Instruction Manual

Vacuum Interrupters, Inc.
A Group CBS Company

MAC-TS4

Magnetron Atmospheric Condition Test Set

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Vacuum Interrupter Replacement

Vacuum Interrupters, Inc. can provide you a replacement vacuum interrupter for virtually any manufacturers' medium voltage circuit breaker or contactor.

Additionally, Vacuum Interrupters, Inc. can provide vacuum interrupter pole assemblies and replacement vacuum interrupter parts or components for virtually any manufacturers' medium voltage circuit breaker. Our engineers can also design replacement or custom vacuum interrupters for obsolete circuit breakers.

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About the User's Guide

This user's guide describes the functions and features of the Vacuum Interrupters Inc. MAC-TS4. This technical document is intended to act as a simplified reference for users of the equipment, allowing for safe, quick, and efficient use of the MAC-TS4 features.

Before You Begin

DANGER!

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

ATTENTION

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

DANGER!

Ensure the high voltage wire and connectors are in safe, working condition.

DANGER!

Keep a safe distance from high voltage circuit when test is being performed.

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1. Theory of Operation

Principles of operation for the MAC series test sets.

1.1 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 gas as a function of pressure and gap length. The Paschen curve for dry air is presented in Figure 1.

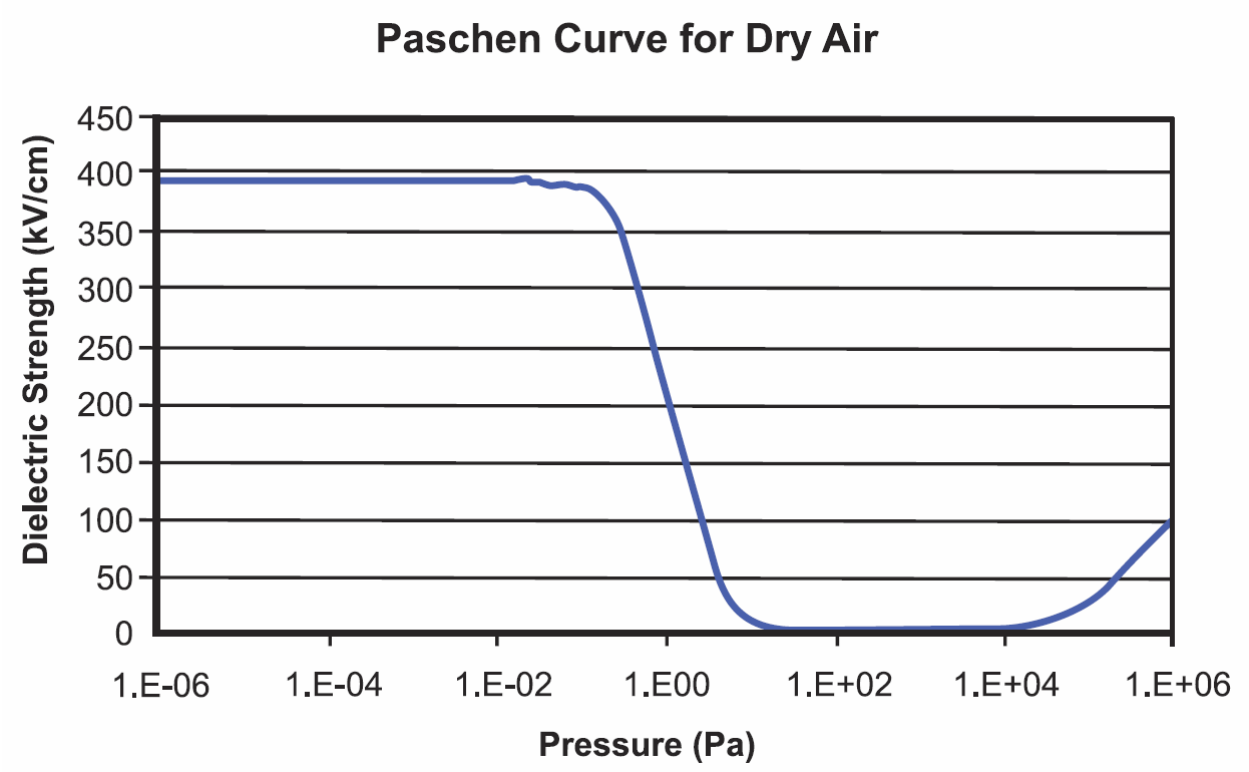


Figure 1. Paschen Curve for Dry Air

The majority of vacuum interrupters are manufactured with an internal pressure between $1x10^{-4}$ Pa and $1x10^{-5}$ Pa. Vacuum interrupters begin to fail a high potential test at internal pressures around $1x10^{-1}$ Pa. The vacuum interrupter should be replaced well before it reaches the failure point to reduce the risk of injury to personnel or damage to equipment in the event of a catastrophic failure. 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.

1.2 Penning Discharge Principle

The MAC test 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.

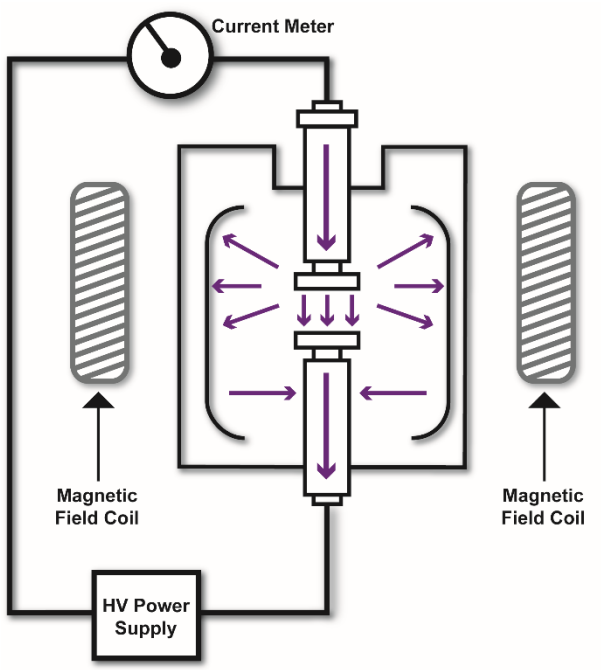


Figure 2. Test Setup using Penning Discharge Principle.

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 vacuum interrupter can be easily determined through the Penning Discharge principle.

2. Test Procedure

The test procedure of the MAC-TS4 is described in the following section.

Figure 3. Vacuum interrupter in a fixed magnetic field coil.

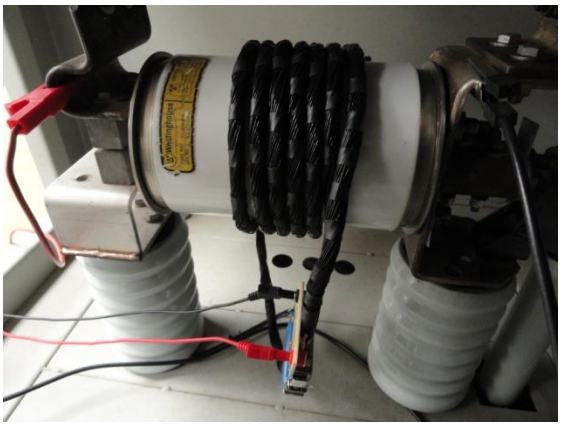


Figure 4. Vacuum interrupter wrapped with flexible magnetic field coil.

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

2. Open vacuum interrupter contacts to the manufacturer rated contact gap using breaker mechanism, if installed. If the vacuum interrupter is removed from the breaker mechanism, a simple jig can be fabricated to open the contacts. Make sure to protect the movable end from torsion in the case of manually opening the contacts.

