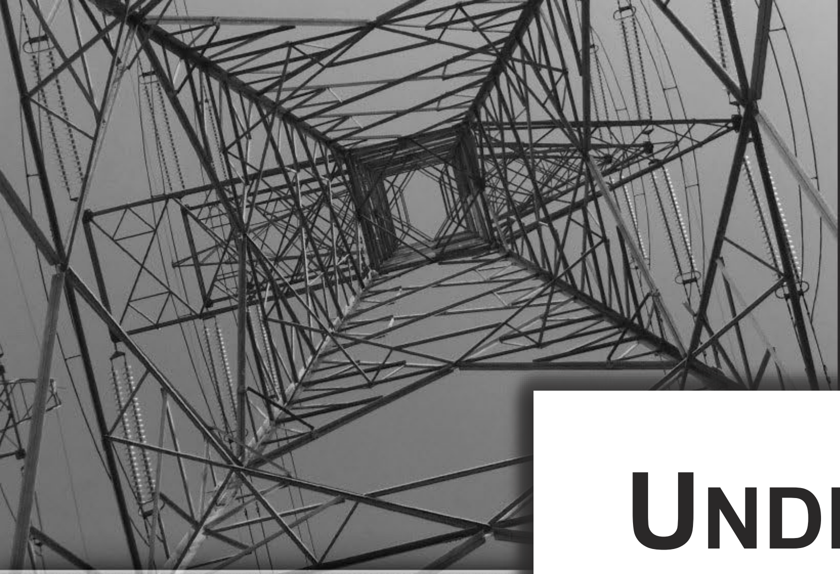
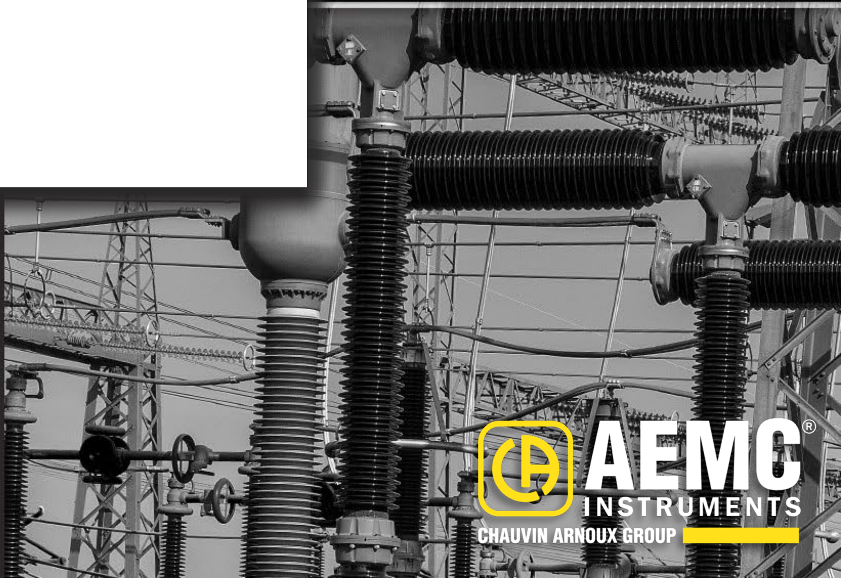



UNDERSTANDING INSULATION RESISTANCE TESTING

MAY 14, 2025





AEMC® INSTRUMENTS
CHAUVIN ARNOUX GROUP

PRESENTER: *GREGG WONG*

Technical Trainer Manager AEMC® Instruments

- Degree in Electrical Technology and Engineering
- NICET certified
- CTT+ Certified Technical Trainer
- 8+ years of former field service experience
- Professional Member of the Lightning Protection Institute
- Completed over 80+ seminars and webinars on Electrical Test and Measurement
- Developed and deployed training for Google, Stanford University, the US Navy, 3M, and others

CompTIA CTT+ CERTIFIED

LPI LIGHTNING PROTECTION INSTITUTE

AEMC® INSTRUMENTS CHAUVIN ARNOUX GROUP

AEMC® Instruments Headquarters

- Administration
- R&D
- Engineering
- Manufacturing
- Calibration Lab
- Marketing and Sales Support

15 Faraday Drive
Dover, NH 03820
www.aemc.com

Tech Support

800-343-1391 x351

Global Profile

- Established in 1893 in Paris, France
- Began operation in the USA in 1976
- Over 1000 employees worldwide
- 7 manufacturing locations

4 in France (1893)

1 in Italy (1975)

1 *in USA* (1976)
(Dover, NH)

