} \qquad \text{becomes}$$

$$f = \frac{1}{2\pi\sqrt{100^{-6} * .1^{-6}}} \quad \text{when solved,}$$

reveals a ringing or resonance frequency of approximately 50 kHz. The period of said 50 kHz sinusoid is equivalent to

$$\frac{1}{f}$$

or approximately 0.00002 second. This is well within the sample window width detailed previously.

What happens to these frequencies if the inductance of the tested coil is raised by several orders of magnitude? For example, what if the coil inductance is now 5 henry, or 50,000 times greater?

$$f = \frac{1}{2\pi\sqrt{5*.1^{-6}}}$$ when solved, reveals a frequency of approximately 225 hZ

The period of this signal is $\frac{1}{f}$ or approximately .0044 seconds.

This is more than double the capability of the data acquisition sample width hardware to capture it! Therefore, the question becomes: how do we capture such a signal and display it appropriately across several orders of magnitude?

The answer is to employ the Hi L technique. The Hi L technique, in practical terms, functions as a test range extender. In other words, it allows the Baker AWA-IV-2,-4 to deliver sensitive test results when employed on much higher inductance's than the original, highly successful Baker AWA-IV surge test circuit.

Using the Hi L technique

The Hi L technique can be used to test DC shunt or compound motor insulation, evaluate shunt fields, and test interpoles

Fully testing DC shunt or compound motors with the Baker AWA-IV requires some additional programming and consideration of the motor in terms of its separate windings.

Knowing that the separate windings can operate at different voltages helps determine appropriate test voltages. Because there are separate windings, test IDs need to be tailored to the windings

An effective method of performing this test sequence is to program two test IDs, each being selected once during the test sequence of the DC motor.

#1 Test ID armature

Armatures can be low inductance and very low resistance. They can also be vulnerable to surface contamination due to brush carbon or other materials. A suitable test ID should include:

1) Temperature correction

2) Kelvin resistance–with two leads selected

3) Meg-Ohm, with a suitable value of pass/fail for meg-ohm value defined.

4) DA/PI test, with a suitable value of pass/fail defined

5) DC Test, such as the DC Hipot

6) Standard Surge test–with two leads selected, by virtue of two leads resistance

#2 Test ID field

Shunt fields are generally high inductance, quite higher in resistance, and arranged in pairs. Using the Hi L technique could result in more sensitive evaluation characteristics.

1) Temperature correction

2) Kelvin resistance-with two leads selected

3) Meg-Ohm, with a suitable value of pass/fail for meg-ohm defined

4) DA/PI test, with a suitable value of pass/fail defined

5) DC test, such as the DC Hipot

6) Surge test-with two leads selected, by virtue of two leads resistance, and Hi L selected

i **NOTE**

Hi L technique is only selected for the shunt fields!

Fine tuning the technique

40HP DC Motor, straight shunt, 500V armature, 300V field. Motor leads marked F1, F2 and A1, A2. These are the shunt field leads (F1,F2) and armature leads (A1,,A2)

Plugging in the two previously discussed sets of test IDs we could arrive at the following:

Figure 87. Test ID for F1-F2 300V field.
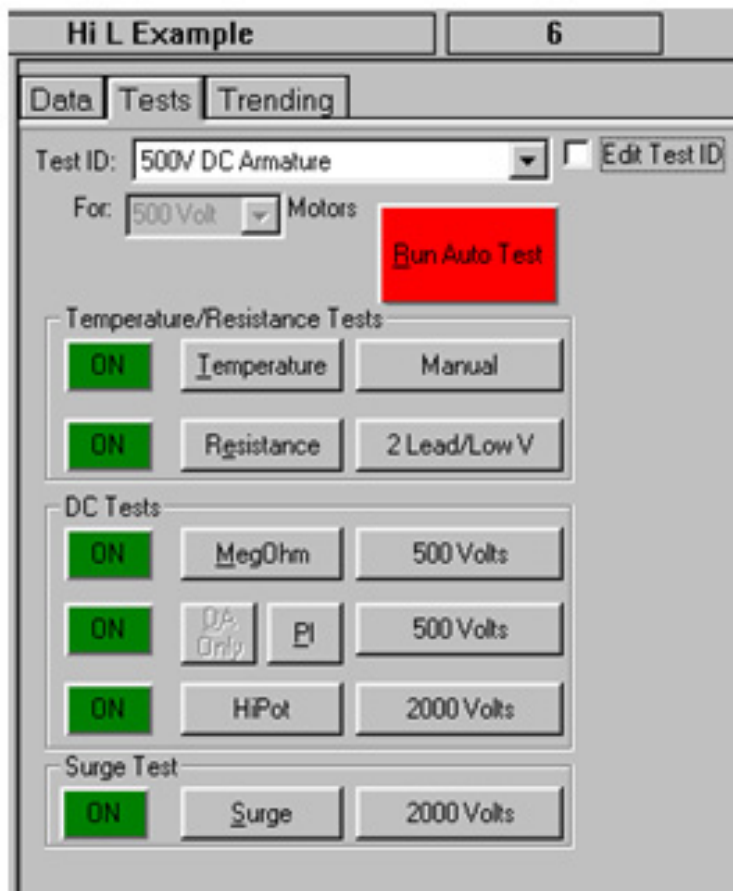
Figure 88. Test ID for A1–A2 500V armature.

Because we know this is a DC straight shunt motor, further enhancing the test is possible:

- Expect the DC resistance of the armature (A1–A2) to be quite low.
- Expect potential brush carbon contamination.
- Expect DC resistance of the fields (F1–F2) to be much greater than the armature.
- Expect the ability to employ the Hi L technique on the shunt fields.
- Employ target corrected resistance detection for trending.
- Consider employment of Test-Ref, for A1–A2 and F1–F2 for trending.
- Consider steps to code, or lock the acquisition time-base for the specific motor.

Here are the steps required to fine tune the settings:

1) DC resistance of the armature is likely quite low A1-A2, so click on the **Resistance Enable** radio button to ensure an accurate, repeatable measurement.

2) Click on the **Temperature Enable** radio button, and consider enabling **Target Corrected Resistance** (in anticipation for using trending later).

3) Given that you are now aware of the low resistance of the armature, take steps to code the surge test sequence, specifically for the low resistance. This equates to a lower value of time-base, (not necessarily 10, it could be 50).

4) Be sure to turn off the Hi L.
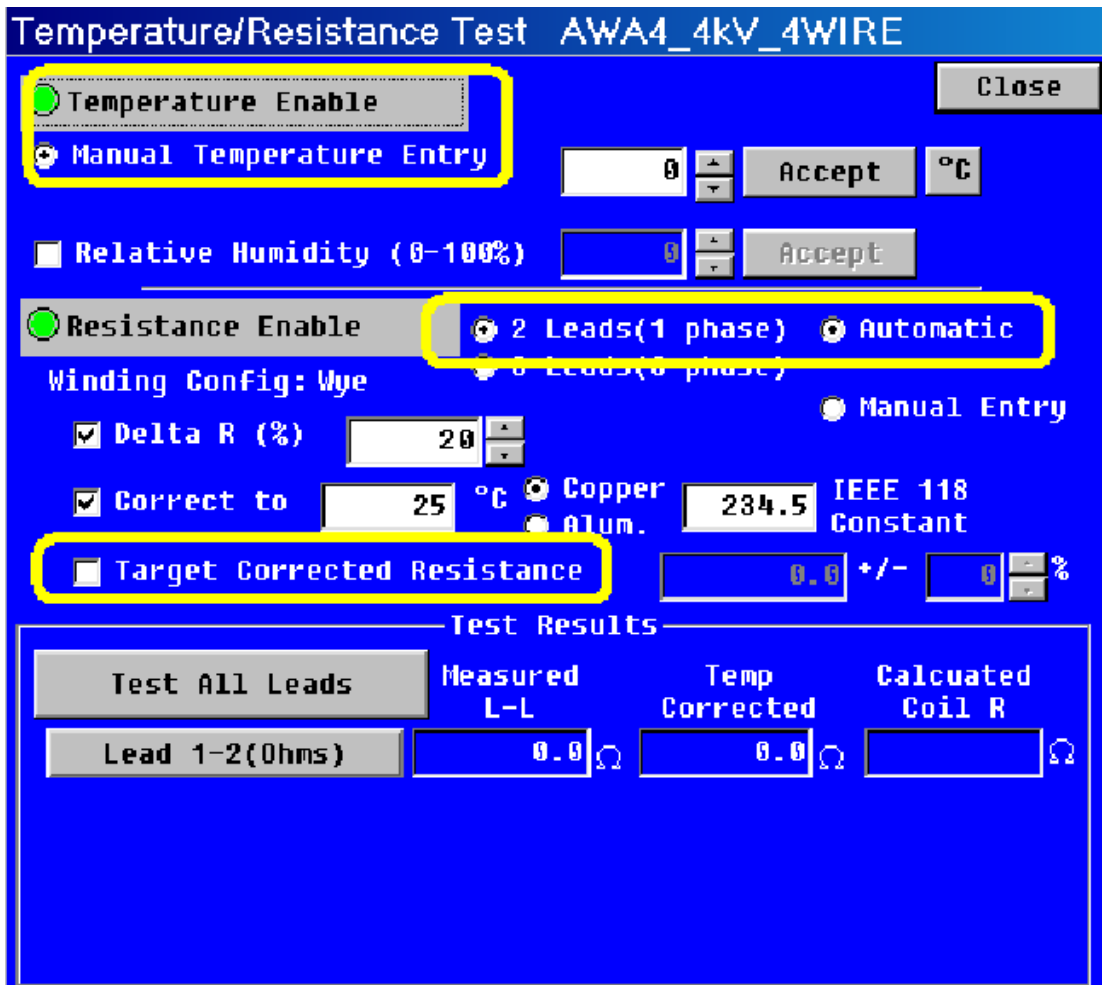
Figure 89. Hi-L temperature resistance.

5) For the shunt fields, employ the hard coded time-base, and the Hi L technique. The following illustrations show the steps to program the time-base, specifically for the shunt fields.
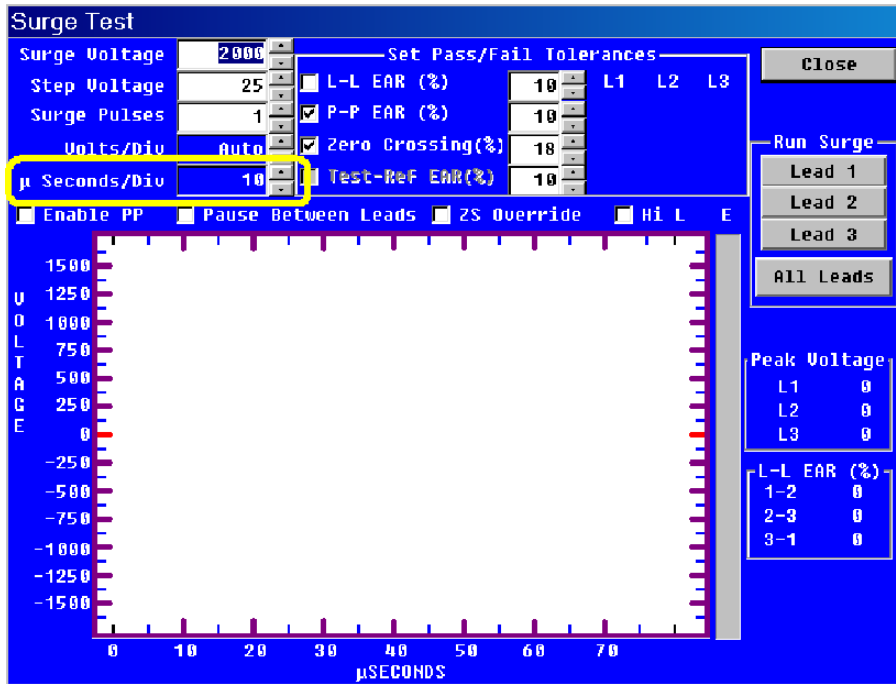
Figure 90. Hi-L surge test.

6) Set micro-seconds to 200, and be sure to select Hi L, save the test ID when done.
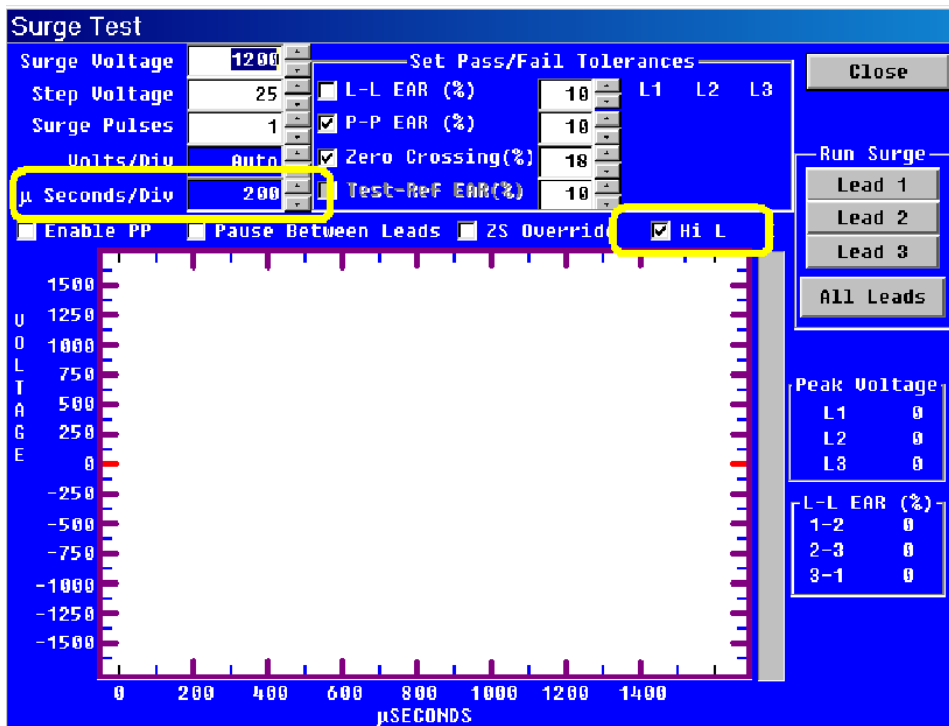
Figure 91. Hi-L surge test.

When you have these steps in place, the successive test data should look similar to the following example.

Figure 92. Hi-L results.

DC motor/generators

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

Armatures

The Span surge test is used to test armatures with the Baker AWA-IV.

Span testing

This method uses the brushes of the assembled DC motor to make the connections with the commutator for testing the armature. Any number of bars can be used in this test. 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").

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.
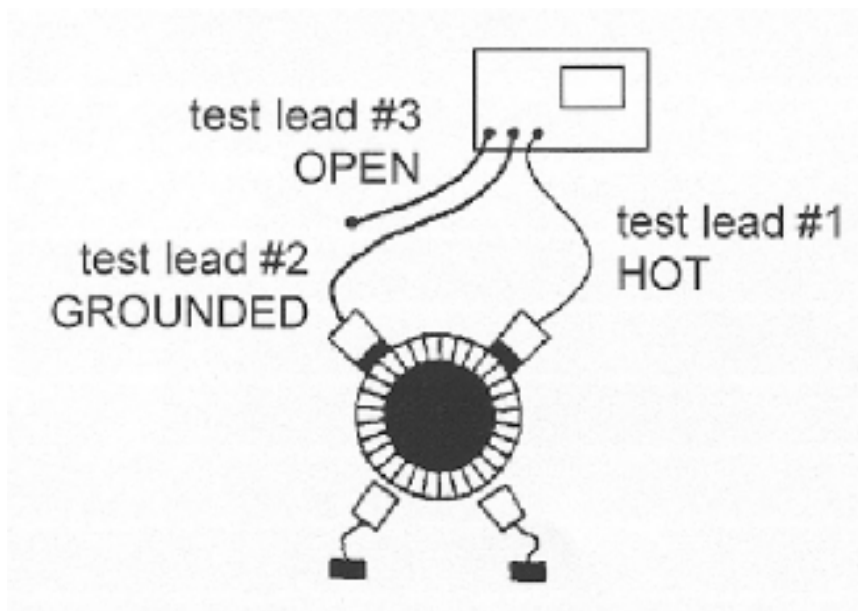
Figure 93. Span testing.

> ℹ️ **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 pigtail connections from the leads at the brush rigging for all sets of brushes to isolate the armature from the power source.

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

> **NOTE**
>
> While it is not necessary, we recommend releasing the Test button each time the armature is turned. Doing so minimizes the chances of marking the commutator.

If the test button 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 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.

Determining 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 with the surge test using the motor's brushes is illustrated below.
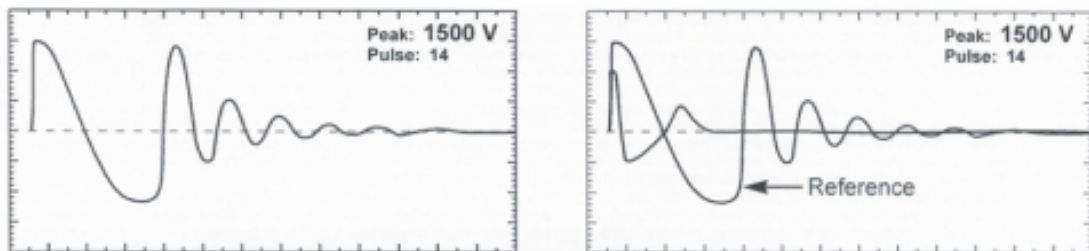
Figure 94. Fault located under the ground brush. Fault grounded under the hot brush or outside of the surge test span.

Notes and tips for span testing armatures

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

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

- First, always HiPot the armature to ground. This gives an upper limit for the maximum voltage to apply when surge testing.

- The greater the span surge test voltage is, the more adequate the stress between bars is (ideally, 335 volts according to Pashen's Law). Voltage stress is measured by the differential or drop between each bar. For example, a 10-bar span with 1000 volts applied to it will result in a 100 volt stress between bars. If the span is lowered to five bars, 1000 volt applied to the span will result in 200 volts between bars.

- Consider, however, that a 10-bar span at 335 volts between bars would require a span test voltage of 3350 volts. This potential to ground at the first coil might 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 could make it more difficult to achieve 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 you 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 a 7-bar spanned might match that for an 11-bar span. In addition, the patterns could show a rhythmic shift consistently throughout the 360 degrees of rotation. For example, 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 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 examples in the next section show wave pattern comparisons for a typical 4160V stator. Distortion is caused by the non-symmetrical distributed capacitance in the input portion of the winding.

Notes and tips for testing large AC stator/motors

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

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

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

Rotor loading (coupling) when testing assembled motors

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

1) Loss of wave pattern amplitude: the inductive loading of the rotor causes rapid dampening of the wave pattern (little to no cycles of the ringing pattern).

2) Separated wave pattern comparisons for good windings: imbalance in the inductive coupling between the rotor and stator winding causes the wave patterns of two good phases to appear separated when they are compared. By turning the rotor, this coupling effect can be balanced out so the wave patterns superimpose.

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

Not all motors exhibit this characteristic. It is most prevalent in smaller, high-efficiency motors with small tolerance air gaps. Separation of wave patterns that are due to rotor coupling can be determined when the wave patterns separate from the first positive peak downward, cross one another at the bottom (first most negative point) and separate again as they go upward (positive).
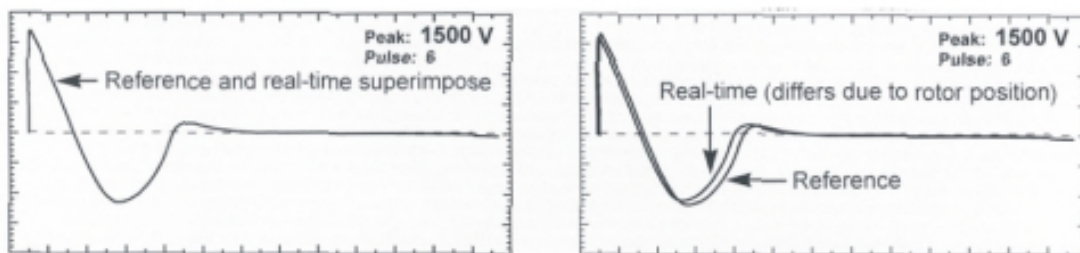
Figure 95. Wave pattern comparisons for motor with rotor in place.

The recommended procedure for testing assembled motors where rotor coupling could occur is as follows. Refer to "Three-phase motor surge test and setup" for detailed instructions for surge testing. Perform a manual surge test from the test screen within the Baker AWA-IV.

1) Surge test phase #1 of the motor. The Baker AWA-IV will perform the test and display the waveform on the screen. These waveforms will stay visible while other leads are being tested.

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.

3) Repeat step for phase #3. All three waveforms will be displayed on the screen. Differences will be visible.

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

> ℹ️ **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. Flickering wave patterns clearly indicate a fault in assembled motors whether rotor coupling is present or not.
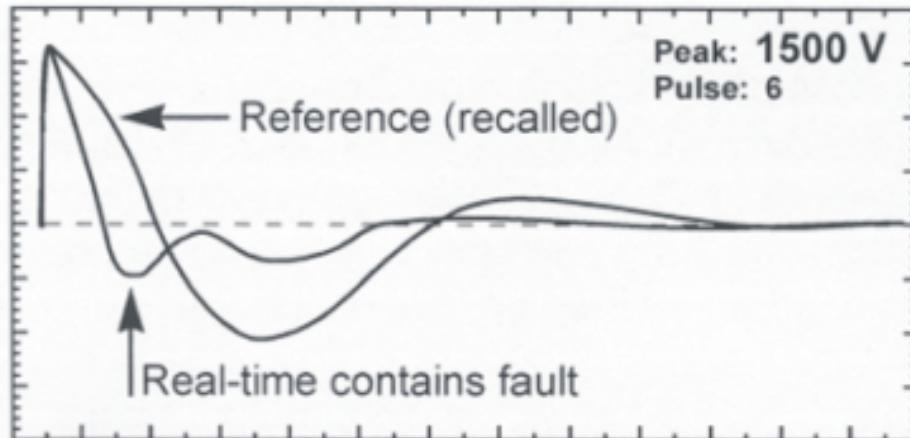
Figure 96. Motor with rotor in place and with faulty windings. One trace shift significantly to the left.

Testing assembled motors from the switchgear

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

Follow all the procedures for surge testing. 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.

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 along with 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 might 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.

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

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 might not be sensitive enough to detect a single shorted winding. It could 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 support 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 #3 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.
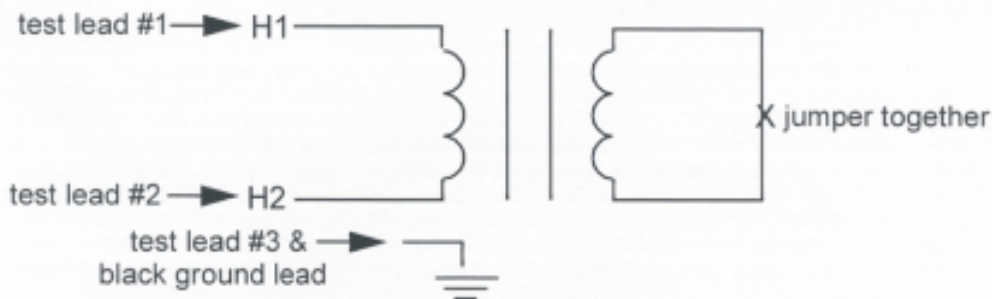
Figure 97. Single-phase transformer connections.

4) After completing the test, reverse the tests leads (connect test lead #2 to H1 and test lead #1 to H2) and repeat the surge test. This is commonly referred to as shooting in the other direction.

5) Repeat this test process for each TAP position.

Three-phase transformers

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

> **NOTE**
>
> A wye-wye transformer with the star point internally tied can be surge tested without opening the tie point.

1) Use Test Lead position #1.

2) Connect the black ground test lead to the frame (ground) of the transformer.

3) Follow the appropriate chart below for connecting wye-wye or delta-wye transformers. The transformer windings should be surge tested for all the configurations shown.

4) Test procedures are the same as single-phase transformer testing (refer to "Single-phase motors and two-terminal devices").

Determining a fault

To determine a fault when surge testing a transformer winding, follow the procedure of the two-terminal device (refer to "Single-phase motors and two-terminal devices").

Wye-Wye transformers

Test Lead #1	Test Lead #2	Jumper
H1	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

8 Data transfer and database maintenance

Data Transfer feature

The **Data Transfer** feature offers a way to transfer motor and test information from one database (source) to a second database (destination). The transferred information is not deleted from the source database, but only copied to the destination database. Data Transfer can be used to combine two existing databases into one centrally located database. It can also be used to re-organize existing database into more convenient groupings. When motor data or Test IDs need to be moved, the Data Transfer feature provides this functionality.

Transferring motor and test result data

Two databases need to be open to transfer motor information, test result data, and Test IDs: a source database and a destination database. Both databases must exist before beginning the transfer. For example, if the transfer is to a new destination database, it will need to be created prior to beginning the data transfer.

To create a new database, select the **File**–**New** menu item or click on the **New** icon in the toolbar.

You have two alternatives for starting the Data Transfer feature: click on **Database** in the main menu then **Data Transfer**, or click on the **Data Transfer** icon in the toolbar.

Figure 98. Data transfer buttons.

When the data transfer is started, the software will open a *Source* window and will default to the folder in which the currently open database resides. For example, in the graphic below the example database is open in the main program, so when the **Data Transfer** button is clicked the *Source* window defaults to the `AWAData40` folder with the `Example.mdb` for the file name. Pick the default database or choose another database to transfer data from as need.
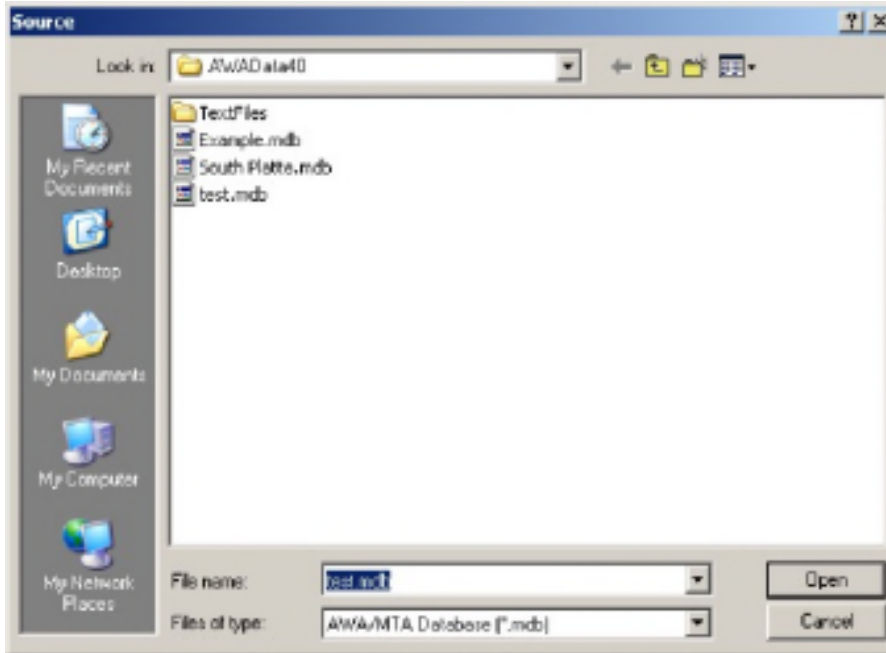
Figure 99. Select source Baker AWA-IV database

When the source database has been chosen, click the **Open** button. The *Data Transfer* window appears with the source database opened on the left side. This is the same Motor ID tree structure as used elsewhere in the software.
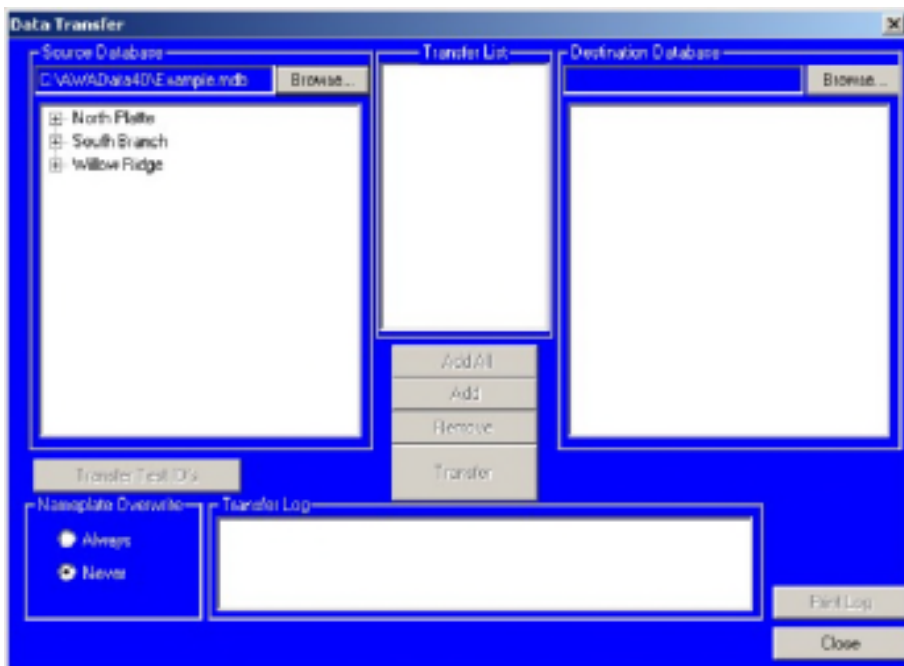
Figure 100. Data transfer source selection.

