Vacuum Interrupters, Inc.
A Group CBS Company

Vacuum Interrupter Conditioning (VIC) Workshop

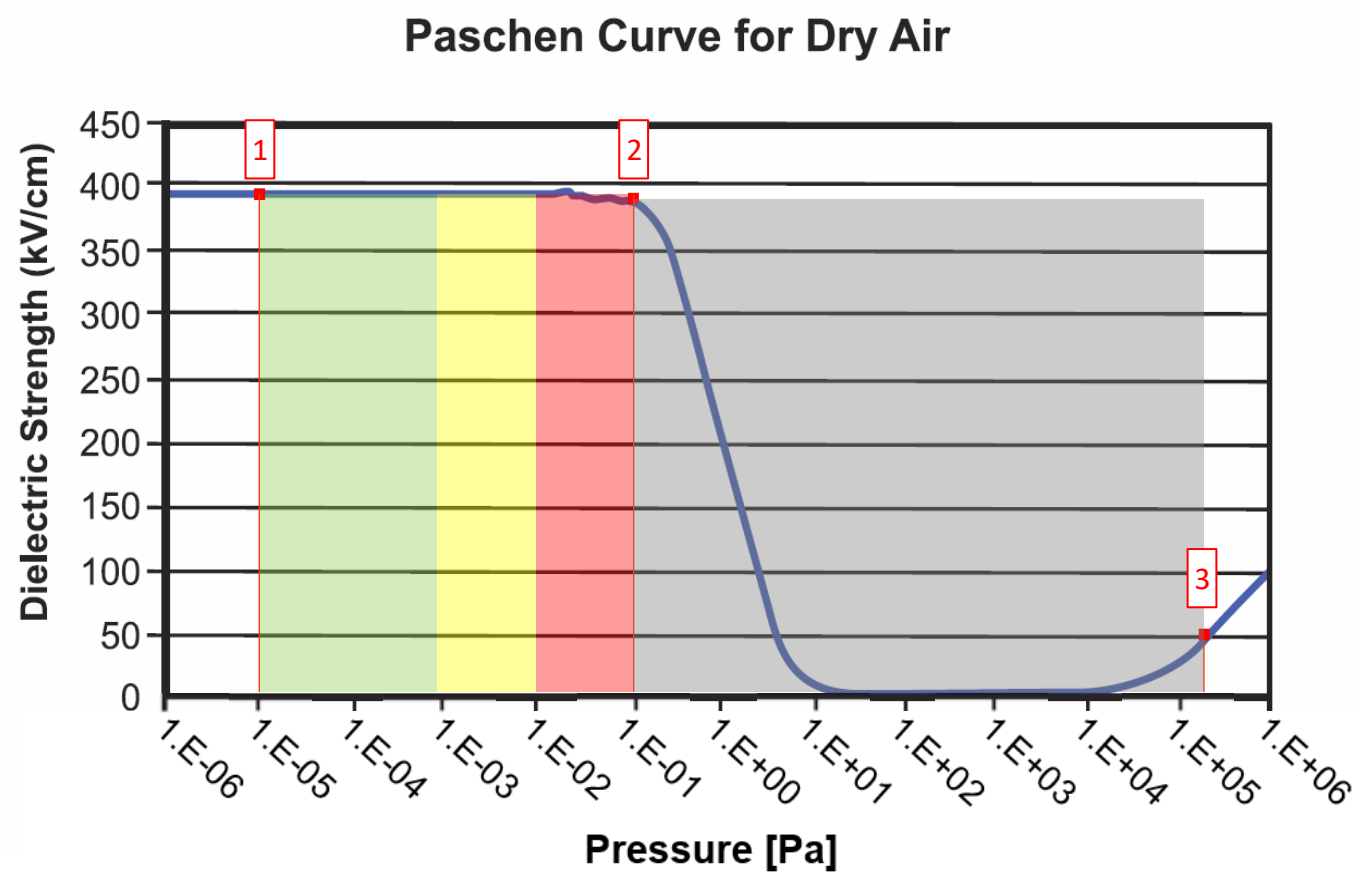
Outline and Agenda

- Introduction.
- Science, Physics and Magic.
- Why we need this.
- Break (30M)
- Presentation.
- Workshop Demonstration Hands On!

Introduction

- Millions of VIs in service today
- Many have exceeded original life estimates
- Increasing number of failures
- Replacing all aging VIs is not feasible

