

**Magnetron Atmospheric Condition Test Set**



## MORE PRODUCTS BY VACUUM INTERRUPTERS, INC.

### Vacuum Interrupter Replacement

Vacuum Interrupters, Inc. can provide replacement vacuum interrupters for virtually any manufacturer's medium voltage vacuum circuit breaker or contactor. Our engineers can also design replacement or custom vacuum interrupters for obsolete circuit breakers or specialized applications.

### Vacuum Breaker Pole/Part Replacement

Vacuum Interrupters, Inc. can provide replacement poles and interrupters for virtually any manufacturer's medium voltage vacuum circuit breaker or contactor, as well as replacement parts. Our engineers can also design replacement or custom vacuum interrupters and poles for obsolete circuit breakers or specialized applications.

### VI MAC Test Set

The Magnetron Atmospheric Condition (MAC) Test Set allows users in the field to test various vacuum breakers and contactors to obtain an accurate measurement of the current pressure inside each vacuum interrupter, and helps predict the remaining service life of the interrupter.

### VI CBT Test Set

The Circuit Breaker Timer (CBT) from Vacuum Interrupters, Inc. is a simple and portable timer unit for performing timing tests on circuit breakers in the field. The CBT can also be used as a switch-box for operating breakers during maintenance, and it includes a 120VAC/125VDC power supply built in allowing operation of any breaker using one of these power schemes. The CBT also includes custom cables which attach to the breaker secondary contacts for operation, eliminating the need to attach to the breaker control circuitry using alligator clips or other methods.

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## ABOUT THIS USER'S GUIDE

This user's guide describes the functions and features of the Vacuum Interrupters Inc. Magnetron Atmospheric Condition (MAC) test set. This technical document is intended to act as a reference for users of the equipment; allowing for safe, quick, and efficient use of the MAC test set and its associated features.

All users of this product must read and follow any and all instructions or information provided within this manual. If after carefully reading this document in its entirety there are any questions or concerns regarding its content, or if any further information is required, please contact Vacuum Interrupters Inc. with the information shown below. Users are required to read and understand this document before operating this equipment.



### DANGER!

This is a red hazard alert warning alert; red hazard alert alerts contain information pointing out potential hazards to personnel and equipment.

### ATTENTION!

This is a green information alert; green information alerts are used to place emphasis on valuable information the user will want to pay particular attention to.

### NOTE

This is a special note alert; gray note alerts are used to highlight conditional information that the user may need to remember.

## 1 STANDARD FEATURES AND COMPONENTS

This section outlines the standard features and components of the Vacuum Interrupters Inc. MAC-TS4 Test Set. For users who have purchased additional options, see the corresponding appendices in this manual, which outline each specific option.

### 1.1 Overview

The MAC-TS4 from Vacuum Interrupters Inc. is a portable, user friendly test set for performing testing and measuring of the internal pressure of vacuum interrupters found in many types of medium and high voltage switchgear. The main objective behind the unique design and simple operation of the MAC-TS4 is to allow the operator to test various vacuum interrupters in the field and determine with a high degree of accuracy the internal pressure of each vacuum interrupter, something previously not possible for users outside of the OEM factory.

Armed with this information, users can more accurately estimate the remaining life of an in-service vacuum interrupter. This allows smarter and more economical choices to be made during critical maintenance times while helping to avoid costly unexpected shutdowns and critical equipment malfunctions.

### 1.2 Specifications

This following table contains relevant specifications for the Vacuum Interrupters, Inc. MAC-TS4 Test Set.

MAC-TS4 General Specifications	
Dimensions	16.9" × 12.6" × 9.8" (430mm × 320mm × 250mm)
Weight	28.4 lbs. (12.9Kg)
Measure Range	1 × 10 <sup>-5</sup> Pa to 1 × 10 <sup>-1</sup> Pa
Measure Accuracy	+/- 10% of the reading
Display	Back-lit LCD screen (320 × 240 pixels); viewable in bright sunlight and low light conditions
Printer	Built-in 2.2-in. wide thermal printer
Internal Test Record Storage	Up to 500 test results
Computer Interface	One USB interface
Computer Software	Windows®-based software
Certifications	CE certified
Environment	-10°C to +50°C (+15°F to +122°F)
Operating Humidity	85% Rh @ 40°C (104°F) non-condensing
Altitude	2,000 M (6,562 ft.) to full safety specifications

### 1.3 Components and Included Accessories

This section will highlight the various components of the Vacuum Interrupters Inc. MAC-TS4 Test Set which users must be familiar with in order to operate the unit. This section will only discuss the components which are pertinent to the preparation, setup, or operation of the MAC-TS4 and will not

include those that are not necessary for these procedures. Detailed descriptions of each component follow after Figure 1 below. If for any reason users would like more information about any of the components found on the MAC-TS4, please contact Vacuum Interrupters, Inc.



Figure 1-1: VI MAC-TS4 Test Set

- High Voltage Output Port** – The high voltage output port on the MAC-TS4 provides the high voltage supply when testing vacuum interrupters. This port is used in conjunction with the High Voltage Cable.
- Magnetic Coil Output** – The magnetic coil output ports on the MAC-TS4 provide the voltage output for the magnetic field coil when performing a MAC test.
- Signal Input** – The signal input port on the MAC-TS4 connects to the end of the interrupter being tested opposite to the High Voltage Cable. This input is responsible for recording the leakage current from the interrupter.
- Ground** – This is the ground port for the MAC-TS4. This port must be connected to a suitable ground before performing any tests
- External Capacitor Port** – The external capacitor port is used to attach an external bank of capacitors to the MAC-TS4 (optional), which is required to operate some Application-Specific Magnetic Field Coil de-signs. The external capacitor bank is NOT required for normal MAC-TS4 operation.
- Display Screen** – The display screen provides the user interface to the MAC-TS4.
- Main Power Fuse** – This 250V/5A fuse is attached to the AC power outlet on the side of the MAC-TS4, and protects the test set from over-current on the main AC connection.
- PC USB Connection** – The MAC-TS4 is equipped by default to be linked with an external PC. When an external PC is connected to the tester running the Vacuum Interrupters Inc. MAC-TS4 PC Software, users may control test parameters, perform tests, and save results to their PC directly from the MAC-TS4.
- Power Switch** – The main power switch for the MAC-TS4. The switch illuminates red when power is on.
- HV Fuse** – This 250V/3A fuse protects the high voltage circuit of the MAC-TS4 from accidental damage due to improper setup or operation.



## DANGER!

The high voltage fuse on the MAC-TS4 will NOT protect the user or test set from all errors in test setup. Therefore, it is **EXTREMELY IMPORTANT** to ensure the MAC-TS4 is set up properly prior to operation to avoid personal injury or damage to the test equipment.

Contact Vacuum Interrupters Inc. with any questions regarding proper setup and operation of the MAC-TS4 prior to operating.

- Fuse 1** – This 250V/3A fuse protects the capacitor charging circuit of the MAC-TS4 from excessive charging current.
- Fuse 2** – This 250V/3A fuse protects the capacitor discharge circuit of the MAC-TS4 from irregularities during the discharge process.
- Printer** – The MAC-TS4 comes with a built-in thermal dot-matrix printer for printing test results without the need for an external PC or printer. The printer accepts standard 2.2 inch thermal printer paper rolls for printing test reports. Contact Vacuum Interrupters Inc. to obtain replacement paper.
- Selection Knob** – The selection knob is used to cycle through and select options in the MAC-TS4 built-in user interface.
- Flexible Magnetic Field Coil** – The flexible magnetic field coil is used to generate the magnetic field necessary for the MAC test. It is the standard testing coil shipped with the MAC-TS4. It can be used to test the vast majority of vacuum interrupters quickly and easily including those that are still installed.



Figure 1-2: Flexible Magnetic Field Coil

- Grounding Cable** – The ground cable included with the MAC-TS4 allows the operator to easily attach the tester to any known ground source for testing. Standard cable is 8 feet in length.



Figure 1-3: Grounding Cable

- Signal Cable** – The signal cable for the MAC-TS4 connects to the vacuum interrupter being tested, and records the leakage current signal induced by the high test voltage. Standard cable is 10 feet in length.



Figure 1-4: Signal cable

- High Voltage Cable** – The high voltage cable clamps to one end of the vacuum interrupter being tested, and provides the high voltage supply to the interrupter during testing. Standard cable is 10 feet in length.