After the *Data Transfer* dialog is displayed, click on the destination database **Browse** button to locate the destination database. A destination file open dialog box appears and will default to the same folder used to open the source database.

Choose a destination database to open and click on the **Open** button. The *Data Transfer* window returns with both databases open.
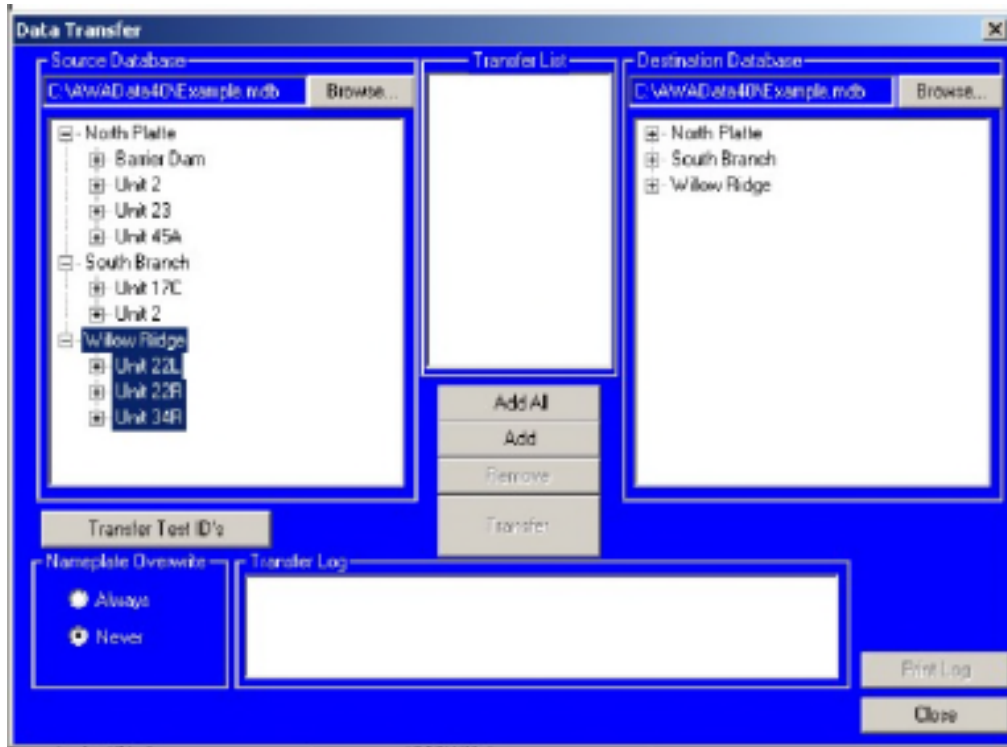
Figure 101.   Data Transfer destination database section.

If either database is not the one you need, click on the **Browse** button next to the database you want to change then locate and select the database needed.

When both the source and destination databases have been open, the **Add All** and the **Add** buttons are enabled.

Highlight the data you want to transfer then click the **Add** button to move them to the **Transfer List**. Alternatively, you can double click on a motor and it will automatically be added.

If you want to add all data, click on the **Add All** button.

The **Transfer List** displays all motors that will be transferred when you click the **Transfer** button.

If there are motors in the **Transfer List** that do not need to be transferred, remove them by selecting the motor(s) and clicking the **Remove** button. When the **Transfer List** is finalized, press the **Transfer** button.

When you click on the **Transfer** button, the software runs through the **Transfer List** adding the motor (nameplate) information if the motor does not exist in the destination database. If the motor does exist, no motor information is added.

The software then adds test records that do not exist in the destination database. It compares the time/date stamp with existing test result records, and if the source time/date equals a test result record in the destination database, it does not transfer the record. If the application does not find a matching time/date, it adds the source test result record to the destination database.

The software creates a log during the data transfer process. Information logged is source/destination database names, Motors IDs added, and number of records updated. If the transfer encounters any problems, it also logs the Motors ID and reason the transfer failed. You can print this log by clicking on the **Print Log** button.

Transferring test IDs

Test IDs are transferred separately from the Motor IDs.

To transfer Test IDs, you will follow essentially the same process described in the "Transferring motor and test result data" section above. The source and destination databases must both be open before any transfer can be performed. When both databases are open, the **Transfer Test IDs** button will be enabled. Click on this button to open the *Transfer Test ID's* window.
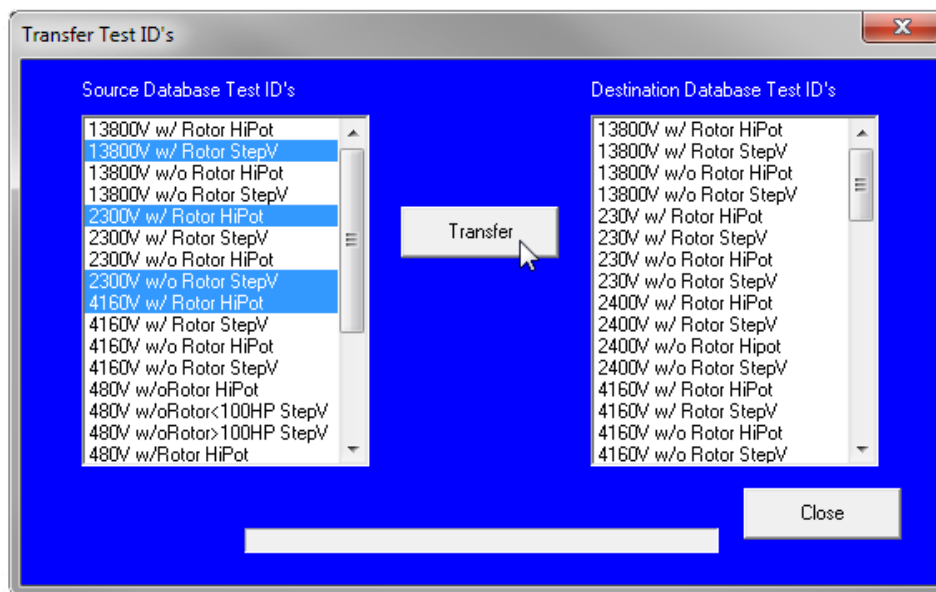
Figure 102. Transfer test IDs.

The window displays all Test IDs in the source database, along with the Test IDs currently found in the destination database. Choose the source Test IDs to transfer by highlighting them. To select multiple IDS, use the shift and control keys on your keyboard while clicking on the Test IDs.

With the desired Test IDs highlighted, click on the **Transfer** button to start the transfer.

The software will transfer (copy) the requested Test IDs to the destination database. If the Test ID exists in the destination database, it will not be transferred the Test ID and the software will display a message stating there cannot be duplicate Test IDs. If this message appears, click on the **OK** button and the transfer will continue. As in the motor and test result record transfer, the application writes to the Transfer Log, recording what action has been taken. When finished transferring Test IDs, click on the **Close** button to return to the *Data Transfer* window.

Archiving a database

The **Archive** feature provides another tool to help you move data. The tool helps you back up and move whole databases from one computer to another. In comparison, the **Data Transfer** tool moves motor/test information from one database to another.

> **NOTICE**
>
> It is important to retain a current backup copy of database(s) on some persistent storage medium such as a CD or flash drive, or a backed up network drive.

Figure 103. Archive.

The archive provides an easy means to backup Baker AWA-IV data. Use the archive option for more than just a backup. It is the best way to put a database on a flash drive or CD to move it from one computer to another. If the archive option is used to copy and compress a database, use the **Restore** option (discussed next in this chapter) to extract the database from the storage device back to a hard drive.

To archive a database, it must be opened in the Baker AWA-IV application.

1) Click on **Database** in the main menu then **Archive**.

2) The *New Archive* window appears showing the default folder, with a zip file extension by default. The **Save in** folder defaults to the path specified by using the **View** menu, **Options** and **File Locations** menu items.

3) Accept the default or browse to the folder where the archived file is to reside.
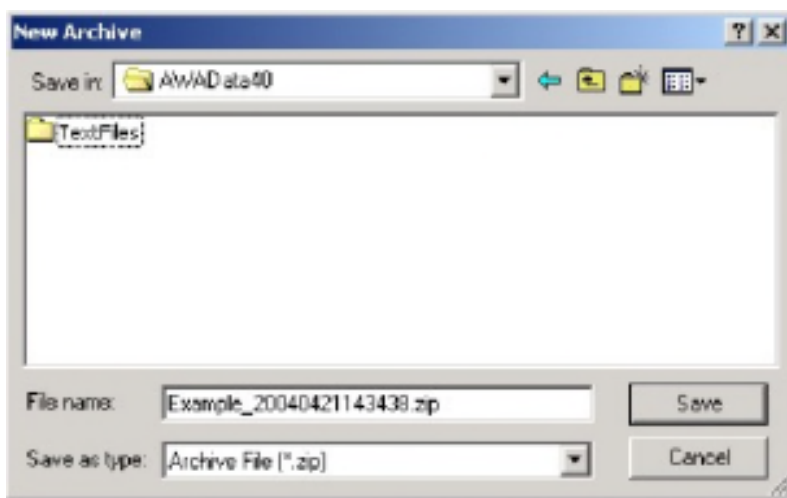
Figure 104. New archive.

NOTE

If the default is the floppy drive or CD-Rom drives make sure there is a diskette/CD in the drive before archiving.

The default name of the archived (zip) file will be a combination of the database name and the time/date of the archive. For example, if the database name is `Example.mdb` then the archived file name will be `Example_YYYYMMDDHHMMSS.zip`. The YYYYMMDDHHMMSS indicates the year/month/day/hour/minute/second when the file was archived.

When the archive is finished, the following message will be displayed.

Figure 105. Archive complete.

It is important to note the location of the archived file (.zip or .cab). Click on the **OK** button to return to the Baker AWA-IV application.

Restoring a database

To view archived data with the Baker AWA-IV software, the database must be restored first. To restore an archived database, WinZip will need to be installed.

1) Click on **Database** then **Restore**.

Figure 106. Restore database menu item.

2) The *Select Archived Database* window appears. Select the database (.zip or .cab file) to restore and open it.
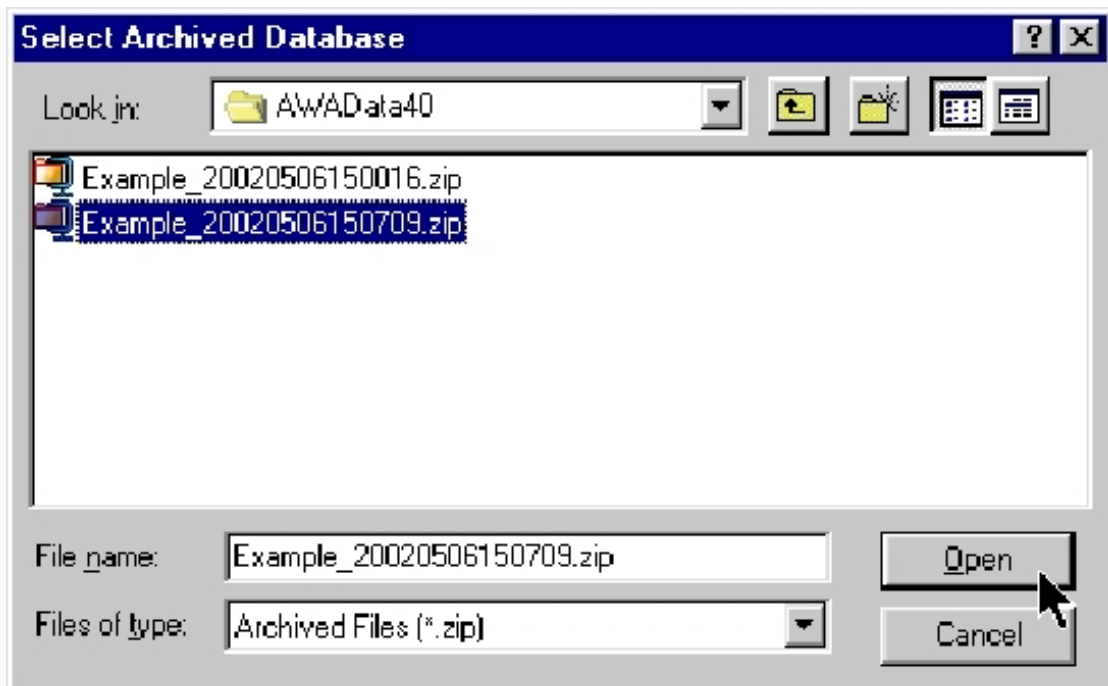
Figure 107. Data transfer buttons.

3) After choosing the archived database to restore, choose the folder to extract the archived database into. If the database is to be restored to a different folder, browse to that folder. When the appropriate folder is located, click the **OK** button.
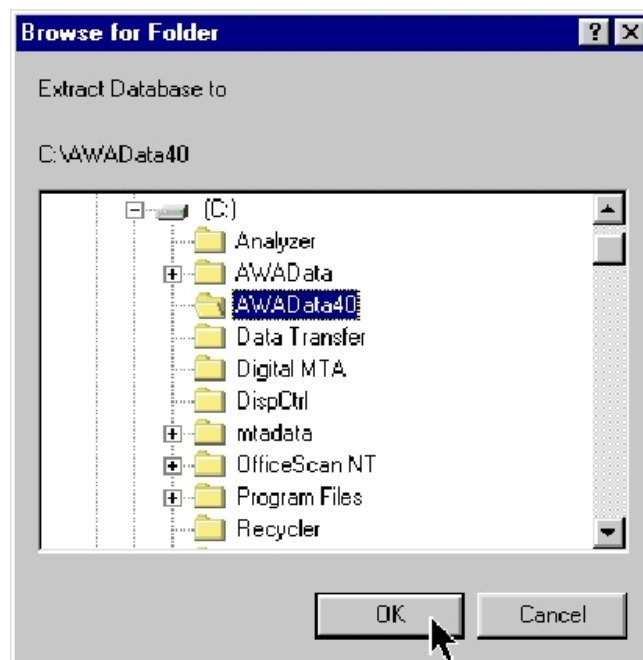
Figure 108. Browse for folder.

The application will extract the archived file. If a database with the same name exists the user will be prompted with the following.
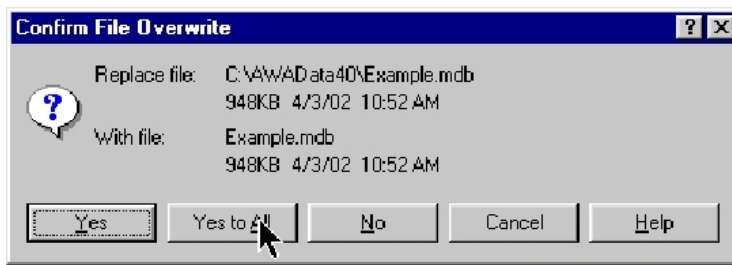
Figure 109. Confirm file overwrite.

Overwrite the existing database by choosing Yes or Yes to All, or choose Cancel if the database should not be overwritten. If the archived database is still needed, rename the existing database through Windows Explorer then restore again, or restore using another folder that does not contain the same named database.

When the archived database is extracted, the software will return to the Baker AWA-IV application's main screen. Choose **File – Open** menu item to open the newly-restored database.

Converting an older database

As of version 4, the Baker AWA-IV software uses a different database structure than prior versions. The test results data are arranged differently, the database keys are different, and several tables have been combined or added in addition to many other improvements. One of the major changes is that the surge data is no longer stored in a separate set of files in a Srg folder; all surge waveform data is now stored in the database.

Care needs to be taken when upgrading to this new version of the database. After installation of the new software, the old databases along with the old Baker AWA-IV software executable will still be on the Baker AWA-IV.

Here are a few suggestions for making the change to the Version 4+ database:

1) Make a backup copy of all old databases. Use WinZip, an older standalone version of the Data Transfer archive feature, or simply use Windows® Explorer® to make a copy.

2) Install the new Baker AWA-IV Version 4+ software.

3) Convert all old databases to the new version by opening each of the old databases with the new Version 4+ software.

4) Verify data has been correctly converted in the new databases. The old software and the old databases will still be on the machine in addition to the new versions.

5) When you are confident that the data is correct, remove the old databases and the old executable from the Baker AWA-IV to avoid confusion as to what version to use. The older version of the AWA can be found in the `C:\AWA` folder with the name `AWA.exe`. The new Baker AWA-IV is in the same folder; however, the version 4+ executable is named `Baker AWA-IV.exe`. To remove the old software, delete the `AWA.exe` and all short cuts to it. The old data is in the `C:\AWA Data` folder. After saving data to an archived folder the AWA `Data` folder can be deleted. As always, it is advisable to keep an archived copy.

If data resides on a network or desktop(s), make sure that all databases, not just those stored on the Baker AWA-IV, have been upgraded. This will ensure the old databases do not get inadvertently used for new testing.

Remove the old AWA executable from all desktop machines to prevent old databases from being inadvertently used.

Converting the data

Version 4+ software stores database files in a different place than prior versions, Database files are now in `C:\Baker AWA-IVData40`. Older versions stored database files in subfolders within `C:\AWAData`. Of course, these locations are the default locations programmed into the software; databases can be stored anywhere on the machine's disk or network.

When using Version 4+ software for the first time, the databases from previous versions will have to be converted. The conversion process happens automatically when the application opens an older database.
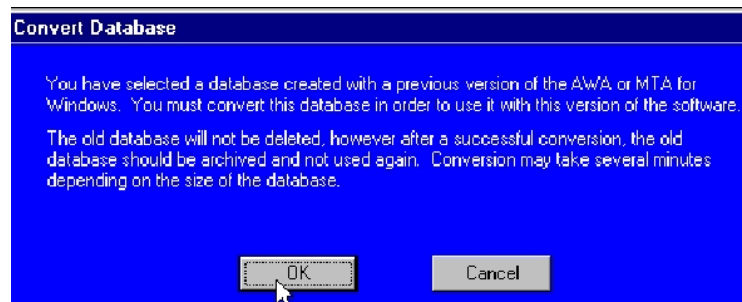
Figure 110. Convert database message.

To open an older database, click on **File** then **Open** and the window will open so you can select the old database from the `C:\AWAData` folder where it is stored.

The software will automatically identify the database as an old database and presents you with the above message indicating the database will be converted.

The Version 4+ software then opens a *Convert Database Into* window with a new database name filled in: the new name is the old one with a `_Rev4` appended to it. The database name can be changed to whatever is desired; however, it is recommended that a consistent naming convention and an unambiguous location be used.
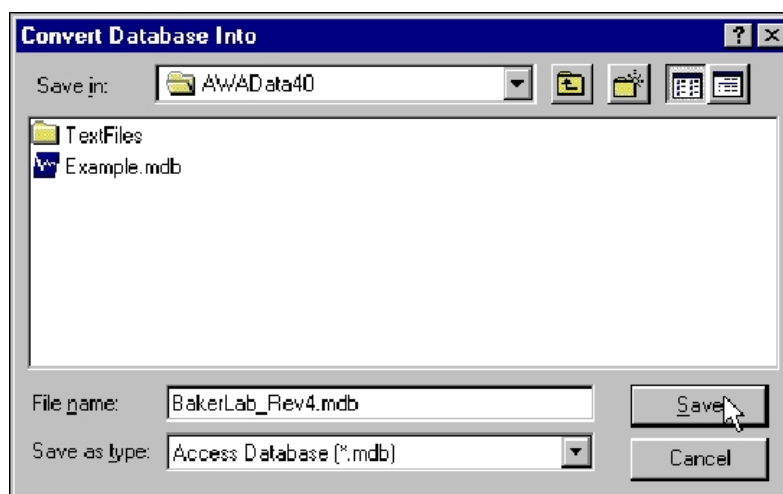
Figure 111. Convert database information.

After a file name is entered, click the **Save** button. The conversion will begin immediately. All Test IDs, Motor IDs and test result data will be converted. When the conversion is concluded the application will open the converted database.

9 Motor testing theory and reference

Coil resistance testing principles and theory

Temperature compensation

The effect of temperature on both copper resistance and ground wall resistance can be substantial. Knowledge of temperature is especially important if test data is to be compared or trended to previous measurements. The temperature is entered manually into the AWA from acquired temperature readings of a third party device. The AWA will correct the coil resistance tests to 25°C(per IEEE 118) and the IR (insulation resistance/Meg-Ohm) reading to 40°C per IEEE 43. The effects of temperature will be discussed further in each section below as it applies to each test.

Principles of coil resistance testing

The coil resistance test is simple to perform and is an immediate indication of the health of the conductor(s) in a winding. The coil resistance test involves an injection of a known constant current through the winding, and then measurement of any voltage drop or delta across the winding. The coil resistance is then calculated using Ohm's law. If a coil is shorted somewhere in the winding's interior, the resistance will be lower than normal. You can compare the coil resistance test result to previous measurements of the same coil, measurements of identical coils, or to the motor nameplate value to identify a bad coil.

Variations of wire conductivity associated with the winding's temperature can affect measured resistance. Measured resistance values should be corrected to reflect conductivity at a common temperature, usually 25 °C (77 °F), before comparisons are made between two measurements. See IEEE 118 for more information on correcting resistance measurements to 25 °C (77 °F).

Windings can be made with both copper and aluminum. The variation of resistivity to temperature is different for each material. Therefore, the wire material must be known before compensating resistance to 25°C/77°F.

Because windings found in many motors have very low resistances, an injected current might have to be as high as several amps to accurately measure any voltage drop across the coil. One of the difficulties encountered with measuring voltage drop across the coil itself is the effect of the contact resistance of clip leads used to connect to the motor's winding. Contact resistances can be comparable or even greater than the resistance of some coils.

Indications of problems in a motor

If the resistance readings are significantly different from the motor nameplate data, or if 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 substantially higher, there can be other problems, such as one or more of the following:

- A loose or corroded wire nut connection
- An incorrect amount of turns or incorrect wire gauge used during a rewind job
- An incorrect gauge of cable/feeder used from motor control to motor terminals
- Poor or incorrect solder technique used to connect phases
- Phases/Coil groups are misconnected

Inductance, impedance, and phase angle measurement principles and theory

The windings in a motor form magnetic poles, which allow the motor to generate torque. For AC induction motors, the magnetic field from the stator windings interacts with the magnetic field of the squirrel cage rotor to generate a shaft torque. For DC motors, the interaction of the magnetic field from the stator field winding and the rotating armature winding also generates a shaft torque. Likewise, the interactions of the fields generated by the windings of a synchronous motor create shaft torque. The common agents in the different designs of these motors are windings—loops of wire that, along with a current, create a magnetic field.

Windings—loops of wire—have physical properties of inductance and resistance. Each specific coil or winding will have a characteristic inductance as well as resistance. Reason would suggest that a problem in a winding should show up as a change in inductance and resistance. Therefore, measurements of inductance and resistance are made to evaluate the winding's overall health; more specifically, to evaluate the winding's ability to create a magnetic field.

A short review of inductance and impedance in general is appropriate. In general, if a coil with N windings is excited with a voltage source V, there will be a current I drawn from the source.
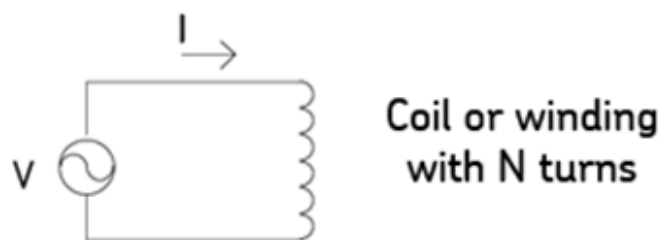
Figure 112. Basic coil winding schematic.

Just how much current flows through the coil, and the phase relationship between the voltage and the current depends on the resistance of the coil's wire, geometry of the coil, the number of coil turns, as well as the magnetic permeability of the material in the coil's vicinity.

A graphical representation of the voltage and current is shown below:
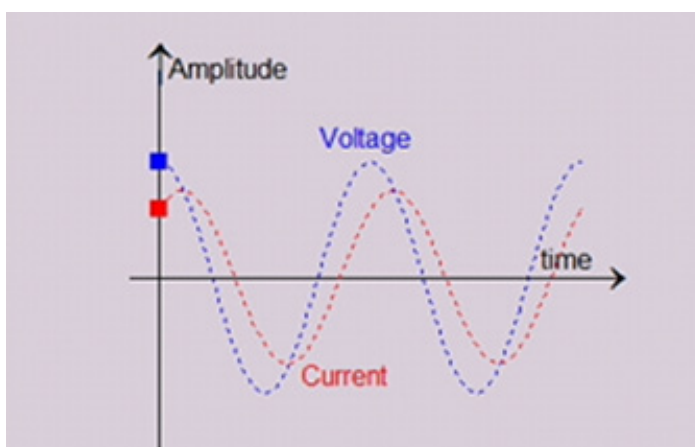
Figure 113. Representation of voltage and current over time.

Note the phase shift between the voltage and current. The ratio of the voltage and current amplitudes along with this phase shift are used to determine the coil's impedance.

The voltage and current are related by a "complex" impedance Z defined as:

$$Z = \frac{V}{I}$$

The impedance Z will have a component in phase with the voltage (called the real part) and a component (called the reactive part).

$$Z = R_{real} \; jX_{reactive}$$

The real part of the impedance not only represents the component of current in-phase with the applied voltage, it represents the part of the coil's impedance that absorbs power. The reactive part of the impedance represents the ability of a coil to make a magnetic field. So, finally, the motivation for measuring a coil's impedance is clear: the ability of a coil to make a magnetic field, which is so important to the operation of a motor, is represented by the reactive component of the impedance of a coil.

Specifically, the measurement of inductance, which is proportional to the reactive impedance, is most often used when measuring a coil's inductive or magnetic properties. The reactive impedance (X) and inductance of a coil (L) are related as follows:

$$L = \frac{X_{reactive}}{2\pi f}$$

where f is the frequency of the source. By measuring the changes in the inductance L, changes in the coil's ability to make a magnetic field are determined. From a physical standpoint, the number of turns in a coil, the material properties surrounding the coil (that is, the motor core), and the shape of the coil all combine to determine the coil's inductance. The following equation shows how these parameters combine to determine a coil's inductance:

$$L = A_{physical\_geometry} \; B_{material\_properties} \; N^2$$

where the constant A describes the physical shape of the coil, the constant B describes the material properties of the coil's core, and N describes the number of turns in the coil. For example, a solenoid's inductance is found to be:

$$L = \mu_r \mu_0 N^2 \frac{A}{l}$$

where μ0 is the magnetic permeability of air, μr is the relative permeability of the coil's core (approximately 1000 for electrical steels), N is the number of turns, A is the solenoid area, and l is the solenoid length.

There are other formulas for a coil's inductance, but the key thing to take away from these formulas is the contribution to the inductance value from the physical shape of the coil, the contribution to the inductance from materials properties, and the contribution to inductance by the number of turns (squared).

A motor's designer carefully chooses the shape and turn count of the coil along with the core material to generate the magnetic field required to produce the desired motor shaft torque.

From a maintenance point of view, changes in inductance represent changes in turn count or changes in properties of the motor's core.

To summarize, a motor's inductance can be used to "measure" the ability of a motor to operate. In a perfect world, an inductance measurement would be a great way to precisely perform motor diagnostics. However, the world of a real motor is not as simple as our description might lead you to believe; we'll discuss more about the realities of inductance testing later.