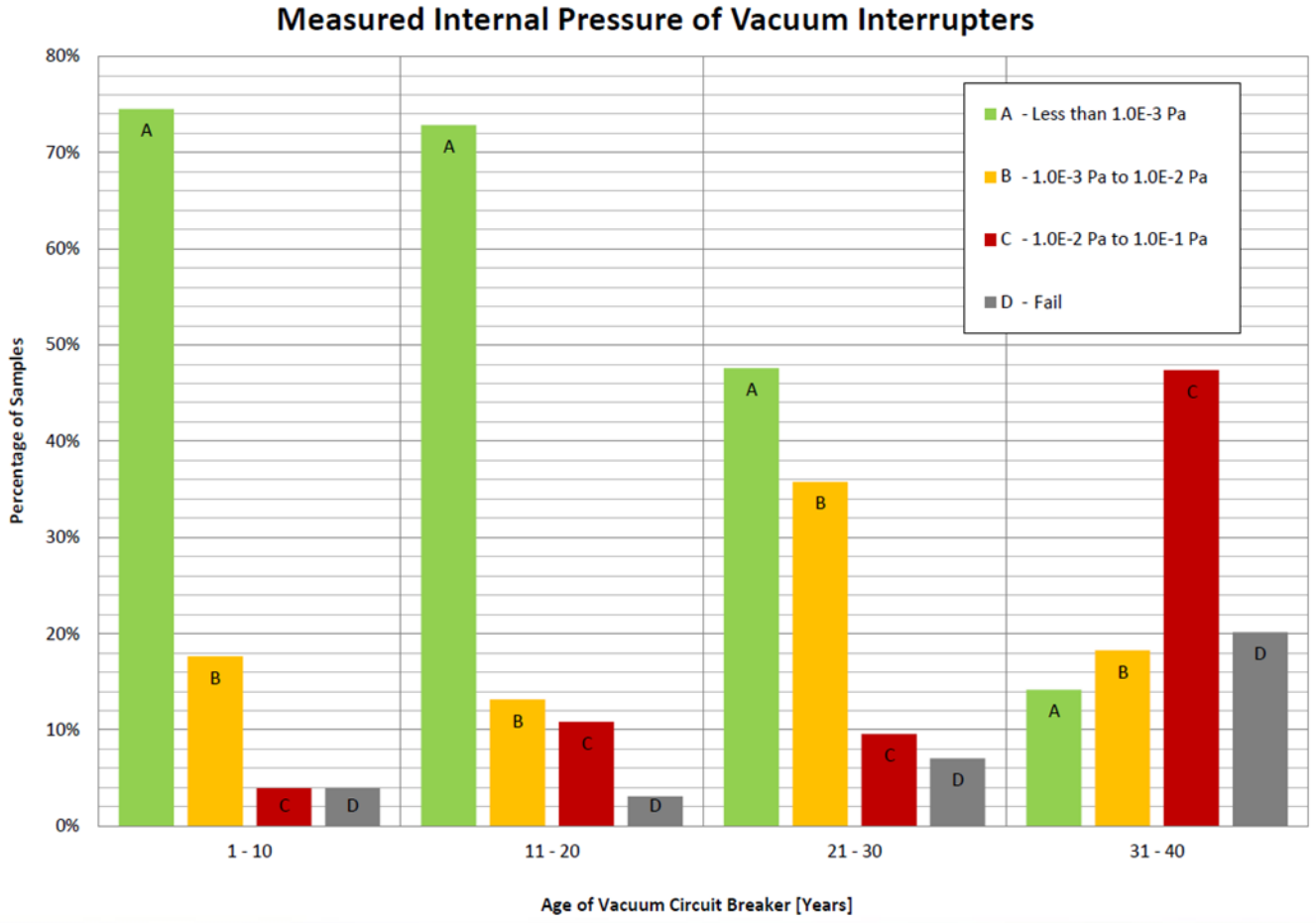
Breakdown Voltage



Reference Points:

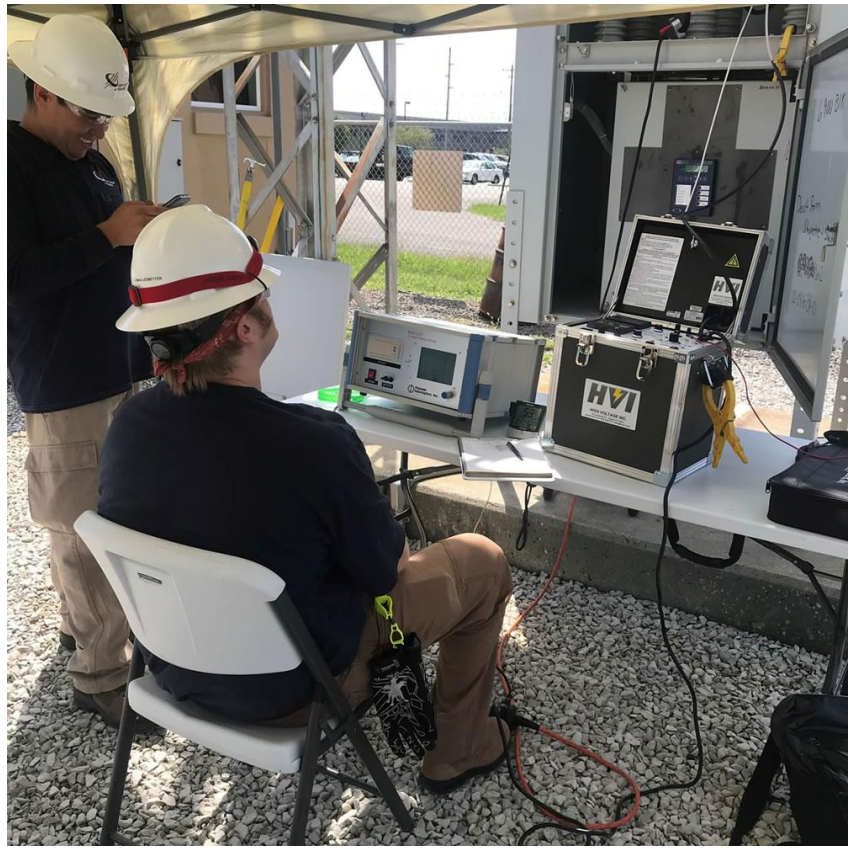
1. New VI Pressure
2. Critical Pressure
3. Atmospheric Pressure