3. Select the appropriate magnetic field coil. The MAC-TS4 has the capability to test vacuum interrupters using the fixed or flexible magnetic field coils. The fixed magnetic field coil offers the advantage of a uniform, highly repeatable magnetic field; however, the vacuum interrupter must be removed from the breaker. If the vacuum interrupter is installed in the breaker or an appropriate fixed coil is not available, the flexible magnetic field coil can be used.

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.

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. For the **fixed** magnetic field coil:

Place the vacuum interrupter into the fixed magnetic field coil while allowing approx. ½" of clearance between the vacuum interrupter and the interior of the magnetic field coil. Make sure that a conductive surface of the vacuum interrupter is making contact with the signal return plate at the bottom of the fixed coil. If the end cap of the vacuum interrupter is insulated or does not make contact, the black, signal wire can be connected directly to end of the vacuum interrupter that passes through the bottom of the fixed magnetic field coil. (See Figure 5)

For the **flexible** magnetic field coil:

Wrap the flexible magnetic field coil around the vacuum interrupter to be tested. In order to acquire sufficient magnetic field for the test, a minimum of FIVE full wraps is necessary for accurate results. Secure 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. Secure the flexible magnetic field coil to prevent it from making contact with the bus, bus brackets, or metal end-caps of the vacuum interrupter when testing is in progress. (See Figure 6)

5. For the **fixed** magnetic field coil:

Connect the red, high-voltage clamp to the conductor of the vacuum interrupter that is on top, and connect the black, signal wire with the signal input of fixed magnetic field coil. (See Figure 5)

For the **flexible** magnetic field coil:

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. (See Figure 6)

6. For the **fixed** magnetic field coil:

Connect the Magnetic Coil Output wire with the fixed magnetic field coil current input. (See Figure 5)

For the **flexible** magnetic field coil:

Connect the Magnetic Coil Output wire with the flexible magnetic field coil connector. (See Figure 6)