Figure 1-5: High voltage cable

- Magnetic Coil Output wire** – This wire connects the magnetic field coil to the Magnetic Coil Output ports on the MAC-TS4. Standard cable is 10 feet in length.



Figure 1-6: Magnetic Coil output wire

### 1.4 Principles of Operation

This section outlines the principles of operation for Magnetron Atmospheric Condition testing. Users are highly encouraged to familiarize themselves with this section so that the function and limitations of the MAC-TS4 are better understood.

#### 1.4.1 Paschen's Law

Paschen's Law is an equation that gives the breakdown voltage, which is the voltage necessary to start a discharge or electric arc, between two electrodes in a medium as a function of pressure and gap length. It is this theory that governs how effectively vacuum interrupters function to break electric potential, and prevent arcing when a breaker's contacts are opened. The Paschen curve for dry air is presented in Figure 7 for reference.

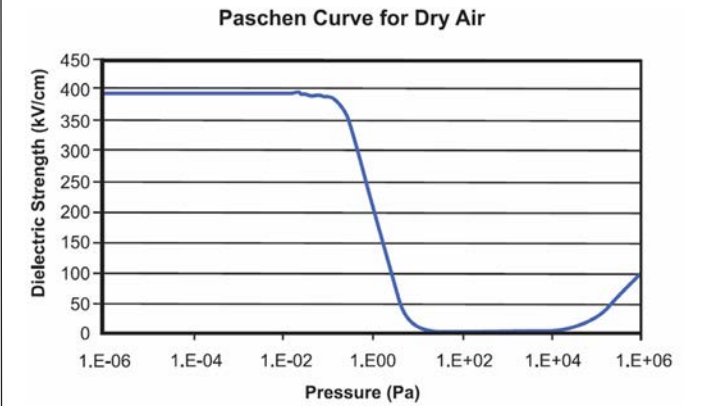


Figure 1-7: Paschen Curve for Dry Air

The majority of vacuum interrupters are manufactured with an internal pressure between  $1 \times 10^{-4}$  Pa and  $1 \times 10^{-5}$  Pa. Vacuum interrupters begin to fail a high potential test at internal pressures around  $1 \times 10^{-1}$  Pa. A vacuum interrupter should be replaced well before it reaches the high potential test failure point to reduce the risk of injury to personnel or damage to equipment in the event of a catastrophic failure during an interruption operation.

It should be noted that the internal pressure is not the only method of failure for a vacuum interrupter. At the time of MAC testing, contact wear, number of mechanical operations, and general cleanliness of the vacuum interrupter should be taken into account to determine an overall condition. See Section 4: Interpreting Results for more information.

#### 1.4.2 Penning Discharge Principle

The MAC test for vacuum interrupters is based on the Penning Discharge Principle which is named after Frans Michael Penning (1894-1953). Penning showed that when a high voltage is applied to open contacts in a gas and the contact structure is surrounded with a magnetic field, the amount of current flow between the plates is a function of the gas pressure, the applied voltage, and the magnetic field strength. Figure 8 below shows a simplified setup for performing a current measurement with the Penning Discharge Principle.



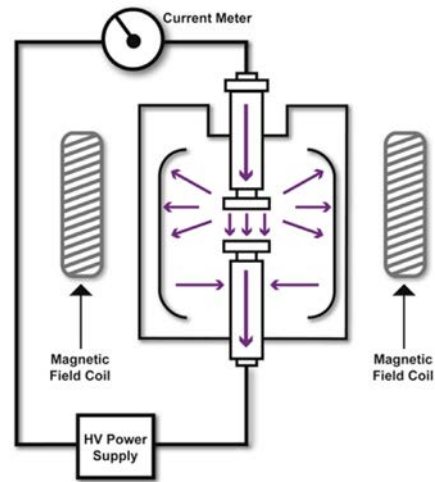


Figure 1-8: Test Setup using Penning Discharge Principle.

Charged particles (ions) can be generated from high voltage supplied across an open vacuum interrupter. When a strong magnetic field is applied, these ions will move, thereby producing a current across the open contacts. This ionization

current is directly proportional to the pressure inside the vacuum interrupter. With a known pressure-ionization current curve, the pressure inside a particular vacuum interrupter can be easily determined through the Penning Discharge principle.

### 1.4.3 Vacuum Interrupter Conditioning Effect

Research has shown that repeated testing of vacuum interrupters using tools such as High Potential Test Units or the MAC-TS4 can temporarily cause the effective pressure inside a vacuum interrupter to lower by varying degrees. This hysteresis effect can result in erroneous and/or deceptive results when performing multiple tests in short order, such as using both a MAC-TS4 and a Hi-POT on an interrupter.

In order to achieve the most accurate measurement with the MAC-TS4, Vacuum Interrupters, Inc. strongly recommends performing MAC testing prior to any High Potential Testing.

Please consult with Vacuum Interrupters Inc. for more information on interrupter conditioning, or to receive a free whitepaper on this phenomenon.

## 2 SETUP

This section will instruct the user on the setup and testing procedures for the MAC-TS4. It is important for users to read this section thoroughly, and understand all instructions and steps before attempting to use the test set in order to avoid damage to the test set, or injury to the operator.

### 2-1 Pre-Test Checklist

Before performing any testing with the MAC-TS4, it is important to perform the following checks:

1. Inspect all plugs, and receptacles for any damage. Tighten connections where necessary to ensure a proper connection is made.
2. Inspect all cables for damage or wear. Replace any damaged cable immediately by contacting Vacuum Interrupters, Inc.
3. Check all fuses on the test set and replace any that are blown.
4. Read and understand Section 2: Setup and Section 3: Operation of this manual. Contact Vacuum Interrupters, Inc. with any questions.

### 2-2 Setup Procedure

To set up the MAC-TS4 for testing a vacuum interrupter, perform the steps listed in this section exactly as described. The images shown with the text instructions are provided for illustration purposes only, and may not exactly match the equipment to be tested.

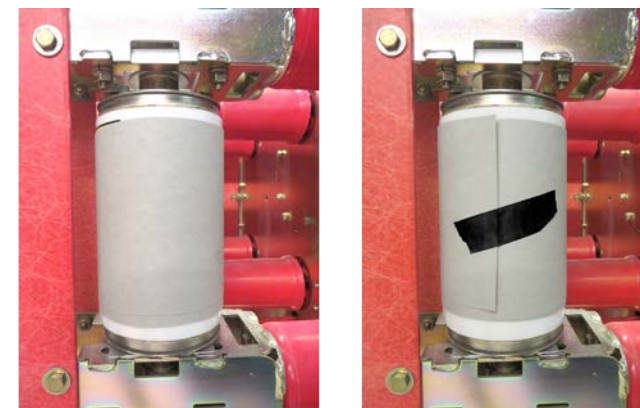
1. Using denatured alcohol and a clean cloth, remove any contamination from the surfaces of the vacuum interrupter to be tested.



2. If installed, ensure that the breaker mechanism is in the OPEN position.
  - a. If the vacuum interrupter is removed from the breaker mechanism, special fixtures or jigs may be required to perform testing. Vacuum Interrupters, Inc. offers specialized magnetic coil fixtures for testing a variety of removed interrupters in this way. See Appendix C: Fixed Magnetic Field Coils for more information and specific setup instructions for this option, or contact Vacuum Interrupt-ers, Inc. to discuss your application.
3. Attach the magnetic field coil to the vacuum interrupter to be tested. If using a Fixed Coil or Application-Specific coil option, see the applicable Appendix for detailed installation steps. For the standard flex coil:



- a. For exposed interrupters, wrap the outside of the interrupter tightly with a piece of the included insulating paper to ensure any metal on the interrupter where the magnetic field coil will be wrapped is insulated. The paper may be held in place with a small piece of tape if necessary.



- b. Wrap the flexible coil around the center of the interrupter. In order to acquire sufficient magnetic field for the test, a MINIMUM OF FIVE FULL TURNS is necessary for accurate results.

### ATTENTION!

If using the flexible magnetic field coil, it must be wrapped around the vacuum interrupter with each winding tightly against the next; otherwise the accuracy of the pressure measurement will be affected.