Vacuum Interrupters in the Field

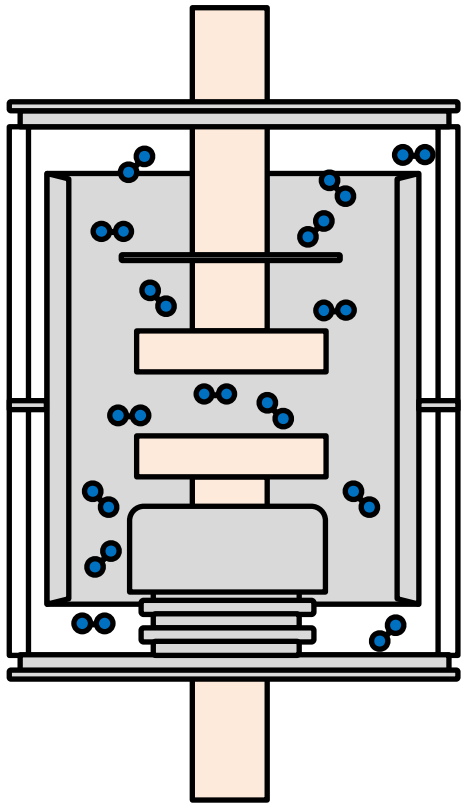


Vacuum Interrupter Conditioning (VIC)

- Field-Portable Process
- Extend vacuum life of VIs that have few operations and little contact wear
- Average improvement of a full magnitude or more 5 + years of new life for VIs whose vacuum is approaching end-of-life



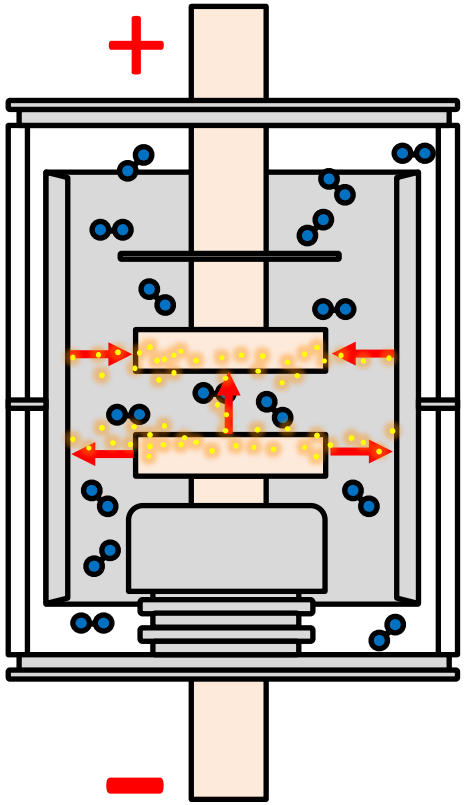
Before VIC Process



Gas Molecule

Gas molecules accumulate over the life of the vacuum interrupter.