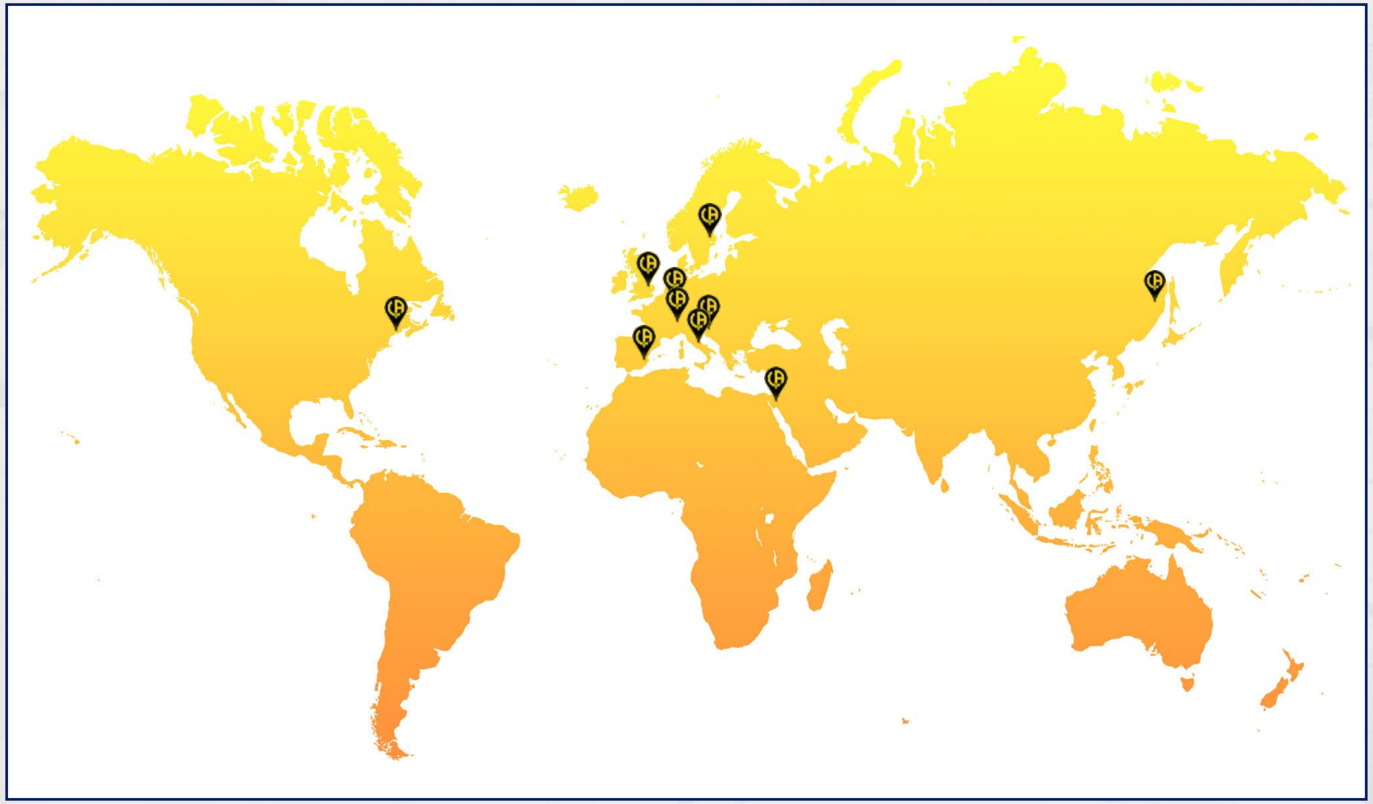
1 in Shanghai (2000)

10 Subsidiaries

Austria	China
Germany (1969)	Italy
Lebanon	Spain
Sweden	Switzerland
United Kingdom	***USA*** *(Dover, NH)*

CHAUVIN ARNOUX GROUP

Portable and laboratory electrical test & measurement instruments



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Chauvin Arnoux *Historique*

1905

Invention of the ***Magneto Ohmmeter***. In 1923 the measurement became independent of the rotation speed of the magneto.

1934

Invention of the transformer clamp, ***first Ammeter Clamp***

1960

Invention of the ***Monoc Controller***, with a single switch and dial. It is ***the*** reference for several generations of electricians.

1989

PROWATT-3 ***Programmable Energy Analyzer***. Already in a construction site box and equipped with a multitude of accessories (clamps, cords, connected printer, etc.).

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CHAUVIN ARNOUX *HISTORIQUE*

1994

The ***CA 6411 & CA 6413 Earth Clamps*** introduce a new concept: rapid control of interconnected earth loops.

2012

Innovation with the **True InRush**®, for measuring starting current, and outputs from ***PEL 100 recorders*** and the ***smallest field oscilloscope:*** |***the HandScope***.