7. Connect ground terminal to suitable ground.

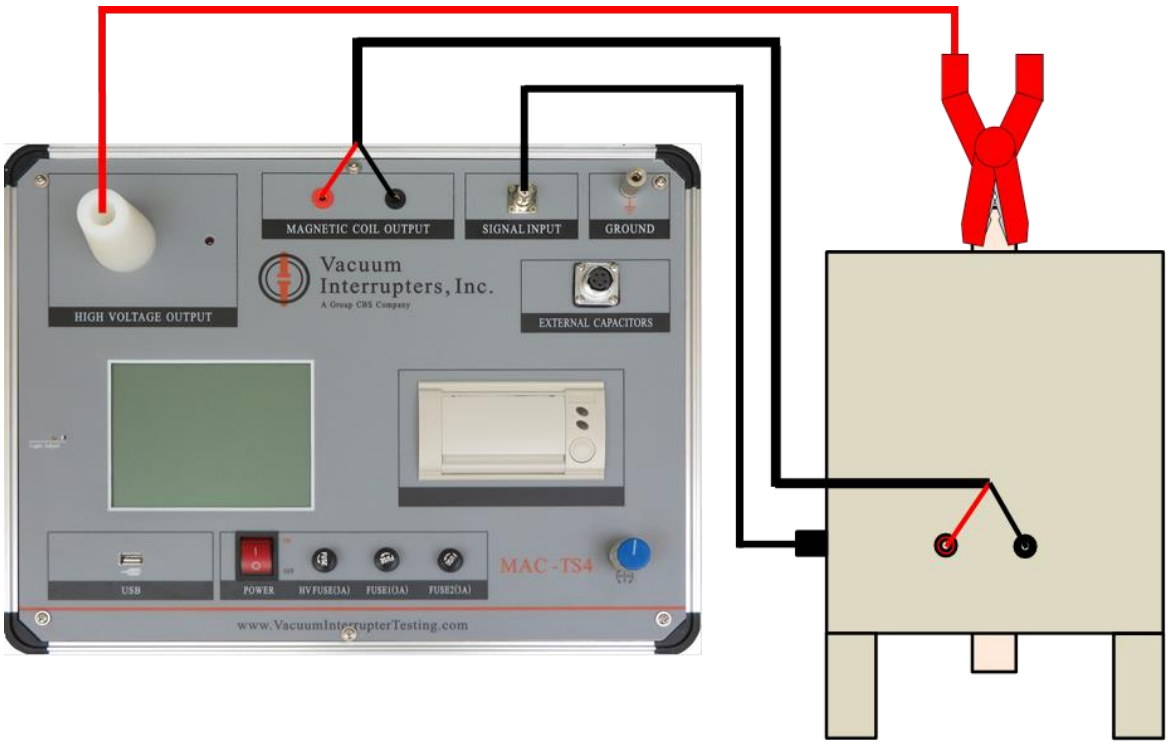


Figure 5. Fixed magnetic field coil connection diagram

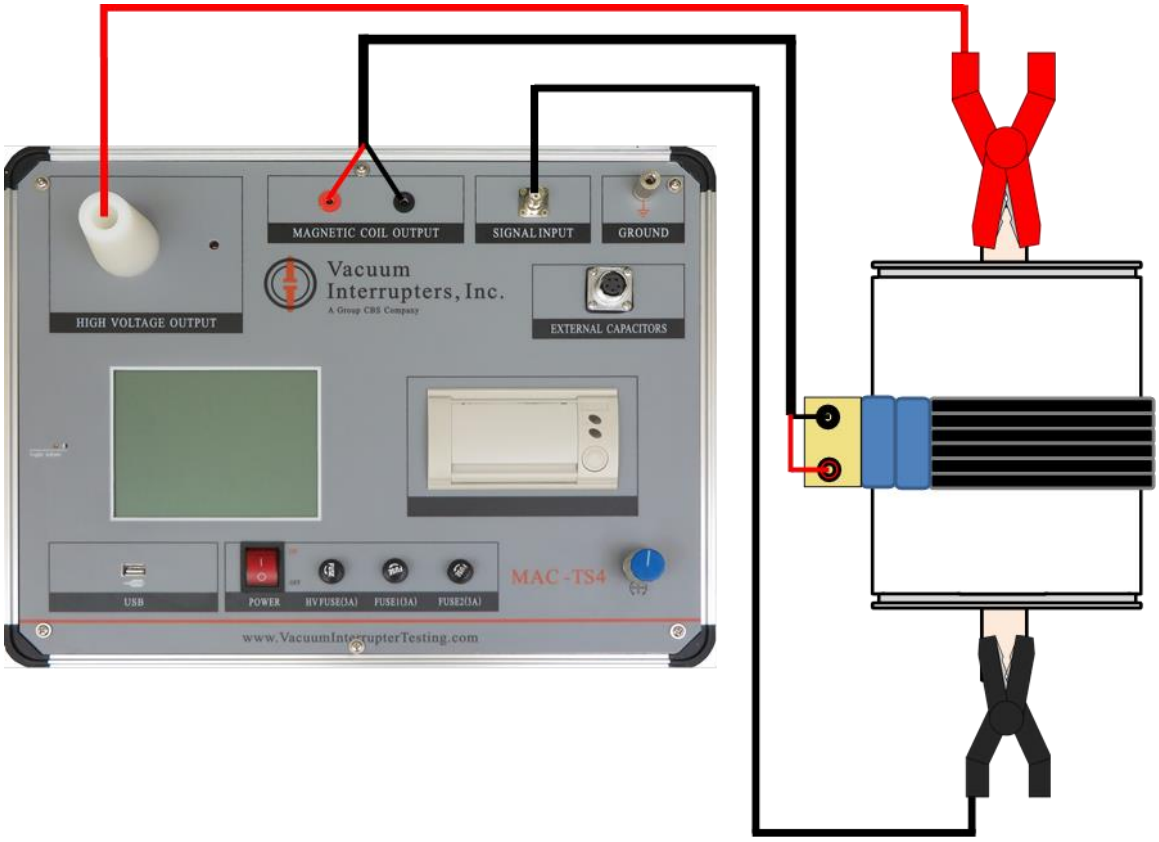


Figure 6. Flexible magnetic field coil connection diagram

8. Turn power on to MAC-TS4 test set.
9. Select [VI Test] from the MAC-TS4 main menu with the selection knob.
10. Select the appropriate 'Curve Number', based on the outer diameter of the center of the vacuum interrupter, from the Curve Selection Table (Table 1). In most cases, this is the outer diameter of the insulation of the interrupter shown by the red arrows in Figure 6. Values can be changed by pressing down on the selection knob, rotating selction knob until desired value is shown, and pressing down again on the selection knob to lock in selection.

