Vacuum Interrupters, Inc.
A Group CBS Company

Vacuum Interrupter Testing
Using
Magnetron Atmospheric Condition (MAC)
Test Equipment

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Reasons for Testing with MAC Test Equipment

History

- The majority of vacuum interrupters were installed in the 1980's and given an original life expectancy of 20 years.
- Vacuum interrupters installed in this period have far exceeded their manufacturer specified life expectancy.
- Failure of a vacuum interrupter could result in unnecessary downtime and damage to surrounding equipment.

Traditional testing methods

- Vacuum integrity Pass or Fail test using high voltage ac test set.
- Not capable of determining level of vacuum inside interrupter.
- Not capable of determining the life expectancy of vacuum interrupters

Predicting the Remaining Life of Vacuum Interrupters in the Field

Applying the Magnetron Atmosphere Condition Assessment (MAC) test in a field environment

INTRODUCTION

Historical perspective

Historically, air-magnetic and oil interrupters were the only types of interrupters used on circuit breakers rated at 2.4 kV and higher. The air interrupters predominated the lower voltages in this range – from 2.4 kV up to 25 kV. Above 25 kV, oil interrupters were the more commonly used primarily because of their ability to interrupt higher arc energies.

Air-magnetic interrupters

Air-magnetic interrupters degrade somewhat each time they are opened under load, and they degrade significantly if they are interrupted under fault. The contacts can be repaired or replaced if required; however, the maintenance of these types of circuit breakers was not always properly scheduled sometimes resulting in failures.

In addition to the maintenance problem, the arc-chutes are very large and heavy. Some of the arc chutes on these breakers are also somewhat fragile and can be broken if not properly handled.

Oil interrupters

Oil interrupters are also very heavy. More importantly, the interrupter itself is submerged in oil and is difficult to reach for inspection. Testing methods such as contact micro-ohmmeter tests, insulation resistance tests, power factor tests, and the like are quite reliable in determining the condition of the interrupter. However, like air-magnetic interrupters, these units were not always maintained as they should be.

In addition to maintenance and size problems, stricter environmental requirements make using these types of interrupters subject to increased regulation and higher cost of maintenance.

What accounts for the amazing popularity of the vacuum interrupter?

Partially as a response to many of the issues with air-magnetic and oil interrupters, widespread use of vacuum interrupter (VI) technology and SF-6 technology in electric power distribution systems started over thirty years ago. In the intervening years, the VI has become the choice for the vast majority of circuit breakers applied between 1000 volts and 36,000 volts.

Figure 1. External view of a typical vacuum interrupter.

The VI (See Figures 1 and 2) is light-weight, sealed from the atmosphere, and has a very long predicted useful life. Since VI technology was first used in the industry, typical predictions have been 20 or 30 years.

Thus there are a number of features that have led to its wide acceptance as a superior interrupting technology. These features include the following:

- It is a relatively compact and sealed unit.
- The travel required to open is very short with distances that vary with age and manufacturer. The actual travel distance varies with VI geometry and voltage level; however, typical distances range from approximately 8 mm (0.314 in) to 12 mm (0.472 in).
- It has the longest expected service life of any interrupting method.
- When a VI experiences one of their relatively rare failures, the resulting damage is sometimes much less than air-magnetic interrupters. However, they still can fail spectacularly causing great damage.

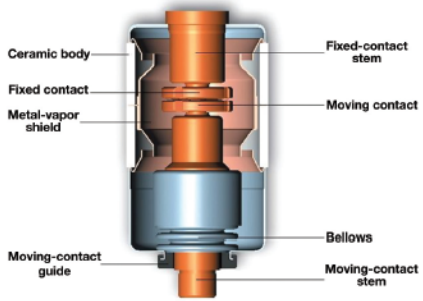

Figure 2. Internal view of a typical vacuum interrupter.

Why do vacuum interrupters work?

The VI's high interrupting capacity is based on the physical principle discovered by Louis Karl Heinrich Friedrich Paschen (1865-1947). Paschen did original experimental research and discovered that the dielectric strength of a gas is a function of the gas pressure (p), the distance between the two electrodes (d), and the type of gas. This relationship is given in Equation 1.

$$V = \frac{apd}{\ln(pd) + b}$$

Paschen's Equation 1.

Note that a and b are constants that are derived for dry air.

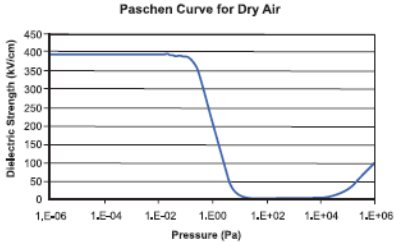

Figure 3. Paschen's curve for dry air.