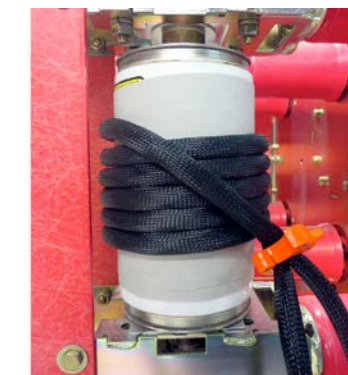


- c. Secure the flexible magnetic field coil with the included cable clamp to prevent it from making contact with the bus, bus brackets, or metal end-caps of the vacuum interrupter when testing is in progress.

### ATTENTION!

An air gap of at least 1 inch (or a proper level of insulation), is required between the magnetic field coil and any metal fixtures that will have high voltage applied during testing. This includes, but is not limited to, metal interrupter end caps, bus bars, the MAC High Voltage test cable, and other related fixtures.

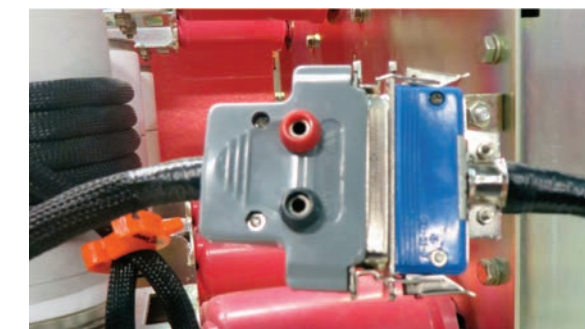
DO NOT allow the cables for the flexible field coil to touch the bus, high voltage cable, or to approach any surfaces that may have high voltage applied during testing. Failure to do so may result in arcing and/or severe damage to the coil or test set. If it is not possible to meet these conditions, DO NOT PROCEED WITH TESTING. Contact Vacuum Interrupters Inc. to discuss your application.



- d. Connect flexible magnetic field coil connectors together with clips attached on both sides of the connector. Ensure that the flexible magnetic field coil is wrapped tightly around the center of vacuum interrupter where the contacts separate.

### DANGER!

Damage may occur to test set if high voltage is applied to fixed/flexible magnetic field coil. Keep high voltage circuit and magnetic field circuit separated.



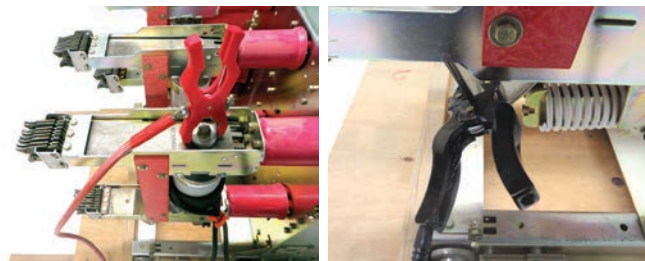
4. Connect ground terminal of the MAC-TS4 to suitable ground.



- Connect the red, high-voltage clamp to one conductive end of the vacuum interrupter, and connect the black, signal wire with the opposite conductive end of the vacuum interrupter.

### NOTE

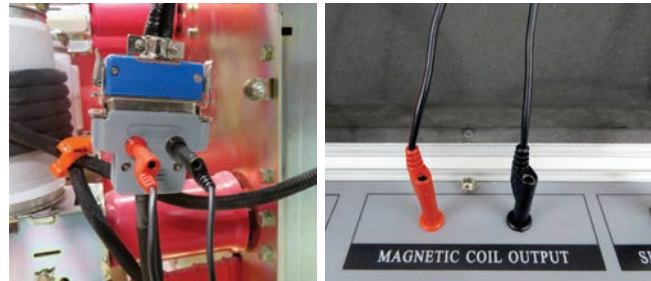
If the ends of the interrupter are inaccessible, clamp the high voltage and signal cables to the bus bars of the breaker, as close to the interrupter as possible. See Appendix C: Fixed Magnetic Field Coils for specific setup instructions if using one of these coil options for testing.



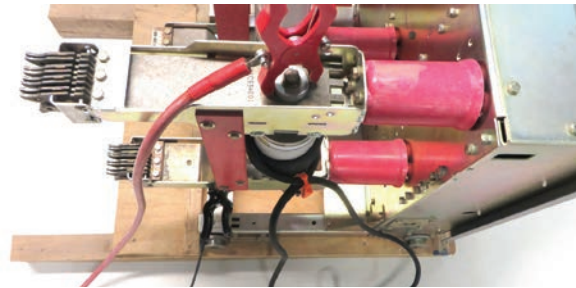
- Connect the red high voltage cable to the test set, and then connect the black signal cable to the test set.



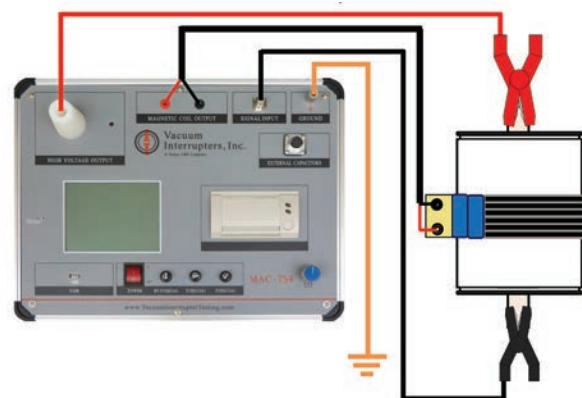
- Connect the Magnetic Coil Output wire to the matching ports on the magnetic field coil connector. Also connect the other end of the wire to the corresponding ports on the MAC-TS4.



- Ensure that the High Voltage, Signal, and magnetic field coil wires are separated, and are not positioned in such a way that they may touch each other during testing, as indicated below.



- Using the diagram below, ensure that all previous connections have been made properly on the test set. If all connections are correct, then the MAC-TS4 is ready for use.



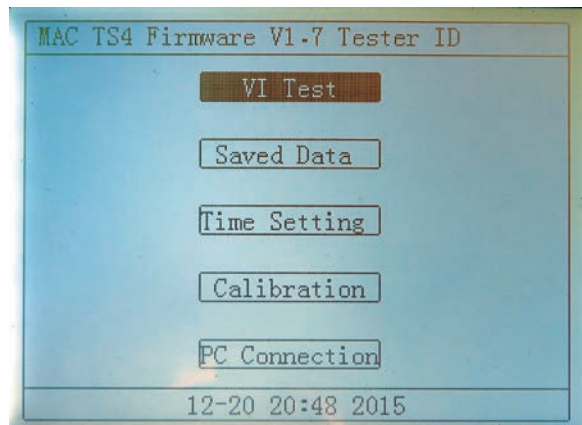
## 3 OPERATION

This section covers basic operation steps for the MAC-TS4. This section includes instructions on performing a MAC test, reviewing saved test results on the test set, and configuring the internal clock on the test set.

### 3.1 Performing a Test

To initiate a MAC test, the user should follow the steps below.

- Ensure that the MAC-TS4 is properly set up, as described in Section 2: Setup.
- Turn power on to MAC-TS4. The power switch and screen should light up, and lights on the printer should illuminate.
- Select [VI Test] from the main menu (shown below).

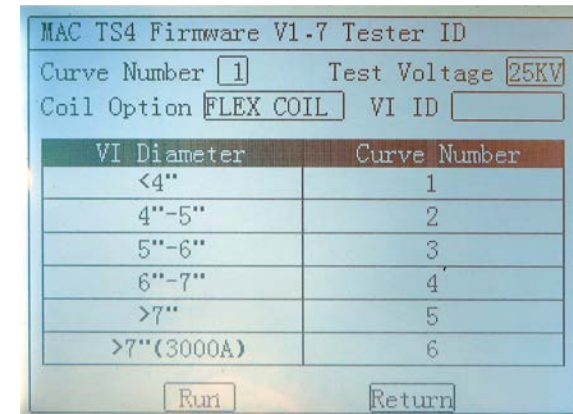


- Change the highlighted field on the screen by rotating the Selector Knob.

- Press down on the Selector Knob to confirm the selection.



- From the test setup screen (shown below), select the appropriate 'Curve Number' based on the outer diameter of the center of the vacuum interrupter from the Curve Selection Table. In most cases, this is the outer diameter of the insulation of the interrupter.



- Values can be changed by pressing down on the Selector Knob, and then rotating the knob until desired value is shown. Press down on the Selector Knob again to lock in the selection.

- Select the appropriate 'Test Voltage':
  - For contact gaps greater than 0.25", the 25kV test voltage should be selected.
  - For contact gaps less than or equal to 0.25", the 12kV test voltage should be selected.