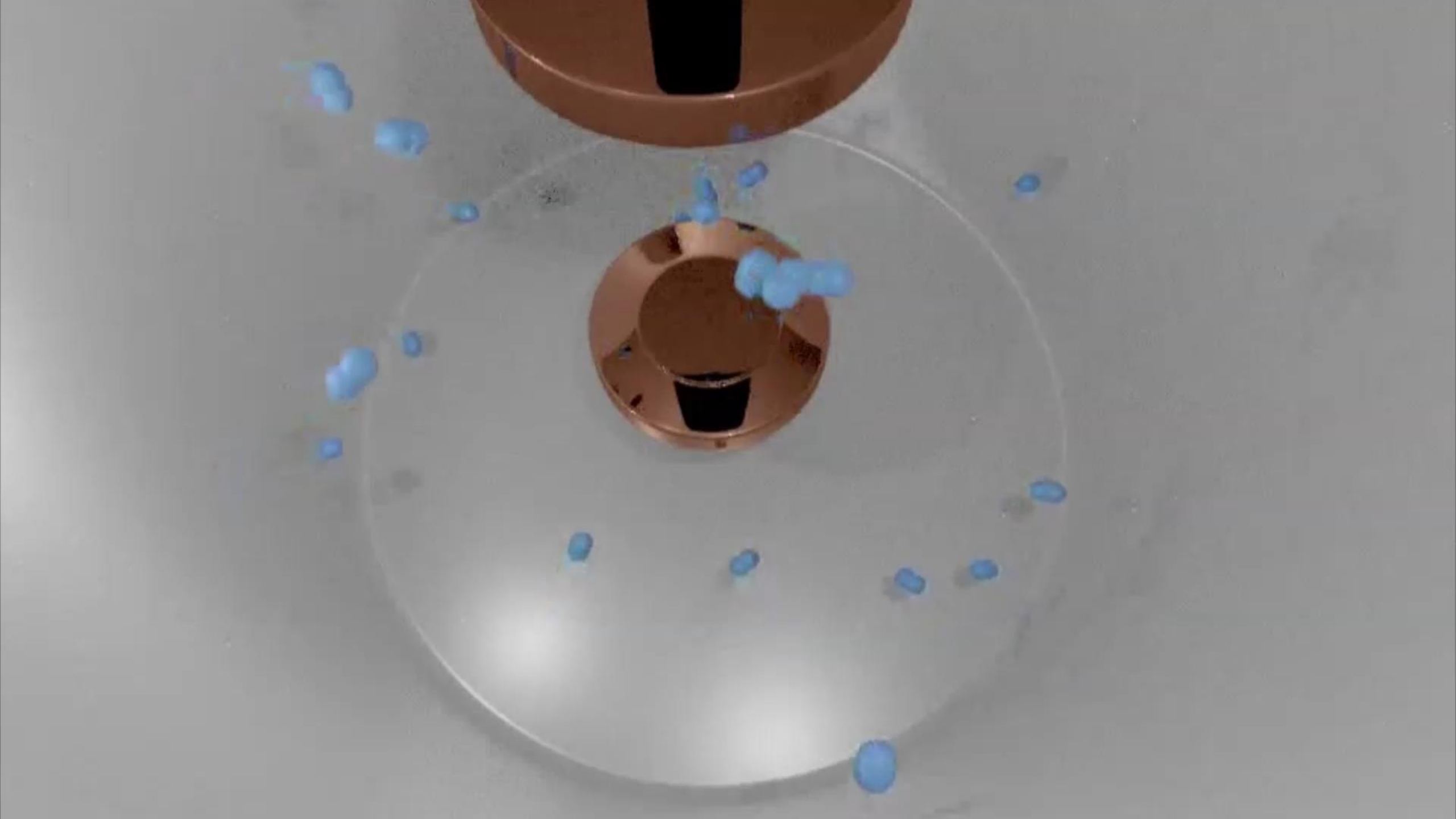
High Voltage Supplied



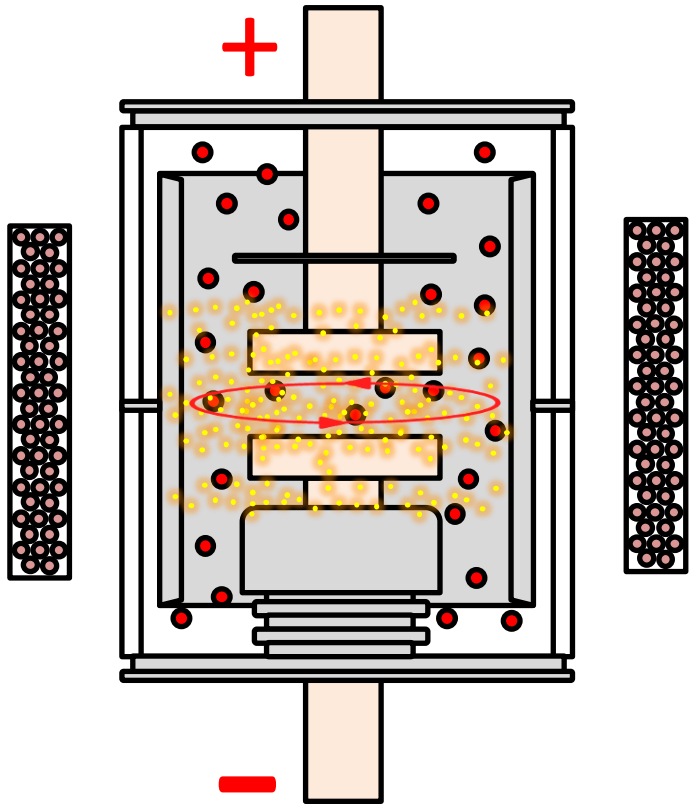
Gas Molecule

Electron

Electrons flow in short paths between the contacts resulting in a small leakage current and no molecule collisions.



High Voltage Applied/Magnetic Field Applied

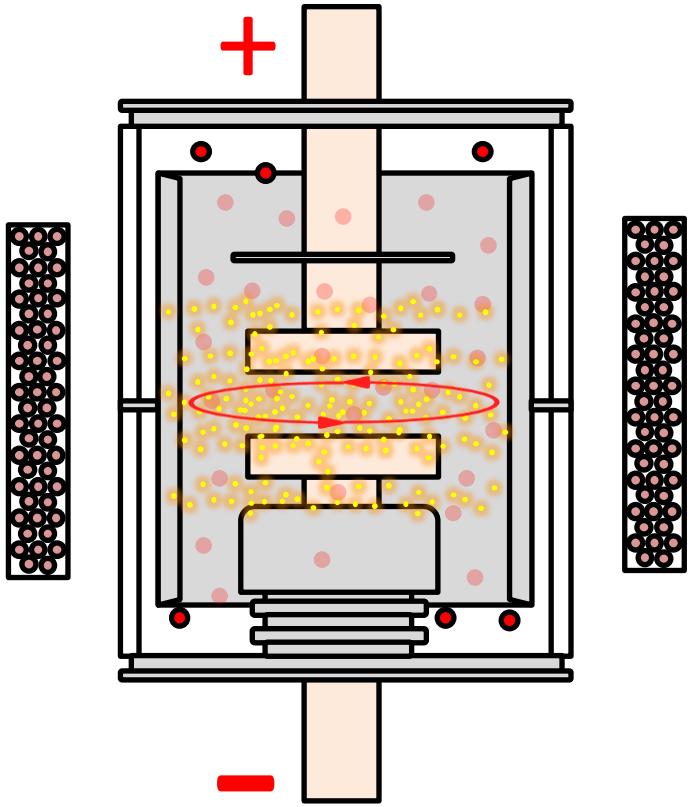


Gas Ion

Electron

Electrons trapped in the magnetic field cause cascade ionization of the gas molecules. Some combine resulting in fewer gas molecules.