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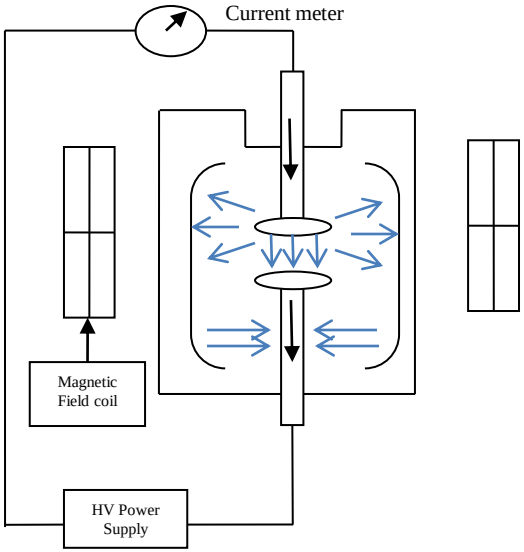
MAC Testing Technology

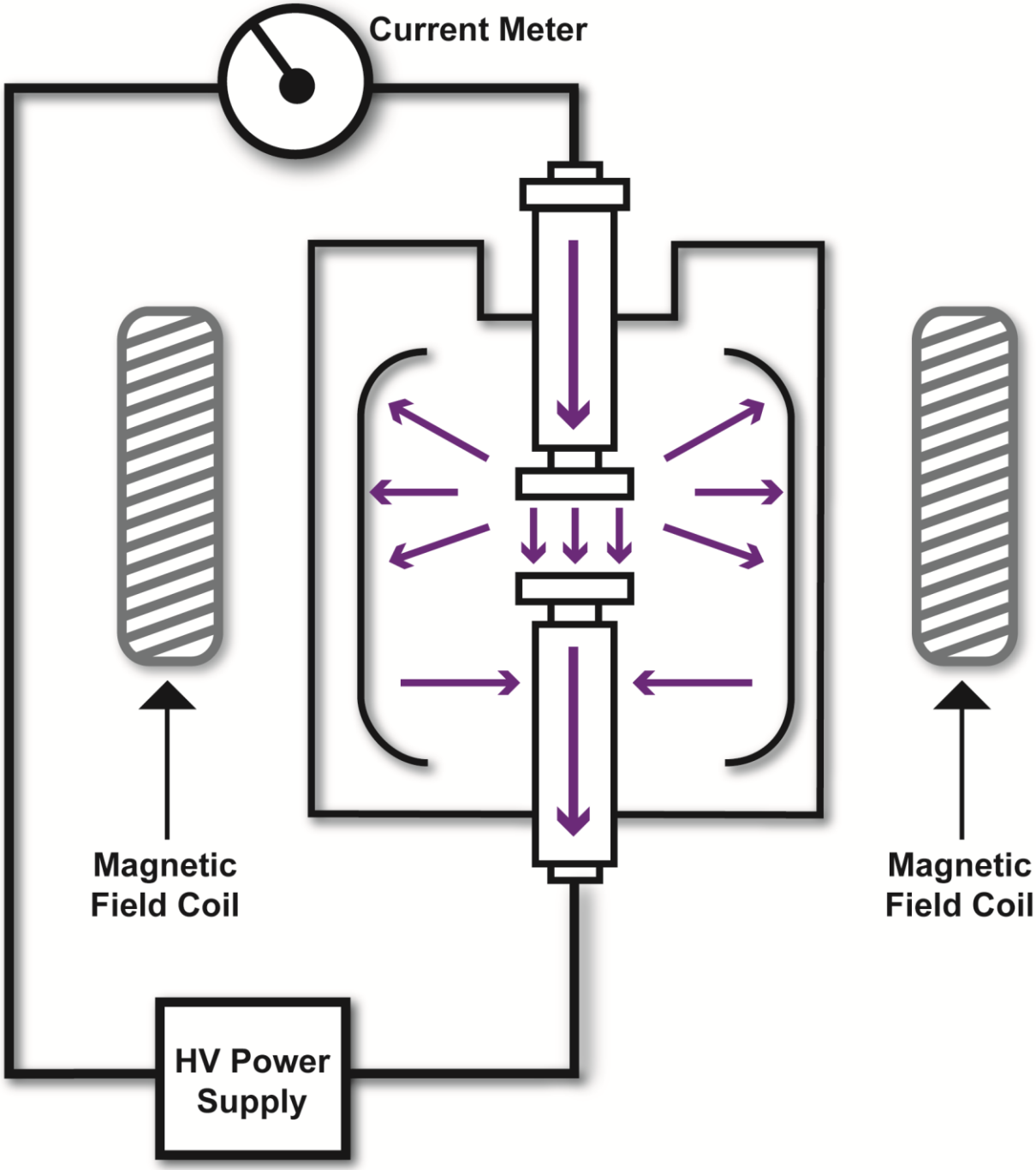
- MAC vacuum interrupter testers use the Penning discharge principle to determine the level of vacuum inside a vacuum interrupter
- The test results obtained are compared to an "ionization current – pressure curve" that we have determined in our lab for that particular type of vacuum interrupter using a vacuum test system
- The test results are compared to the lab generated curve
- Using this data together with other parameters, trend to failure can be predicted using condition based predictive maintenance
- Now you will find Vacuum Interrupters near the dry air dielectric failure pressure and you have to be prepared for that.
- During acceptance testing of new gear some few VI will be found to have a lower pressure by several magnitudes this will disturb the manufacturers and cause a problem.
- The spec typically will say pass the Go/No-Go test.