Measuring a coil's inductance

To make a coil's inductance measurement, the voltage across the coil and the current through the coil are measured. However, just the amplitudes of the voltage and current are not sufficient to get coil inductance; the phase difference between the voltage and current is also required. Practically, a voltage amplitude measurement and the voltage phase with respect to some fixed phase reference are measured. Describing the voltage cosine of a certain amplitude and phase is shown in the following formula:

$$V(t) = V_0 \cos(\omega t + \alpha)$$

where V0 is the nominal voltage, ω is the angular frequency, τ is time, and α is the phase angle of the voltage with respect to a reference. For notational convenience, the voltage is often written in a vector notation as:

$$V = V_0 < \alpha$$

The current through the coil is described as:

$$I(t) = I_0 \cos(\omega t + \beta)$$

where I0 is the nominal current, ω and τ are as before for voltage, and β is the phase angle of the current with respect to the same reference as voltage. Again, for notational convenience, the current is written in vector notation as:

$$I = I_0 < \beta$$

This kind of vector notation is expressed as "voltage at an angle alpha" or "current at an angle beta."

The impedance of a coil is completely described by the ratio of voltage and current along with the phase relationship between the two. The impedance is written as:

$$Z = \frac{V_0}{I_0} < (\alpha - \beta)$$

Using the notation above, a proper impedance or inductance measurement will require measuring the following four items:

$$V_0, \alpha, I_0, \beta$$

From these four parameters, the true AC impedance of a circuit is measured precisely as described in the equations above, which yields an accurate terminal inductance.

The effect of temperature on inductance measurements

Unlike DC coil resistance tests where the change of resistivity of the wire is well known, the change in inductance as temperature varies is not well known. The core material properties, which have such a strong effect on inductance measurements, are not well established in terms of how those properties change with temperature. To make the inductance measurement even more imprecise, the magnetic permeability of electrical steel also varies from one part of the lamination sheet to another part just due to the way the lamination sheet is fabricated. Therefore, there is no option to "temperature correct" inductance measurements.

Uses of the inductance measurements

Finding a hard turn-turn fault

The simplest application of inductance measurements is to determine if a winding has hard shorts. The idea is fairly simple: a serviceable winding will have a normal—or nominal— inductance related to the number of turns in the winding:

$$L \propto N^2$$

A winding with a short between two adjacent turns would have a decreased inductance of:

$$L \propto (N-1)^2$$

For example, a stator made of form wound coils (eight turns per coil, five coils per group, and four groups per phase) has 8 x 5 x 4 = 160 turns in a phase leg. With just one turn shorted, the phase leg would have 159 turns. The percentage change in inductance would be:

$$\Delta L = \frac{160^2 - 159^2}{160^2} \, 100 = 1 \cdot 25\%$$

To identify a hard short, compare inductance readings that should be the same. For example, measure the phase to phase inductances of the three phases of an AC induction machine's stator (without the rotor installed). If the stator is form wound, all three inductance readings will be very close to the same. If not, there is the possibility of a hard short in one of the windings.

From the example above, it is clear that the inductance measurement has to be very accurate. In practice, the inductance measurement is influenced by material properties of the core, the saturation state of the core, temperature effects, and so on. It's tough to declare a winding bad when inductance measurements are within a few percentage points of each other. If the stator is random wound, but of the lap winding type, the inductances should be close if the winding is short free. With a short present in the random wound winding, there can be a very large change in the inductances observed because of the possibility of the first and last turns being shorted. If the stator made of concentric coils, there will be a known inductance variation because the concentric windings are not all exactly the same shape. Unfortunately, the spread in inductance readings due to the slightly different coil lengths make it very difficult to declare a winding to have a short or not.

To summarize, inductance values can be used to determine hard shorts in some motor windings, but not all. Knowledge of the windings is important before passing judgment on a winding's integrity.

Example: the inductance of a GE 350HP 1750RPM 7kV stator with a short was measured at 60Hz and 1000Hz. The data is shown below:

Table 1. *OD #2 at 60Hz inductance.*

	L	L(%)	D	Z	Phase
L1-L2	168.38	1.30063	0.994	63.79	84.32
L2-L3	170.57	0.184675	0.075	64.48	85.7
L3-L1	170.255	1.101289	0.0839	64.41	85.206

Table 2. *OD #2 at 60Hz inductance.*

	L	L(%)	D	Z	Phase
L1-L2	167.75	1.675112	0.0206	985.117	88.8
L2-L3	170.56	2.884615	0.009	1071.73	89.5
L3-L1	165.64	1.273847	0.0128	1040.86	89.26

The bar chart below shows the percentage "change" in inductance between phases of this wye-connected motor. Along with the inductance percentage values, the line-to-line error area ratio (EAR) surge test values for the same motor are also shown.
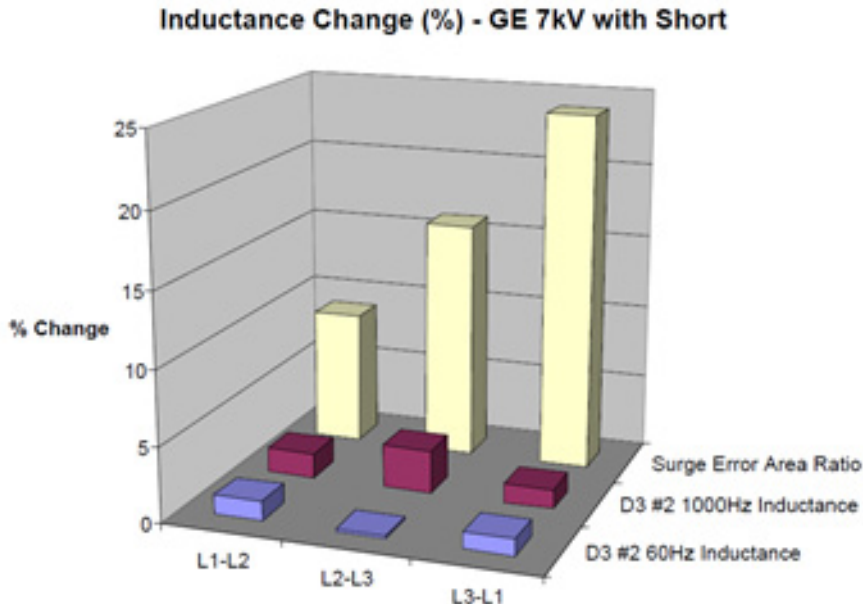
Figure 114. Percentage "change" in inductance between wye-connected motor phases.

Clearly, there is a change in inductance that is measurable for the stator with a short. The change shows up in inductance measurements at both 60Hz and 1000Hz. It is also clear from this chart that there is a much greater change in L–L EAR values of the stator with the surge test, making the surge test a much more sensitive method for finding turn shorts in windings.

Rotor Influence Check (RIC) testing theory

The theory of the RIC test is based in the fundamentals of an AC induction motor. AC induction motors are constructed with a stationary winding wound on the stator with a rotor containing a "squirrel cage." The squirrel cage winding acts like a transformer secondary where a current will flow; but in this case, the secondary is allowed to rotate. The interaction of the magnetic fields caused by the squirrel cage current and the stator current creates a torque on the rotor that makes the rotor spin. The genius of this design is that the stator currents are the agent that—through the transformer effect—induces the currents in the squirrel cage.
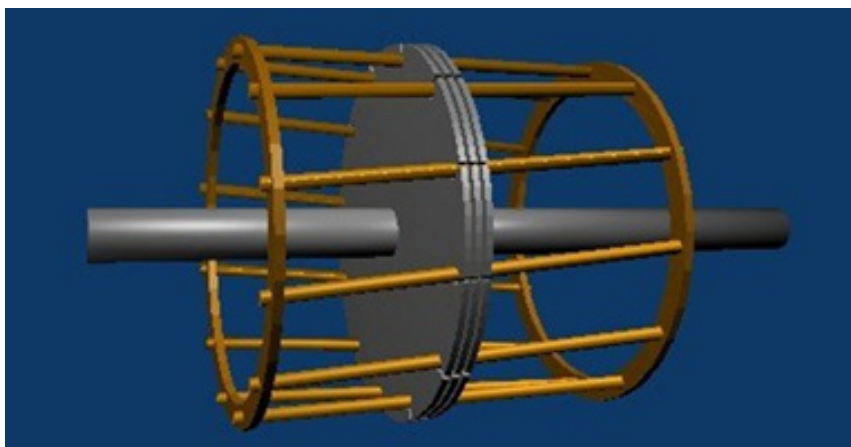
Figure 115. Squirrel Cage Illustration (from Wikipedia).

An AC induction motor is similar to a transformer, so a quick reminder of how a transformer works is in order. A normal transformer will behave such that the impedance of the secondary circuit will appear as impedance in the primary circuit. For example, if the secondary of a transformer is shorted, the primary will also appear to have a short. Likewise, if the secondary of the transformer is left open, the primary will also appear to be open. In general, if some resistance is placed in the secondary, a resistance will appear in the primary; but the value will be different than the actual secondary resistance value. (The primary resistance value is the ratio of the primary and secondary turns squared times the actual secondary resistance.)

$$R_{primary} = \left(\frac{N_1}{N_2}\right)^2 R_{secondary}$$
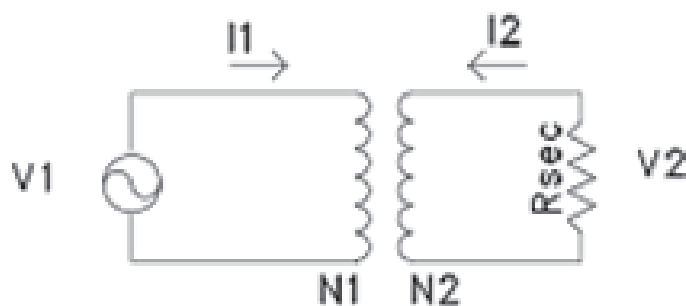
Figure 116. Basic transformer schematic.

Because the squirrel cage is a transformer secondary, it stands to reason that the impedance of the squirrel cage should "transfer" to the primary (stator) of the motor. Clearly, the squirrel cage looks like a short, so a short should also "appear" in the stator circuit. But if the secondary winding (rotor) is broken, no short will appear in the primary circuit. There are several "bars" in the squirrel cage, so if just one bar is broken, the stator impedance should look like "a little less of a short."
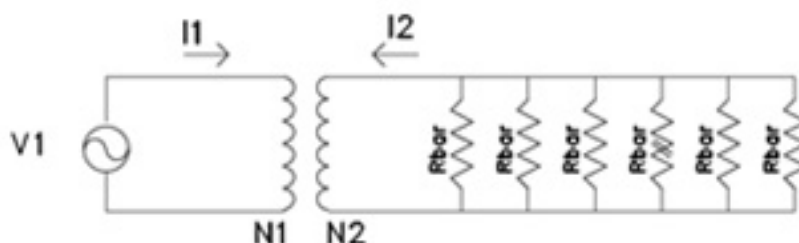
Figure 117. Transformer model of a rotor in an ACIM.

This small change in stator impedance is the concept behind using stator measurements to find problems in the rotor.

In addition to broken rotor bars, RIC testing advocates claim that other issues with the rotor promoted can be identified. If the rotor is placed in the stator bore so that the rotor is not centered, there will be a difference in "transformed" impedance observed at the stator leads for each of the three phases. Also, if the rotor "wobbles" inside the stator bore, then a difference in stator impedance will also be observed.

In summary, the RIC test is reportedly able to find three rotor problems:

- Static air gap eccentricity
- Broken rotor bars
- Dynamic air gap eccentricity

To actually perform a RIC test, inductance measurements at the stator terminals are made in shaft angle increments of 5 or 10 degrees. The resulting inductance measurements are then plotted: inductance on the Y axis and shaft angle on the X axis. A typical plot is shown below:
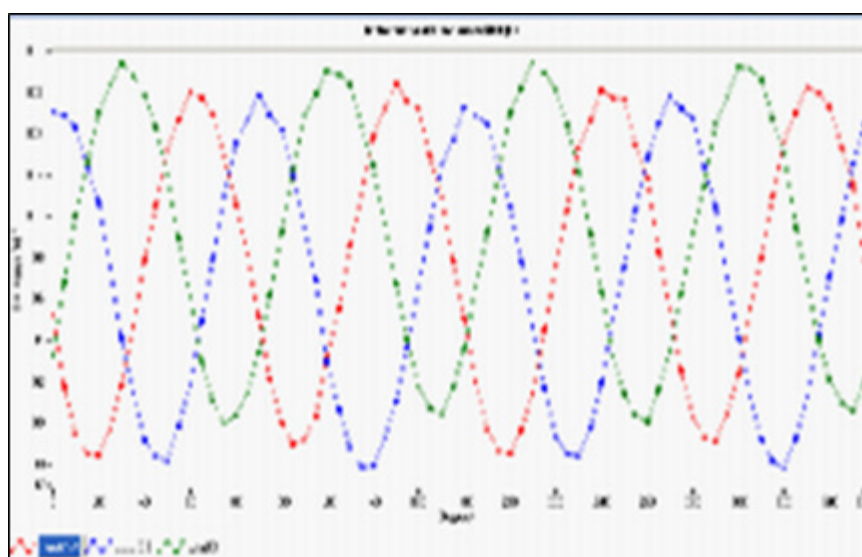
Figure 118. Typical RIC test curves.

A plot of a motor with a broken bar is shown below. Note how the plot of inductance vs. rotor position is erratic and not as uniform as the plot above.
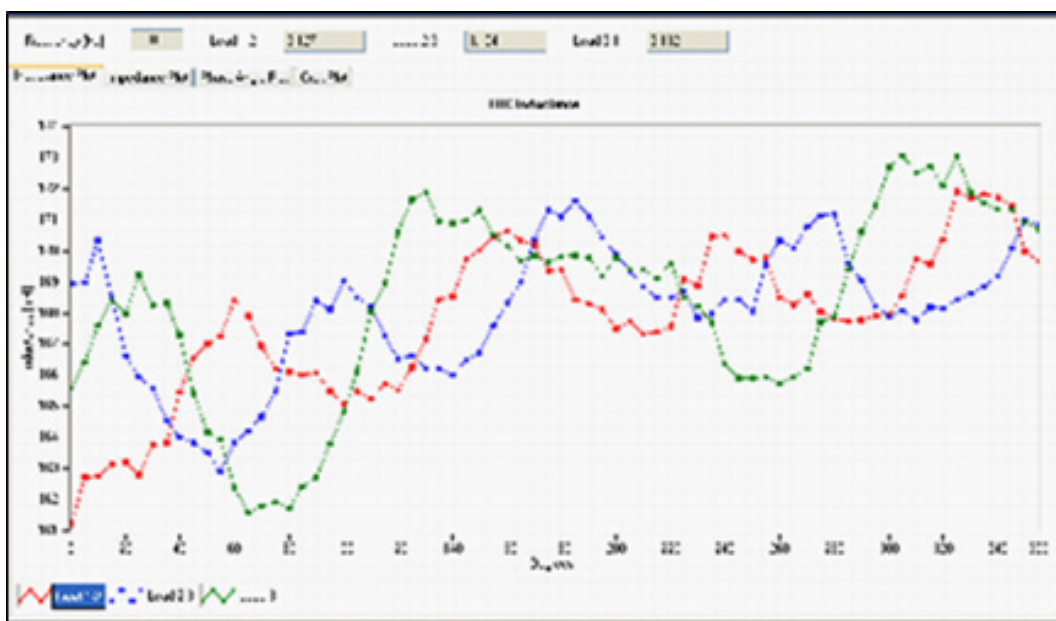
Figure 119. Dayton 5hp (B2) with drilled bar: inductance measurements.

There are problems with RIC testing. Namely, the test is quite unreliable and either misses rotor issues or declares there is a problem where there really isn't one. For example, the RIC test curves shown below are from a motor with a bar drilled in several places as shown in the photo that follows the graph.
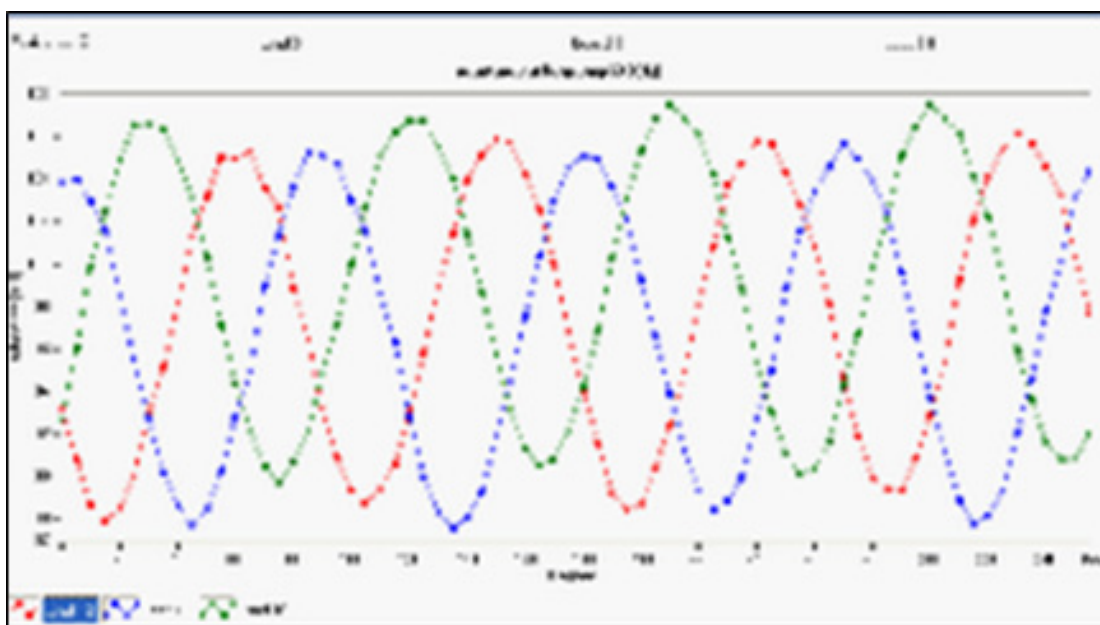
Figure 120. Delco 3hp after running under full load. Curves do not suggest a broken rotor bar.
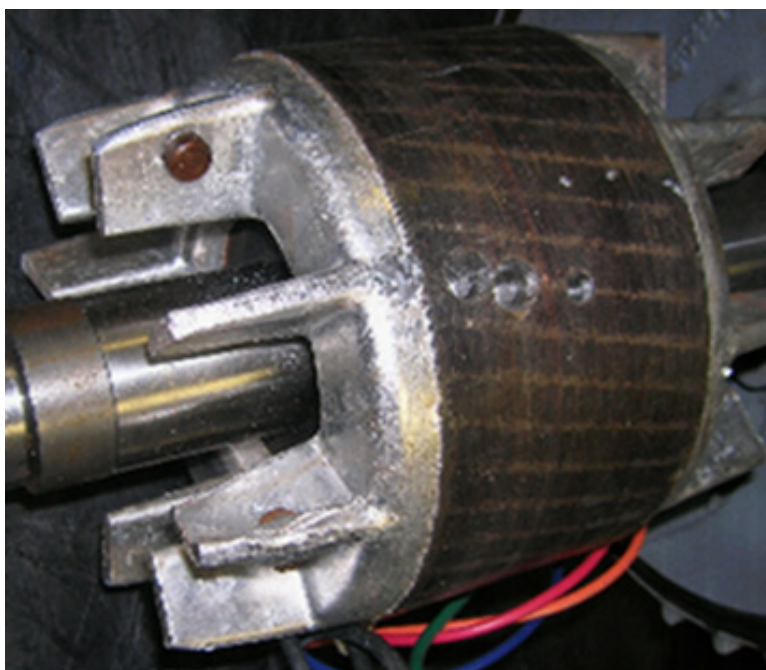
Figure 121. Delco 3hp showing rotor bars drilled completely through

Great care must be taken before using the RIC test to condemn a motor. The load of the motor at last shutdown, eccentricity, and steel material properties all influence the RIC test; so much so that reliable rotor bar detection is difficult.

DC motor armature bar-to-bar resistance and impedance test

The DC resistance and the AC impedance of adjacent bars of a DC motor's armature can identify shorted turns within the armature winding. However, armatures are very unique windings in the sense that every bar on the commutator is in parallel with all the other bars. Because the bars are all in parallel, the DC bar-to-bar resistance will be very low: milliohms or even smaller. Likewise, the bar-to-bar inductance will be very low: microhenries or smaller.

Due to the low DC resistance and low inductance observed, a four-wire measurement is required when making bar-to-bar measurements. If a simple two-wire measurement is made, there will be severe errors in the data—with the errors of many 100s of percent possible.

The indications of a shorted coil in the armature are a drop in the DC resistance between the adjacent bars, and a drop in the inductance between the bars. An example of just such a short is provided below. Two bar charts are shown of the bar-to-bar resistance and inductance. Note how the bar-to-bar resistance goes to zero when testing the bars with the shorted coil. Also, the inductance value drops to zero. In general, the resistance / inductance vs. bar number plots will have some variation, as shown below. However, bars with shorted coils will be obvious.
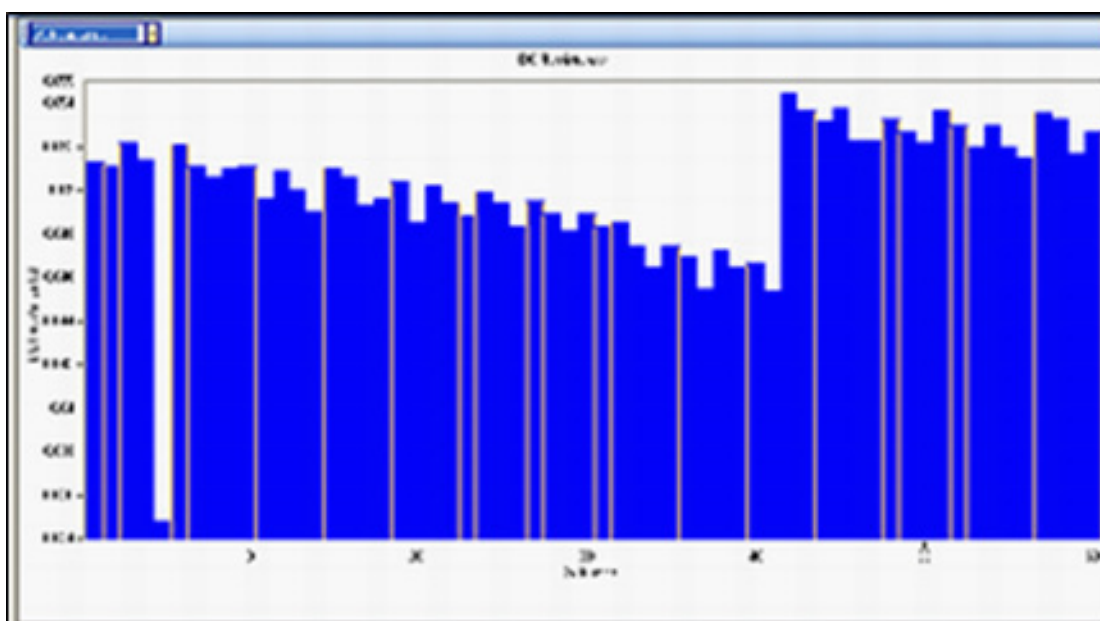
Figure 122. Example 1—graph of resistance and inductance done on a PC.
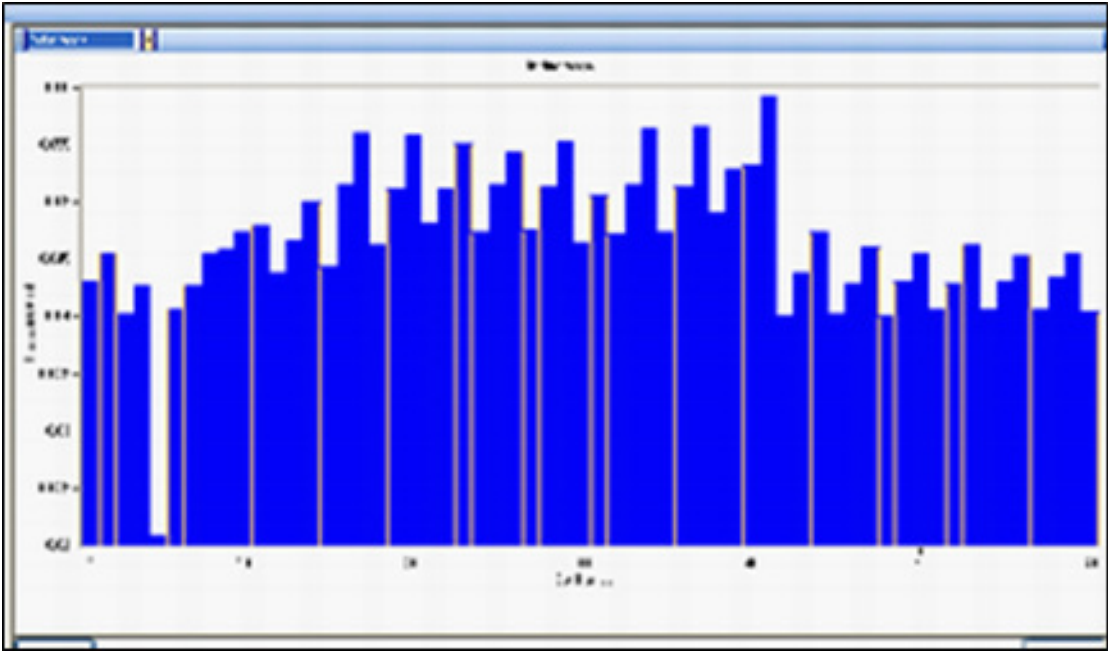
Figure 123. Graph of resistance and inductance done on a PC.
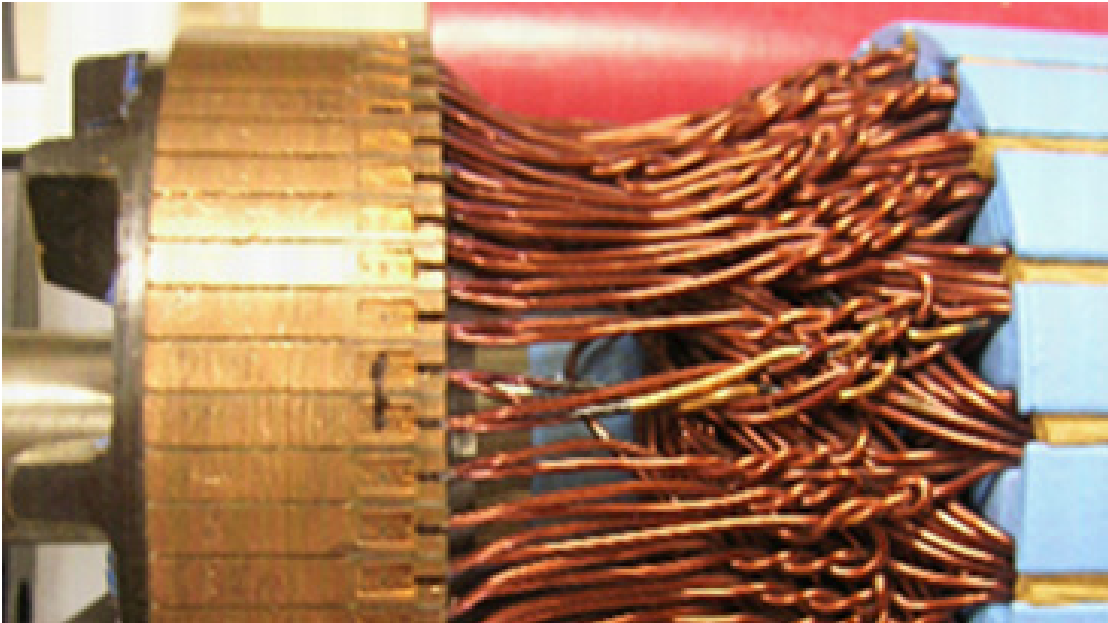
Figure 124. Example of a burned coil.

DC motor interpole coil testing

Like any other winding, the resistance and inductance of interpoles (from DC motors) can be used to look for the presence of shorts in the coils. Normally, there are two, four, or six interpoles in a DC motor. The general idea is that all interpole coils should have nearly the same resistance and inductance values.

Figure 125. Interpole coil.