### NOTE

Most vacuum circuit breakers have a contact gap greater than 0.25" (6.35mm), and should therefore use the 25kV test voltage. Many vacuum contactors have contact gaps less than 0.25" (6.35mm) and would therefore use the 12kV test voltage. This is a good general rule for testing, but the user should still always check the equipment manufacturer's documentation for contact gap specifications before testing. Contact Vacuum Interrupters Inc. for further information.

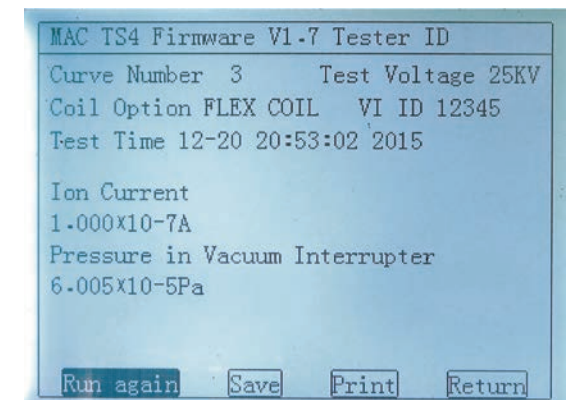
- Select the appropriate 'Coil Option' for the magnetic field coil being used.
  - Select 'FLEX COIL' if using the flexible magnetic field coil.

- Select 'FIXED COIL' if using a fixed magnetic field coil. See Appendix C: Fixed Magnetic Field Coils for more information on this option.
  - Some application-specific coils will show as their own coil option when connected. See the applicable Application-Specific Coil Manual for information on the use of these options.
- Input an alphanumeric 'VI ID' for reference, if desired. It is recommended to use a VI ID for recalling test results saved on the MAC-TS4.
- Select [Run]. Adhere to the safety warning and double check that all components are set up properly as described in Section 2, then select [OK] to begin test.

### DANGER!

Keep a safe distance from high voltage circuit and magnetic field coil when test is being performed. The test system produces voltages exceeding 25kV, and can cause serious injury if the cables are contacted during testing.

- Several status indicators will be displayed while the test is in progress. Indicators include Status messages on the screen, and a red light next to the High Voltage Output any time the tester is applying high voltage. Do not touch the test set while testing is in progress, and wait for the testing to complete.
- When the test is completed, a results screen will display (shown below). On this screen, the pressure result will be shown under 'Pressure in Vacuum Interrupter', and several other parameters from the test will also be displayed.



- Test results can be saved to the internal memory of the test set by selecting the [Save] option from the final results screen.



## ATTENTION!

Tests are not saved automatically upon completion. The user must select [Save] in order to save the result before selecting [Return] or [Run Again], otherwise the result will be lost.

- b. Test results can be printed by selecting the [Print] option on the final results screen.
6. Once a pressure result has been obtained, refer to Section 4 of this manual for information on interpreting this pressure result.
7. If the pressure in the VI is at an unsatisfactory level or if there are flaws in the test setup, an error may be displayed. See Section 5: Troubleshooting for more details.

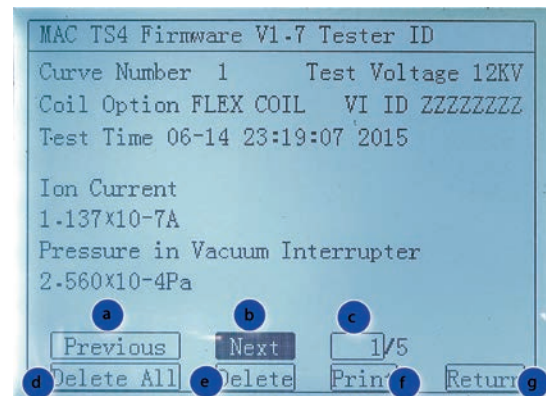
## ATTENTION!

Repeated testing on the same vacuum interrupter in a short period time will cause the pressure value to be artificially reduced. This effect is due to the capacitance of the vacuum interrupter and interaction with internal gas molecules. Once the vacuum interrupter has been subjected to a current through its contacts, the pressure measurement will return to the initial value. See Section 1.4.3 for more details.

### 3.2 Reviewing Saved Results

With the MAC-TS4 it is possible to save and review tests directly from the test set. This allows easy retrieval of results for documentation or inspection purposes. In order to review results that have been saved onto the test set, users should proceed through the following steps:

1. Plug in the MAC-TS4, and turn it on.
2. From the main menu screen, select the [Saved Data] option.
3. The screen that displays is very similar to the results screen seen at the end of a MAC test, including the VI pressure and other test information. The function buttons on this screen are explained below:

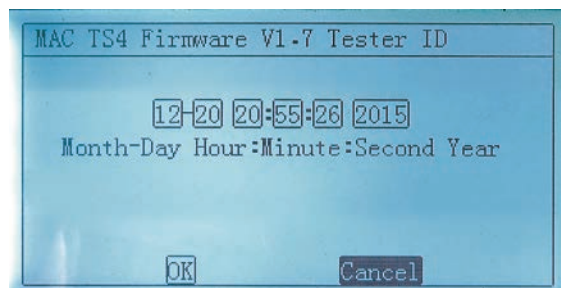


- a. The [Previous] button displays the previous saved test result.
  - b. The [Next] button displays the next saved test result.
  - c. The Result Count box allows the user to enter a specific result number to view.
  - d. The [Delete All] button erases all tests currently stored in the tester memory.
  - e. The [Delete] button deletes the currently displayed test from the tester memory.
  - f. The [Print] button prints a paper test report with the MAC-TS4's built-in printer.
  - g. The [Return] button brings the user back to the main menu.
4. Review the saved tests as desired by using the navigation functions described above, and when reviewing is complete, select [Return] to go back to the main menu.
  5. Power down and unplug the MAC-TS4.

### 3.3 Setting Time and Date

Every test report from the MAC-TS4 include a date and time stamp for accurate tracking of test history. To set the time and date on the MAC-TS4, the user should do the following:

1. Plug in the MAC-TS4, and turn it on.
2. From the main menu screen, select the [Time Setting] option.
3. The screen that displays offers option fields to set the time and date that will appear on the MAC test reports. To set the date and time, utilize a known time source to determine the current date and time, then use the selection knob on the MAC-TS4 to set each field to the correct value.