Penning Discharge Principle

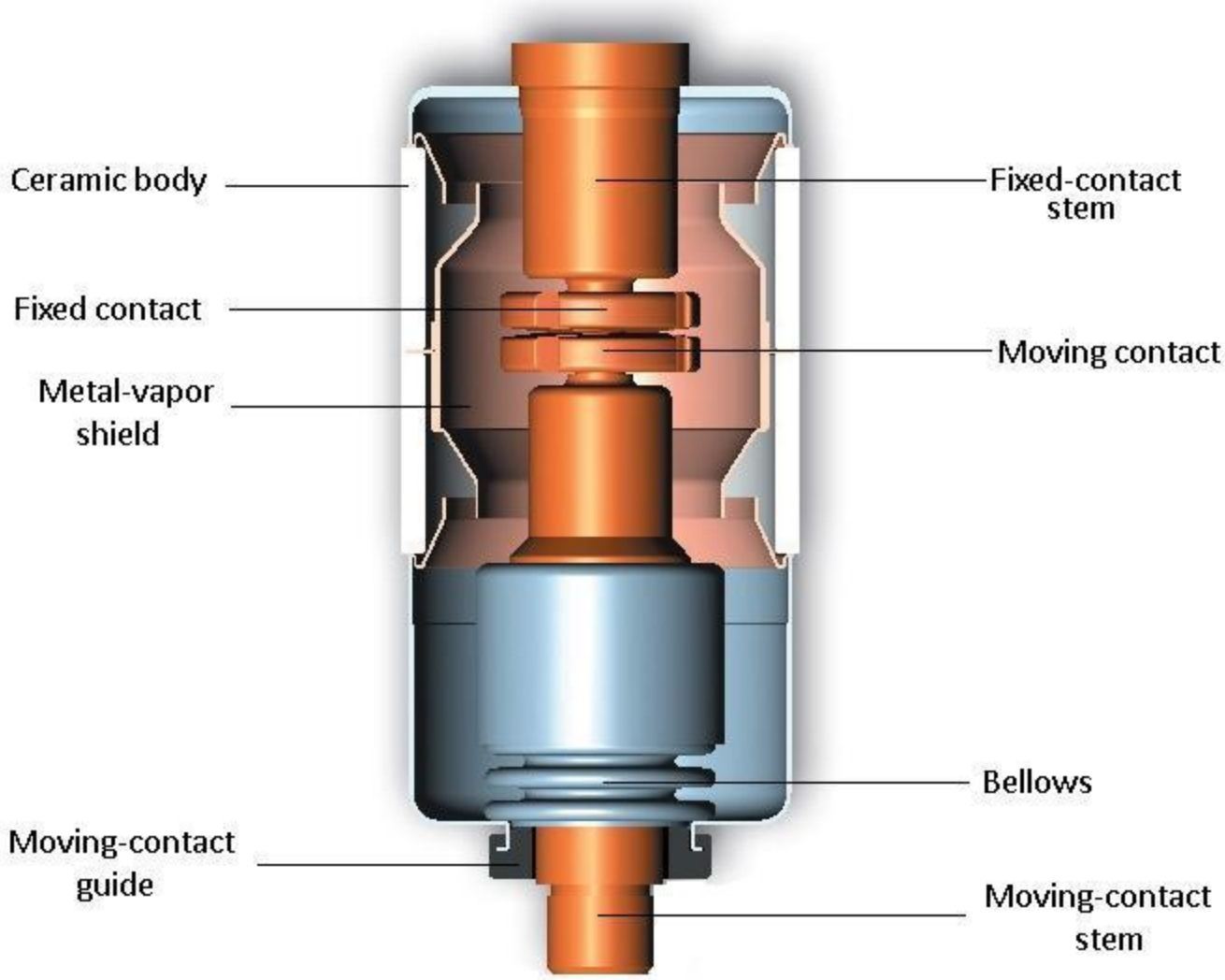
- Charged particles (ions) can be generated from high voltage supplied across an open vacuum interrupter. When a strong magnetic field is applied, these ions will move, thereby, producing a current across the open contacts. This ionization current is directly proportional to the pressure inside the vacuum interrupter. With a known pressure-ionization current curve, the pressure inside a vacuum interrupter can be easily determined through the Penning Discharge principle.