> **NOTICE**
>
> Often, the interpoles are removed from the stator during a DC motor refurbishment. The interpoles are placed on a cart or work surface where they are also refurbished. When making the inductance measurement, the environment of the coil has a significant effect on the inductance value. All of the coils should be placed in the same place on a work surface that has no steel in the area. Even a brad or nail in a wooden shop bench top can change the inductance value of a coil.

The test results below show resistance and inductance data from four identical interpoles.

Table 3. *Test results from four identical interpoles.*

Interpole	DC Resistance (milliohms)	Inductance (microhenries)
1	8.214	69.2
2	8.214	88
3	8.218	77.4
4	8.218	69.3

The resistance measurements show that all four coils are basically the same. However, the inductance values show some variability, which suggests a problem with the coils. In this case, the variability was caused by tools located near the coils and steel support legs supporting the wooden workbench top. If proper measurements are made, a change in inductance will follow a change in the DC resistance; confirming a real short in a coil.

> **NOTICE**
>
> If the interpoles are left mounted in the stator and inductance measurements are made of each individual coil, L value differences caused by variations in the stator steel can be observed. Before condemning a particular coil, ensure that you are confident in the integrity of the measurements.

DC testing principles and theory

High-voltage DC testing of electric motors determines the integrity of the ground wall insulation system of a motor's winding. The ground wall insulation system consists of the wire's insulation, slot liner insulation, wedges, and varnish.

Before going further, we need to discuss the meaning of a "HiPot test." The label "HiPot test" describes the general idea of high-voltage testing and describes a specific type of high-voltage insulation stress test. One must differentiate between the concept of HiPot testing and the specific HiPot test based on the discussion's context.

To perform any of the high-voltage DC tests the red test leads from the tester connect to the motor's three-phase coils and the black test lead connects to the motor's steel core/frame. The voltage on the red test leads raises to a predetermined test voltage. 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.

Megohm test

The megohm test applies a DC voltage to the windings of a motor after first isolating the winding from ground. Usually, you choose the test voltage to be at or near the motor's operating voltage (see IEEE 43).

The purpose of the megohm test is to accurately measure the insulation resistance of the ground wall insulation. The insulation resistance (IR) is a function of many variables: the physical properties of the insulating material, temperature, humidity, contaminants, and so on.

We calculate the IR value using Ohm's law, dividing the applied voltage by the measured leakage current:

$$IR = \frac{Applied\ voltage}{Measured\ leakage\ current}$$

This leakage current is the current that is actually able to pass from the winding through the ground wall insulation to the motor's steel core plus any surface leakage currents that flow through moisture or contaminants on the insulation's surface. To accurately determine the insulation resistance, you must reduce the surface leakage to an inconsequential level. The winding might need to be cleaned or heated to evaporate any moisture on its surface.

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, and so on. We can compensate for the effects of temperature by converting the IR value to a standard temperature of 40 °C (104 °F), as shown later in this chapter. The effects of humidity and contaminants cannot be readily taken into account. You must use good judgment when analyzing IR values from motors that may be wet, dirty, loaded with carbon dust, and so on.

A suggested test voltage for the megohm test is 1.7 times the applied/operating line voltage for the motor. For example, a 480 V motor would be tested at 480 V × 1.7 = 816 V DC. You can also find recommended test voltages in IEEE 43-2000, NEMA MG-1-1993, and EASA technical manuals. Test voltages near the line-to-line operating voltages are often used. For example, 480 V class motors would use 500 V; 2300 V class motors would use 2300–2500 V; 4160 V class motors would use 4000–5000 V.

When first applying the voltage to a motor or when increasing the voltage, you will observe an unusually high current. 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. We usually call this capacitor the "machine capacitance."

Polarization index (PI) test quantitatively

The polarization index (PI) test quantitatively measures the ability of the ground wall insulation to polarize. The PI test is the most confusing DC test due to the subtleties involved in interpreting its 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," (or "absorption current)" develops, adding to the insulation leakage current. The test results become confusing when attempting to attribute variations in the PI value to the polarization ability of the insulator or other affects such as humidity, moisture, and instrument error.

We typically perform the PI test at the same voltage as the megohm test. It takes 10 minutes to complete.

We calculate the PI value by dividing the IR at 10 minutes by the resistance at one minute, as shown below:

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

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:

Table 4. *IEEE 43 Minimum acceptable values for thermal classes.*

NEMA Class	Minimum Acceptable Values
NEMA Class A	1.5
NEMA Class B	2.0
NEMA Class F	2.0
NEMA Class H	2.0

NOTE

Always consult any standard's most recent edition (IEEE 43 in this case) for the latest minimum values and accepted practices.

The tester will automatically calculate the PI value at the end of a 10-minute test. At the test's conclusion, you may store the PI value in the tester for later recall.

Effects of temperature

Temperature has a 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).

Insulation resistance drops in half for every 10 °C (18 °F) rise in temperature. Therefore, before making any judgments regarding the health of a motor's insulation based on a trend of past megohm measurements, all measurements used in the trend should be compensated or corrected for temperature. The temperature compensation of the insulation resistance means the user must convert all the IR measurements used in the analysis to the same temperature. The recommended temperature to use is 40 °C (104 °F). Use the following formula to make the calculation:

$$R_c = \left[(1/2) \wedge \left\{ \frac{40-T}{10} \right\} \right] \times Rr$$

For example, if an insulation resistance/megohm value is 5,000 megohms at 30 °C (85 °F), the compensated IR value at 40 °C (104 °F) is 2,500 megohms.

Some insulating materials developed in recent years for wire insulation do not readily polarize. For example, the newer inverter grade wire insulation does not significantly polarize. As recommended in IEEE 43, if the one minute insulation resistance is greater than 5,000 megohms, 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, you 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.

Dielectric absorption (DA) test

We often substitute the dielectric absorption (DA) test for the PI test for the following reasons:

- Some insulation systems do not polarize, or polarize so fast the process is not observed
- Some motors are so small that a PI test will offer no useful information
- Some motors have such a small total current leakage that it is not possible to resolve the polarization current
- Sometimes users do not have or do not want to take the time to perform the full requisite 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 one minute, the DA test is the IR ratio at three minutes and 30 seconds:

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

There are no accepted minimum or maximum values of the DA test, and the DA value often appears to be subject to trends.

> ### NOTE
>
> Other times can be used for DA testing. Always consult any standard's most recent edition (IEEE 43 in this case) for the latest values and accepted practices.

Any change in the DA value indicates that something is changing in the ground wall insulation system. The stator may be contaminated or wet, and the stator may also be running hot and burning insulation. Usually, changes in the DA accompany a change in one of the other recognized tests, such as the megohm test, PI test, or the DC over-voltage test.

High potential (HiPot) test

The high potential (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 applies a DC voltage to the machine's windings as in a megohm test, but at a higher voltage—usually more than twice the voltage of the motor's operating voltage. Therefore, we often call the HiPot test a "proof" test. The insulation resistance value at the high applied voltage is not of much interest with the HiPot test. What is of interest is the value of the leakage current and, more specifically, whether the observed leakage current is within acceptable limits.

The choice of test voltage depends on whether we are testing a new motor (or coil) for acceptance, or whether we are testing an existing motor for continued service. Consult your organization's policies regarding the HiPot test voltage to use. The simple formula of "2V + 1,000" generally results in a good test voltage for the HiPot test for motors already in service. You can find other recommended HiPot test voltages in IEEE 95, ANSI C50.10-1977, IEC 34.1, and NEMA MG-1.

The HiPot test usually lasts one minute with the leakage current recorded at the end. Record the leakage current at the end of this minute for future comparisons. Between the time when the voltage is applied to the motor and the time when the leakage current measurement is taken, you should carefully observe the leakage current and watch for any variances in leakage current that may indicate weak insulation. You should consider such variations an insulation failure.

Step voltage test

The Step Voltage test is performed to a voltage of what the motor typically sees during starting and stopping. The test voltages are governed by IEEE and are posted below for reference.

> **NOTE**
>
> IEEE references NEMA MG 1-2006 Part 12, Page 2 and states that in no case should the test voltage be less than 1500 volts.

The DC voltage is applied to all three phases of the winding, raised slowly to a preprogrammed voltage step level, and held for a specified time period. It is then raised to the next voltage step and held for the specified time period. This is continued until the target test voltage is reached. Typical steps for a 4160-volt motor are 1000-volt increments, holding at one minute intervals. For motors less than 4160, the step voltages should be 500 volts. An example step test sequence is provided in the following illustration.
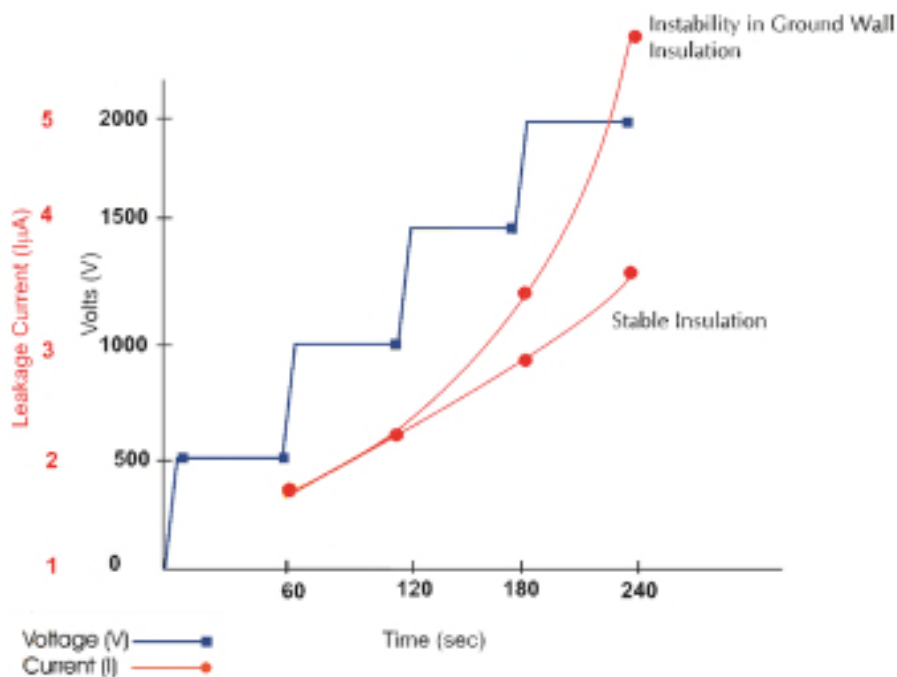
Figure 126. Step voltage test example.

Data is logged at the end of each step to ensure that the capacitive charged polarization current is removed and only the real leakage current remains. This process ensures a true indication of the ground wall insulation condition.

If the leakage current (IµA) doubles at this point, insulation weakness is indicated and the test should be stopped. If the leakage current (IµA) raises consistently less than double, the motor insulation is in good standing.

The step voltage test is necessary to ensure that the ground wall insulation and cable can withstand voltage spikes encountered during normal operation.

Surge testing principles and theory

Surge tests detect insulation damage between turns within a motor's winding; there is no other test or way to determine if this type of insulation problem exists. A surge test applies a high-current impulse to a winding using a fast rise time, which 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, it will produce an arc between the wires. You can detect the arc 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 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 increases.

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

The coil will respond to the surge pulse with a ringing or damped sinusoidal waveform pattern. Each coil has its own unique signature ringing or wave pattern, which can be presented on a test display screen as shown below.
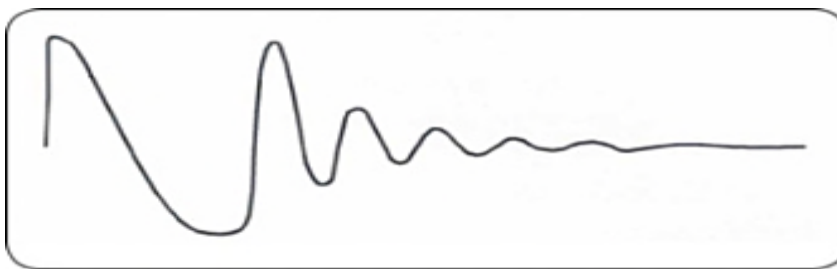
Figure 127. Ringing wave pattern resulting from surge testing.

The wave pattern observed during a surge test directly relates to the coil's inductance. (Other factors can influence the wave pattern, but inductance is the primary.) The coil becomes one of two elements in what is known as a "tank circuit," which is an LC-type circuit made up of the coil's inductance (L) and the surge tester's internal capacitance (C).

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

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

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

A surge test can detect a fault between turns due to weak insulation. If the voltage potential is greater than the dielectric strength of a turn's insulation, one or more turns may short 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 increase the frequency of the ringing pattern from the surge.

The voltage or amplitude of the surge wave pattern also reduces due to the decrease in inductance of a coil with a fault between turns. The following formula determines the voltage (where the current (i) varies according to time (t):

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

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, misconnections, or open connections. A surge test also performs partial ground wall testing 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.

Surge test display

A complete surge test screen is provided below for reference. The Baker DX was used to generate this example.
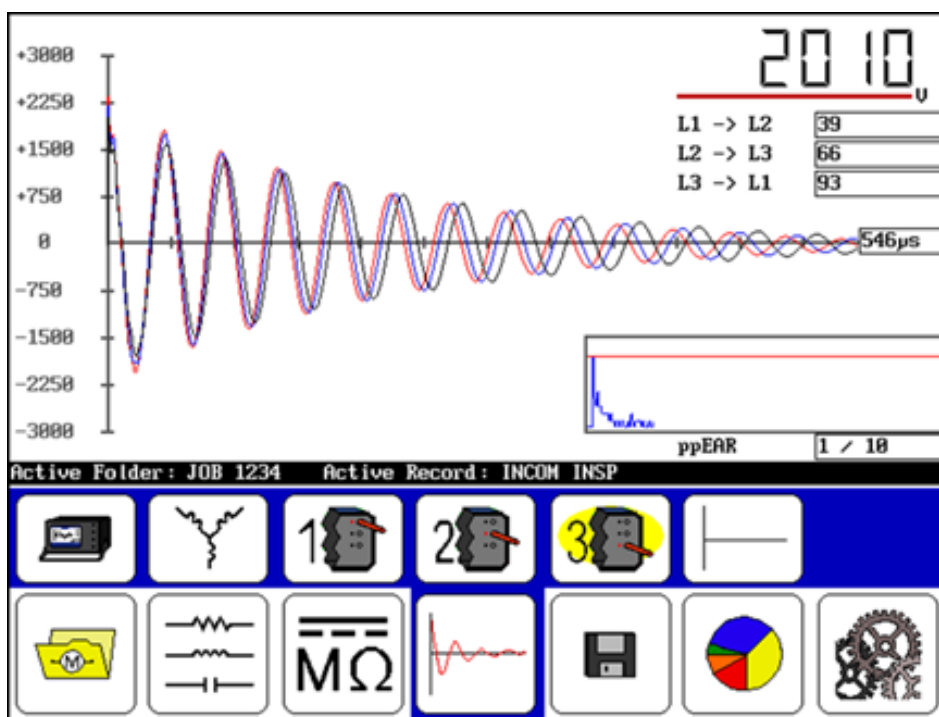
Figure 128. Completed surge test screen.

> **NOTE**
> The flicker in wave patterns displayed when arcing occurs between the windings or phases cannot be stored in the Baker DX. As soon as you release the PTT button, the wave pattern freezes. This is the only wave pattern that can be stored.

For each direction a 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 you see anything other than good patterns, there is a possible fault. Refer to the "Determining a fault" section below for explanations of wave patterns indicating good or faulty windings. For determination of wave patterns for a variety of devices, refer to chapter 15 "Surge testing applications." Keep in mind that fault determination is often a result of experience.

Example: comparison to a master coil

Occasionally a manufacturer may want to test against a standard. In such a situation, a selected standard coil is surge tested, results are stored in memory, and then they are recalled to the screen. All unknown coils would be tested and compared to the standard coil's wave pattern. Standard testing demonstrates the coil's ability to withstand minimum test voltages and you can compare the signature waveform to the standard's single waveform.

Determining 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. The figure below illustrates this. This type of fault is generally one that indicates a failure of the turn-to-turn short.
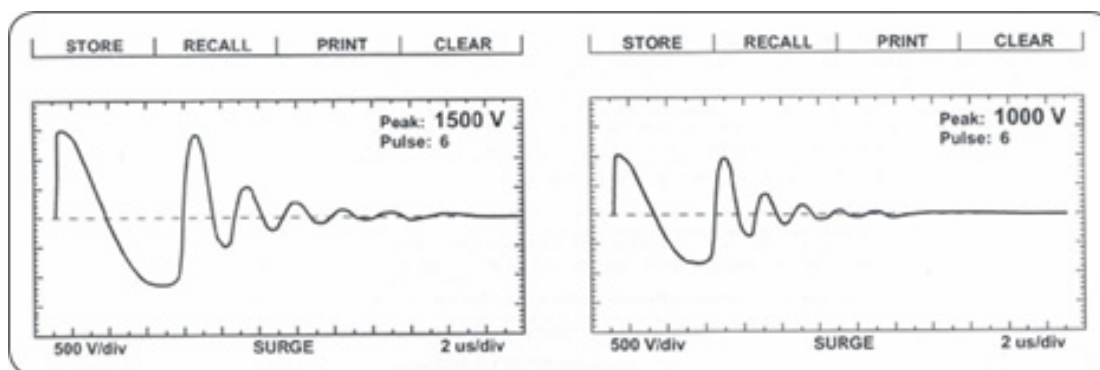
Figure 129. Good coil waveform (left) vs. bad (right).

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. Audible sounds often accompany arcing. It may be desirable to store the wave pattern by this arcing for reference if you can release the test or freeze the wave pattern at the moment when the wave pattern appears most affected by the fault (for example, reduced amplitude and increased frequency or shift to the left).

NOTE

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

Motivation for surge testing

Motors are subjected to high-energy, high-voltage transients in everyday operating environments. These transient pulses can damage the insulation in the motor and—given enough time—cause a catastrophic failure with the motor. High-energy, high-voltage transients are typically caused by:

- Motor start-up current coupled with contact bounce in the MCC
- Lightning strikes in the power system
- Inverter drive transients
- Line surges caused by tripped motors or transformers elsewhere in the power system

One of the primary functions of a tester is to simulate real-world transient voltages likely to be encountered by the motor without the high energy typical of real-world transients. Such 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 breaking several times. As a result of interrupting the current, an inductive "kick back" voltage spike develops. Large inrush currents along with the high inductance of electric motors are what give these "kick back" voltage spikes their high energy.

Lightning strikes

Lightning strikes often hit power systems or grids. Although a great amount of effort is made to protect grids from lightning damage, high-voltage transients caused by strikes can still reach 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 preset speed. The switching of the current, combined with the obvious fact that the motor is an inductor, results in the motor drive electronics generating high-speed transients. These transients impress on the motor where they can slowly degrade the insulation in the motor windings.

Line surges

The stored energy in a motor or transformer must dissipate when that motor or transformer trips offline from its power system. Either the device absorbs the energy or the energy pushes out onto the power system where other transformers or motors absorb the energy. Often, large transient voltage spikes are generated when this energy is released on a power system. Such spikes can easily damage motors, especially if the motor has weakened insulation.

IGBT switching technology

Baker DX surge testers use Insulated Gate Bipolar Transistors (IGBTs) 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 Baker DX in much the same manner as in the drives. However, SKF 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 microseconds.
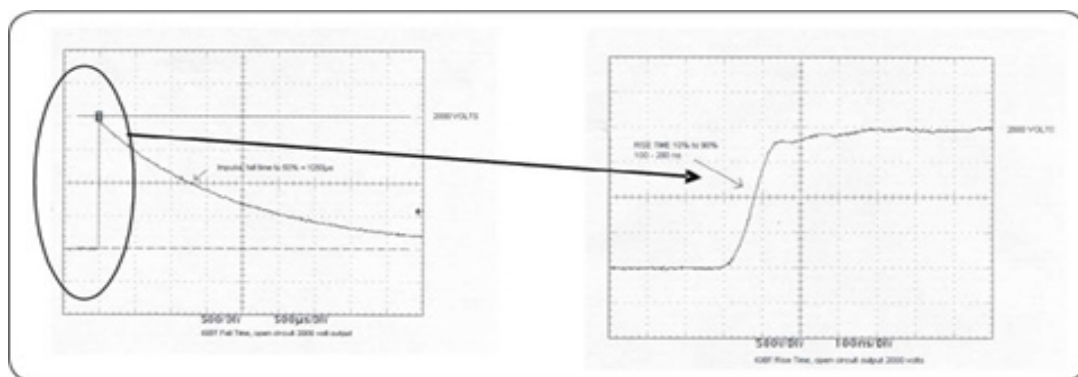
Figure 130. IGBT fall and rise times.

Surge testing applications

Maintenance testing

You will rarely find solid turn-to-turn (hard-shorted) winding faults in motors during maintenance testing. This condition is usually only found after the motor has failed.

Solid turn-to-turn winding faults happen when the insulation on adjacent copper wires has failed to the point that adjacent wires weld together. It is rare in maintenance testing because of a transformer action that occurs within the windings, which induces very high current in the shorted coils.

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 time to failure is seconds to minutes. When the ground wall insulation is damaged to the point that line current flows to ground, the ground current circuit breaker will trip and stop the motor.

During surge testing, steady separation in the wave pattern comparisons is most often the result of the rotor coupling with the stator (refer to the "Rotor loading (coupling) when testing assembled motors" section found later in this chapter). In this case, a consistent double wave pattern displays at all voltage levels.

The key to maintenance testing 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 460 V motor that shows a good trace at 500 V, but shows an unstable, flickering pattern (regardless of rotor coupling) at 1,500 V definitely contains a fault. When detecting the fault above operating voltage, time is available to schedule service for the motor before a hard short and rapid failure occurs.

Consider a 460VAC motor. The peak voltage with respect to ground is:

$$V_{Peak} = V_{rms} + \sqrt{2}/\sqrt{3}$$

This 391volts is the highest voltage any turn in the winding can see with respect to ground. During normal operation, the motor will be in an environment where transients as high as 4 x 391V = 1564V exist. These transients are due to contactors opening and closing, other components on the bus being energized/de-energized, lightning strikes, and so on. Now suppose that the motor has an insulation fault at 500 V. This motor will probably fail while in service well before it can be surge tested because the normal electrical environment the motor experiences will continuously stress the fault.

Therefore, the surge test's goal is to detect weakness well above the motor's operating voltage, as much as twice the operating voltage plus 1,000 volts. Refer to the recommended voltages for a thorough description of how to determine test voltages along with standards references (IEEE, IEC, EASA, and so on) that explain the reasons for these recommendations.
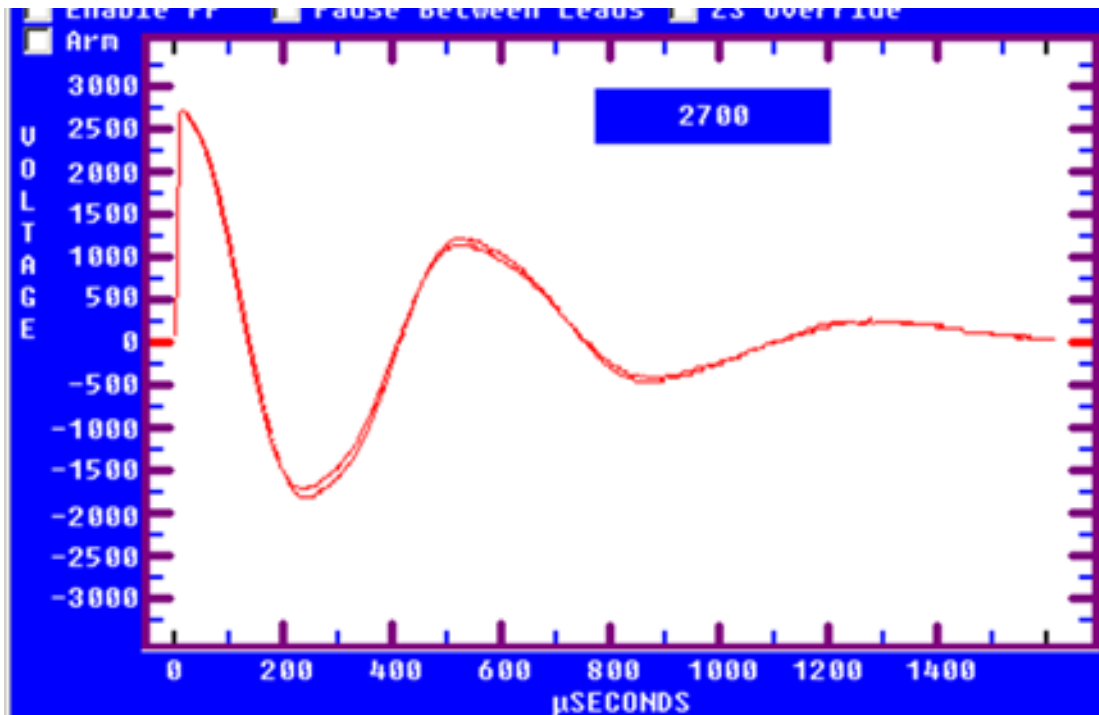
Figure 131. Comparing waveform separation acquired during test.

An arcing turn-turn is present in the stator by noting the separation in the two waveforms. Although there is very little difference between the waveforms, the real time data analysis performed by modern surge testing equipment can automatically catch such small shifts.

Application notes

- If there is indication of an open circuit, 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, check test leads weekly to make sure there is no breakage. You can check test leads easily 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.

> **NOTE**
>
> The DX will not allow an open lead test to continue. A message similar to the one shown below will appear.
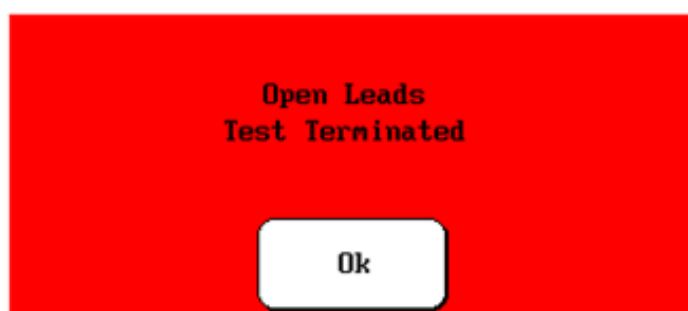
Figure 132. Open leads message dialog.

Single-phase motors and two-terminal devices

1) Connect test lead No. 1 to one side of the device.

2) Connect test lead 2 to the opposite side of the two-terminal device.

3) Connect the ground lead and test lead G of the tester to the frame or metal core material.

4) Run a surge test on lead 1 and watch for the left shift.

5) Run a test on leads two and again watch for the left shift.

Determining 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:

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

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. Audible sounds often accompany arcing. It may be desirable to store the wave pattern produced by this arcing for reference if you 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 (refer to the previous section "Single-phase motors and two-terminal devices"). A surge test is recommended for form coil testing because only surge tests can generate the turn-to-turn voltage that is required in these low-impedance coils.

Determining a fault

Refer to the previous section on "Single-phase motors 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 to 80% 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.

- Calculating a test voltage for AC form-wound coils uses many formulas. 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 test voltage of:

$$\text{Test voltage} = \text{Number of turns} \times 500\text{ V}$$

Three-phase motors

Wave patterns for three-phase windings are all compared to each other. We recommend the following procedure:

1) Connect test lead No. 1 to phase A terminal.

2) Connect test lead No. 2 to phase B terminal.

3) Connect test lead No. 3 to phase C terminal.

4) Connect the BLK G lead to the frame or core of the winding.

5) Begin with test lead No. 1. This indicates the test lead will be hot while leads No. 2 and No. 3 provide a ground path for the surge impulse.

For each test, check the display for a wave pattern. If you see three good wave comparisons, there is every indication to believe the motor is good. If you see anything other than good patterns, there is a possible fault.

Determining 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. Audible sounds often accompany arcing. It may be desirable to store the wave pattern produced by this arcing for reference if you 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).

The DX testers have the ability to detect changes in shape of the waveforms using the Pulse to Pulse EAR feature. The ppEAR will compare successive pulses to each other as the test proceeds. If there is a change in amplitude or shift in frequency, the ppEAR number will jump up.

In the repair shop: Separation of compared wave patterns on form-wound (without rotor installed) stators indicates a hard fault, such as a solid turn-to-turn or group-to-group short, an incorrect turns count, or misconnections.