High Voltage Applied/Magnetic Field Applied



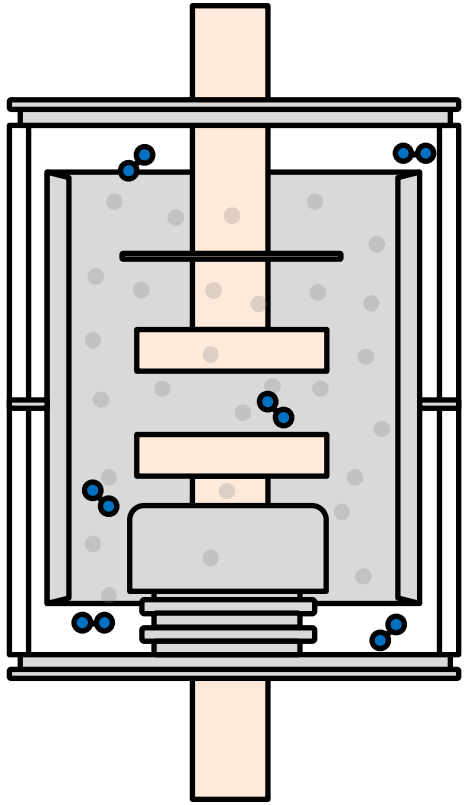
Gas Ion

Electron

Deposited Ion

Many of the ionized gas molecules get deposited converted to OXIDE on the clean, inner surfaces or trapped behind obstructions in the VI.

After VIC Process

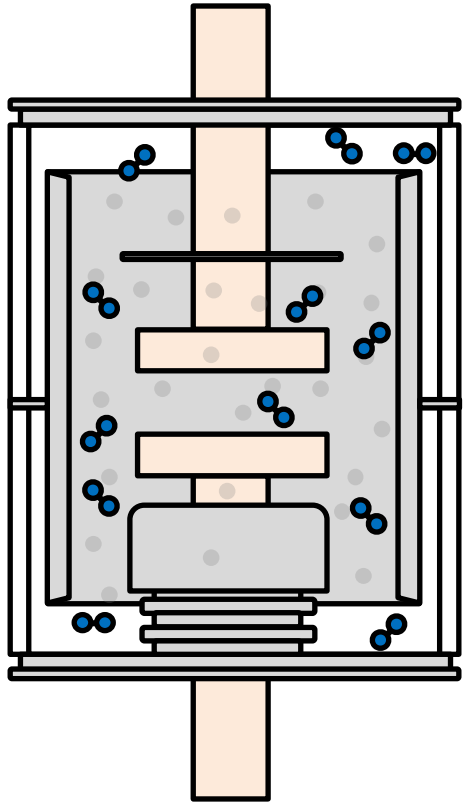


Gas Molecule

Permanent Deposits

The remaining gas molecules begin to recombine after removing the high voltage and magnetic field.

After VIC Process



Gas Molecule

Permanent Deposits

Only a fraction of the of the original gas molecules remain, resulting in lower pressure than we started!
PRESTO

Case Study Outline

- Case Study #1
  - GE PowerVac VIs that were partially submerged in salt water during Hurricane Sandy in 2012
- Case Study #2
  - ABB R-Mag manufactured in December 2009.
- Case Study #3
  - Eaton VCP-WRG manufactured in 2011.

Case Study #1

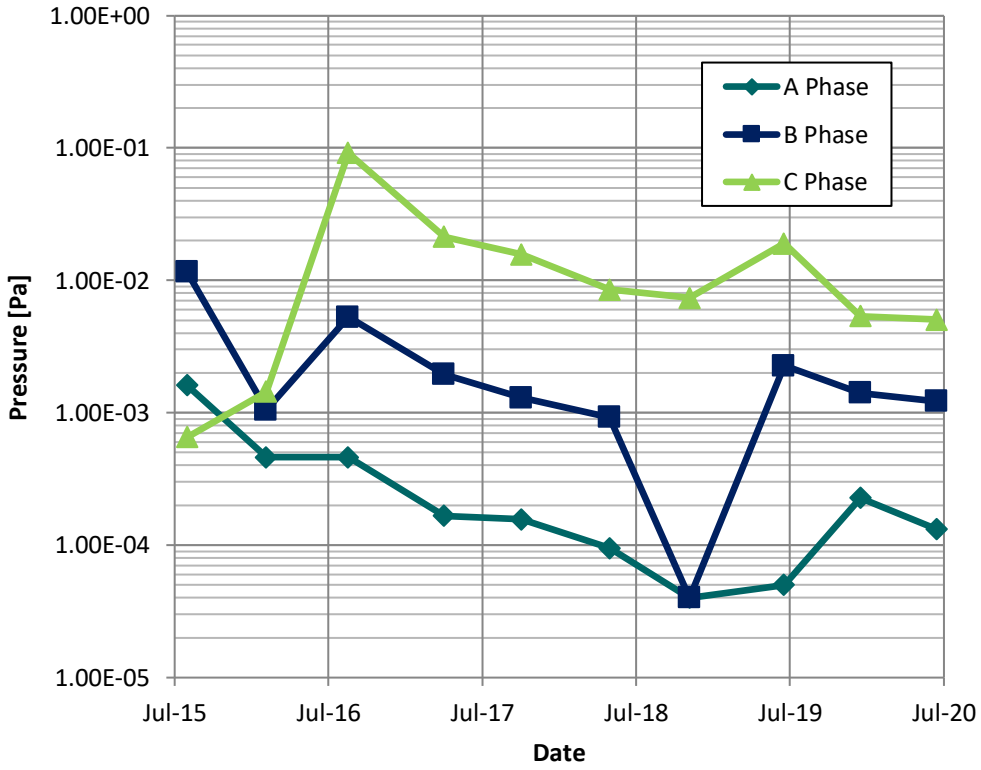
Pratt Paper – Hurricane Sandy

- **Three VIs from a GE PowerVac VCB that was exposed to salt water during Hurricane Sandy in 2012**
- **The VIs have been tested every 6 months since they have been taken out of service.**