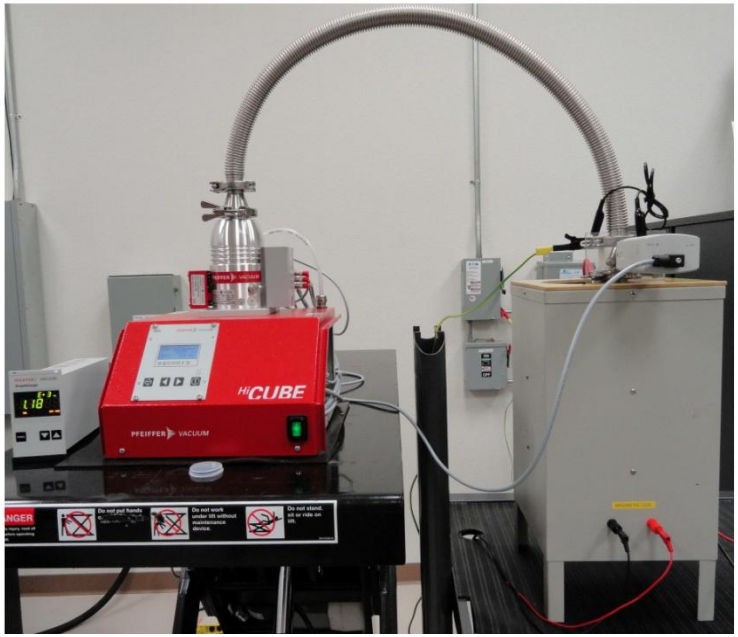
J. Eichmeier, *Moderne Vakuumelektronik. Berlin, Germany: Springer*-Verlag, 1981, pp. 243–273