Separation of waveforms for random-wound or concentric-wound windings is to be expected—even for good windings. Random wound motors with concentric windings will always show a shift that is due to the slightly different coil sizes for each of the winding's phases. Excessive separation indicates a winding failure in these types of windings.

In the field: In assembled motors, separation of the wave patterns is often the effect of rotor coupling, also known as rotor loading (refer to the "Rotor loading (coupling) when testing assembled motors" section found later in this chapter).

Two or more single coils

Use a surge test to test two or more identical single coils separately and then compare their wave patterns against each other.

1) Connect test lead No. 1 to one side of coil No. 1. and the ground test lead G to the other side.

2) Surge test the first coil and store the results in memory.

3) Surge test the second coil or any number of identical coils. Compare the display to the 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.

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 testing DC field coils, 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 magnetic properties 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 375 V is required to initiate an arc between two conductors in air. This would suggest a minimum voltage for surge testing to be greater than 375 V per turn. Because of the sometimes non-linear distribution of the surge pulse, it is recommended to use a minimum surge potential of 500 V per turn 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 are generally 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.

- Many two-terminal devices have very high turns count. The waveform displayed is similar to that of an open circuit. In this case, the coil's impedance 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

Test wound rotor motors 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 follow:

1) Remove the brushes touching the slip rings.

2) Short together the slip rings with jumpers. The jumpers limit the induced voltage on the rotor windings caused by the currents induced when testing the stator.

3) Perform a surge test on the stator as would be done on a three-phase induction motor.

> **_i_ NOTE**
> Because the rotor is shorted out, there is 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. Again, the stator is shorted to limit the induced voltage on the stator windings caused by currents induced when testing the rotor.

6) Perform a surge test on the rotor as if it were a stator. Choose the test voltage for the rotor carefully.

> **_i_ NOTE**
> Check the motor nameplate for rotor voltage to calculate the rotor test voltage level. Rotor voltage is not the same as stator voltage.

Determining 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. Audible sounds often accompany arcing. It may be desirable to store the wave pattern produced by this arcing for reference if you 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).

During comparison, separation of the wave patterns indicates incorrect turns count. Interpret the separations as for three-phase motors.

Synchronous motor/generator

Test the synchronous stator as a three-phase induction motor. You should test the rotating fields individually.

1) Before surge testing the stator, remove the DC leads to the brush boxes or lift all of the brushes off of the slip rings.

2) Short the slip rings for the rotating fields together.

3) Perform a surge test on the stator following the procedure for three-phase motors.

4) Individual poles are surge tested as outlined in the procedures for testing single-phase motors and two-terminal devices. An example test voltage is 600 V per pole, but for your purposes you should check with the manufacturer for the proper test voltage or carefully evaluate the insulation system's dielectric strength and choose an appropriate test voltage. It is not necessary to disconnect the pole piece leads before testing.

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.

i **NOTE**
> You can test one field and store its surge wave pattern for reference. You can then compare the other fields to this reference pattern in a procedure similar to that of two or more single coils.

Determining faults

Two types of faults may exist in synchronous motors and generators: pole piece faults or stator winding faults.

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.

i **NOTE**
> The turn insulation on pole windings can by very thin. Take care not to overstress the insulation with too high of a test voltage. Also, the windings might compress as the rotor spins during operation, which can short adjacent turns. Unfortunately, simulating centrifugal forces is not possible when surge testing.

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. Separation of waveforms indicates either hard shorts or unequal rotor coupling for the difference stator phase windings.

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 specified for three-phase motors.

Field coils for DC motors

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 V. However, an evaluation of the dielectric strength of the turn insulation is required choose an appropriate test voltage.

DC motor/generators

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

Armatures

There are two methods of performing surge tests on 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 each of these tests.

Bar-to-bar surge test

Bar-to-bar armature surge tests are 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 armature testing. On a disassembled motor, the armature can be tested with appropriately insulated HV probes. You can use any number of bars in this test. You can either surge test adjacent bars or you can test a specific number or "span" of bars. 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 tests of armatures").
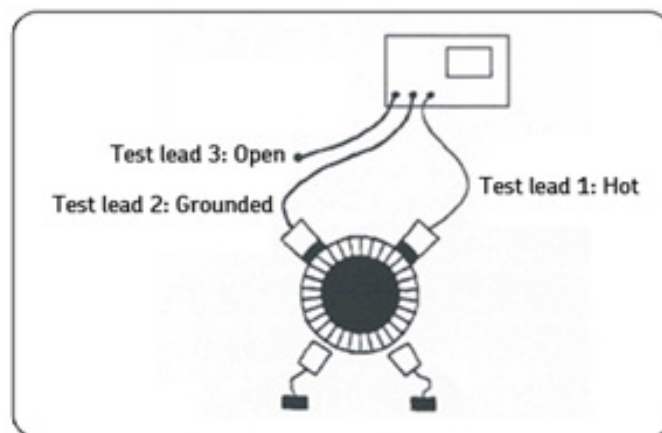
Figure 133. Span test setup.

Determining faults

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. The illustration below shows an example of a fault discovered after performing a surge test using the motor's brushes. On the left, we see the results of a good surge result, while on the right we see the results for a fault grounded under the brush or outside of surge test span.
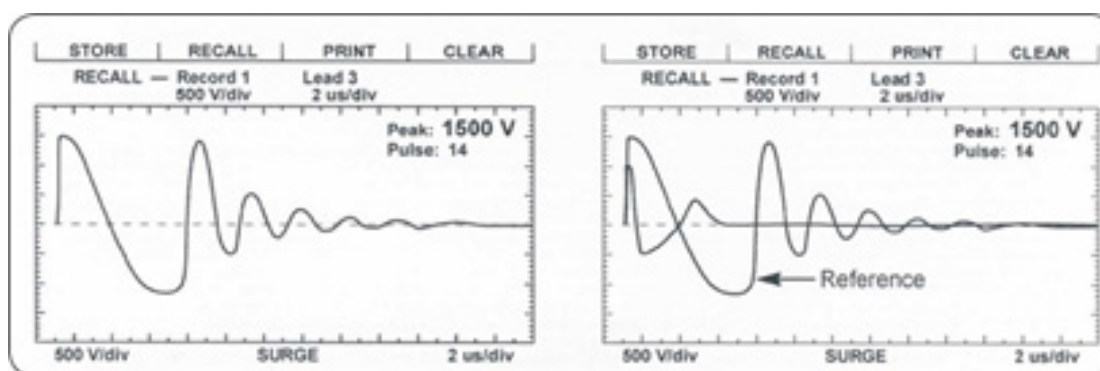
Figure 134. Comparing good (left) and short results (right).

Usually, as soon as the bad bar is placed under the hot brush or probe, the wave pattern will show the shift as noted above. Given the very parallel nature of armatures, the waveforms will start changing (with respect to the reference) as soon as testing gets close to the shorted bar. Over the short, the waveform shift will be the greatest. When the ground brush or probe is over the short, there will still be a shift, but not as great as when the hot brush/probe is over the short.

Notes and tips for span tests of armatures

- A test fixture may be used instead 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 move the fixture around the commutator during testing or rotate the armature. Procedures for testing and fault determination are the same.

- Always HiPot the armature to ground first. This gives an upper limit for the maximum voltage to apply when surge testing.

- The greater the span surge test voltage is, the more adequate the stress between bars is (ideally, 375 V according to Paschen's Law). Voltage stress is measured by the differential or drop between each bar. For example, a ten-bar span with 1,000 V applied to it will result in a 100 V stress between bars. If the span is lowered to five bars, 1,000 V applied to the span will result in 200 V between bars.

- Consider, however, that a ten-bar span at 375 V between bars would require a span test voltage of 3750 V. 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 2,200 V.

- 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 wave pattern's response when a fault exists. It gives an indication of what the user should expect to see.

Testing large AC stators/motors

Large AC motors are tested the same was as small AC motors. The connections and grounding are the same and the waveforms look like good ringing patterns. However, there are a few items to be aware of. First, some large AC motors have a very high inductance, which means they ring with a very low frequency. For manually controlled instruments, be sure to zoom out to see the full ringing pattern.

Second, some large motors will exhibit extra features at the beginning of the waveform. These features can be caused by reflections of the surge pulse inside the motor, corona or partial discharge in the windings, or reflections on feeder cables (if testing from the switch gear). The screen capture below shows an example:
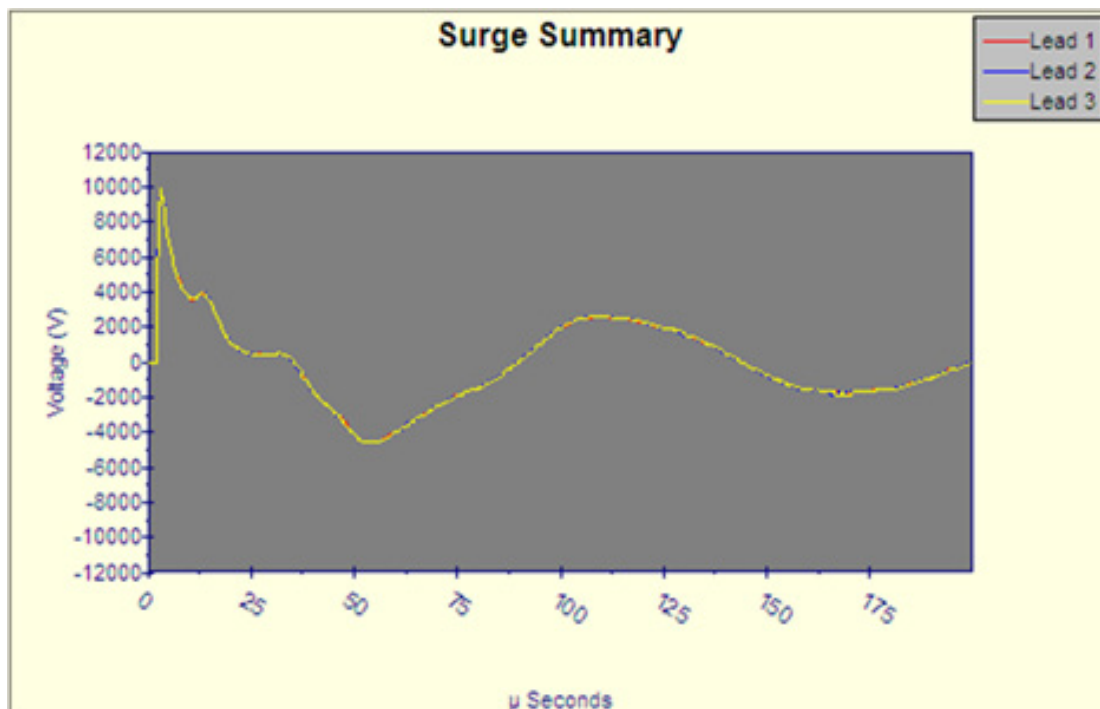
Figure 135. Surge waveforms for a 6600V, 8500HP, 8 pole motor.

Note, the small features in the first positive cycle, which in this case are caused by the surge waveform bouncing off the grounded end of the motor and returning to the tester (example source: 6600V, 8500HP, 8-pole motor).

Notes and tips for large AC stator/motors

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

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

- Perform the surge test on each of the parallel windings individually for the highest degree of fault sensitivity.

- For the highest surge test sensitivity, separate the winding into smaller groups, such as individual phases and perform the surge test on these smaller groups.

Rotor loading (coupling) when testing assembled motors

When testing assembled motors, the rotor can influence the shape of the surge wave pattern. These influences include:

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.
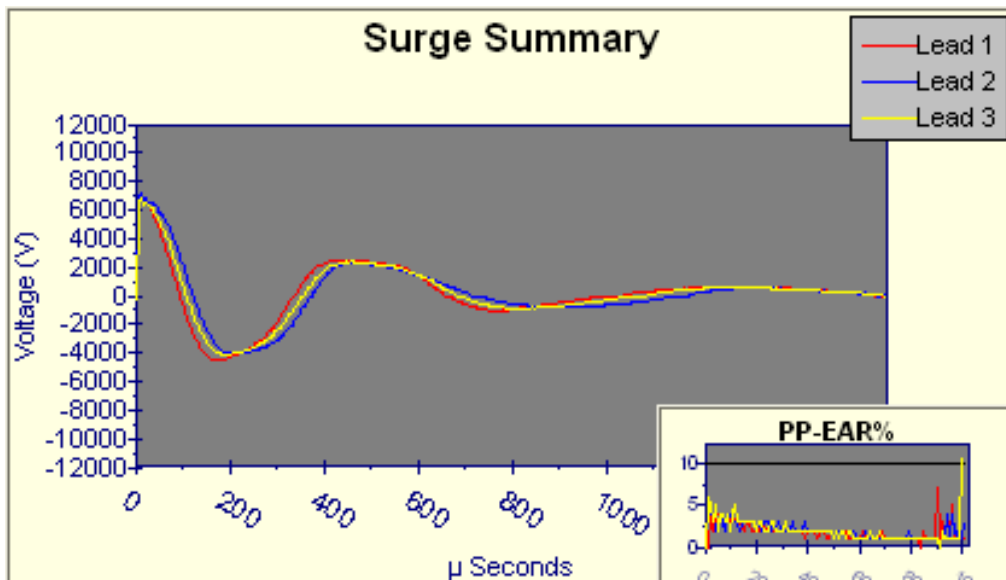
Figure 136. Example of rotor loading on surge test.

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.
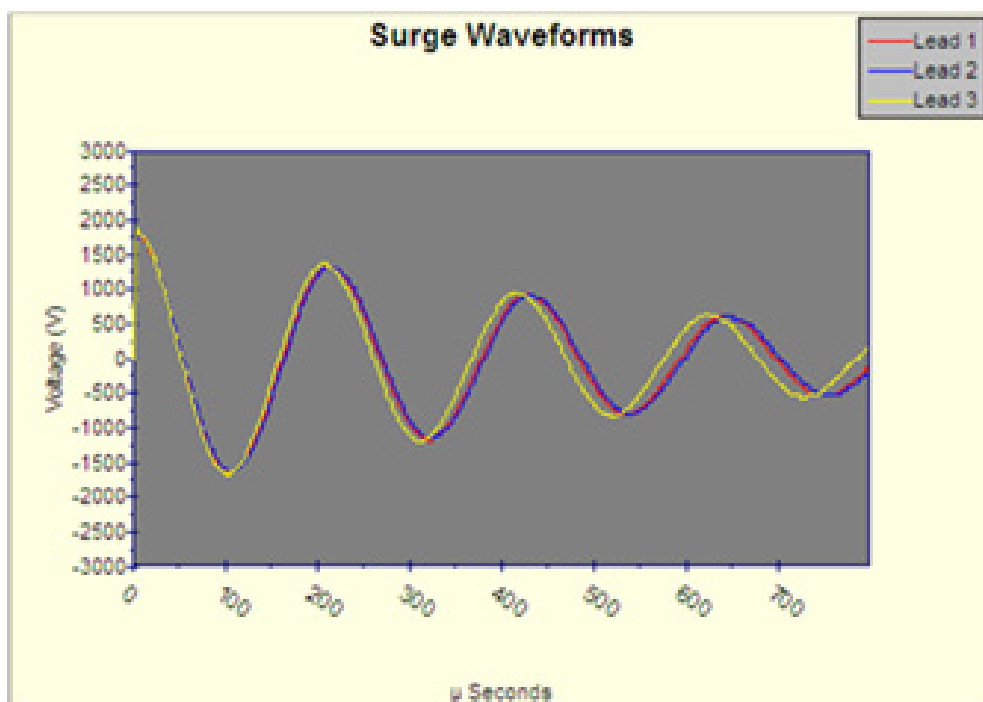
Figure 137. Surge waveform showing rotor coupling.

We can understand rotor loading when we consider the rotor as a secondary of a transformer. When one phase being surged has a different number of rotor bars under its stator windings than the other phase being surged and compared, there is a different transformer action existing for each phase. When we compare them, the wave patterns on the display indicate this difference by displaying separated wave patterns.

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).
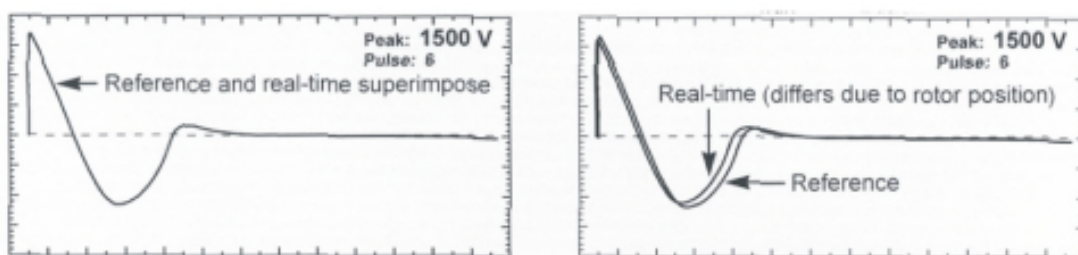
Figure 138. Wave pattern comparison for motor with rotor in place.

We recommend the following procedure for testing assembled motors where rotor coupling may occur.

1) Surge test phase No. 1 of the motor.

2) Surge test phase No. 2 of the motor. During the test, carefully turn the rotor until the wave pattern superimposes that of phase No. 1 on the display.

3) Repeat the steps for phase No. 3.

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

The 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.
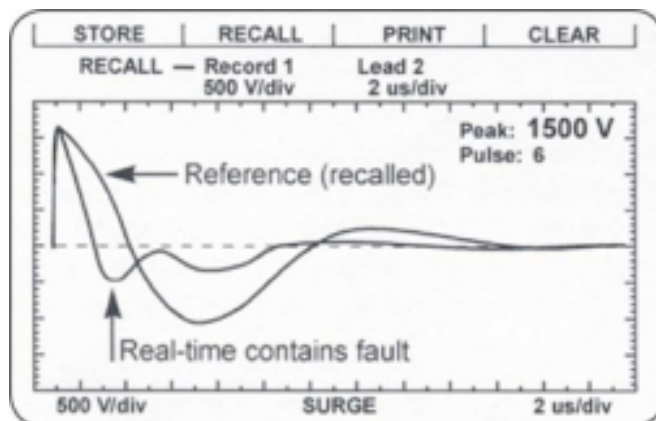
Figure 139. Motor with rotor in place; fault windings showing one trace shift significantly to the left.

Testing assembled motors from the switchgear

The surge and HiPot tests are valid tests when performing tests from the switchgear at the motor control center. Not only are the motor's windings tested, but the insulation on the connections and feeder cables are tested.

Follow all the procedures for 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
>
> *To avoid injury or death from severe electrical shock, you must de-energize the motor before testing. Connect the test leads to only the load side of the open disconnect.*

After megohm/PI/HiPot testing, ground the winding for four times the amount of time the winding was energized.

Notes and tips for testing from the switchgear

- Properly tag the test motor during the test as a safety precaution.

- All limitations and guidelines covered for testing assembled motors apply here (refer to the previous "Rotor loading (coupling) when testing assembled motors" section).

- You must disconnect any power factor capacitors in the circuit. If power factor capacitors are present, you will not observe a waveform when the voltage rises.

- Disconnect surge arrestors.

- The feeder cable's capacitance, as well as the motor's ground wall capacitance, will load the surge test circuit. As a result, the will need a significantly higher internal charge voltage to reach the required test voltage. If the surge tester is too small to handle both the cable and the motor load, you will observe a trace, but will not reach the proper test voltage. A higher output surge tester model will be required or you may have to test the motor while disconnected from the feeder cable.

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

Transformers

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

The surge test is only one of many tests that you should perform 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.

Single-phase transformers

1) Jumper (short out) the secondary side (low side) of the transformer.

2) Select test lead No. 1. Follow the diagram below to connect test lead No. 1 to H1 and lead No. 2 to H2 of the transformer.
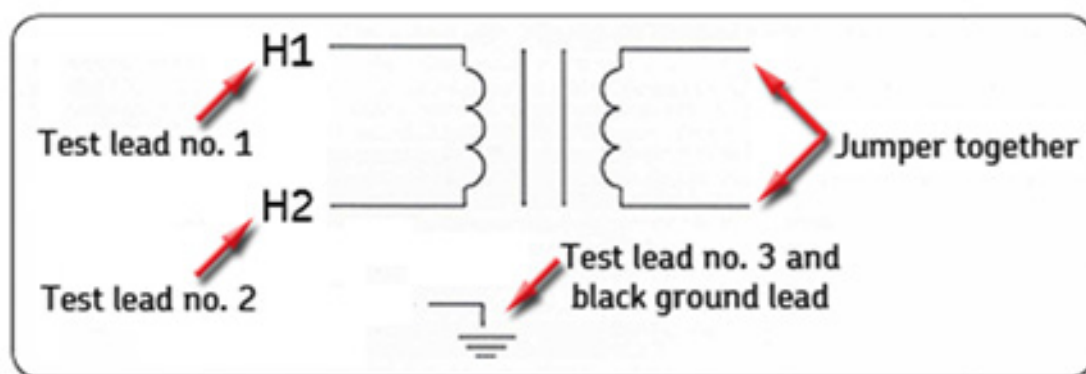
Figure 140. Single-phase transformer connections.

3) Connect the black GRD lead and test lead No. 3 to the frame.

4) Perform a surge test on the winding following the procedures outlined for single-phase motors and two-terminal devices. The discussion of determining a fault applies.

> ℹ **NOTE**
>
> Secondary winding insulation problems reflect into the primary winding and will show on the display.

5) After completing the test, reverse the test leads (connect test lead No. 2 to H1 and test lead No. 1 to H2) and repeat the surge test. This is commonly known as "shooting in the other direction."

6) 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 you must surge test each line high side connection point to the other end of its own coil, and that the secondary side of the coil being surged must be shorted out (with jumpers connected 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 No. 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. You should surge test the transformer windings 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).

Table 5. *Wye-wye transformers.*

Test Lead No. 1	Test Lead No. 2	Jumper
H1	H0	X0 to X1
H2	H0	X0 to X2
H3	H0	X0 to X3

Table 6. *Delta-wye transformers.*

Test Lead No. 1	Test Lead No. 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

Determining 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).

10 Typical winding faults

This chapter is designed to assist with interpreting test results. Although it is not a substitute for experience gained in the field, it might assist those new to motor testing by providing examples. It will also explain each of the failure messages the software generates when a failure is detected.

Both pass/fail results and quantitative data for tests are recorded by the AWA. They are stored as results records. For some testing situations, such as quality control in a motor shop, the pass/fail results may be the only data of consequence. In a predictive maintenance or troubleshooting situation, pass/fail results may be less important than the quantitative data from the test. For quality control, predictive maintenance, and troubleshooting different factors will determine the voltages used in testing and the way fault detection is handled.

Due to the wide range of motors and their test parameters, always refer to the motor manufacturer and published standards for appropriate voltage levels and acceptance limits.

Basic wave patterns used to determine faults

There are several basic wave patterns (for assembled motors, refer to "Rotor Loading"):

1) Good stable trace—indicating turn-to-turn and phase-to-phase insulation integrity.

2) Instability and separation—indicating a fault or weakness in winding or phase insulation.

3) Open circuit—indicating an open phase or disconnected test leads.

4) Grounded phase.

5) Separated waveforms—indicating a solid turn-to-turn or phase-to-phase short (if the rotor is not in place).

The motor windings are considered good if all three leads wave patterns are the same and remain stable up to the specified test voltage.

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

i **NOTE**

> Variation from these wave patterns is to be expected. Do not consider these wave patterns to be absolute. Due to the variety of motor windings and connections that exist, each winding will have its own signature wave pattern.

Good stable trace
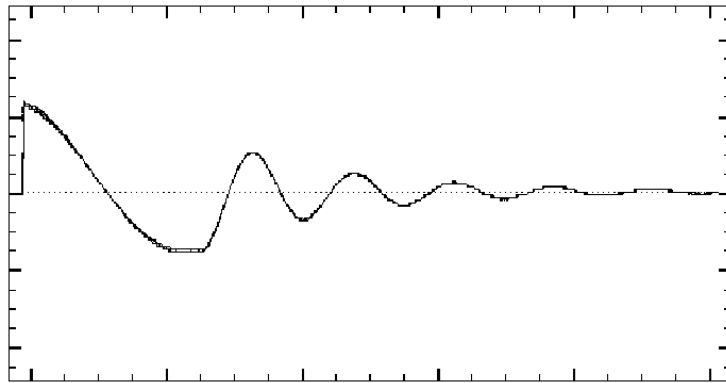
Figure 141. Good stable trace.

Arcing turn-to-turn short
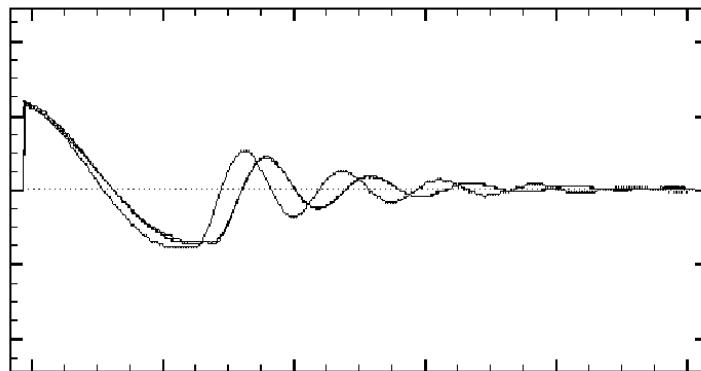
Figure 142. Arcing turn-to-turn short.

In this waveform, the solid line represents an unstable, intermittent shorting in the windings. Notice its shift to the left of the dotted line.

Open circuit

When an open condition exists in the tested phase, a pattern resembling a ski ramp is seen. This is due to a loss of continuity throughout the tested winding. If only one phase is open, normal waveforms will appear for the other phases. This pattern is also seen when nothing is connected to the surge test leads.
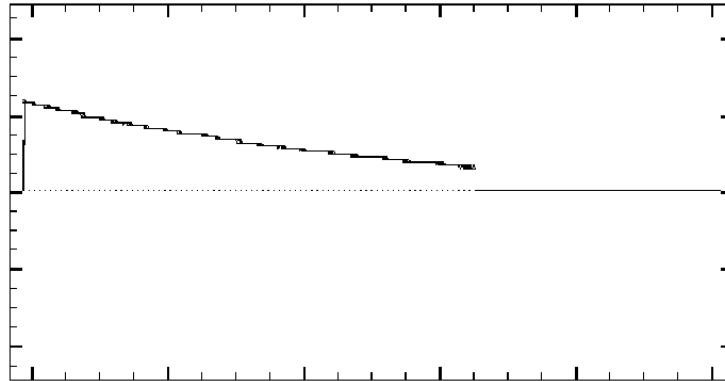
Figure 143. Open circuit.

Hard short to ground

If a hard short to ground exists, the Megohm or HiPot test will detect it. It can also be detected when Surge testing. The wave pattern will appear as a relatively flat line. The example below illustrates a grounded phase.
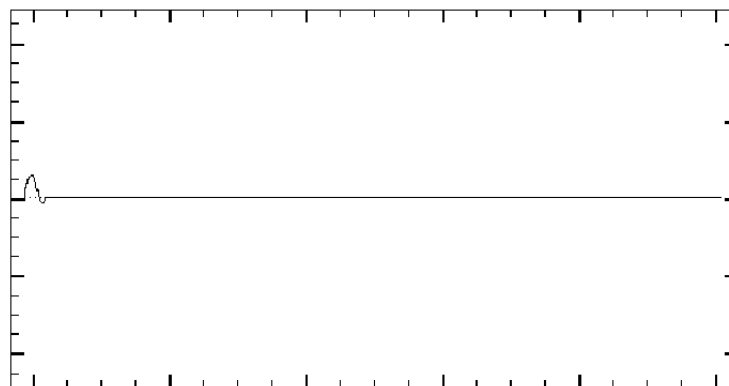
Figure 144. Hard short to ground.

Solid turn-to-turn short (fused or welded short)
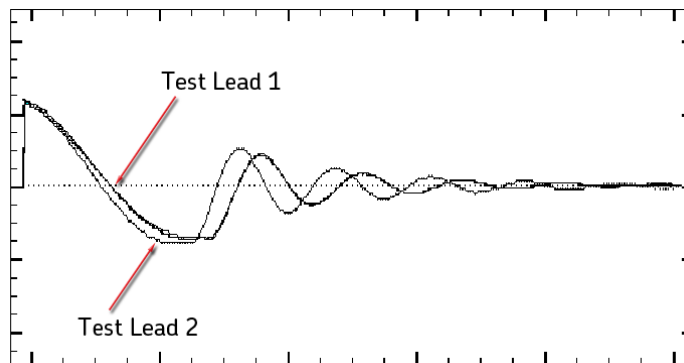
Figure 145. Solid turn-to-turn short.