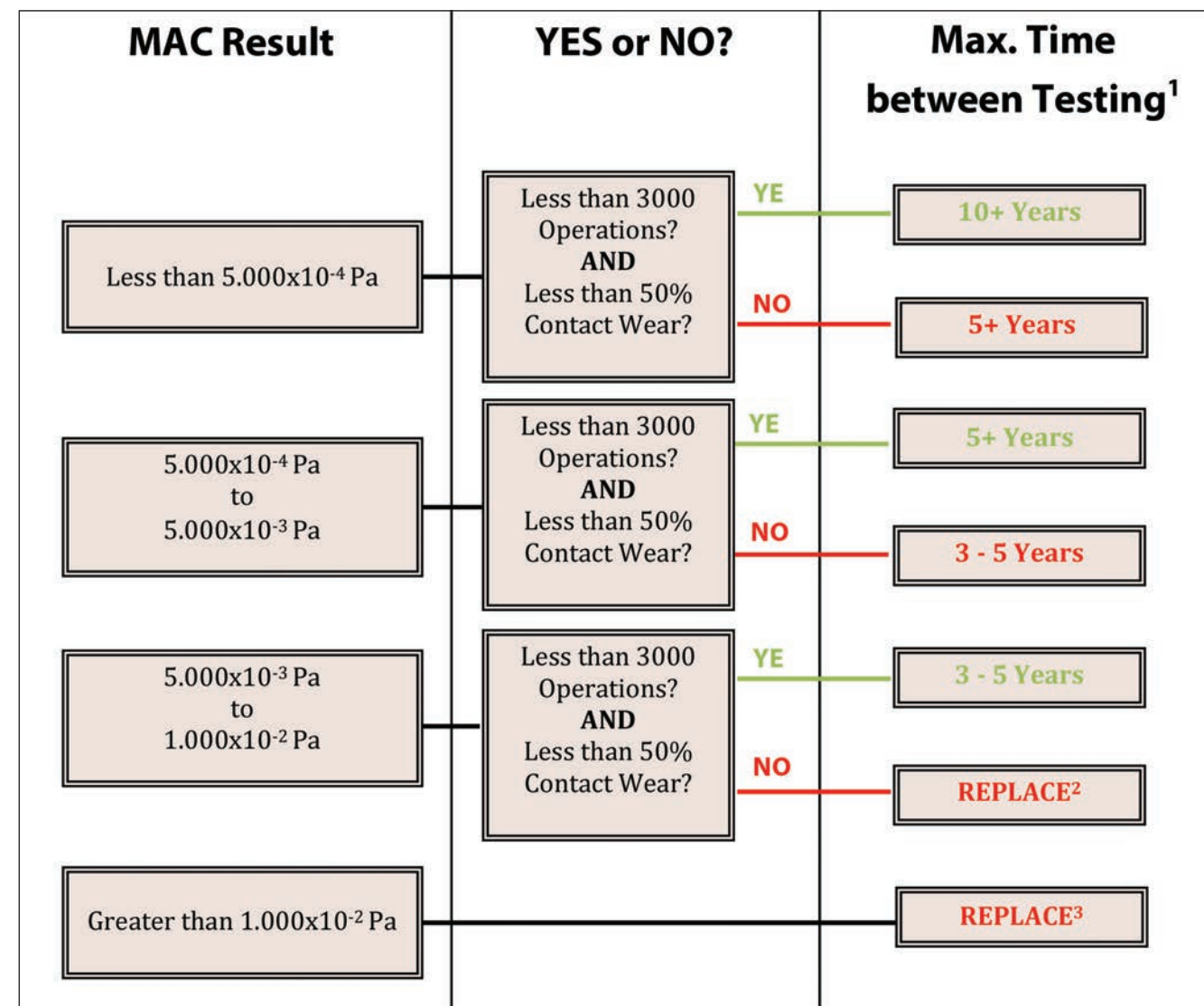


4. When complete, select [Return] to go back to the main menu, and then turn off and unplug the MAC-TS4.

## 4 INTERPRETING RESULTS

Each MAC test should output a pressure result for the vacuum interrupter being tested. The following flowchart is the criteria used by Vacuum Interrupters, Inc. to interpret the

pressure result. Please contact Vacuum Interrupters, Inc. with any questions regarding interpreting the results of a MAC test.



1. This is the recommended maximum period of time between testing of the vacuum interrupter based on the MAC result, contact wear, and mechanical operations.
2. Replacement is recommended due to a combination of MAC result, excessive mechanical operations and/or excessive contact wear.
3. Replacement is recommended because the VI's insulating ability can be negatively affected with an internal pressure in this range.

Figure 9: Results Interpretation Flowchart

## 5 TROUBLESHOOTING

This section provides some common issues and solutions that users may encounter in the field. Please contact Vacuum Interrupters, Inc. to address any issues not covered by this section.

Problem	Possible Cause	Solution
Device will not power on.	Power Cord not fully inserted.	Check that power cord is fully inserted into receptacle.
	Main power fuse is blown.	Check the power fuse, and replace if necessary, with standard 250V/5A fuse.
Test set returns to main screen during test, without giving final result screen.	Interrupter contacts are not open.	Make sure VI contacts are in open position and repeat test.
	Short or improper connection between high voltage wire, magnetic field coil, or signal return.	Check high voltage, magnetic field coil, and signal connections. Ensure that there is no conductive path between any of the cables and repeat test.
	VI pressure is at an unsatisfactory high level (greater than 1x10 <sup>-2</sup> Pa).	Contact Vacuum Interrupters, Inc. for further troubleshooting steps.
“Breakdown between contacts” result.	Interrupter contacts are not open.	Make sure VI contacts are in open position and repeat test.
	Short or improper connection between high voltage wire, magnetic field coil, or signal return.	Check high voltage, magnetic field coil, and signal connections. Ensure that there is no conductive path between any of the cables and repeat test.
	VI pressure is at an unsatisfactory high level (greater than 1x10 <sup>-2</sup> Pa).	Contact Vacuum Interrupters, Inc. for further troubleshooting steps.
“Fail to generate ION current” result.	Flexible magnetic field coil is not properly connected.	Make sure the flexible magnetic field coil connectors are attached to the test set, properly color matched, and that the magnetic field coil and all connectors are fully seated and undamaged, then repeat test.
	There may be physical damage to the magnetic field coil.	Contact Vacuum Interrupters, Inc. for troubleshooting steps.
Insufficient space to wrap flexible magnetic field coil around VI properly.	The vacuum interrupter is physically too small to wrap with the flexible magnetic field coil.	Contact Vacuum Interrupters, Inc. to check the availability of a custom magnetic field coil for your application.
	The vacuum interrupter is inaccessible from the outside of the equipment.	VI must be removed from circuit breaker in order to perform testing.

## APPENDIX A: OPTIONS AND ACCESSORIES

The Vacuum Interrupters, Inc. MAC-TS4 comes standard with the features described in Section 1 this manual. However, Vacuum Interrupters, Inc. also offers several options and accessories for the MAC-TS4 Test Set to suit different customers' testing needs.

All options and accessories are available for purchase at the time of the Test Set purchase or after the fact. Depending on which options are purchased, Vacuum Interrupters, Inc. may send a field representative to install newly purchased options or require that the unit be sent back to the Vacuum Interrupters, Inc. facility. Contact Vacuum Interrupters, Inc. for more information.

If a desired option or upgrade is not listed in this section, contact Vacuum Interrupters, Inc. to discuss your application. Vacuum Interrupters, Inc. is constantly working with its customers to provide customized solutions for each application, and new options may exist that are not listed in this manual.

The remainder of this section will provide a brief overview of the different options available for the Vacuum Interrupters, Inc. MAC-TS4. For detailed information on any accessory, see the appropriate appendix addressing that accessory. For pricing and purchasing information or other questions, contact Vacuum Interrupters, Inc.

- **MAC-TS4 PC Software** – The MAC-TS4 PC Software is a special program for Microsoft Windows® Operating Systems which allow users to control the MAC-TS4 over a PC connection. The software allows testing, saving and archiving of tests, and several other functions. All

MAC-TS4 units are shipped with a flash drive containing a copy of the PC software. See Appendix B: MAC-TS4 PC Software for more information.

- **Fixed Magnetic Field Coils** – Fixed Magnetic Field coils allow users to easily perform highly repeatable tests on removed vacuum interrupters, without having to worry about wrapping the flexible magnetic field coil around each interrupter to be tested, or for interrupters that may be too small to test with the flexible magnetic field coil. Fixed Test Coils are ideal for service shop or lab environments where precision, repeatability, or ease and speed of setup are of primary importance. See Appendix C: Fixed Magnetic Field Coils for more information.
- **Application-Specific Magnetic Field Coils** – Application-specific magnetic field coils are customized solutions for testing vacuum interrupters that are still installed in their breakers, or pole assemblies. Application-specific field coils are perfect for rapidly testing large numbers of the same breaker by eliminating the need for setup and winding of the flexible magnetic field coil, as well as for situations where it is not possible or practical to remove interrupters for testing. Application Specific coils are also useful when the interrupters to be tested are not directly accessible for use with the flexible magnetic field coil. Many application-specific coils are available; contact Vacuum Interrupters, Inc. to discuss your application and requirements.

The MAC-TS4 PC Software is a custom PC application from Vacuum Interrupters, Inc. for downloading a MAC-TS4 test set

## APPENDIX B: MAC-TS4 PC SOFTWARE

from a standard PC over a USB connection. The MAC-TS4 Software allows the user to take tests and save them directly to the PC, download saved tests from the MAC-TS4 and save them on the PC, as well as generate testing reports from previous test results.

### B.1 System Requirements

In order to run the MAC-TS4 PC Software, the user must meet the following requirements:

8. A PC running Microsoft Windows® XP or higher with Administrative Privileges (for driver installation only)
9. 1 Free USB Port
10. At least 120MB of free hard drive space (plus extra space to store test results and reports).
11. Local Installation of Microsoft Office® (For generating reports)

### B.2 Software Installation and Setup

This section briefly describes the software setup procedure in order to get the MAC-TS4 to communicate with the PC software. All necessary software and drivers, as well as a brief instructional 'README' file are included on a flash drive that is shipped with the MAC-TS4. Users are highly recommended to read this section of the manual to become familiar with the installation process before reading the README file, or attempting to install the software. It is highly recommended to make a backup copy of this software upon receipt, and store the flash drive in a safe place for future use. For any problems with installing this software, contact Vacuum Interrupters, Inc.