Current Meter
Magnetic
Field Coil
Magnetic
Field Coil
HV Power
Supply

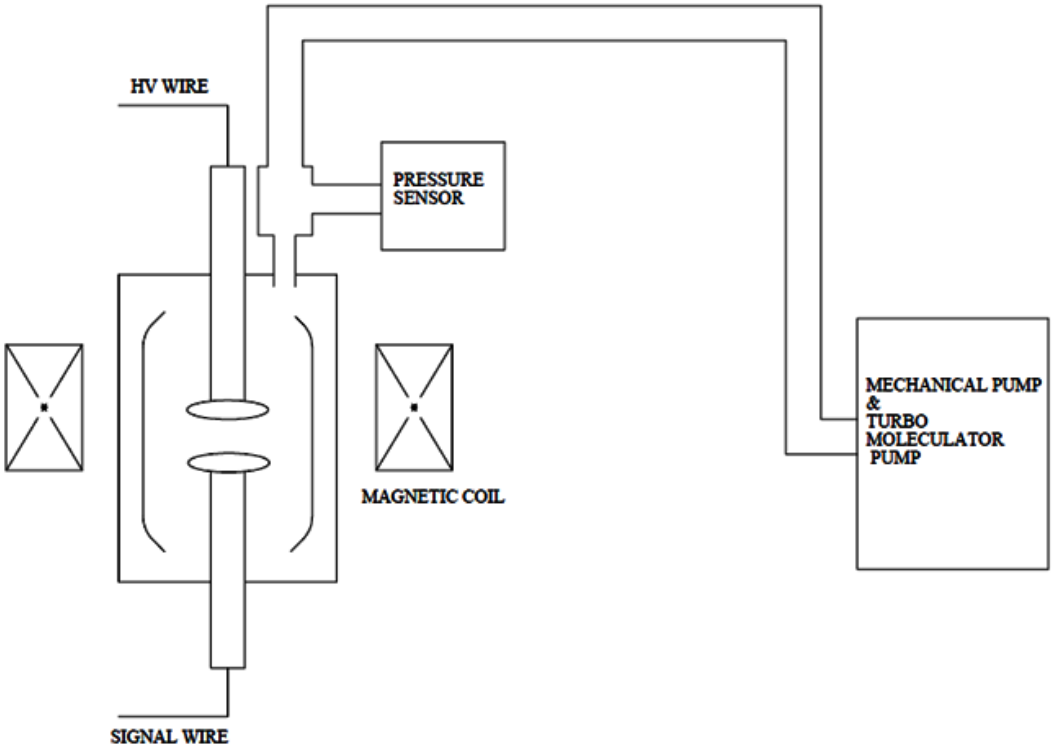
Typical Vacuum Interrupter



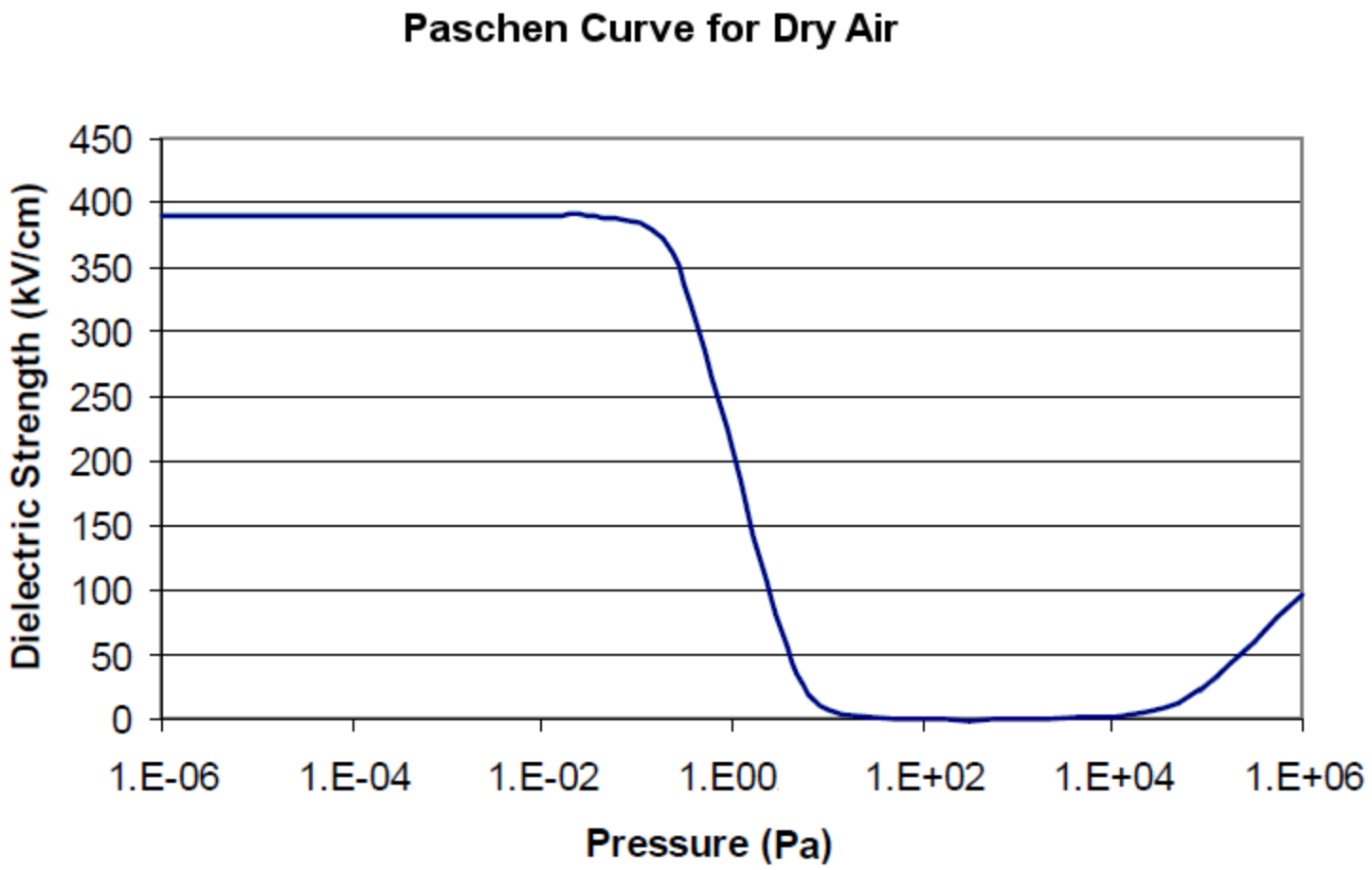
Vacuum Test System



In order to create the 'ionization current - pressure curve' for the MAC-TS1 and MAC-TS2 Testers, 40 data points are required for each unique vacuum interrupter within the range 1x 10 $^{-1}$ Pa -1x10^{-5} Pa.




HiCUBE
PFEIFFER VACUUM
DANGER
MAC-TS1


Paschen Curve for Dry Air
Dielectric Strength (kV/cm)
450
400
350
300
250
200
150
100
50
0
1.E-06
1.E-04
1.E-02
1.E00
1.E+02
1.E+04
1.E+06
Pressure (Pa)

Vacuum Interrupters, Inc.

BREAKER MAC TEST REPORT

Test Setup

MAC Tester Model:	MAC-TS 1
HV Setting:	HV3
Curve/Current:	Current
Mag. Field Coil Type:	Flexible/3 Wraps
Date of Test:	1/30/2012

Breaker Data

Reference:	00294800
Manufacturer:	GE
Model:	VB 4.16-350-3
Rated Current:	1200A
S/N:	0315A-1509-001-12
DoM:	Jan-86
Operations Counter:	3334
VI Type:	44B1

MAC Result

A Phase:	3.210E-05	Pa
B Phase:	2.393E-03	Pa
C Phase:	1.878E-05	Pa

Contact Wear

A Phase:	0.024	in	Resistance:	18	µΩ
B Phase:	0.055	in	Resistance:	18.9	µΩ
C Phase:	0.102	in	Resistance:	18.5	µΩ

Observations

This GE Power-Vac medium voltage power circuit breaker was tested as part of a VI general evaluation. It was found to have B Phase VI pressure and C phase VI wear to be reaching limits that would indicate a cautious approach to future use and circuit criticality. The number of operations, age, internal pressure and wear of the B Phase VI would lead us to recommend that the B phase VI is replaced. The number of operations, age, and wear of the C Phase VI would lead us to recommend that the C phase VI is replaced. Proper cleaning and lubrication is a must when dealing with ageing spring charged mechanisms. See recommendations and quotation in section 4 for further detail.