The waveform above indicates a short in a motor *without* a rotor in place.

Application notes

- Knowledge of all types of wave patterns is not necessary when maintenance testing. It is more important to look for a stable, uniform waveform up to the specified test voltage.

- Test leads should be checked for breakage by firmly grasping the boot and clip in one hand while pulling on the lead with the other. A broken lead will stretch and a good lead will not.

- When an open circuit is indicated, check the connections between all three test leads and the winding being tested.

- Also check for open test leads at the clip end. Test leads should be checked weekly to ensure there is no breakage.

- Baseline testing can be conducted to determine appropriate DC test pass/fail tolerances. Maintenance testing should be performed using Test ID records that are kept consistent from test to test.

- Depending on the severity, motors that fail tests should be considered for service or replacement.

Rotor loading (coupling)

When surge testing assembled motors, the rotor can influence the shape of the surge wave pattern in two ways:

- Dampening effect: The loading of the rotor dampens the ringing of the wave pattern.

- Separated wave pattern comparison 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 eliminated and the wave patterns will be superimposed.

Rotor loading can be understood when the rotor is considered a secondary of a transformer. When one phase being surged has a different number of rotor bars under its stator windings than the other phase being tested, a different transformer action exists for each phase. Two mismatched waveforms are seen on the display.

Rotor loading effects are most prevalent in smaller, high-efficiency motors with small tolerance air gaps. Separation of wave patterns 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).

To compensate for rotor coupling effects, conduct a manual surge test.

> **WARNING**
> *Wear insulated high-voltage gloves and take other safety precautions when testing.*

If the rotor can be turned, surge test the first lead. While testing lead 2, carefully turn the rotor until the wave pattern superimposes over phase 1 on the display. Repeat this procedure for the third phase.

If the rotor cannot be turned, observe the wave patterns. As the test voltage is raised, watch for a sudden shift to the left or instability. This shifting can indicate a fault due to arcing. Deteriorating insulation might not be obvious until higher voltages are reached.

Rotor coupling does not prevent the surge impulse from stressing the turn-to-turn or phase-to-phase insulation. It only changes the ringing of the wave pattern, decreasing sensitivity to interpretation of solid faults. Unstable wave patterns clearly indicate a fault in assembled motors whether or not rotor coupling is present.

Factors affecting tester output

Sometimes full output of the Baker AWA-IV can be below its rated maximum output voltage. This occurs on low-impedance devices or devices that exceed the AWA's capability.

For example, the horsepower of a motor might be too high for the AWA. In this case, the 12,000V Baker AWA-IV might only apply 4000 V when the output is set halfway between min and max . At this mid-point, 6000V is expected. The Baker AWA-IV might then give only a maximum output of 7000V when 12,000V is expected.

The test should be considered successful if the desired test voltage level can be reached. For the example above, if the motor was 3000 horsepower and operated at 2300V, an appropriate test voltage would be 2 x 2300V + 1000V = 5600V. The size of the motor can limit the AWA's output to a level below its rating.

- Adjacent windings such as a start winding, part winding, high-voltage, or low-voltage winding should be jumpered together and in many cases grounded while doing the test. This procedure can eliminate incorrect test results caused by inductive coupling.

Table 7. *Non-VFD issues, causes, and actions with autophasing feature turned on.*

Factor	Effect
Motor larger than recommended max size to test	Capacitance and inductance of motor windings can load the Baker AWA-IV output down. The voltage output is reduced below maximum output, which can damage the Baker AWA-IV if the test is applied for an extended period. Note: The test is considered successful if the test voltage 2E + 1000V is achieved.
Motor RPM is slow.	For each reduction of the motor's RPM, (i.e. 3600 -> 1800) the effective horsepower of the motor that the Baker AWA-IV senses is doubled. Example: A 500 hp/3600 RPM motor = 500 hp. A 500 hp/1800 RPM motor = 1000 hp. A 500 hp/900 RPM motor = 2000 hp, etc.
Motor has high number of poles	Same condition as comment above on motor RPM.
Feeder cable length	Distributed capacitance of the feeder cable loads down the test according to the formula: $$V \max capable = \frac{V\, tester \times tester\, cap}{Tester\, Cap + Cable\, cap}$$ The Baker AWA-IV may be unable to generate the desired test voltage. It is observed that the closer the motor is to the recommended maximum motor size to test, the shorter the feeder cables must be. If the motor is very small compared to the maximum recommended motor to test, the Baker AWA-IV may have sufficient energy such that longer feeder cables, as well as the motor windings, can be tested.
Shielded feeder cable	The above condition becomes extreme. Shielded feeder cables have very high capacitance.
High horsepower motors at Low Operating Voltage	The characteristics of these motors are such that the winding impedance is low, requiring high Baker AWA-IV output energy to surge test the windings. If the Baker AWA-IV output is insufficient to test a motor, then a Power Pack option may be necessary, OR, if testing at the motor or the MCC, very short feeder cables lengths will be needed.
Motor assembled with rotor in place	The presence of the rotor will load the Baker AWA-IV by drawing energy from the Baker AWA-IV like the secondary of a transformer.

Software fault messages

Non-VFD issues, causes, and actions with autophasing feature turned on.

Status	Failure type	Why failed message
PASS		No failure was detected according to the Test Model given.
FAIL	USER ABORT	A User abort has been detected.
FAIL	EMERGENCY SHUTOFF	Emergency Shutoff has been detected
Tested	Tester	No message, cannot determine Pass/Fail because no test criteria was turned on.
FAIL	CANCEL	User cancelled test.

Resistance failure types

Non-VFD issues, causes, and actions with autophasing feature turned on.

Status	Failure type	Why failed message
FAIL	DELTA R	Resistance test result: Fail – DELTA R. Delta R percent is out of tolerance.
FAIL	OPEN LEADS	Test results: Fail-OPEN LEADS. Open Leads Detected.
FAIL	TOLERANCE	Test Results: Fail-TOLERANCE Resistance(s) outside of user defined targeted range.
CAUTION	Reistance out of range	Resistance values must be greater than 0.500 ohms for HIGH VOLTAGE LEADS and greater than 0.001 for the RES LEADS. You may stop Testing, reconfigure Test ID with the appropriate leads, and repeat the test OR continue with the remaining tests.
CAUTION	MAX R Range Exceeded	Test Results: Caution – MAX Resistance Range Exceeded. Possible Open lead(s).
FAIL	No Resistance Solution	Resistance values do not have a solvable solution.
FAIL	NOISY ADC	Instrument detecting excessive electrical noise. Resistance measurements are unstable. Check for noise sources nearby (welders, VFDs, etc.) or a free wheeling rotor.

DC tests failure types

Non-VFD issues, causes, and actions with autophasing feature turned on.

Status	Failure type	Why failed message
FAIL	Over voltage	Over Voltage Condition has been detected.
FAIL	Open ground	An open ground has been detected. Check power cord outlet ground for continuity.
FAIL	Min Meg-Ohm	Test Result. Fail – MIN MEG-OHM. Meg-Ohm value is less than the minimum tolerance.
FAIL	Min PI	PI test results: Fail – Min PI. PI Ratio is less than minimum tolerance.
FAIL	Over current	Test result: FAIL – OVER CURRENT. An over current trip was detected.
FAIL	No steps defined	No steps for Step-Voltage Test exist in this Test ID.
FAIL	Low PRG HPT voltage	The last step voltage is below the previous Meg-Ohm/PI test voltage.

Surge test failure types

Non-VFD issues, causes, and actions with autophasing feature turned on.

Status	Failure type	Why failed message
FAIL	Open leads	Test Results: Fail – OPEN LEADS. Open leads detected.
FAIL	Over voltage	Over Voltage Condition has been detected.
FAIL	Open ground	An open ground has been detected. Check power cord power outlet ground for continuity.
FAIL	ppEAR Limit	Surge test results: Fail – ppEAR LIMIT. Pulse-to-Pulse EAR%.
FAIL	L-L EAR	Surge Test Result: Fail – L-L EAR Lead- to-Lead EAR % is out of tolerance.
CAUTION	Unequal zero crossings	Test results: Caution – UNEQUAL ZERO CROSSINGS Waveforms do not have the same number of zero crossings.

11 Using power packs with 6/12 kV models

The Baker AWA-IV with the 30kV power pack allows the testing of larger, higher voltage motors that are beyond the capabilities of the Baker AWA-IV alone. Experience has shown that the Baker AWA-IV is able to test motors up to 1000hp, 4160V, 1800 RPM.

The PP30 is not able to operate alone; the control functions of the Baker AWA-IV are required.

Review the instructions for stand-alone operation of the Baker AWA-IV before attempting to operate the 30 kV power pack. This chapter provides instruction on how to correctly set up, connect, and operate the power pack.

CAUTION

During testing, do not allow the Baker AWA-IV test leads to lie anywhere near the power pack test leads!

Be sure the Baker AWA-IV test leads are some distance away from the power pack test leads; preferably could on top of the Baker AWA-IV or looped on the power pack handle.

The power pack surge signal can be sensed by the Baker AWA-IV, which will result in interference with its computer.

High voltage activation when using this product. Ensure that all personnel are away from the device under test and not in contact with the load or test leads.

Never attempt testing a load with both 12KV and power pack leads attached to the load at the same time.

WARNING

Some test leads will be open during the test and can be at the same voltage potential as the winding! To avoid severe injury or death, all precautions should be taken to avoide touching these leads!

During testing, do not allow the Baker AWA-IV test leads to lie anywhere near the power pack test leads. Be sure the Baker AWA-IV test leads are away from the power pack test leads, preferably coiled on top of the Baker AWA-IV or looped on the power pack handle. The power pack surge signal can be sensed by the Baker AWA-IV resulting in interference with its signal.

NOTE

The ground fault system on the Baker AWA-IV will render it inoperative without a proper ground. When the host tester is connected to the PP30, an inoperable condition will also affect the Power Pack due to loss of the surge enable signal.

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

Emergency stop button

The Baker AWA-IV tester and the power packs are equipped with a red Emergency Stop (E-Stop) button on the front panel of the unit. Use it to quickly discontinue a test and to shut off power to the power pack's high-voltage circuitry.

The button will remain locked in position until manually retracted by rotating the Emergency Stop button clockwise.
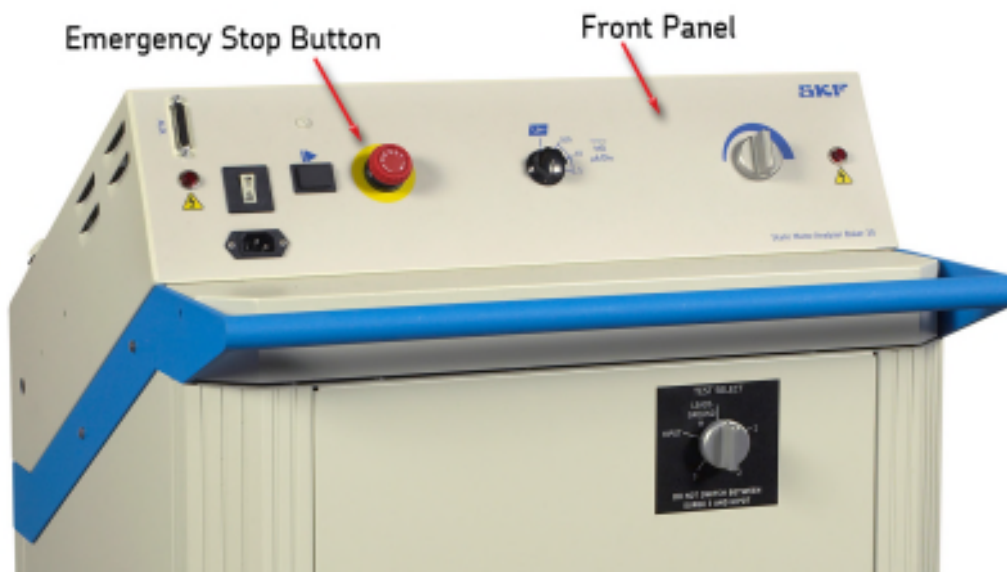
Figure 146. Power pack showing Emergency Stop button.

> ### NOTE
>
> When this button is used, the computer will shut down, and unsaved data will be lost.
>
> Pressing this button in will shut power down to the Baker AWA-IV and power pack. The button will remain locked in position until manually retracted by rotating the E-Stop button clockwise.

Power pack set-up

NOTE
The 30kV power pack must show on its rear panel that it has been calibrated for the specific serial number of the Baker AWA-IV being used to control the power pack. The power pack's calibration is certified only with the Baker AWA-IV that shipped with it.

6) Connect the power pack to the tester. Use the short AC line cord on the power pack front panel or on the left side of the unit to connect to the AWA's power entry receptacle.

7) Connect the 25-pin interconnect cable to 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 Baker AWA-IV and the end marked 30KV into the auxiliary port (AUX) on the front of the power pack.

8) Connect the long AC power cord to the power pack front panel receptacle and then to an appropriate AC power source. See the table in the Preface of this book for appropriate power requirements.

NOTE

The Baker AWA-IV is equipped with a ground fault monitor and indicator. This circuitry should not hinder operation of GFI protected AC power circuits.

9) Power up the Baker AWA-IV and the 30kV power pack. Follow the Baker AWA-IV setup procedures in this manual.

10) After a one or two minute warm up period, both units will be ready for operation.

NOTICE

If the power pack connection to the Baker AWA-IV is maintained and the power pack is turned off, I/O lines are influenced. This may cause problems with Baker AWA-IV operation.

CAUTION

When using the PP30 for high voltage testing, make sure:

1) The AWA's leads are out of the way,.

2) The Baker AWA-IV leads are not hooked together.

3) No printer or CD ROM's are hooked up to the USB port.

Power pack resistance testing

The resistance tests are run with the AWA's test leads. The test sequence is the same as for the AWA's automatic test mode. At the conclusion of Resistance testing, the Power Pack leads must be connected. Do not connect both sets of leads together at any time.

Three-phase test lead option

The power pack is supplied with a three-phase test lead option. One additional knob located on the lower front panel of the power pack, is used to switch between the different leads. The options on this knob are TL1 (test lead 1), TL2, TL3, and HiPot. Some units are equipped with a ground position. With the three-phase test lead option; the operator is required to make only one connection to the motor. The single-phase test lead option requires the operator to manually move the hot test lead between the different leads of the motor.

Output configuration

- Three Red output cables, with insulating jacket rated at 60kVDC, appropriately marked.
- One Black ground cable, also with insulating jacket rated at 60kVDC appropriately marked.
- HiPot: Test Lead 1 energized, leads 2 and 3 open connections.
- Surge Lead 1: Test Lead 1 energized, lead 2 and 3 grounded.
- Surge Lead 2: Test Lead 2 energized, lead 1 and 3 grounded.
- Surge Lead 3: Test Lead 3 energized, lead 1 and 2 grounded.

NOTICE

The power pack control panel function switch must be placed into the HiPot position to perform a HiPot test. Be sure to switch the power pack test lead selector switch into the HiPot position. Both switches must be in their correct positions simultaneously when attempting to perform the test. If the tester is not operated in this fashion, the tests will not be performed correctly, and the data recorded will be in error.

Be sure not to switch the test lead select 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 service.

Shipping

The power pack—when equipped with a three-phase selector switch—is not rated for shipment in any other position than vertical, with all four wheels down, on a level surface.

When shipped, the power pack must be properly labeled with "This side up" warning labels.

Power pack DC testing (three-phase test lead option)

1) After setting up the tester and power pack, on the Baker AWA-IV, select the motor to be tested from the **Explore** tab (motor tree view).

2) Click on the **Tests** tab to get to the main testing window.

3) Select a Test ID that uses voltage requiring the power pack, or create a test that does.

4) Click on the configuration button to the right of the name of the DC test desired. The *DC Tests* configuration window will appear.

5) Adjust the voltage required so that HiPot voltage is at least 2000V.

6) Enable the power pack by checking the **Enable Power Pack** box under the HiPot test parameter column. An error message will appear if a voltage below the minimum for the power pack is programmed after the **Enable Power Pack** box is checked.

> ***i*** **NOTE**
>
> An error message will appear on the Baker AWA-IV screen if the power pack option is selected and a power pack is not connected.

7) Turn the **Output Control** knob on the power pack to **MIN** (full counterclockwise).

8) Select one of the HiPot settings on the power pack **Function** knob. When the HiPot 100 μAmp/Division setting is chosen, a loud relay noise will be heard.

9) Connect the power pack leads to the motor.

10) With the three-phase option, lead 1 will be hot, while leads, 2 and 3 will be open, and the black lead will be the ground.

Table1   *Three-phase motor: HiPot connections.*

Motor leads	Lead 1	Lead 2	Lead 3	Frame
Test leads	Red	Open	Open	Black

- RED = HOT LEAD
- BLK = BLACK FRAME GROUND LEAD

11) To hook up to a three-phase motor, connect test lead 1 or A to motor lead 1 or A, test lead 2 or B to motor lead 2 or B, and test lead 3 or C to motor lead 3 or C.

12) Ensure that the correct test is displayed on the Baker AWA-IV computer screen.

13) Start testing by pressing the power pack's test button (or footswitch) and slowly raise the power pack's output control. Test results should immediately be visible on the Baker AWA-IV screen. If not, recheck the connections and all the switch settings. Also ensure that the interconnect cables have been attached and are secure.

14) Continue to hold the test button (or footswitch) for the duration of the test. Have HiPot setting at 100μA/Div to start. Change the micro-amps per division switch as needed to increase the sensitivity of the data acquisition during test.

For example, if target voltage is needed, and at 100μA/Div you see less then 50μA of leakage current, it is best to switch the PP30 to 10μA per division for better accuracy. If less than 5μA

is leaking at 10μA per division, switch to 1μA per division for best accuracy. (This can be switched during the test).

15) When the test is complete, release the test button (or footswitch) of the power pack and return the **Output Control** knob to its minimum setting.

16) If test results should be saved, click the **Save Results** button on the *Tests* view window.

> **CAUTION**
>
> *Always allow sufficient time for the test winding to completely discharge before disconnecting the test leads. The recommended practice is to discharge the winding for a duration of at least four times the duration of the DC HiPot test for high-voltage windings.*

> **NOTE**
>
> The overcurrent trip Levels that activate the HIPOT Trip are 10 times the μ/Amp Division setting on the tester. Release the Test button and press the HiPot and Lead 3 on the Baker AWA-IV to reset the over current trip and begin testing again.
>
> For HiPot operation of the 12kV host tester alone, the host tester and the Power Pack must both be powered up.

Power pack Surge testing (three-phase lead test option)

1) After setting up the power pack and tester, on the Baker AWA-IV, select the motor to be tested from the **Explore** tab.

2) Click on the **Tests** tab to get to the main testing screen.

3) Select a Test ID that uses a voltage requiring the power pack, or create a test that does.

4) Click on the configuration button to the right of the Surge test. The *Surge* configuration window will appear.

5) Adjust the voltage required so that surge voltage is at least 5000V.

6) Enable the power pack by checking the **Enable Power Pack** box. An error message will appear if a voltage below the minimum for the power pack is programmed after the **Enable Power Pack** box is checked.

7) Click on the **Pause between Leads** button in the *Surge Configuration* window.

8) Turn the **Output Control** know on the power pack to **MIN** (full counterclockwise).

9) Select the **Surge** setting using the **Function** knob on the power pack.

10) Connect the power pack leads to the motor. The power pack has three hot leads and one ground lead for the three-phase option.

Table2   *Three-phase motor; Surge test connections.*

Motor leads	Lead 1	Lead 2	Lead 3	Frame
Surge lead 1	Hot	Ground	Ground	Black

Motor leads	Lead 1	Lead 2	Lead 3	Frame
Surge lead 2	Ground	Hot	Ground	Black
Surge lead 3	Ground	Ground	Hot	Black

Nuisance failures (Surge test)

If nuisance nested failures are observed, lift the black ground lead off for surge testing. If this eliminates the nested failures, the problem is due to ground capacitance. This is a problem sometimes encountered when using the Baker AWA-IV and power pack for testing. It may scale itself (surge wave) into the wrong sweep rate. It is suggested to configure a Test ID for the specific Motor ID. This ID can be set up to force data acquisition at a user-defined sampling rate (μSeconds/Div).

1) 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.

2) On the Baker AWA-IV, select the surge lead and store test results of three-phase windings for surge comparison.

3) Ensure that the correct test is displayed on the screen.

4) Start testing by pressing the power pack's **Test** button (or footswitch) and slowly raise the **Output Control**. Test results should immediately be visible on the tester screen. If not, recheck the connections and switch settings. Also, ensure that the interconnect cables have been attached and are secure.

5) Continue to hold the **Test** button (or footswitch) for the duration of the test.

6) When the test has completed, release the **Test** button (or footswitch) on the power pack and return the **Output Control** knob to its minimum setting.

Table3   *Three-phase motor; Surge test connections.*

Motor leads	Lead 1	Lead 2	Lead 3	Frame
Test leads	Red	Open	Open	Black

7) Switch the leads according to the table above to surge different motor leads. Repeat steps 8-11.

8) If test results should be saved, click the **Save Results** button on the *Test* view window.

Power pack DC testing (single-phase lead option)

1) After setting up the power pack and tester, on the Baker AWA-IV, select the motor to be tested from the **Explore** tab.

2) Click on the **Tests** tab to get to the main testing screen.

3) Select a Test ID that uses a voltage requiring the power pack, or create a test that does.

4) Click on the configuration button to the right of the name of the DC Test desired. The *DC Tests* configuration window will appear.

5) Adjust the voltage required so that the HiPot voltage is at least 2000V.

6) In the *DC Tests* window, check the Enable Power Pack box. An error message will appear if a voltage below the minimum for the power pack is programmed after the **Enable Power Pack** box is checked.

7) Connect the power pack leads to the motor. The power pack has only one hot lead and two ground leads.

   - RED = hot lead

   - BLU = blue ground lead

   - BLK= black frame ground lead

8) Turn the **Output Control** knob on the power pack to **MIN** (full counterclockwise).

9) Select one of the HiPot settings using the power pack **Function** knob. When the HiPot 100 μAmp/Division setting is chosen, a loud relay noise will be heard.

10) Ensure that the correct test is displayed on the tester's screen.

11) Start testing by pressing the power pack's **Test** button (or footswitch) and slowly raise the **Output Control.** Test results should immediately be visible on the tester's screen. If not, recheck the connections and switch settings. Also, ensure that the interconnect cables have been attached and are secure.

12) Continue to hold the **Test** button for the duration of the test.

13) Set the micro-amps per division switch to HiPot 100μA/Div to start. Change the switch as needed to increase the sensitivity of the data acquisition during test.

For example, if target voltage is needed, and at 100μA/Div is less then 50μA of leakage current, it is best to switch the PP30 to 10μA per division for better accuracy. If less than 5μA is leaking at 10μA per division, switch to 1μA per division for best accuracy. (It is okay to switch during the test).

14) When the test has completed, release the **Test** button of the power pack and return the **Output Control** knob to its minimum setting.

15) If test results should be saved, click the **Save Results** button on the *Tests* window.

> ### NOTE
>
> The overcurrent trip levels that activate the HiPot trip are 10 times the μAmp/Division setting on the tester. Release the **Test** button and press the HiPot and Lead 3 on the Baker AWA-IV to reset the over current trip and begin testing again.

Power pack Surge testing (single-phase test lead option)

1) After setting up the power pack and tester, on the Baker AWA-IV, select the motor to be tested from the **Explore** tab.

2) Click on the **Tests** tab to get to the main testing screen.

3) Select a Test ID that uses a voltage requiring the power pack, or create a test that does.

4) Click on the configuration button to the right of the Surge test. The *Surge* configuration window will appear.

5) Adjust the voltage required so that Surge voltage is at least 5000V.

6) In the *Surge* configuration window, check the **Enable Power Pack** box. An error message will appear on the Baker AWA-IV screen if the power pack option is selected and accepted and no Power Pack connection is detected.

7) Click on the **Pause between Leads** button in the *Surge* configuration window.

8) Turn the **Output Control** knob on the power pack to **Min** (full counterclockwise).

9) Select the **Surge** setting using the **Function** knob on the power pack.

10) Connect the power pack leads to the motor. The power pack has only one hot lead and two ground leads.

Table4   *Single-phase motor; Surge test connections.*

Motor leads	Lead 1	Lead 2	Lead 3	Frame
Test phase A	Red	Blue	Open	Black
Test phase B	Open	Red	Blue	Black
Test phase C	Blue	Open	Red	Black

11) 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 is used instead of the frame grounding.

12) On the Baker AWA-IV screen, you may select the surge lead and store test results of three-phase windings for surge comparison. Ensure that the correct test is displayed on the Baker AWA-IV screen.

13) Start testing by pressing the power pack's **Test** button (or footswitch) and slowly raise the **Output Control**. Test results should immediately be visible on the tester's screen. If not, recheck the connections and switch settings. Also, ensure that the interconnect cables have been attached and are secure.

14) Continue to hold the **Test** button (or footswitch) for the duration of the test.

15) When the test has completed, release the **Test** button (or footswitch) on the power pack and return the **Output Control** to its minimum setting.

16) Switch the leads according to the table above to surge different motor leads. Repeat steps 10–15.

17) If test results should be saved, click the **Save Results** button on the *Tests* window.

> **CAUTION**
>
> *Always allow sufficient time for the test winding to completely discharge before disconnecting the test leads. The recommended practice is to discharge the winding for duration of at least four times the duration of the DC HIPOT test for high-voltage windings.*

Combining Baker AWA-IV host and PP30 tests

To completely test a large motor, functions from both the Baker AWA-IV and the PP30 are used together. The Baker AWA-IV is used to perform the winding resistance test and the Meg-Ohm and PI tests. The PP30 is used to perform the HiPot test and the Surge test. The test data collected by both instruments is then combined into a single test record in the database.

An example of the procedure is shown. For this example, both a new Motor ID and a new Test ID will be created. The Motor is a 4160V 300rpm motor that will be tested at 4000V for the Meg-Ohm/PI test and 9300V for the HiPot and Surge test.

Because this motor is a large slow motor, the 12kV Baker AWA-IV by itself will not be able to reach the 9300V Surge test voltage—the PP30 will have to be used. Although the Baker AWA-IV can perform the 9300V HiPot test, we will set up the PP30 to perform the test.

Briefly, the procedure will be to:

1) Create a new Motor ID.

2) Create a new Test ID.

3) Set up the Test ID for the test voltages above.

4) Perform the tests with the Baker AWA-IV doing the Resistance, Meg-Ohm/PI tests, and the PP30 doing the HiPot and Surge tests.

Creating a new motor ID

1) Select the **Data** and **Nameplate** tabs on the right hand side of the Baker AWA-IV software screen.
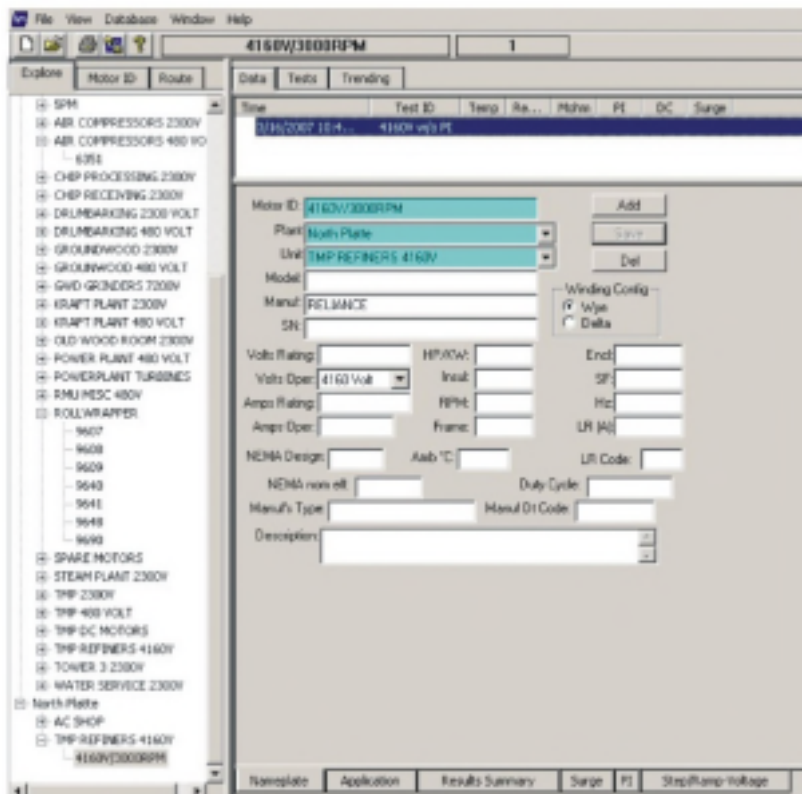
Figure 147. Creating a new Motor ID.