Case Study #1

Pratt Paper – Hurricane Sandy

- Early VIC Pilot project 2013
- Proof of Concept for VIC
- Poor Pulse control (Aha Moment)
- Salt Water contamination study
- Ongoing ageing study specimen
- Still is program.



Case Study #2

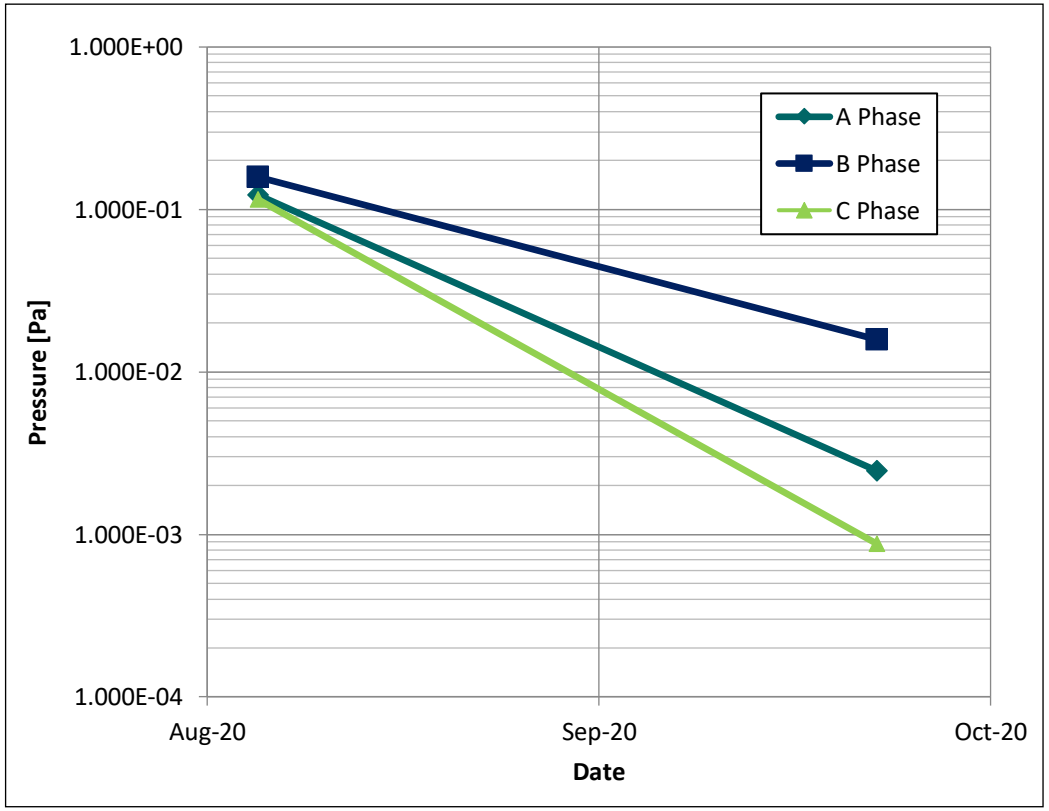
City Light and Power – Fort Campbell, KY

- **ABB R-Mag 15kV/600A**
- **Manufactured in Dec. 2009**
- **In mid-2020, MAC testing identified all 3 vacuum interrupters as being at a critical pressure in the $1x10^{-1}$Pa range**
- **A VIC process was performed on the breaker in early-August 2020**