Tested by: Jerod Day

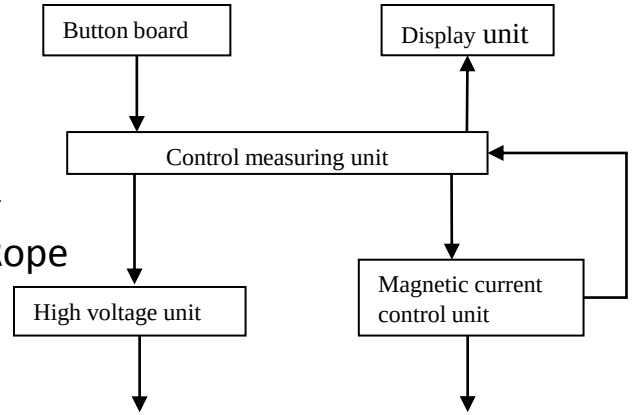
Conditioned Based Predictive Maintenance

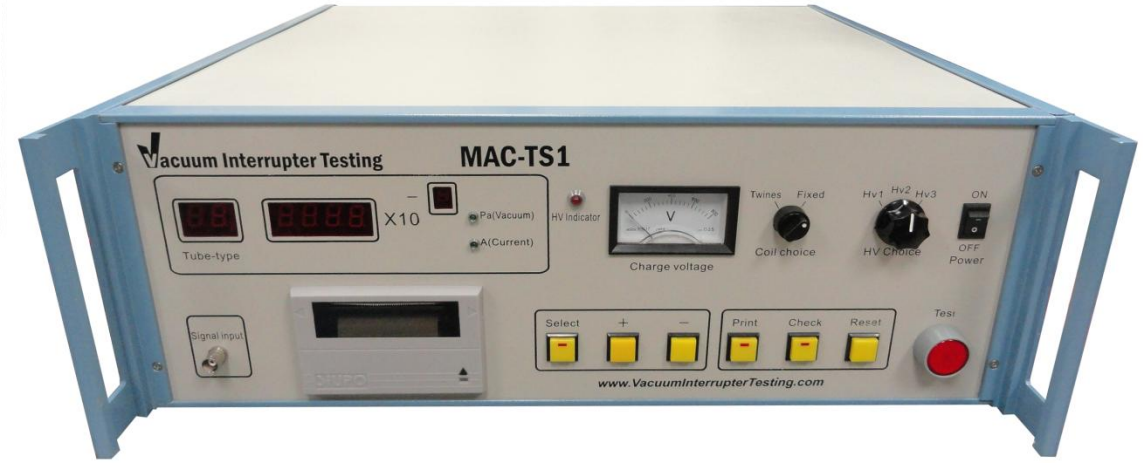
- Breaker type and serial number
- Breaker date of manufacture
- Breaker condition and atmosphere
- Breaker operating conditions
- Number of operations
- Known vacuum interrupter batch or type strengths or decencies
- Vacuum interrupter part number and serial number
- Vacuum interrupter wear indication
- Vacuum interrupter contact resistance
- MAC test data
- MAC database trend information.
- Circuit criticality

MAC-TS1 Test Set

Technical features

- Light weight unit for lab/shop use
- Measurement range: 1 x 10^{-5} Pa ~ 1 x 10^{-1} Pa
- Measurement accuracy: <10 % in 1 x 10^{-4} ~ 1 x 10^{-1}
- Uses Fixed Magnetic Field Coil or Flexible Magnetic Rope
- Easy and safe to operate





Vacuum Interrupters, Inc.
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MAC-TS1 Product Bulletin

Magnetron Atmosphere Condition (MAC) Analysis

Specifications and Ratings

Pressure Range	Error	Dimensions	Weight	Vacuum Interrupter Test Set Type
$1x10^{-3}$ mbar — $1x10^{-7}$ mbar	<10%	7.63" H x 20.56" W x 20.56"D	43.4 lbs	Penning Discharge Magnetron

Standard Features

- Accurate Vacuum Measurement in Shop or Field
- Trending data to predict Vacuum Interrupter failure
- Shop assessment to determine if Vacuum Interrupter is serviceable during overhaul.
- Database of 3000 Vacuum Interrupters assures reliable data.
- Condition based maintenance program based on all parameters available.
- Technology based on actual factory test parameters when Vacuum Interrupter was new.
- Failure evaluation service for Vacuum Interrupters.