VI Diameter	Curve Number
< 4"	01
4" - 5"	02
5" - 6"	03
6" - 7"	04
> 7"	05
> 7" (3000A)	06

Table 1. Curve Selection Table

11. 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.

12. Select the appropriate 'Coil Option' for the magnetic field coil being used. Select 'FIXED COIL' if using a fixed magnetic field coil. Select 'FLEX COIL' if using the flexible magnetic field coil.

13. Input a 'VI ID' for reference, if desired. It is recommended to use a VI ID for recalling test results in the future.

14. Select [Run]. Adhere to safety warning and select [OK] to begin test.

DANGER!

Keep a safe distance from high voltage circuit when test is being performed.

15. When the test is completed, a pressure result will be displayed under 'Pressure in Vacuum Interrupter'. If the pressure in the VI is at an unsatisfactory level or if there are flaws in the test setup, an error will be displayed. See Troubleshooting section.

ATTENTION

Repeated testing on the same vacuum interrupter in a short period time will cause the pressure value to reduce. This is a conditioning effect due to the capacitance of the vacuum interrupter. Once the vacuum interrupter has been subjected to a current through its contacts, the pressure measurement will return to the initial value.

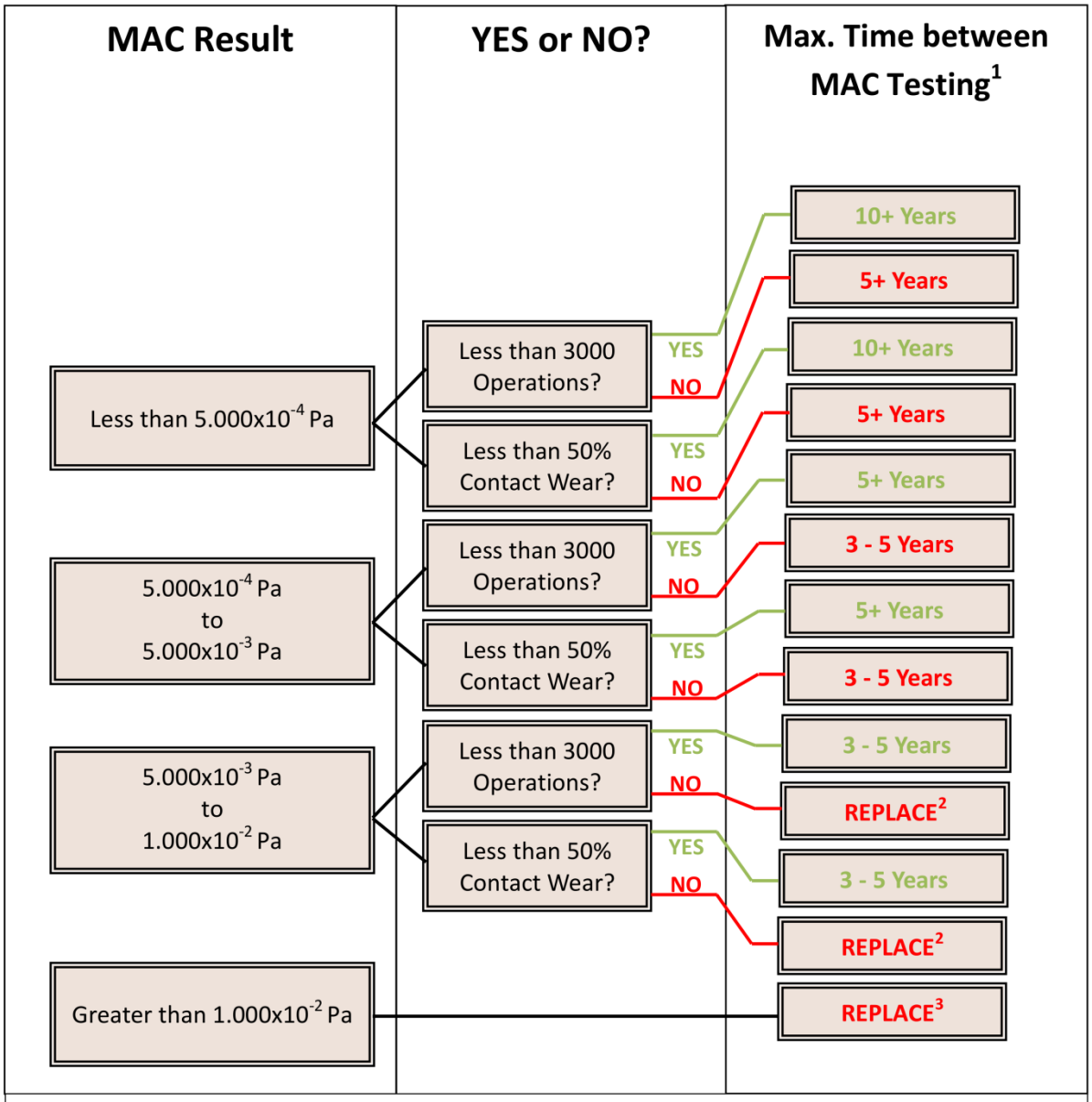
16. Test results can be saved to the MAC-TS4 internal memory by selecting the [Save] option.