Case Study #2

City Light and Power – Fort Campbell, KY

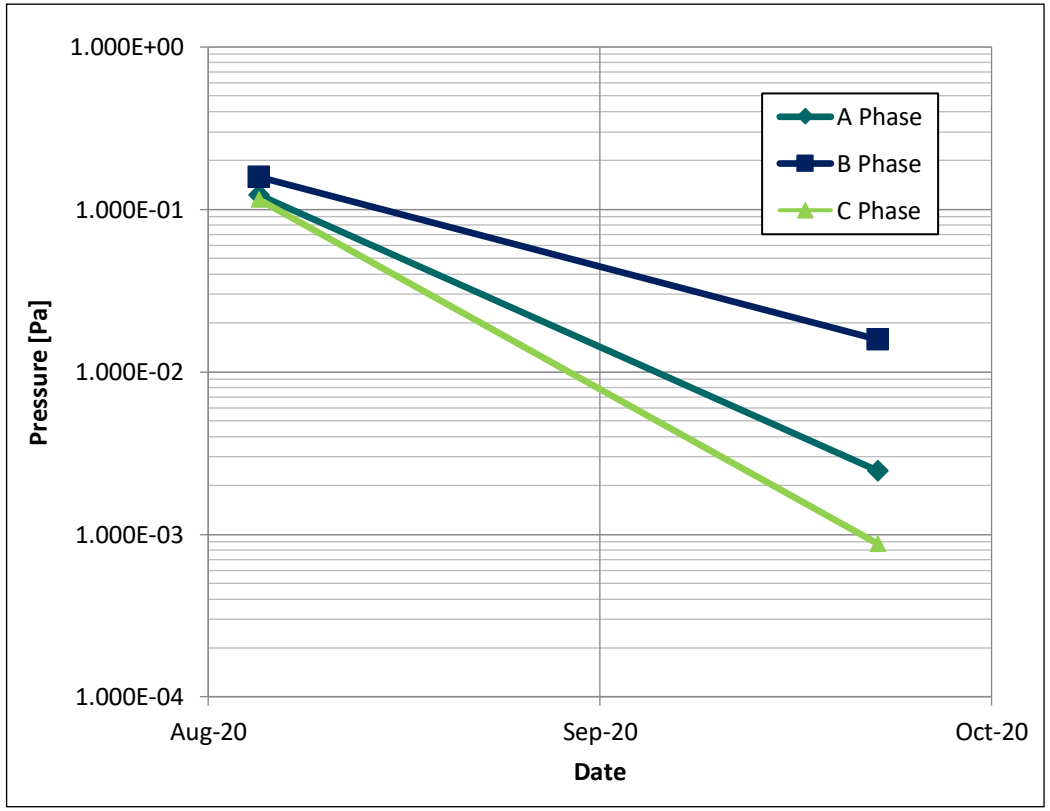
- A condition check and 2nd VIC process were performed in late-September 2020 giving enough time for any temporary effects to reverse.
- At that time, the vacuum improvements were 1.7, 1.0, and 2.1 magnitudes for A, B, and C phases, respectively.



Case Study #2

City Light and Power – Fort Campbell, KY

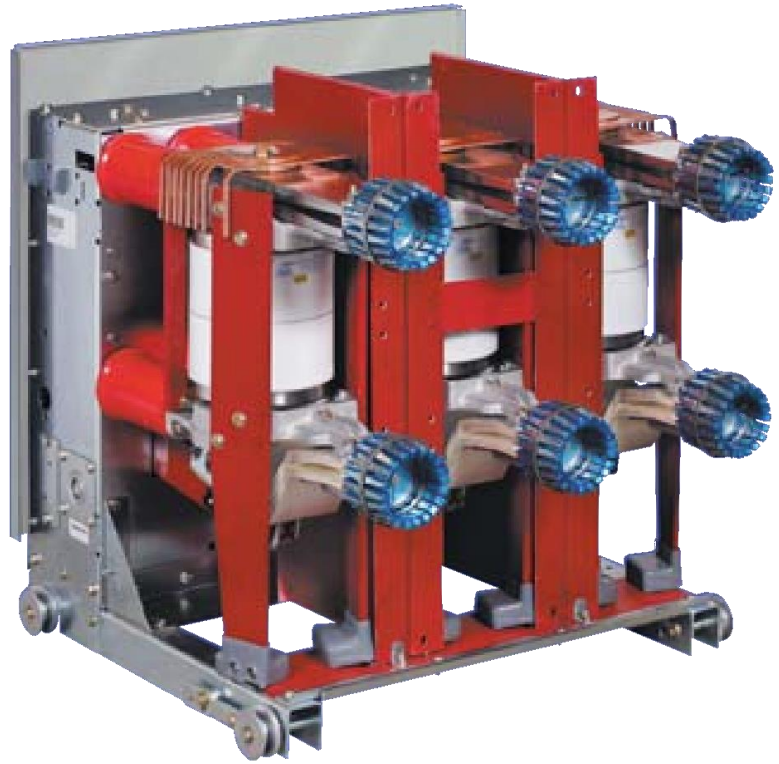
- **Based on these results, we expect further improvement to A and B phases after the 2nd VIR process.**
- **Improvements from additional VIR processes will diminish as they approach the 1x10-4Pa range, based on our experience.**



Case Study #3

Portland General Electric

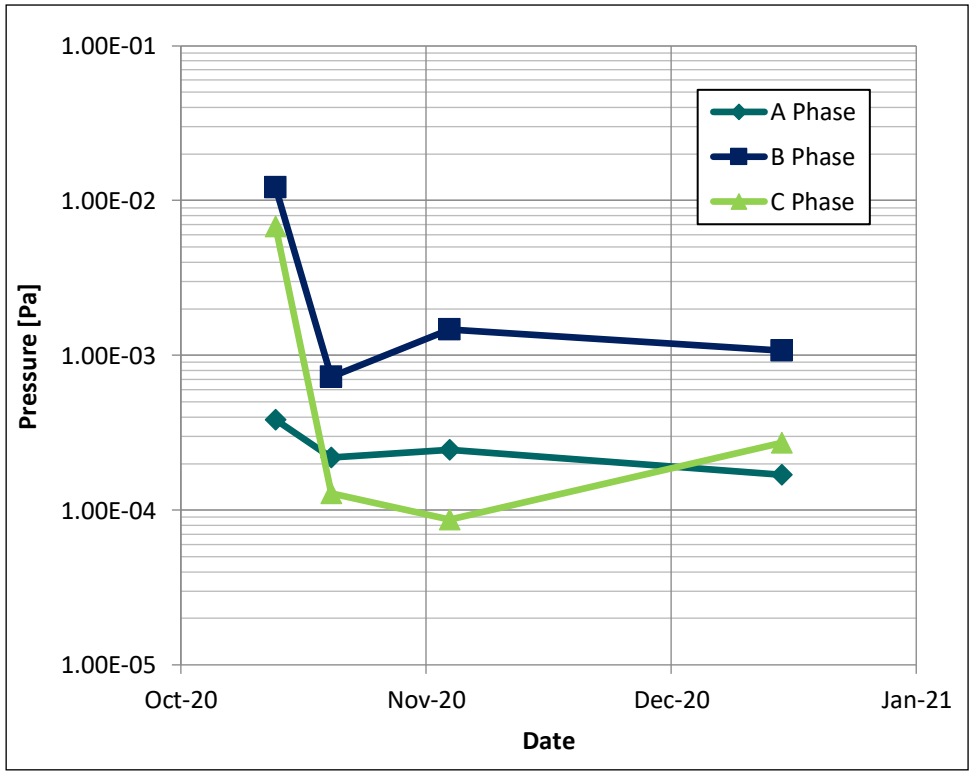
- **Eaton VCP-WRG 15kV/2000A/63kA**
- **Manufactured in 2011**
- **In Aug. 2020, MAC testing identified B phase VI as approaching a critical pressure in the $1x10^{-2}$Pa range**
- **A VIC process was performed on the breaker in September 2020**