Product Image

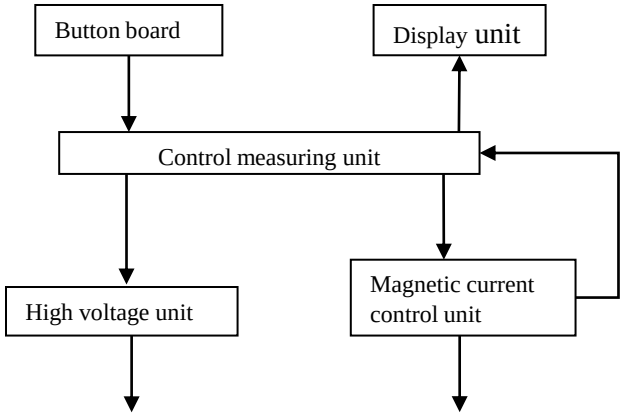
Magnetic Field Coil

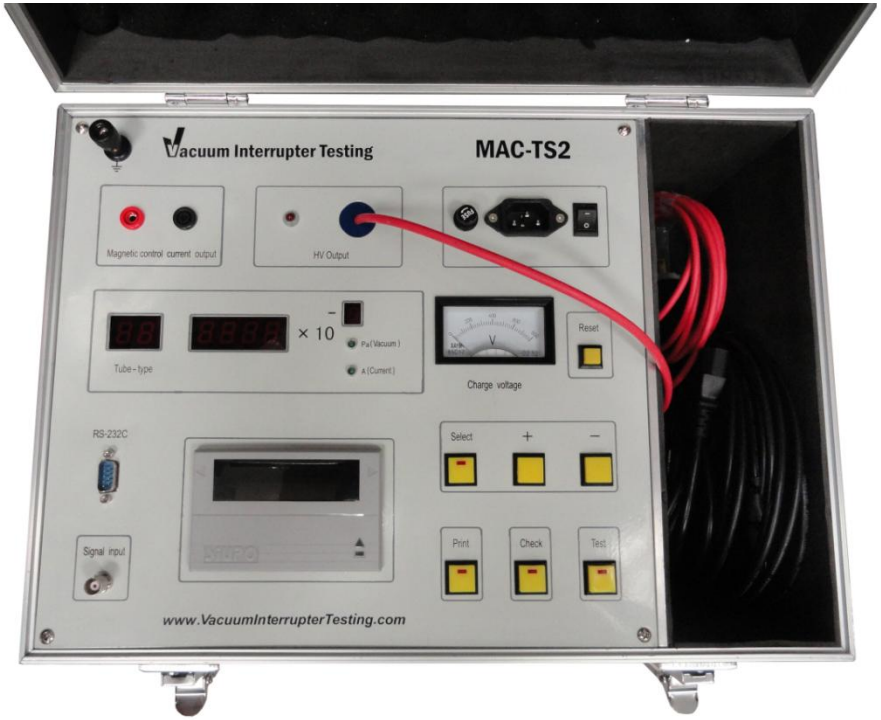
A lab-based magnetic field coil for testing individual vacuum interrupters that have been removed from a breaker or contactor. The coil allows for a consistent, uniform magnetic field and accurate vacuum interrupter condition measurement. The magnetic coils are used in conjunction with the MAC-TS1 tester. The magnetic field coil comes in various sizes to accommodate most vacuum interrupters.

MAC-TS2 Test Set

Technical features

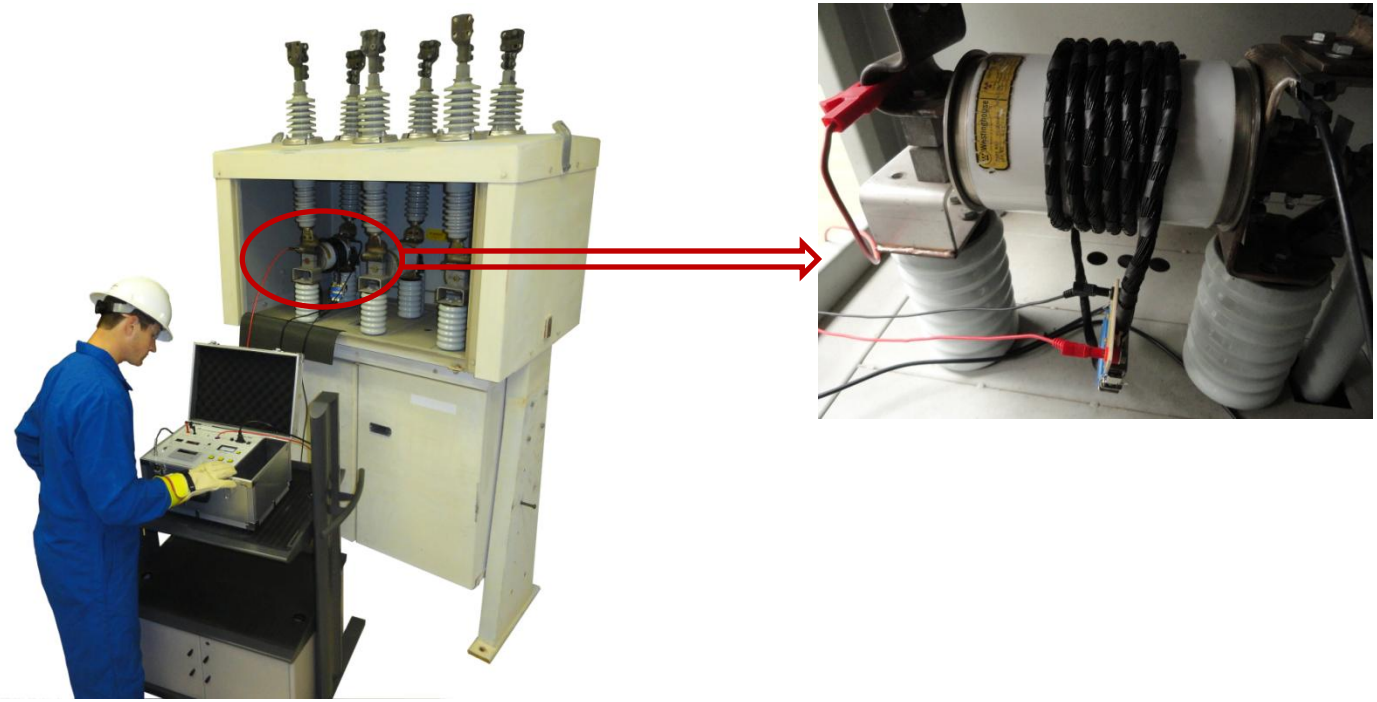
- Light weight, portable test set for field or shop use
- Measurement range: 1 x 10^{-5} Pa ~ 1 x 10^{-1} Pa
- Measurement accuracy: <10 % in 1 x 10^{-4} ~ 1 x 10^{-1}
- Easy and safe to operate
- Operates only with flexible magnetic field coils.