2) Press the **Add** button to add a new Motor ID. The screen capture below shows a new motor called 4160V_300RPM. For this example, no other information on the **Nameplate** tab is filled in.

3) Press the **Tests** tab to get to the testing window to create a new Test ID.

4) Click on the **Edit Test ID** checkbox.

5) Enter the password for editing Test IDs.

6) Click on the **Add** button to open the *Create New Test ID* dialog box as shown below.
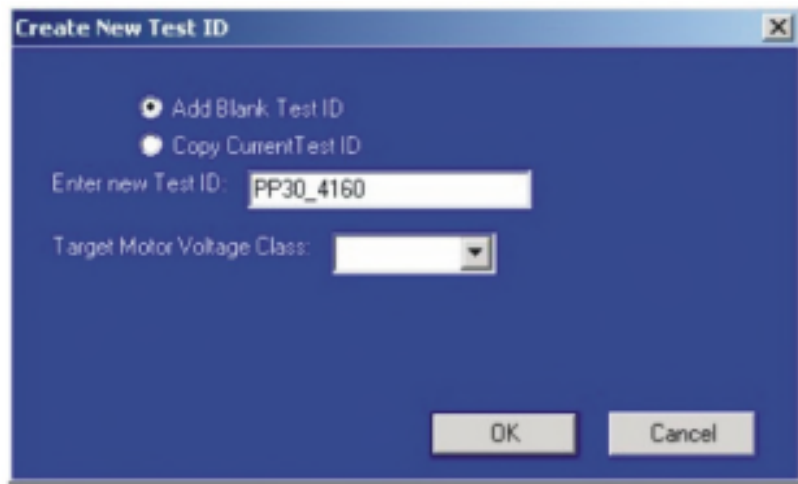
Figure 148. Creating a new Test ID.

7) Click on the **Add Blank Test ID** radio button.

8) Enter the new Test ID in the appropriate field. In this example, we use PP30_4160.

9) Use the **Target Motor Voltage Class** dropdown menu to select a voltage class. For this example, we would select a voltage class of 4160.

10) Click **OK** to continue.

11) In the **Tests** tab, turn on the Resistance, Meg-Ohm, PI, HiPot and Surge tests.

12) Open each Test configuration window to properly configure each of the tests. The HVDC test setup window is shown in the example below.
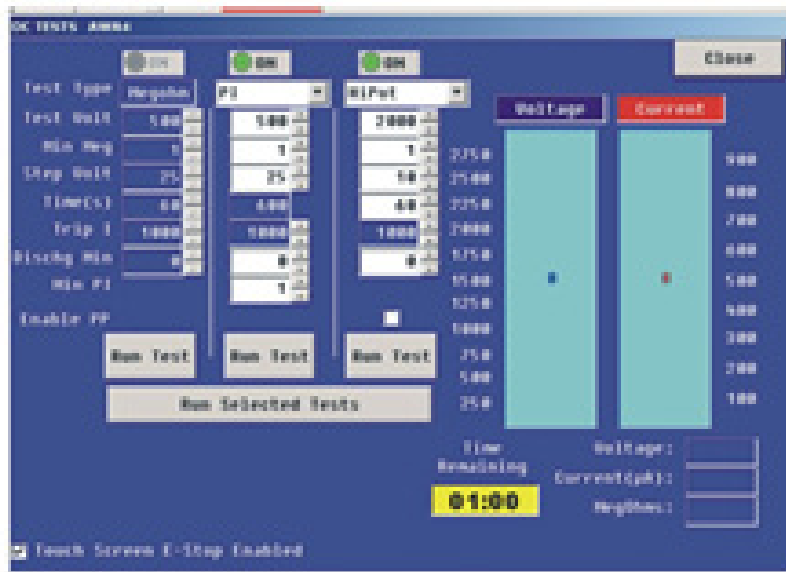
Figure 149. Configuring DC tests a new Test ID.

13) Notice that all tests have been turned on, the desired test voltages entered, and the **Enable PP30** box under the HiPot column has been checked, indicating that the PP30 will be used for the HiPot test.

Appendix A — Baker AWA-IV troubleshooting

Please review this section before you call Baker Instrument Company, an SKF Group Company, or return the unit.

Self help and diagnostics

Problems in testing often crop up. If you are experiencing a problem and believe the problem might be with the Baker Instrument Company, an SKF Group Company, Surge/DC HiPot 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 the appropriate response. Either department may be reached toll-free at 800-752-8272 or 970-282-1200 for assistance.

Repair parts

> **WARNING**
> **Electrical 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.

Step #1: Basic information

Record all basic instrument information including:

- Model number
- Serial number
- Product number
- Software version number

> **NOTE**
> All information above except for software version number is located on the rear panel product label. Software version can be found by starting the software and clicking on the Help-About Baker AWA-IV... menu item. If the tester has special options installed, please note these. Any instrument information derived is helpful! A great tool would be a printout or sketch of the waveforms displayed on the tester.

Step #2: Applications or service problem?

Generally, if a problem is noted only when testing a specific motor/generator or other coil type, then applications would be involved. See "Applications: What to do first!" Please call the sales department for applications assistance.

If the problem is not 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 on common application problems. Please have basic information about the tester and specific information about the motor being tested available when calling or faxing to assist sales/support 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, all information from the motor nameplate would be 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, attention: Applications.

Common application problems

There are a few common application-related problems. Please review the following cases.

1) The Baker AWA-IV will not give the desired output test voltage for the apparatus under test.

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

  1.2 The Baker AWA-IV may be at fault in this case. Do not continue testing until Baker Instrument Company, an SKF Group Company, applications department is contacted.

2) Separation of compared surge wave patterns is seen when surge testing known-good coils, brand new motors or windings. Often, separation is seen in all three comparisons for three phase motors, but to varying degrees.

  2.1 Generally, this is caused by unbalanced impedance in windings which is inherent to the design. It most commonly occurs in basket or concentric wound motors. The phases are not magnetically balanced due to different coil lengths.

  2.2 When acceptance testing, waveforms that are separated because of improper turn counts, misconnections, or reversed winding groups may be seen.

  2.3 This condition may also be seen in DC fields or rotating poles. Coils being compared must be tested in identical configurations.

2.4 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 ground lead removed from the motor frame. If the separations disappear, the problem was capacitance to ground. Be sure the winding has passed the DC tests before doing the Surge 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.

3.1 The coil under test is probably too high an impedance to get a good working pattern. The coil may be very high in resistance.

3.2 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.

Precautions for proper operation

- Never raise the output control to attain a display from a blank screen.

- Never attempt simulated problems by disconnecting the leads and positioning them to arc against each other.

- Never come in contact with the item being tested and the test leads, or with the tester and the item being tested.

- Never attempt a two-party operation.

- Never attempt a burn-out of a detected fault with the tester.

- Always know what test is being performed and when.

Service: What to do first!

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

Open condition display

Note the figures below. Is the surge waveform like this?
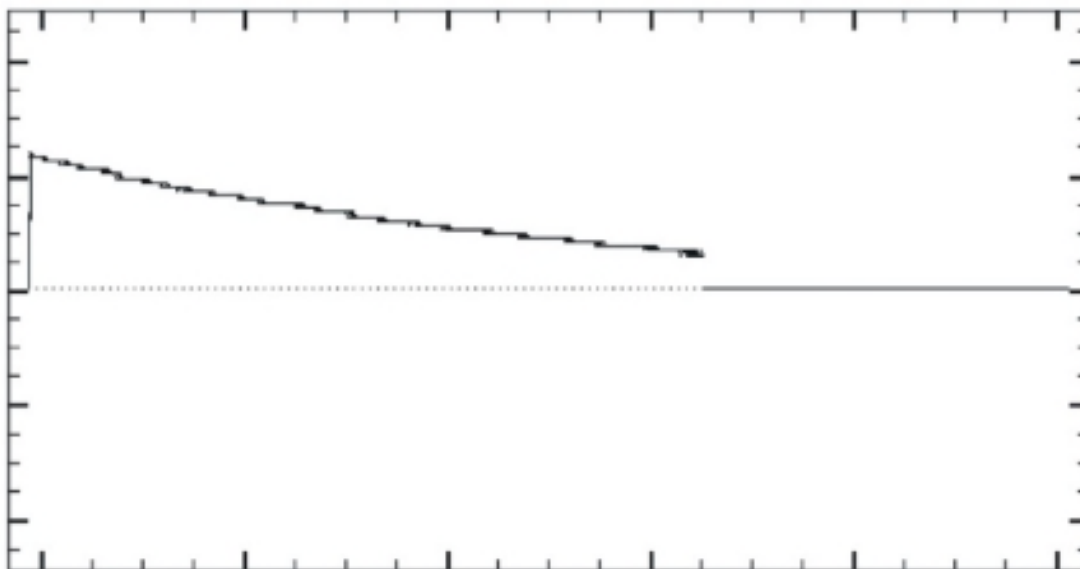
Figure 150. Open condition.

If yes, the unit may have at least one broken test lead causing an open condition. In most cases, the test lead that is under test and gives this pattern is the broken lead.

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

HiPot display checks

1) The HiPot display shows only the voltage or current bar. One of three problems might exist.

   1.1 The item being tested is in fact faulty and has either low insulation resistance or open connections.

   1.2 The Baker AWA-IV has an internal problem.

   1.3 The tester has a test lead problem as shown above for an open condition.

Disconnect the test leads from the motor and isolate the tester from any grounded surface. Reduce the output to minimum and attempt a HiPot test with an open lead condition. Your 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 Baker AWA-IV is working properly.

If the display still shows no voltage bar, call the 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 the serviced epartment.

HiPot over current trip check

1) Either the HiPot trip lamp 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:

• Has the unit recently been moved to a new location with possibly an ungrounded outlet?

• Is the unit being operated in a field where the AC power source is unknown?

• Is the unit being operated on a scope cart that has its own outlet or power source?

• Is the unit being operated using a two-wire extension cord?

• Is the unit being operated on a transformer-isolated circuit?

If you answer "yes" to any of these questions, the unit is probably operational and indicating that there is open AC line ground connection.

In the case of numbers 1–3 above, use an outlet tester to ensure proper wiring connections to the outlet.

Limited output surge waveform

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

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

Proper storage of leads/unit

After the instrument has been correctly shut down, the high-voltage and resistance leads can be placed back into the nylon bag with the power cord. This can be carefully placed on top of the touchscreen and the lid closed for storage. By not placing the leads in the nylon, bag and putting them directly onto the touchscreen can break or damage this screen. If the screen is damaged, the unit will not operate properly and have to be sent to Baker Instrument

Company, an SKF Group Company, for replacement. Even though these units come with a comprehensive one-year warranty, exterior damage of this type is not covered.

Take care to keep the unit dry. This instrument should not be stored in any location where water entry to the instrument can occur. Humidity will also affect the operation of the instrument.

Checking test leads for broken sections

Either prior to using the instrument or at least once a month, each test lead should be inspected for broken sections. If the tester has a broken lead, the instrument will not work properly and give erroneous results. Within the first six inches from the tester panel, strain-reliefs and 12–18 inches from the clips are the typical spots where the leads are broken. There are two methods to check for breaks in the leads: a manual check and an overcurrent trip test.

Manual break check

1) Inspect the lead wire for any cuts or nicks in the wire sheath.

2) Take the clip in one hand and grip the lead wire in the other had approximately 12–18 inches from the clip.

3) Grip the lead wire approximately six inches from the strain relief on the tester.

4) Steadily, pull the lead. If the lead stretches, it is broken. If it does not have any give, it is good.

Overcurrent trip test

The black ground lead is the most often broken lead. This is an easy test to verify if the black lead is broken.

1) Connect all leads together (clip to clip) (three red, one black ground).

2) Place tester in either Meg-Ohm or DC HiPot mode. Initiate test.

3) If the tester immediately shows an overcurrent trip, the black test lead is good. If the tester continues to ramp up to the test voltage, the black test lead is broken.

Open circuit test to verify tester operation

While doing periodic testing there are some instances that the tester will immediately trip when first initiating testing. When this occurs, there is generally some question by the operator if the motor is truly bad or if the tester is operating correctly. A simple open circuit test verifies tester operation.

1) Unhook all leads from the motor being tested.

2) Place all leads some place safe: on the floor, over the edges of a plastic trash can, and so on. Ensure that the test clips do not touch.

3) Place the black lead away from the red leads.

4) Initiate either a Meg-Ohm or a DC HiPot test.

5) If the tester is operating correctly, it will ramp up to the test voltage with minimal leakage current and will not overcurrent trip. If the tester is not operating correctly, it will overcurrent trip immediately like when it was attached to the motor.

6) If the tester is operating correctly, reconnect to the possible bad motor and retest. If it is not operating correctly the service department for assistance.

Third party software warning

⚠️ **NOTICE**

Even though Windows XP Embedded® does not allow the installation of general software packages, do not install spy ware or spam blockers, screen savers, virus detectors or wireless Internet software to the tester. It will corrupt testing procedures and operations. Many of these types of software packages, when installed on the tester will continue to poll/ use CPU resources of the computer even when not open on the desktop, creating conflicts.

Baker AWA-IV calibration information

Baker AWA-IV calibration information and documentation can be acquired by calling Baker Instrument Company, an SKF Group Company, at 800-752-8272 or 1-970-282-1200. Please ask a service representative for document number 76-001-003.

Warranty return

Please review the warranty notes and shipment sections at the beginning of this manual before sending your 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 to you.

Warranty return form

Please copy and fill out all the following information and return this form with the tester. Make a copy of all records prior to 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:_____

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: _____

Software Version #: _____

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 the copy 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

Appendix B — Software basics and installation

Navigating the software interface

Familiarity with Windows® and basic computer skills is assumed. For operators unfamiliar with Window®, the following texts might be helpful.

- Liming, Sean D, "Windows XP Embedded Advanced," October 2003.

- Cseri, James Beau, *Windows XP Embedded Step by Step*, RTC Books, San Clemente, CA, January 2003.

Working with the Baker AWA-IV software requires that the user be comfortable using multiple windows, a variety of keyboard commands, and a pointing device (mouse). To enhance navigation, hot keys (keyboard shortcuts and toolbars) have been added to the programs.

On the Baker AWA-IV, one window may serve several purposes. For example, the Motor Tree View window shows the motor tree and also allows use of Routes and access to the Route Editor.

Selecting items

As with most modern computer interfaces, the common way to select an item is to point at the item with the pointer device (mouse) and double-click with the left button while holding the device still. In many cases, a single click will not select an item, but will highlight it. The appearance of highlighted and selected items varies depending on the screen design.

Another method of selection applies to menu labels that have an underlined character. For example, on the menu bar, the **File** menu has an underlined **F.** Use the Alt key and the underlined key (F) together to perform the same function as a mouse click on the menu option. When Alt-F is typed, the **File** dropdown menu appears.

Shading

The shading of the images on the various screens of the programs is significant. Gray shaded fields are generally non-editable. When a field has a white background with black text, it is editable.

Buttons

Square and rectangular buttons with labels supply commands to the Baker AWA-IV. For example, look at the *Nameplate* window to see the **Add, Update**, and **Del** buttons. Small square buttons such as the one next to **Edit Test ID** field in the **Tests** tab are called check boxes. They display a checkmark when active. Round buttons called, radio buttons, fill with black when active; radio buttons begin tests in semi-automatic mode.

Text fields

Areas that can have text typed into them are called text fields. To edit text fields, click in them and then type. Some text fields require information and others do not. Your will be prompted to enter missing information required by the Baker AWA-IV if a necessary field has been left blank.

Scroll bars and Windows® icons

The scroll bars on the bottom and right sides of the window allow the user to view parts of the window that do not currently fit on the screen. Icons in the upper right hand corner of the window allows it to be minimized to take up less computer screen space, maximize to fill the screen, or closed. The small printer icon in the upper left corner of the screen is a printing shortcut. The program icon that appears next to the Baker AWA-IV software on the top of the window allows you to minimize and maximize the display or exits the program.

Baker admin or user shell

The Windows XP Embedded® operator interface offers a tamper resistant user shell that does not allow software additions or any changes to the overall operating system of the instrument. Two modes are available – the Baker admin and user shell. There are several ways to enter into these modes. The Baker admin shell can be reached from a desktop shortcut or form inside the Baker AWA-IV software via left Alt key and F12. The user shell can only be entered into via the left Alt key and F12. The Baker admin shell allows the addition of printer drivers, add or configure network or Ethernet support, upgrade AWA software or other basic features of Windows XP® Embedded software. When the user shell is employed the only operation of the instrument is within the Baker AWA-IV software. To switch between these two modes, the instrument must be rebooted to activate the mode desired. Even within the admin mode of the Windows XP® Embedded software most third party software will not load onto the instrument successfully. This is employed to stabilize the testing environment of the instrument.

Software installation

Because there are periodic upgrades and fixes to computer driven products, it makes sense to keep in touch. Contact Baker Instrument Company, an SKF Group Company, by calling 970-282-1200 or 800-752-8272 (US only) or access the website at www.bakerinst.com. There is download section, where the latest software can be downloaded.

Desktop install

It makes sense to do a lot of the report generation on a desktop PC. Desktop monitors are larger, the Baker AWA-IV unit is not tied up while reports are being printed, and it is easier to share data with other people on the network, who have the desktop software present at their workstation.

When it is time to install the programs from CD-ROM or over the network, be sure to check the Readme.txt files, this is where the latest information about the upgrades can be found.

Appendix C — Technical specifications and applicable standards

Table 8. *Surge test specifications.*

Parameter	Baker AWA-IV 2kV	Baker AWA-IV 4kV
Output voltage	0-2160 Volts	0-4250 Volts
Max output current	200 amps	400 amps
Pulse energy	.2 joules	.9 joules
Storage capacitance	.1F	.1µF
Sweep range	2.5-200 µS/Div	2.5-200 µS/Div
Volts/division	500/1000/2000/ 3000	500/1000/2000/ 3000
Repetition rate	5 Hz	5 Hz
Voltage measurement and accuracy	+/- 12%	+/- 12%

Table 9. *DC High Potential (HIPot) test specifications.*

Parameter	Baker AWA-IV 2kV	Baker AWA-IV 4kV
Output voltage	0-2160 Volts	0-4250 Volts
Max output current	1000 µ amps	1000 µ amps
Current resolution	.1/10/100/1000 µ amps division	.1/10/100/1000 µ amps division
Overcurrent trip settings	1/10/100/100 µ amps	1/10/100/100 µ amps
Full scale voltage and current measurement and accuracy	+/- 5%	+/- 5%
Meg-ohm accuracy	+/- 10%	+/- 10%
Max Meg-ohm reading	50,000 MΩ	50,000 MΩ

Table 10. *Physical characteristics.*

Parameter	Baker AWA-IV 2kV	Baker AWA-IV 4kV
Weight	24 lbs.	24 lbs.
Dimensions (W x H x D)	15 x 8 x 8 inches	15 x 8 x 8 inches
Power requirements	85-264VAC 50/60 Hz @ 500 watts or more	85-264VAC 50/60 Hz @ 500 watts or more

Table 11. *Accuracy of measurements—Coil resistance test. Four-wire Kelvin method resistance test (use separate test leads).*

Range	Resolution	Full-scale accuracy
*10Ω– 100Ω	.1Ω	+/- 5%
2Ω – 20Ω	.1Ω	+/- 5%
.2 – 2Ω	.05Ω	+/- 5%
.05 – .6Ω	.005Ω	+/- 5%
.005 – .07Ω	.0002Ω	+/- 5%
.001 – .01Ω	.0001Ω	+/- 5%

* Above 100Ω is reported as a potentially open circuit.

Table 12. *Testing accuracy for HiPot Measurements.*

Range	Approximate maximum measurable current	Resolution	Full-scale accuracy
100 µ A/Div	900 µA		+/- 5%
10 µ A/Div	90 µA	+/-5% from 9 µA-90 µA	+/- 5%
1 µ A/Div	9 µA	+/-5% from .9 µA-9 µA	+/- 5%
.1 µ A/Div	.9 µA +/- .045 µA	+/-5% from .1 µA-.9 µA	+/- 10%

Table 13. *Voltage measurement accuracy—Surge test.*

Range	Resolution
500V/Div	+/-12%
1000V/Div	+/-12%
2000V/Div	+/-12%

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)
- IEEE 434-1973 Guide for Functional Evaluation of Insulation Systems for Large High-Voltage Machines
- IEEE 522-1992 Guide for Testing Turn-To-Turn Insulation on Form-Wound Stator Coils for Alternating-Current Rotating Electric Machines.
- NEMA MG1-1993 Motors & Generators

Reprints or EASA standards are available from:

www.easa.com

1331 Baur Boulevard

St. Louis, MO 63132

Phone: 314-993-2220

FAX: 314-993-1269

Reprints of IEC standards are available from:

International Electrotechnical Commission (IEC)

www.IEC.ch

Reprints of IEEE standards are available from:

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

Reprints of NEMA standards are available from:

National Electrical Manufacturers Association (NEMA)

Global Engineering Documents

Phone: 1-800-854-7179

International: 303-379-2740

Appendix D — Database definition

Version 4.0 database definition

The AWA database is an Access 97 database (.mdb) it can also be converted to an Access 2000 database and be used by the AWA. The Access database is divided into several tables. The motor information and test results data is contained in the following tables: MotorID, TestResults, TestResultsParameters, TestResultsPI, TestResultsPrgHiPot, and SurgeWaveform. The testing criteria used to run the tests are contained in the following tables: TestId, TestIdPrgHiPot, and RefSrgWaveform. Two addition tables are used, one is the DatabaseInfo table and the other is the Route table.

Nameplate table—(MotorID)

The MotorID table contains the nameplate information for each motor added to the database. There is only one motor record per motor. The motor_key is the primary keyed field. It is automatically generated when a new motor is added.   The Motor ID field is a unique identifier that the user gives each motor.

Table 14. *Field name descriptions.*

Field name	Type	Description
motor_key	Long integer	Automatically generated number used as the primary key.
tree_level_1	Text (25)	First level used in the tree view. Motor location 1 user defined field label, defaults to Location.
tree_level_2	Text (25)	Second level used in the tree view. Motor location 2 user defined field label, defaults to Building.
motor_id	Text (30)	User entered Motor Identification value. It must be unique.
manuf	Text (25)	Manufacturer of the motor.
manuf_type	Text (25)	NEMA MG 1 requires manufacturer's type but may vary depending on manufacturer.
manuf_date_code	Text (16)	Manufacturer's nameplate date.
model	Text (25)	Manufacture's Identification of model type.
sn	Text (25)	Manufacture's serial number.
hpkw	Single	Nameplate horse power or kilowatts.
rpm	Single	Revolutions per minute (RPM).

Field name	Type	Description
voltage_rating	Text (16)	Nameplate voltage ratings.
voltage_operating	Single	Name Plate Voltage used as a Voltage Class.
amps_rating	Text (16)	Nameplate current (amps) ratings.
amps_operating	Single	Operating current (amps).
frame	Text (16)	Frame type code indicating dimensions.
insulation_class	Text (8)	Locked rotor current in amps.
lockec_rotor_current	Single	Locked rotor current in amps.
locked_rotor_code	Text (4)	A letter code that groups motors based on KVA/hp. (KVA code)
service_factor	Single	Factor when multiplied by hp, gives the allowable hp loading.
enclosure	Text (16)	Classifies the motor as to its degree of protection from the environment and method of cooling.
freq_hz	Long integer	Input frequency usually 50 or 60 Hz.
NEMA_design_code	Text (4)	NEMA codes assigned to define torque and current characteristics of the motor.
NEMA_nom_efficiency	Short	This represents an average efficiency of a large population of like motors.
max_ambient_temp	Single	The maximum ambient temperature at which the motor can operate and still be within the tolerance of the insulation class at the max temperature rise in C.
duty_cycle	Text (16)	Defines the length of time during which the motor can carry its nameplate rating safely.
user_defined_description	Text (64)	User defined motor description field.
winding_config	Text (8)	Wye or Delta winding configuration.

Test results table—(TestResults)

The TestResults table has a test_resultno that is auto generated each time a test results record is added either after a test is performed or in the Application View of the AWA software.

Table 15. *Field name descriptions.*

Field name	Type	Description
test_resultno	Long integer	Automatically generated number used as primary key. Foreign key in other test result tables.
motor_key	Long integer	Used as the foreign key. (Primary key of MotorID table). Links the test results to the Motor ID's.
testdate_time	Date/Time	Time stamped at the time the test results are saved.
testid	Text (25)	Test ID used for this set of test results.
test_level_1	Text (25)	First level used in the tree view. Motor location 1 user defined field label, defaults to Location.
test_level_2	Text (25)	Second level used in the tree view Motor location 2 user defined field label, defaults to Building.
testfor	Text (25)	Enter the entity for which the motor is being tested.
testby	Text (25)	Enter the person who is performing the test on the motor.
baker_sn	Long integer	Serial number on the Baker Tester being used for the test.
baker_tester_type	Text (25)	Type of Baker tester being used for the test. (AWA, D12R, and so on).
baker_calibration_date	Text (20)	Last date that the tester was calibrated.
baker_pp30sn	Long integer	Serial number of the Power Pack, if any.
use	Text (25)	Enter how the motor is being used.
verthoriz	Text (16)	Enter vertical or horizontal mounting.
starter	Text (16)	Motor starter type.
start24h	Text (16)	Number of starts per 24hr.

Field name	Type	Description
percentld	Text (4)	Percent of load being applied.
roomno	Text (25)	Room number. Can also be used as a job number.
mcc	Text (25)	Motor control cabinet Identification.
app_volts1	Double	Application phase 1 voltage.
app_volts2	Double	Application phase 2 voltage.
app_volts3	Double	Application phase 3 voltage.
app_amps1	Double	Application phase 1 current.
app_amps2	Double	Application phase 2 current.
app_amps3	Double	Application phase 3 current.
repairno	Text (16)	Repair number.
install	Text (8)	Date the motor was installed at the current location.
basic	Text (8)	Date when the motor had basic service.
rewind	Text (8)	Date the motor was last rewound.
memo_used	Yes/No	Indicates a memo has been entered.

Table 16. *Temperature test results.*

Field name	Type	Description
temp_status	Text (8)	Contains the status of the test, PASS or FAIL if a test has been performed or blank if no temperature test has been conducted.
temp_why_failed	Text (25)	Reason why motor failed (if it failed).
temp_temperature	Double	Temperature of motor, always stored as Celsius.
temp_degF_C	Yes/No	False if temp was entered as C. True if temp was entered as F.

Table 17. *Resistance test results.*

Field name	Type	Description
resist_status	Text (8)	Contains the status of the test, PASS or FAIL if a test has been performed or blank if no resistance test has been conducted.
resist_why_failed	Text (25)	If the motor failed, reason why.
resist_balance1	Double	Balance resistance for lead 1.
resist_balance2	Double	Balance resistance for lead 2.
resist_balance3	Double	Balance resistance for lead 3.
resist_12	Double	Lead 1 to lead 2 resistance.
resist_23	Double	Lead 2 to lead 3 resistance.
resist_31	Double	Lead 3 to lead 1 resistance.
resist_corrected1	Double	Corrected resistance for lead 1.
resist_corrected2	Double	Corrected resistance for lead 2.
resist_corrected3	Double	Corrected resistance for lead 3.
resist_delatR_max	Double	Max delta resistance test tolerance.
resist_coil1	Double	Coil resistance for lead 1.
resist_coil2	Double	Coil resistance for lead 2.
resist_coil3	Double	Coil resistance for lead 3.
resist_corrected_coil1	Double	Corrected coil resistance for lead 1.
resist_corrected_coil2	Double	Corrected coil resistance for lead 2.
resist_corrected_coil3	Double	Corrected coil resistance for lead 3.

Table 18. Meg-Ohm test results.