1. First, plug in the flash drive that was included with the MAC-TS4.
2. Navigate to the flash drive in Explorer, and launch the “MAC-TS4 DriverInstaller\_vX.X.X.exe” executable from the flash drive on the PC in order to install the serial communication drivers for the MAC-TS4.



## NOTE

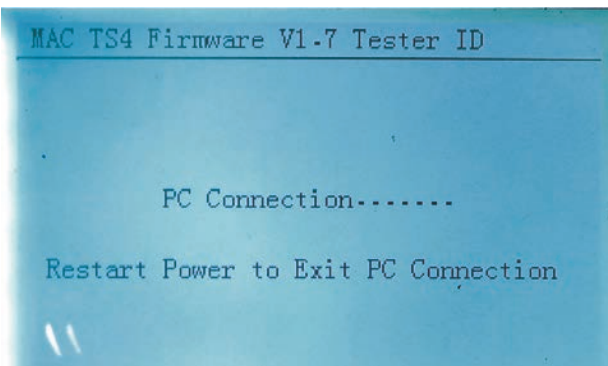
Administrative privileges are required to install drivers on Windows operating systems. If the user of the PC that is being set up with the MAC PC software does not have administrative privileges, the user should contact their IT department to acquire appropriate permissions.

- Once the driver installation is complete, copy the "MAC-TS4 SOFTWARE" folder from the flash drive to a convenient location on the computer (such as the Desktop) where it can be easily accessed. The specific location is not critical.
- Once the software is copied, and the driver has installed successfully, the flash drive can be removed.
- The PC is now ready to run the MAC-TS4 in PC Connection mode.

### B.3 Tester Setup and Connection

This section includes instructions on how to place the MAC-TS4 in PC Connection mode for performing testing and other operations with the MAC-TS4 PC Software.

- Plug in and turn on the MAC-TS4.
- Next, connect the USB link cable to the USB port on the MAC-TS4, and to a free USB port on the PC.
- Place the MAC-TS4 in PC connection mode, by selecting the [PC Connection] option from the main menu.
- From this point onward, the screen of the MAC-TS4 test set will display the screen below, and all interaction must be done with the MAC PC software.



- Now, on the PC navigate into the folder "MAC-TS4 SOFTWARE" on the PC that was copied earlier, and launch the "MAC-TS4.exe" executable to bring up the MAC Test Software.

## NOTE

If the PC software is already running before the MAC-TS4 is plugged into the PC and placed in PC connection mode, exit and restart the PC software to ensure connectivity with the MAC-TS4.

- The tester should be automatically detected by the PC software. Test the connection by clicking the "Download" button in the PC software interface. Any saved tests from the tester should appear in the main screen, and the "Tester ID" and "Download Time" fields should become populated.

## NOTE

If no tests are available on the MAC-TS4, then no tests will appear in the main window when "Download" is clicked.

Index	VI ID	Test Time	Test HV	Coil Option	Curve Number	Ion Current	Pressure
1	ZZZZZ	6-14 23:19:7 2015	12KV	FLEX	1	1.137*10.7A	2.560*10.4Pa
2	ZZZZZ	6-14 23:38:27 2015	12KV	FIXED	1	2.875*10.3A	6.256*10.1Pa
3	ZZZZZ	6-14 23:36:15 2015	12KV	FLEX	1	2.875*10.3A	5.577*10.1Pa
4	ZZZZZ	6-14 23:49:25 2015	25KV	BLOCK	1	1.000*10.7A	2.555*10.4Pa
5	ZZZZZ	6-14 23:50:48 2015	25KV	BLOCK	1	1.200*10.7A	2.562*10.4Pa

- The MAC-TS4 is now ready to use in PC Connection mode.

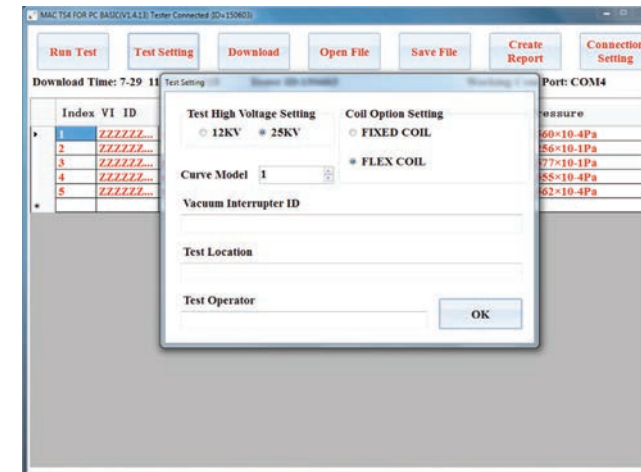
### B.4 Operation

This section will instruct the user on the various operational features of the MAC-TS4 PC Software.

#### B.4.1 Performing a Test

To take a test with the MAC-TS4 PC software, users should be familiar with operating procedures for the the MAC-TS4 test set, as described in Section 3 of this manual.

- Ensure that the MAC-TS4 is properly set up, as described in Section 2: Setup, and that the MAC-TS4 has been properly placed in PC Connection mode, as described in Section B.3: Tester Setup and Connection above.
- Select the "Run Test" button from the software. A pop-up screen will allow the user to set the testing options, in a similar manner to setting up a test with the MAC-TS4 operating in Stand-alone mode.



- Select the appropriate 'Curve Number', based on the outer diameter of the center of the vacuum interrupter, from the Curve Selection Table shown below. In most cases, this is the outer diameter of the insulation of the interrupter.

VI Diameter	Curve Number
< 4"	1
4" - 5"	2
5" - 6"	3
6" - 7"	4
> 7"	5
> 7" (3000A)	6

- Select the appropriate 'Test Voltage':
  - For contact gaps greater than 0.25", the 25kV test voltage should be selected.
  - For contact gaps less than or equal to 0.25", the 12kV test voltage should be selected.

## NOTE

Most vacuum circuit breakers have a contact gap greater than 0.25" (6.35mm), and should therefore use the 25kV test voltage. Many vacuum contactors have contact gaps less than 0.25" (6.35mm) and would therefore use the 12kV test voltage. This is a good general rule for testing, but the user should still always check the equipment manufacturer's documentation for contact gap specifications before testing. Contact Vacuum Interrupters Inc. for further information.

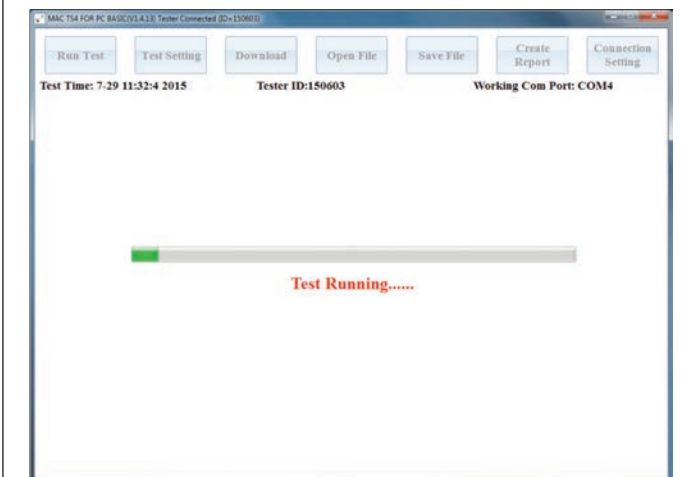
- Select the appropriate 'Coil Option' for the magnetic field coil being used.
  - Select 'FLEX COIL' if using the flexible magnetic field coil.
  - Select 'FIXED COIL' if using a fixed magnetic field coil. See Appendix C: Fixed Magnetic Field Coils for more information on this option.

- Some application-specific coils will show as their own coil option when connected. See the applicable Application-Specific Coil Manual for information on the use of these options.
- Input a 'VI ID' for reference, if desired. It is recommended to use a VI ID for recalling test results saved on the MAC-TS4.
- Select "OK" and double check the displayed test settings, and that all components are set up properly as described in Section 2. If the setup and all settings are correct then select "OK" to begin test.