Flexible Magnetic Field Coils

A flexible magnetic coil for testing vacuum interrupters while installed in a breaker or contactor, making it ideal for field use. The flexible magnetic field coils are used in conjunction with the MAC-TS1 or MAC-TS2 test sets. The flexible magnetic field coil comes in various lengths to accommodate most vacuum applications.



Vacuum Interrupter Testing

A Group CBS Company

MAC-TS2 Product Bulletin

Portable Magnetron Atmosphere Condition (MAC) Analysis

Specifications and Ratings

Pressure Range	Error	Dimensions	Weight	Vacuum Interrupter Test Set Type
$1x10^{-3}$ mbar — $1x10^{-7}$ mbar	<10%	10.25" H x 18.25" W x 13.25" D	33 lbs.	Penning Discharge Magnetron

Standard Features

- Accurate Vacuum Measurement in Shop or Field
- Trending data to predict Vacuum Interrupter failure
- Shop or Field assessment to determine if Vacuum Interrupter is serviceable during overhaul.
- Database of 3000 Vacuum Interrupters assures reliable data.
- Condition based maintenance program based on all parameters available.
- Technology based on actual factory test parameters when Vacuum Interrupter was new.
- Failure evaluation service for Vacuum Interrupters.

Product Image

 2616 Sirius Rd. Denton, TX 76208 Phone: 940-382-3300 Fax: 940-382-9435

Summary

- Vacuum interrupter testing utilizing MAC testers can provide a viable means of determining the condition of vacuum interrupters prior to failure.
- When used with the patent pending, flexible magnetic field coil, vacuum interrupters can be tested in place while installed in your circuit breaker or contactor.
- Using condition based predictive maintenance in conjunction with MAC tester data, trend to failure of vacuum interrupters can be predicted.
- Vacuum Interrupters Inc. can supply replacement Interrupters for all types of Circuit Breakers and Motor controllers.

Vacuum Interrupters, Inc.
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Vacuum Interrupters, Inc.

A Group CBS Company

Providing replacement vacuum interrupters for virtually all medium voltage contactors and circuit breakers!

Solutions for all your vacuum interrupter requirements.

Additionally, Vacuum Interrupters Inc. can provide you a vacuum interrupter pole assembly 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.

- **Individual Vacuum/Bottle Interrupters or Complete Pole Assemblies**
  - In shop replacement at our facility
  - Field replacement at your facility
  - Local replacement at nearest Group CBS affiliate service location.
- **GE - General Electric vacuum circuit breaker:** VB - VB1 - PVD - LimitAmp - PowerVac vacuum interrupter.
- **For example:** we stock replacement vacuum interrupters for the GE Limitamp AC Motor Controller's PowerVac PV-74A vacuum interrupter (also referred to as PV74A or PV 74A) that is part of GE vacuum bottle assembly part number 55C679806G1RP.
- **Another example:** we also stock a replacement for the PV 40A1 vacuum interrupter used in the GE PowerVac VB 13.8-500 and VB1 13.8-500 vacuum circuit breaker that is part of assembly part numbers 0282A2751G052 or 0282A2751G0G54 or 0282A2751G0G68.
- **Square D - Eaton vacuum circuit breaker:** VR - HVC - VAD1 - VAD2 - VAD3 vacuum interrupter.
- **Westinghouse - Cutler Hammer - Eaton vacuum circuit breaker:** VCP - VCPW - R Type - DVP - DHP-VR Amp Guard vacuum interrupter.
- **Siemens - Allis-Chamlers vacuum circuit breaker:** FCV - FSV - MSV - 3AF - GMI vacuum interrupter.
- **ABB - BBC - Gould - ITE vacuum circuit breaker:** VHK - VHR - VHX vacuum interrupter.

When you have vacuum interrupter failure, need additional information, or to discuss your requirements, contact us for immediate assistance.

Call 940-382-3300

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