17. Test results can be printed by selecting the [Print] option.

3. Interpreting Test Results

3.1 Criteria for Interpreting Results

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



[1] This is the recommended maximum period of time between MAC tests 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 7. Interpreting Test Results Flowchart

4. Troubleshooting

Problem	Possible Reason/Solution
Device will not power on.	1. Check that power cord is fully inserted into receptacle.
	2. Check the power fuse.
Returns to main screen during test.	1. Make sure VI contacts are in open position and repeat test.
	2. Check high voltage, magnetic field coil, and signal connections. Ensure that there is no conductive path between any of the cables and repeat test.
	3. VI pressure is at an unsatisfactory level.
“Breakdown between contacts” result.	1. Make sure VI contacts are in open position and repeat test.
	2. Check high voltage, magnetic field coil, and signal connections. Ensure that there is no conductive path between any of the connections and repeat test.
	3. VI pressure is at an unsatisfactory level.
“Fail to generate ION current” result.	1. Make sure the flexible magnetic field coil connectors are attached. Repeat test.
	2. Check magnetic field coil electrical connections to MAC test set. Repeat test.
	3. There may be physical damage to the magnetic field coil. Contact customer support for troubleshooting steps.
Not sufficient space to wrap flexible magnetic field coil around VI.	1. Contact customer support to check the availability of a custom magnetic field coil for your application.
	2. VI must be removed from circuit breaker in order to perform testing.

5. Specifications

Physical Specifications:	16.9” × 12.6” × 9.8” (430mm × 320mm × 250mm) Weight: 28.4 lb (12.9Kg)
Input Power:	120V AC 50/60Hz (standard), 230V AC 50/60Hz (optional)
Measure Range:	1×10^{-5} Pa to 1×10^{-1} 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:	Stores up to 500 test results
Computer Interface:	One USB interface
Computer Software:	Windows®-based software
Certifications:	CE certified
Environment: Operating:	-10°C to +50°C (+15°F to +122°F)
Humidity:	85% Rh @ 40°C (104°F) non-condensing
Altitude:	2,000 M (6,562 ft) to full safety specifications

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