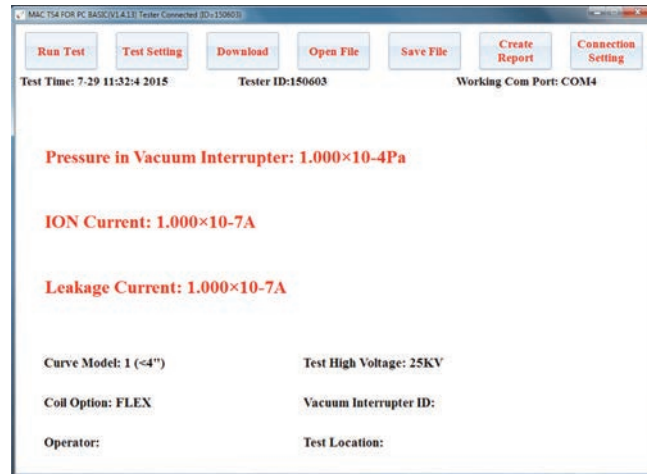
## DANGER!

Keep a safe distance from high voltage circuit and magnetic field coil when test is being performed. The test system produces voltages exceeding 25kV, and can cause serious injury if the cables are contacted during testing.

- The test unit will display several status indicators while the test is in progress. Indicators include Status messages and progress bar on the screen, and a red light next to the High Voltage Output any time the tester is applying high voltage. Do not touch the test set while testing is in progress, and wait for the testing to complete.



- When the test is completed, a results screen will display (shown below). On this screen, the pressure result will be shown under 'Pressure in Vacuum Interrupter', and several other parameters from the test will also be displayed.



11. Test results can be saved to the PC by selecting the "Save File" option from the menu.

### ATTENTION!

Tests are not saved automatically upon completion. The user must select "Save File" in order to save the result before selecting any other options; otherwise the result will be lost.

12. Once a pressure result has been obtained, refer to Section 4 of this manual for information on interpreting this pressure result.
13. If the pressure in the VI is at an unsatisfactory level or if there are flaws in the test setup, an error may be displayed. See Section 5: Troubleshooting for more details.

### ATTENTION!

Repeated testing on the same vacuum interrupter in a short period time will cause the pressure value to be artificially reduced. This effect is due to the capacitance of the vacuum interrupter and interaction with internal gas molecules. Once the vacuum interrupter has been subjected to a current through its contacts, the pressure measurement will return to the initial value. See Section 1.4.3 for more details.

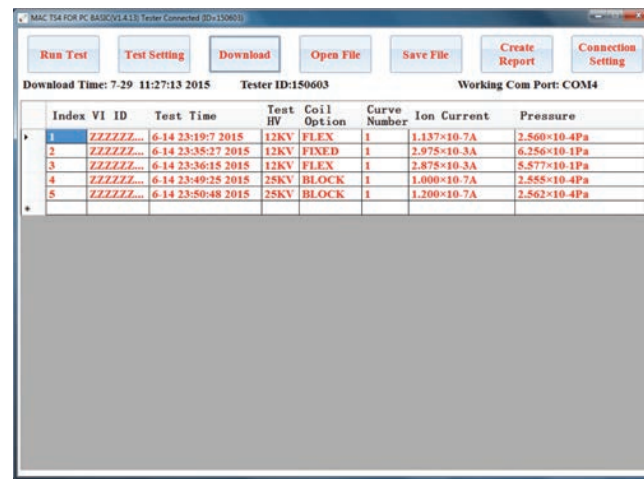
#### B.4.2 Downloading and Saving Previous Tests

To download saved tests from the MAC-TS4, do the following:

1. Ensure that the MAC-TS4 has been properly placed in PC Connection mode, as described in Section B.3: Tester Setup and Connection above.
2. Click the "Download" button in the PC software interface. Any saved tests from the tester should appear in the main screen, and the "Tester ID" and "Download Time" fields should become populated.

### NOTE

If no tests are available on the MAC-TS4, then no tests will appear in the main window when "Download" is clicked.



3. The test download process is complete. Immediately upon download success, the user will be asked if they want to save the downloaded files. Select "Save" to save them.

### NOTE

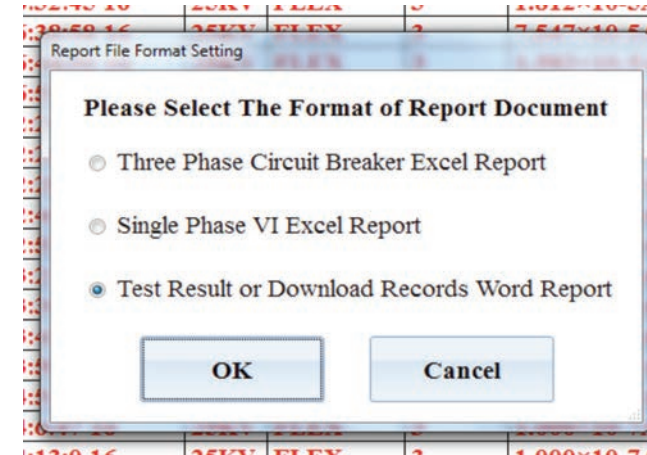
Downloading previous tests from the MAC-TS4 does not automatically remove them from the test set. To remove the tests from the test set, they must be cleared as described in Section 3.2: Reviewing Saved Results.

4. If the user does not initially save, or more unsaved tests are taken, click "Save File" to save the downloaded tests onto the PC. The user will be asked to pick a save location. Select a location to store the file, and then click "Save" to finish. All currently loaded tests will be saved to the resulting '.vit' file.

#### B.4.3 Generating Reports

The MAC-TS4 PC Software has the ability to generate various test reports for the user, depending on their specific needs or requirements. A locally installed copy of Microsoft Office® is required for report generation.

1. First, download all tests from the MAC-TS4, following the instructions listed in Section B.4.2, or open any ".vit" file previously saved from the MAC PC Software by clicking "Open File" in the menu.
2. Select "Create Report" from the menu. A popup screen will appear showing the user the different available report options.

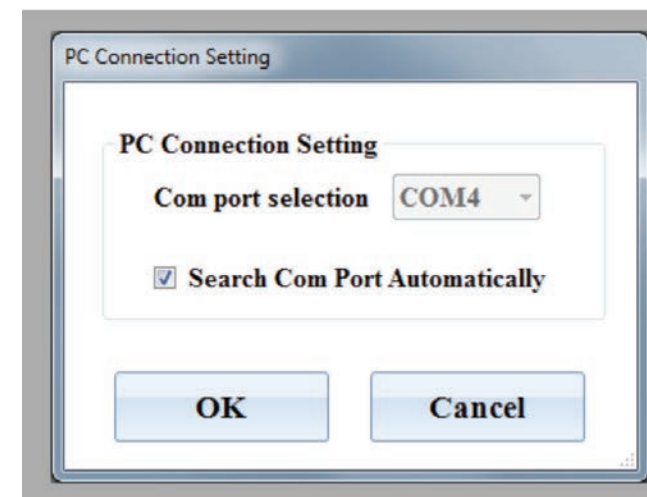


3. Select the desired report option, and click "OK".
4. Depending on the type of report to be generated, the user may then be required to select the test records from a table to be included in the report, as well as some other parameters. Follow the prompts and fill in or select data as required.
5. The user will then be asked where to save the resulting report file. Select a save location, and then click "Save" to save the report file.

#### B.4.4 Changing Connection Settings

The connection behavior for the MAC-TS4 PC Software can be changed manually by the user when problems are encountered with connecting a MAC-TS4 to the PC Software. To change these settings, do the following:

1. Launch the MAC-TS4 PC Software from its installed location.
2. Click "Connection Settings" from the PC Software home screen. A pop-up window will be displayed, showing the available PC Connection Settings.



3. The default option, which should work in most scenarios, is "Search Com Port Automatically". To select a COM port manually, uncheck "Search Com Port Automatically" and pick an available COM port from the dropdown menu.

4. If a COM port was manually selected, and the user wished to return to automatic detection mode, simply check the box next to "Search Com Port Automatically".
5. Click "OK" When finished.