Case Study #3

Portland General Electric

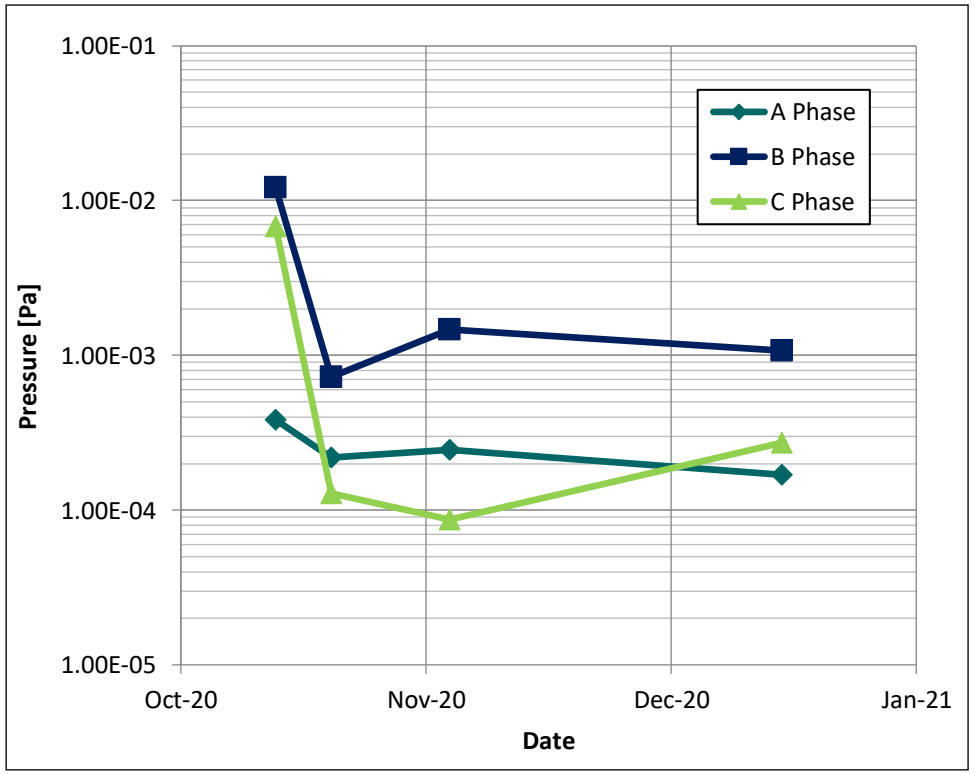
- Three MAC tests were performed over time to check the condition of the VIs post-VIC process
- The suspect VI (B Phase) showed an improvement of 1.0 magnitude after the most recent MAC test



Case Study #3

Portland General Electric

- C Phase showed an improvement of 1.4 magnitudes after the most recent MAC test
- C Phase data indicates a prolonged temporary effect (possibly enhanced by MAC tests) but is still within the range that is expected.



Case Study Synopsis

- Case Study #1
  - We are tracking and continue to test every 6 months
- Case Study #2
  - We were called back to retest and saw reliable results we will retest in the spring and report.
- Case Study #3
  - We will continue to condition this VI thought is mechanical life and report.

Candidates and Process (Field & Shop)

- Few Operations (<3000)
- Age (< 50 years old).
- No mechanical sign of failure
- Contact resistance (<50mA?)
- Low Contact Wear (<50%)
- Internal pressure MAC result showing less than certain “Ion Current” set a threshold

Where do we go from here?

- Group CBS is actively BETA testing and looking for (HP) projects.
- Consider VIC in all vacuum breaker service.
- Considering an Active Users Group through early release.
- Determine VI / Conditioned Based Maintenance Plan.
- More lab work to improve process.
- More data from the field from you!

Conclusion

- This process will allow mid range VIs with no mechanical damage or degradation to stay in service up to 100 years.

- This process should be added to standard maintenance and testing regime to insure maximum life for all VIs

Conclusion

- This should be a normal process before placing any spares in service that have been out of service any length of time.
- VI Inc has processed all new and used Vis in the manner for several years on several thousand interrupters w great success.

Conclusion

This will make the installed VI population more stable and flatten the failure curve adding many years of additional life to the fleet and heading off possible failures in service that occur between maintenance interval.