Field name	Type	Description
Meg-Ohm_status	Text (8)	Contains the status of the test, PASS or FAIL if a test has been performed or blank if no Meg-Ohm test has been conducted.
Meg-Ohm_whyFailed	Text (25)	Reason why motor failed (if it failed).
Meg-Ohm_voltage	Long integer	Voltage used in Meg-Ohm calculations.
Meg-Ohm_current	Double	Current used in Meg-Ohm calculations.
Meg-Ohm_Meg-Ohm	Long integer	Meg-Ohm value = voltage/current.
Meg-Ohm_IR_at_40C	Long integer	Meg-Ohms (insulation resistance) at 40 °C.

Table 19. PI test results.

Field name	Type	Description
pi_status	Text (8)	Contains the status of the test, PASS or FAIL if a test has been performed or blank if no PI test has been conducted. (DA Only DPASS/DFAIL.)
pi_whyFailed	Text (25)	Reason why motor failed (if it failed).
pi_voltage	Short integer	Test voltage for PI test.
pi_da_ratio	Double	3-minute resistance value divided by 30-second resistance value.
pi_ratio	Double	10-minute resistance value divided by 1-minute resistance value.

Table 20. HiPot test results.

Field name	Type	Description
HiPot_status	Text (8)	Contains the status of the test, PASS or FAIL if a test has been performed or blank if no HiPot test has been conducted.
HiPot_whyFailed	Text (25)	Reason why motor failed (if it failed).
HiPot_voltage	Long integer	Voltage at the end of test.
HiPot_current	Double	Current at the end of test.
HiPot_Meg-Ohm	Long integer	Meg-Ohm value = voltage/current.
HiPot_IR_at_40C	Long integer	Meg-Ohms (insulation resistance) at 40 °C.

Table 21. DC High Potential (HIPot) test specifications.

Field name	Type	Description
surge_status	Text (8)	Contains the status of the test, PASS or FAIL if a test has been performed or blank if no surge test has been conducted.
surge_whyFailed	Text (25)	Reason why motor failed (if it failed).
surge_peak_volt1	Short integer	Peak voltage reached for lead 1.
surge_peak_volt2	Short integer	Peak voltage reached for lead 2.
surge_peak_volt3	Short integer	Peak voltage reached for lead 3.
surge_ear1_2	Short integer	Error Area Ratio lead 1 to lead 2.
surge_ear1_3	Short integer	Error Area Ratio lead 1 to lead 3.
surge_ear_2_3	Short integer	Error Area Ratio lead 2 to lead 3.

Memo table—(Memo)

This table contains the memo if any that a user can fill out per test result.

Table 22. *Memo table field descriptions.*

Field name	Type	Description
Test_resultno	Long integer	Foreign key used to link test result records.
motor_key	Long integer	Motor key Identification key.
memo	Memo	Memo field type containing the user entered text.

Polarization Index Test Results table—(TestResultsPI)

The TestResultsPI table contains a record for a test result, only if a DA/PI test has been performed. Then a record containing the motor_key and same test_resultno for each step of the test is added to the table.

Table 23. *DC High Potential (HIPot) test specifications.*

Field name	Type	Description
test_result_no	Long integer	Foreign key used to link test result records.
motor_key	Long integer	Motor Identification key.
piamps15	Double	Current in micro amps @ 15 seconds.
piamps30	Double	Current in micro amps @ 30 seconds.
piamps45	Double	Current in micro amps @ 45 seconds.
piamps60	Double	Current in micro amps @ 60 seconds.
piamps90	Double	Current in micro amps @ 90 seconds.
piamps120	Double	Current in micro amps @ 120 seconds.
piamps150	Double	Current in micro amps @ 150 seconds.
piamps180	Double	Current in micro amps @ 180 seconds.
piamps240	Double	Current in micro amps @ 240 seconds.
piamps300	Double	Current in micro amps @ 300 seconds.
piamps360	Double	Current in micro amps @ 360 seconds.
piamps420	Double	Current in micro amps @ 420 seconds.
piamps480	Double	Current in micro amps @ 480 seconds.
piamps540	Double	Current in micro amps @ 540 seconds.

Field name	Type	Description
piamps600	Double	Current in micro amps @ 600 seconds.
pires15	Double	Resistance in Meg-Ohms @ 15 seconds.
pires30	Double	Resistance in Meg-Ohms @ 30 seconds.
pires45	Double	Resistance in Meg-Ohms @ 45 seconds.
pires60	Double	Resistance in Meg-Ohms @ 60 seconds.
pires90	Double	Resistance in Meg-Ohms @ 90 seconds.
pires120	Double	Resistance in Meg-Ohms @ 120 seconds.
pires150	Double	Resistance in Meg-Ohms @ 150 seconds.
pires180	Double	Resistance in Meg-Ohms @ 180 seconds.
pires240	Double	Resistance in Meg-Ohms @ 240 seconds.
pires300	Double	Resistance in Meg-Ohms @ 300 seconds.
pires360	Double	Resistance in Meg-Ohms @ 360 seconds.
pires420	Double	Resistance in Meg-Ohms @ 420 seconds.
pires480	Double	Resistance in Meg-Ohms @ 480 seconds.
pires540	Double	Resistance in Meg-Ohms @ 540 seconds.
pires600	Double	Resistance in Meg-Ohms @ 600 seconds.
pi_current_1sec	Memo	Comma delimited field containing the current for each second 180 data , if it is a DA only, or 600 if a full PI was run.

Step Voltage test results table—(TestResultsPrgHiPot)

The TestResultsPrgHiPot table contains a record for a test result, only if a Step Voltage Test test has been performed. Then a record containing the motor_key and same test_resultno for each step of the test is added to the table.

Table 24. *Step voltage table field descriptions.*

Field name	Type	Description
test_resultno	Long integer	Foreign key used to link test result records.
motor_key	Long integer	Motor Identification key.
step_order	Long integer	Enumerator used to sort results in step order.
step_voltage	Long integer	Voltage for the given test interval.
step_time	Short integer	Length of step in seconds.
step_ramp_rate	Short integer	Not used at this time.
step_min_Meg-Ohm	Long integer	Minimum Meg-Ohms aloud for the step.
Meg-Ohm_at_endstep	Long integer	Meg-Ohm value at the end of the step.
current_at_endstep	Double	Current in micro amps at the end of the step.
voltage_1sec	Memo	Comma delimited field containing the voltage for each second of the interval, including ramping voltage.
current_1sec	Memo	Comma delimited field containing the current for each second of the interval, including current during ramping of voltage.
time_1sec	Memo	Comma delimited field containing the times progression for each second of the interval, including time during ramping of voltage.

Table 25. *DC High Potential (HIPot) test specifications.*

Field name	Type	Description
test_rsultno	Long integer	Test result number (unique key ties to other test results).
motor_key	Long integer	Motor identification key.
waveFormatVr	Double	Version of waveform record.
xscale	Short integer	Scale index for the x-axis (micro seconds per division).
yscale	Short integer	Scale index for the y-axis (volts per division).
microSecPerPnt	Double	Micro seconds per point (Not used at this time).
voltsPerPnt	Double	Volts per point (Not used at this time).
wave1Full		Full waveform for lead 1.
wave1Mid		Middle waveform for lead 1.
wave1Min		Minimum waveform for lead 1.
wave1PrevFail		Wave form before the failed waveform for lead 1.
wave1ppEAR		Pulse-to-Pulse EAR for lead 1.
wave2Full		Full waveform for lead 2.
wave2Mid		Middle waveform for lead 2.
wave2Min		Minimum waveform for lead 2.
wave2PrevFail		Wave form before the failed waveform for lead 2.
wave2ppEAR		Pulse-to-Pulse EAR for lead 2.
wave3Full		Full waveform for lead 3.
wave3Mid		Middle waveform for lead 3.
wave3Min		Minimum waveform for lead 3.
wave3PrevFail		Wave form before the failed waveform for lead 3.
wave3ppEAR		Pulse-to-Pulse EAR for lead 3.

Test results parameters table—(TestResultsParameters)

This table contains the test parameters used at the time of testing and is associated with the TestResults records by the test_resultno field.

Table 26. *Test results parameters table field descriptions.*

Field name	Type	Description
test_resultno	Long integer	Foreign key automatically generated in the TestResults Table.
test_mode	Text (15)	Will contain one of the following values AUTOMATIC, SEMIAUTOMATIC, MANUAL, or UNKNOWN.
temp_enabled	Yes/No	Temperature test: 1=on; 0=off.
resist_enabled	Yes/No	Resistance test: 1= on; 0=off.
Meg-Ohm_enabled	Yes/No	Meg-Ohm test: 1=on; 0=off.
pi_enabled	Yes/No	PI test: 1=on; 0=off.
HiPot_enabled	Yes/No	HiPot test: 1=on; 0=off.
prgHiPot_enabled	Yes/No	Step Voltage Test enabled: 1=on; 0=off.
surge_enabled	Yes/No	Surge test: 1=on; 0=off.

Table 27. *Test results parameters table; temperature test parameters field descriptions.*

Field name	Type	Description
temp_isAuto	Yes/No	1=Manual; 0=Automatic.
temp_degF_C	Yes/No	1=F degrees; 0=C degrees.

Table 28. *Test results parameters table; resistance test parameters field descriptions.*

Field name	Type	Description
resist_no_leads	Short integer	# of leads (2 or 3) Used also in surge.
resist_deltaR_enabled	Yes/No	1=delta R used in pass/fail; 0=Not used.
resist_ deltaR_maxpercent	Short integer	Max difference in percent.
resist_external_enabled	Yes/No	Always false 0=No external testing.

Field name	Type	Description
resist_isAuto	Yes/No	1=Automatic; 0=Manual
resist_4lead_test_enabled	Yes/No	1=4 lead test enabled; 0=4 lead test disabled (Only disabled at this time)
resist_correct_to_temp_enabled	Yes/No	Correct resistance 1=Yes; 0=No.
resist_temp_correct_to	Short integer	Defines the value that the temperature will be corrected to.
resist_temp_correct_factor	Double	Default 234.5 for copper.
resist_target_coilRes_enabled	Yes/No	1=Coil resistance checking enabled;0=not enabled.
resist_target_coilRes	Double	Coil resistance to compare tested value with.
resist_target_coilRes_tolerance	Long integer	Tolerance set for target coil resistance.

Table 29. *Test results parameters table; Meg-Ohm test parameters field descriptions.*

Field name	Type	Description
Meg-Ohm_test_voltage	Short integer	Target voltage of test.
Meg-Ohm_min_Meg-Ohm	Short integer	Minimum Meg-Ohm value.
Meg-Ohm_test_time	Short integer	Length of test.
Meg-Ohm_ramp_rate	Short integer	Ramp rate.
Meg-Ohm_trip_level	Short integer	HiPot trip value.
Meg-Ohm_discharge_multiplier	Short integer	Number of minutes to discharge.
Meg-Ohm_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP.

Table 30. *Test results parameters table; polarization index test parameters field descriptions.*

Field name	Type	Description
pi_test_voltage	Short integer	Target voltage of test.
pi_min_Meg-Ohm	Short integer	Minimum Meg-Ohm value.
pi_min_ratio	Double	Length of test.
pi_ramp_rate	Short integer	Ramp rate.
pi_trip_level	Short integer	HiPot trip value.
pi_da_only_enabled	Yes/No	1=DA only; anything else PI.
pi_revert_to_da_enabled	Yes/No	
pi_discharge_multiplier	Short integer	Number of minutes to discharge.
pi_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP.

Table 31. *Test results parameters table; HiPot test parameters field descriptions.*

Field name	Type	Description
HiPot_test_voltage	Short integer	Target voltage of test.
HiPot_min_Meg-Ohm	Short integer	Minimum Meg-Ohm value.
HiPot_test_time	Short integer	Length of test.
HiPot_ramp_rate	Short integer	Ramp rate.
HiPot_trip_level	Short integer	HiPot trip value.
HiPot_discharge_multiplier	Short integer	Number of minutes to discharge.
HiPot_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP.
StepHiPot_PowerPack_enabled	Yes/No	Not used.

Table 32. *Test results parameters table; Surge test parameters field descriptions.*

Field name	Type	Description
surge_test_voltage	Short integer	Target voltage of test.
surge_no_leads	Short integer	Number of leads: 2 or 3.
surge_ramp_rate	Short integer	Ramp rate.
surge_pulses	Short integer	Number of pulses surged at test voltage.
surge_time_scale	Short integer	Index indicating the time per division. 0 – 2.5 uS 4 – 50 uS 1 – 5 uS 5 – 100 uS 2 – 10 uS 6 – 200 uS 3 – 25 uS 7 – Auto scaling
surge_volts_scale	Short integer	Index indicating the volts per division. 0 – 250 w/power pack 1000 1 – 500 w/power pack 2000 2 – 1000 w/power pack 4000 3 – 2000 w/power pack 8000 4 – Auto scale
surge_PauseBetweenLeads	Yes/No	1=Yes pause; 0=No do not pause.
surge_zero_enabled	Yes/No	Zero tolerance error checking on/off.
surge_zero_percent	Short integer	Zero tolerance percent.
surge_EAR_enabled	Yes/No	EAR checking on or off.
surge_EAR_percent	Short integer	EAR error tolerance
surge_ppEAR_enabled	Yes/No	Pulse to pulse EAR error checking enabled.
surge_ppEAR_percent	Short integer	Pulse to pulse EAR tolerance percent.
surge_refEAR _percent	Short integer	EAR tolerance with reference wave.
surge_refwave_test_key	Long integer	0=No reference waveform; if any other number then it is a key to the ref waveform record in the RefSrgWaveform table.
surge_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP

Table 33. *Test results parameters table; additional fields descriptions.*

Field name	Type	Description
surge_AT101_enabled	Yes/No	1=AT101 enabled; 0=Not enabled
motor_voltage_class	Long integer	Voltage class of the Test ID used
temp_RH_enabled	Yes/No	1=Relative Humidity enabled; 0= Not enabled
HiPot_rampVTest_enabled	Yes/No	1=Ramped Voltage Test enabled; 0= Not enabled

Test ID table—(TestId)

The TestId table contains information that is used to set up the test criteria. . There is only one motor record per motor. The test_key is the primary key. It is automatically generated when a new test is added. The testid field is a unique Identifier that the user gives each set of test criteria to Identify what motor(s) is meant to be tested. Such as, 480 V w/o PI.

Table 34. *Test ID table field descriptions.*

Field name	Type	Description
test_key	Long integer	Automatically generated number used as the primary key.
testId	Text (25)	Test identification.
datetime_modified	Date/Time	Date and time stamp as to when a Test ID gets updated.
temp_enabled	Yes/No	Temperature test: 1=on; 0=off.
resist_enabled	Yes/No	Resistance test: 1= on; 0=off.
Meg-Ohm_enabled	Yes/No	Meg-Ohm test: 1=on; 0=off.
pi_enabled	Yes/No	PI test: 1=on; 0=off.
HiPot_enabled	Yes/No	HiPot test: 1=on; 0=off.
PrgHiPot_enabled	Yes/No	Step Voltage Test enabled: 1=on; 0=off.
Surge_enabled	Yes/No	Surge test: 1=on; 0=off.

Table 35. *Test ID table; temperature test parameters field descriptions.*

Field name	Type	Description
temp_isAuto	Yes/No	1=Manual; 0=Automatic.
temp_degF_C	Yes/No	1=F degrees; 0=C degrees.

Table 36. *Test ID table; resistance test parameters field descriptions.*

Field name	Type	Description
resist_no_leads	Short integer	# of leads (2 or 3) Used also in surge.
resist_deltaR_enabled	Yes/No	1=delta R used in pass/fail; 0=Not used.
resist_ deltaR_maxpercent	Short integer	Max difference in percent.
resist_external_enabled	Yes/No	Always false 0=No external testing.
resist_isAuto	Yes/No	1=Automatic; 0=Manual
resist_4lead_test_enabled	Yes/No	1=4 lead test enabled; 0=4 lead test disabled (Only disabled at this time)
resist_correct_to_temp_enabled	Yes/No	Correct resistance 1=Yes; 0=No.
resist_temp_correct_to	Short integer	Defines the value that the resistance temperature will be corrected to.
resist_temp_correct_factor	Double	Default 234.5 for copper.
resist_target_coilRes_enabled	Yes/No	1=Coil resistance checking enabled; 0=not enabled.
resist_target_coilRes	Double	Coil resistance to compare tested value with.
resist_target_coilRes_tolerance	Long integer	Tolerance set for target coil resistance.

Table 37. Test ID table; Meg-Ohm test parameters field descriptions.

Field name	Type	Description
Meg-Ohm_test_voltage	Short integer	Target voltage of test.
Meg-Ohm_min_Meg-Ohm	Short integer	Minimum Meg-Ohm value.
Meg-Ohm_test_time	Short integer	Length of test.
Meg-Ohm_ramp_rate	Short integer	Ramp rate.
Meg-Ohm_trip_level	Short integer	HiPot trip value.
Meg-Ohm_discharge_multiplier	Short integer	Number of minutes to discharge.
Meg-Ohm_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP.

Table 38. Test ID table; polarization index test parameters field descriptions.

Field name	Type	Description
pi_test_voltage	Short integer	Target voltage of test.
pi_min_Meg-Ohm	Short integer	Minimum Meg-Ohm value.
pi_min_ratio	Double	Length of test.
pi_ramp_rate	Short integer	Ramp rate.
pi_trip_level	Short integer	HiPot trip value.
pi_da_only_enabled	Yes/No	1=DA only; anything else PI.
pi_revert_to_da_enabled	Yes/No	
pi_discharge_multiplier	Short integer	Number of minutes to discharge.
pi_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP.

Table 39. Test ID table; HiPot test parameters field descriptions.

Field name	Type	Description
HiPot_test_voltage	Short integer	Target voltage of test.
HiPot_min_Meg-Ohm	Short integer	Minimum Meg-Ohm value.
HiPot_test_time	Short integer	Length of test.
HiPot_ramp_rate	Short integer	Ramp rate.
HiPot_trip_level	Short integer	HiPot trip value.

Field name	Type	Description
HiPot_discharge_multiplier	Short integer	Number of minutes to discharge.
HiPot_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP.

Table 40. *Test ID table; Surge test parameters field descriptions.*

Field name	Type	Description
surge_test_voltage	Short integer	Target voltage of test.
surge_no_leads	Short integer	Number of leads: 2 or 3.
surge_ramp_rate	Short integer	Ramp rate.
surge_pulses	Short integer	Number of pulses surged at test voltage.
surge_time_scale	Short integer	Index indicating the time per division. 0 – 2.5 uS 4 – 50 uS 1 – 5 uS 5 – 100 uS 2 – 10 uS 6 – 200 uS 3 – 25 uS 7 – Auto scaling
surge_volts_scale	Short integer	Index indicating the volts per division. 0 – 250 w/power pack 1000 1 – 500 w/power pack 2000 2 – 1000 w/power pack 4000 3 – 2000 w/power pack 8000 4 – Auto scale
surge_PauseBetweenLeads	Yes/No	1=Yes pause; 0=No do not pause.
surge_zero_enabled	Yes/No	Zero tolerance error checking on/off.
surge_zero_percent	Short integer	Zero tolerance percent.
surge_EAR_enabled	Yes/No	EAR checking on or off.
surge_EAR_percent	Short integer	EAR error tolerance
surge_ppEAR_enabled	Yes/No	Pulse to pulse EAR error checking enabled.
surge_ppEAR_percent	Short integer	Pulse to pulse EAR tolerance percent.
surge_refEAR _percent	Short integer	EAR tolerance with reference wave.
surge_refwave_test_key	Long integer	0=No reference waveform; if any other number then it is a key to the ref waveform record in the RefSrgWaveform table.
surge_PowerPack_enabled	Yes/No	1=PP enabled; 0=No PP

Table 41. *Test ID table; additional fields descriptions.*

Field name	Type	Description
surge_AT101_enabled	Yes/No	1=AT101 enabled; 0=Not enabled
motor_voltage_class	Long integer	Voltage class of the Test ID used
temp_RH_enabled	Yes/No	1=Relative Humidity enabled; 0= Not enabled
HiPot_rampVTest_enabled	Yes/No	1=Ramped Voltage Test enabled; 0= Not enabled

Step Voltage test ID table—(TestIdPrgHiPot)

Table 42. *Step Voltage Test ID table fields descriptions.*

Field name	Type	Description
test_key	Long integer	Test identification key.
test_voltage	Long integer	Voltage for this step.
min_Meg-Ohm	Short integer	Minimum Meg-Ohm value for this step.
test_time	Short integer	Length of time for this step.
ramp_rate	Short integer	Ramp rate for this step.
prg_order	Long integer	Step number.
powerpack_enabled	Yes/No	1=PP enabled; 0=No PP

Reference Surge waveform table— (RefSrgWaveForm)

This table contains the waveforms used as test criteria to pass or fail a motor base on a reference waveform.

Table 43. *Reference surge waveform table fields descriptions.*

Field name	Type	Description
refwave_test_key	Long integer	Primary key field it is also stored in TestParameter and TestId tables. Auto generated number.
WaveFormatVr	Double	Version of waveform record.
Xscale	Integer	Scale index for the x-axis (micro seconds per division).
Yscale	Integer	Scale index for the y-axis (volts per division).
MicroSecPerPnt	Double	Microseconds per point (Not used at this time).
VoltsPerPnt	Double	Volts per point (Not used at this time).
peak_volts1	Short integer	Peak voltage reached for lead 1
peak_volts2	Short integer	Peak voltage reached for lead 2.
peak_volts3	Short integer	Peak voltage reached for lead 3.
wave1Full		Full wave form for lead 1.
wave2Full		Full wave form for lead 2.
wave3Full		Full wave form for lead 3.

Database Information table—(DatabaseInfo)

Database information table fields descriptions.

Field name	Type	Description
database_type	Text (25)	Type of database (AWA, MTA).
revised_date	Date/Time	Data and time the database was created or revised.
database_version	Text (25)	Version of the database.
software_version	Text (25)	Software version that is used with this version of the database.
revising_app	Text (25)	Application that revised the database. (AWA, MTA, Data Transfer, and so on).
tree_level_1_field_name	Text (10)	Motor Location field used for this database, default is Location. The record with the most recent date contains the field description used.
tree_level_2_field_name	Text (10)	Motor Location field used for this database, default is Building. The record with the most recent date contains the field description used.

Work list table—(Route)

Table 44. *Work list table fields descriptions.*

Field name	Type	Description
route_id	Text (25)	Name of the route.
motor_key	Long integer	Motor key of the motor belonging to this route.
route_order	Long integer	Order of Motor IDs in Route.

Motor voltage class table—(MotorVoltageClasses)

Table 45. *Motor voltage class table fields descriptions.*

Field name	Type	Description
motor_voltage_class	Long integer	Voltage class (480, 4160, and so on).
class_description	Text (64)	Voltage class description.

Appendix E — Glossary of terms

Insulation Resistance

In the context of the intended use of this equipment, insulation resistance (IR) is determined by application of a known, stabilized DC voltage, and simultaneous measurement of the DC current that passes through or across insulation of the test object.

It is expressed in Meg-Ohms, or 1,000,000 ohms.

Insulation resistance is a circuit parameter, that for electric machines, may exceed several Meg-Ohm's or even several thousand Meg-Ohms.

Polarization Index

For the intended application of this equipment, this is fully expressed as Polarization Index Ratio. In the method used by this equipment, the duration of the test is standardized at 10 minutes. IR is compared at 1 minute and at 10 minutes. Abbreviated as P.I. This technique can provide trend-able test results for condition monitoring purposes.

Dielectric Absorption

In practice, the test is performed at similar, or exactly the same voltage levels as the

P.I. The same principle of leakage measurement is used, and the times of the test is typically a total of 3 minutes. The same measurement of DC leakage current, expressed as a ratio at 30 seconds versus 3 minutes is in effect. This technique can provide trend-able test results for condition monitoring purposes

Meg-Ohm

1 Meg-Ohm is 1,000,000 Ohms (1 million)

Temperature Compensation

It is an established fact that the temperature of the environment has a direct influence on the measurement of both electric coil resistance, and the insulation systems used to maintain the paths where electric current will flow. In the case of electric coils, increased heating leads to an increase in the apparent measured resistance. Conversely, for insulation systems, increase in temperature leads to a decrease in the apparent measured resistance. The idea in effect is that these apparent values can be normalized by conversion factors, leading to the ability to make a more informative judgment of the measured values. This correction enhances the accuracy of trending results

Coil Resistance

In the case of electric motors and generators, coiled loops of wire are used to provide the electric current path. These coils may be windings of several hundreds or more turns of small diameter wire, such as a DC shunt field, or a solenoid. Conversely, they could also be some few turns of very thick and heavy conductor, such as a DC series field or an armature. Therefore, coil resistance could measure several hundred ohms, to less than 1/1000th of an ohm, depending on the electric machine design. An accurate milli or micro ohm meter is essential for making adequate tests in these cases. This technique can provide trend-able test results for condition monitoring purposes.

HiPot

More completely termed the High Potential test. For the intended use of this equipment, the concept is sometimes termed: Proof Test.

A high voltage potential is applied to the electric conductors, while the frame or enclosure of the equipment is held at ground potential. A successful test will pass with negligible or low electric leakage indicated. A failed test will result in a high leakage current, and often an over-current trip condition.

This test is carried out when the consequences of electric machine or insulator's failing test during an equipment outage are grossly outweighed by the severe consequences and equipment damage caused by weak or flawed insulation failure during service.

Step Voltage Test

An enhanced variation of the DC Hipot. The test is comprised of a series of equally timed voltage increases. The leakage current at the conclusion of each step is plotted. Weak or compromised insulation may be revealed by non-linear results, when plotted.

By virtue of this technique, reduced risk of over-current trip and damaging apparatus under test when performed. This technique can provide trend-able test results for condition monitoring purposes.

Ramp Voltage Test

An enhanced variation of the DC Hipot. The test is comprised of a smoothly rising ramped voltage. The rate of rise may be as slow as 5 volts per second. During the rise to the target voltage, the leakage current is constantly monitored and plotted. Discontinuity or non-linear responses of the leakage can reveal weak or compromised insulation.

By virtue of this technique, reduced risk of over-current trip and damaging apparatus under test when performed. This technique can provide trend-able test results for condition monitoring purposes.

Leakage Current

For the purposes of this equipment, leakage current is the DC current, in micro-amperes.

It is measured across, through or over the surfaces of the object under test. In general terms, properly functional insulation exhibits very small, or neglible electrical leakage current.

IuA

This abbreviation stands for: current (I) micro (u) Amperes (A)

Error Area Ratio (EAR)

This is a technique in effect during the Surge test. This technique allows a numeric value to be assigned to an electrical signal generated, and sampled by the test equipment. Since it is possible to assign a number to the signal generated, it becomes possible to make comparisons between previously sampled data, and determine the ratio of difference between the two signals. Specifically, is a very effective technique for discerning electrical differences between electric coils.

L-L EAR

This technique is selectable during the Surge test. Full name: Line to Line Error Area Ratio. This term is used to describe the Error Area Ratio measurement comparison between successive tests of the same test object, specifically in the case of poly-phase induction machines. It is a modern day, enhanced equivalent of the surge comparison test. A numeric value can be assigned to the instantaneous electrical qualities measured between the 3 phases, and judgments can be made about the fitness of the object under test for service/

P-P EAR

This technique is selectable during the Surge test. Full name: Pulse to Pulse Error Area Ratio. This term is used to describe an enhanced, real time, technique that is primarily used to detect electrical weakness in turn to turn insulation in electric coils. It functions based upon successive sampling of the measured wave shape. Variations in successive wave shapes are analyzed and the EAR between them is plotted.

Zero Crossing

This technique is selectable during the Surge test. The technique looks at the zero crossing points of the voltage sinusoid signal sampled during the surge test. As this wave is typically shaped as a damped sine-wave, there are generally several zero crossings. Any shift in zero crossing, specifically in frequency, can be an indication of insulation weakness.

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The Power of Knowledge Engineering

Drawing on five areas of competence and application-specific expertise amassed over more than 100 years, SKF brings innovative solutions to OEMs and production facilities in every major industry world-wide. These five competence areas include bearings and units, seals, lubrication systems, mechatronics (combining mechanics and electronics into intelligent systems), and a wide range of services, from 3-D computer modelling to advanced condition monitoring and reliability and asset management systems. A global presence provides SKF customers uniform quality standards and worldwide product availability.

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