#### B.5 Troubleshooting

Problem	Possible Cause	Solution
An Error occurs when trying to create a report.	No Local copy of Microsoft Office® is installed	Install a copy of Microsoft Office®
Download, Run Test, and Test Settings are greyed out when launching PC Software	MAC-TS4 Test Set was not connected at Software start.	Exit and restart the MAC-TS4 PC Software
		Connect the MAC-TS4 as described in Section B.3 of this manual, then exit and restart the MAC-TS4 PC Software.
Incorrect COM Port Settings.	Following the instructions in Section B.4.4 of this manual, if COM port is set to search automatically, de-select automatic mode and manually select a COM port to retry the connection.	Click "Connection Settings" in the main menu, then immediately click "OK" to retry the connection.
		Following the instructions in Section B.4.4 of this manual, if a COM port was manually selected change to automatic mode to retry the connection.
The MAC-TS4 connection was closed due to an error.	Disconnect the USB Cable from the PC, power off the MAC-TS4, and then re-connect the Tester as described in Section B.3 of this manual.	
USB Cable or Port is faulty.		Try a different USB cable or USB port on the computer, if possible. Contact Vacuum Interrupters Inc. for further troubleshooting steps.



## APPENDIX C: FIXED MAGNETIC FIELD COILS

Fixed testing coils allow users to easily perform highly repeatable tests on removed vacuum interrupters, without having to worry about wrapping the flexible magnetic field coil around each interrupter to be tested, or for interrupters that may be too small to test with the flexible magnetic field coil.

The Vacuum Interrupters, Inc. provides several different sizes of fixed test coils for testing different sizes of interrupters. The different test coil sizes are outlined briefly in this appendix, but setup and usage of each different size coil is identical.

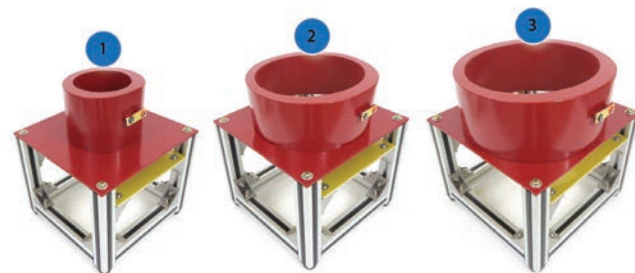


Figure C1: Fixed Magnetic Field Coil Options

### C.1 Options

This section outlines the various fixed field coil options publicly offered by Vacuum Interrupters, Inc. at the time of publication of this document. If a required option is not listed here, contact Vacuum Interrupters, Inc. to discuss any specific needs or requirements.

#### C.1.1 Adjustable Base Coils

The Adjustable Base Coils are a series of fixed magnetic field coils, which come standard with an adjustable base. The adjustable base allows the user to properly set up a MAC Test for interrupters of varying length, using only one fixed coil.

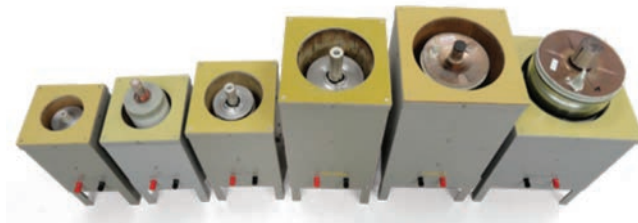
Each magnetic field coil comes with one BNC signal cable to allow direct connection between the Signal port on the coil, and the matching port on the MAC-TS4.

The Adjustable Base Magnetic Field Coils come in three different sizes, shown in Figure C1: Fixed Magnetic Field Coil Options:

1. **Small:** For testing interrupters up to 3.5 inches in diameter.
2. **Medium:** For testing interrupters between 3.6 and 6 inches in diameter.
3. **Large:** For testing interrupters between 6 and 8 inches in diameter.

#### C.1.2 Legacy Fixed Coils

The Legacy Fixed Coils are fixed magnetic field coils that have each been specifically sized to accommodate a specific diameter of vacuum interrupter for testing with the MAC-TS4. Each coil is specially made for the MAC-TS4 to provide a consistent and uniform magnetic field for performing the MAC test, and provide easy set-up and operation when testing large numbers of removed interrupters is required.



As of September 2015, Vacuum Interrupters, Inc. is no longer manufacturing this type of Fixed Magnetic Field Coil; they are considered a legacy product and will no longer be available for purchase. However, Vacuum Interrupters, Inc. will continue to support the Legacy Fixed magnetic field coils currently in the field. For any questions, please contact Vacuum Interrupters, Inc.

### C.2 Setup

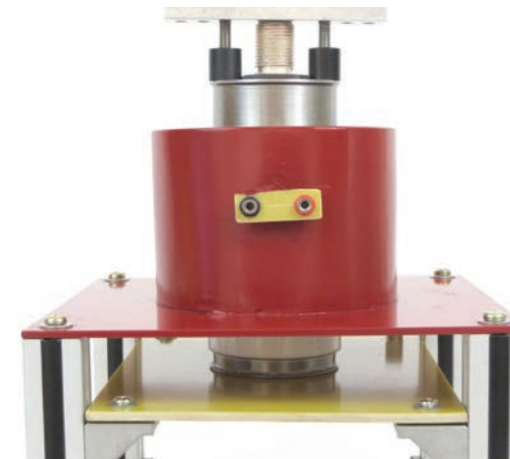
This section outlines the specific steps required to set up a fixed magnetic field coil for testing interrupters that have been removed from their equipment. These setup instructions supplement those found in Section 2, so the user should be familiar with those instructions before reviewing these.

1. If the interrupter to be tested is not already removed from the equipment, remove the interrupter to be tested.
2. Fix the vacuum interrupter in an open position, with a contact gap set according to manufacturer specifications.

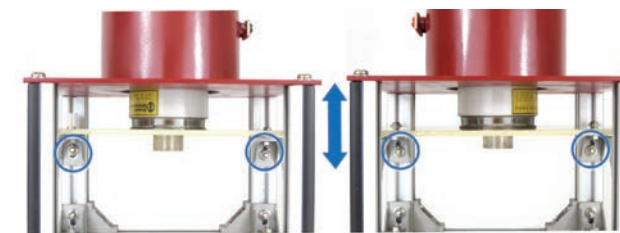
### ATTENTION!

**Vacuum Interrupters, Inc. provides several special fixtures to assist in locking the interrupter in an open position. Contact Vacuum Interrupters, Inc. to discuss your application or to obtain the proper opening fixture for your equipment.**

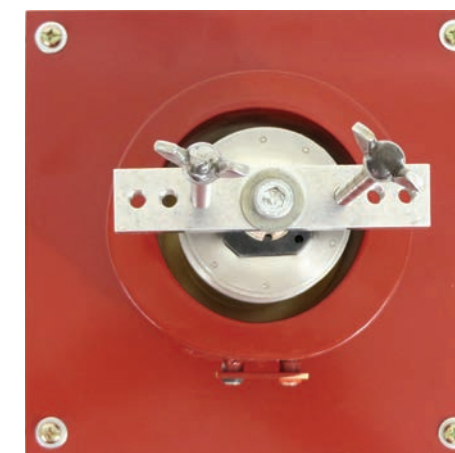
3. Place the interrupter in the magnetic center of the magnetic field coil, then position the interrupter so the center of the interrupter aligns with the center of the magnetic field coil:



- a. For the Adjustable Base Coils: Loosen the bolts on the base of the coil, and slide the base up or down as required to align the center of the vacuum interrupter with the center of the coil.



- b. For the Legacy Coils: Use shims to adjust the height of the interrupter so that the center of the interrupter aligns with the center of the coil area.
4. With the vacuum interrupter properly aligned vertically with the coil, check to be sure that the interrupter is approximately centered in the opening for the fixed coil.



5. Connect the red High Voltage Output cable to the top post of the interrupter. At this time, also connect the Magnetic Coil Output wires to the matching ports on the side of the fixed coil.

6. Connect Signal clamp directly to the bottom terminal of the VI or conductive attachment.
  - a. For the Legacy Coils: If insulating shims were used to change the height of the interrupter, use the clamping signal cable, and attach the signal directly to the bottom post of the interrupter.
7. To complete setup for testing, please refer to the instructions in Section 2.2: Setup Procedure.

### C.3 Troubleshooting

Problem	Possible Cause	Solution
Every MAC test shows minimum pressure result.	Signal Cable improperly attached.	If using a Legacy Coil and insulators were used to elevate the interrupter in the coil, check to be sure the Signal Cable is clamped to the bottom of the interrupter, and is not connected to the port on the coil.
"Fail to generate ION current" result.	Magnetic field coil is not properly connected.	Make sure the magnetic field coil connectors are attached to the test set, properly color matched, and that the magnetic field coil and all connectors are fully seated and undamaged, then repeat test.
	There may be physical damage to the magnetic field coil.	Contact Vacuum Interrupters, Inc. for troubleshooting steps.







# **Vacuum Interrupters, Inc.**

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