2021

Launched a compact, affordable, and user-friendly power and energy logger the **PEL 52.** The smaller PEL is geared toward the residential and light commercial applications.

2023

Introduced the Class A **Model 8345 PowerPad® IV,** an advanced power quality analyzer capable of accurately measuring, logging and reporting harmonics, transients, and other power quality concerns.

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CHAUVIN ARNOUX GROUP

Product Groups

- Ground / Earth Resistance Testers
- Micro-Ohmmeters
- Megohmmeters / Insulation Testers
- Power Quality Analyzers, Meters & Loggers
- Data Loggers
- Environmental Testers
- Digital Multimeters
- Clamp-On Meters
- Cable Testers
- Oscilloscopes
- DC Power Supplies
- Decade Boxes
- Current Measurement Probes
- Electrical Test Tools
- Transformer Ratiometers
- Infrared Thermography

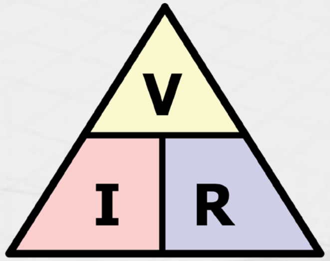
Agenda – Insulation Testing Motors

1 **Definitions & Basic Concepts**
Resistance Testing & Insulation Basics

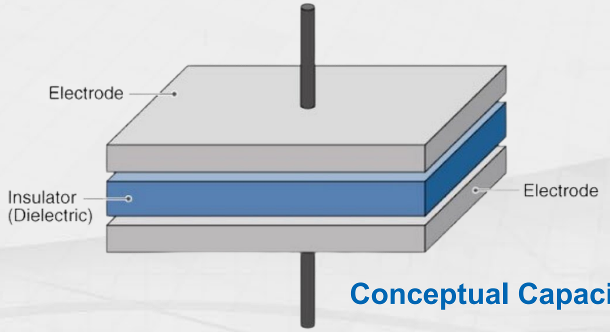
2 **Instruments & Testing Methods**
Functionality of megohmmeters & methods

3 **Applying IR Testing to Motors**
Basics & Comprehensive IR Measurements

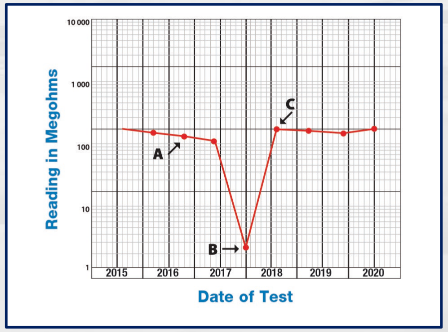
4 **Testing Plans & Maintenance Strategies**
Adding IR testing to a Maintenance Plan



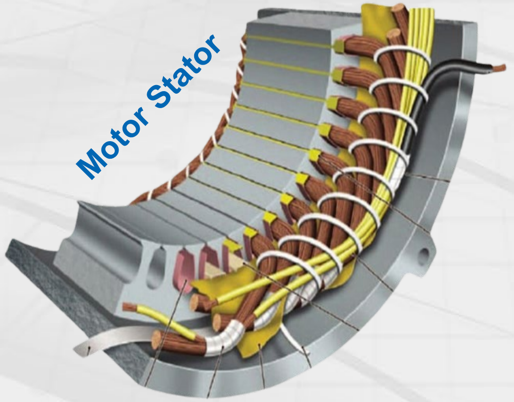
Ohms Law Triangle



Conceptual Capacitor



Trend Graph



Motor Stator

Model 6526
1kV Megohmmeter

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References Used in This Presentation

1. **ANSI NETA** – **ATS** (2017) & **MTS** (2015)

2. **IEEE 43** – Recommended Practice for Testing Insulation Resistance of Electric Machinery

3. **IEEE 62.2** – Diagnostic Field Testing of Electrical Power Apparatus Machinery

4. **Paul Gill** – Electrical Power Equipment Maintenance and Testing 2nd edition

Goals for this Seminar

Basic understanding of the principles

- Insulation / Dielectrics
- Insulation testing theory
- Motor insulation components
- Resistance testing methods

Mastery

- IR Test instruments – Megohmmeters – 1 kV range
- Quantifying insulation qualities with resistance measurements–accurately
- Test methods – Ir_t resistance profiling, and ratio tests (DAR, PI)

My goals as your instructor

- Improve your electrical testing knowledge!
- Bring awareness to the **S-R-S-C** around insulation testing
- Equip you with the knowledge to improve, qualify, or create an IR testing plan for your facility

Section 1:

Electrical Resistance Testing Basics & Dielectric Theory

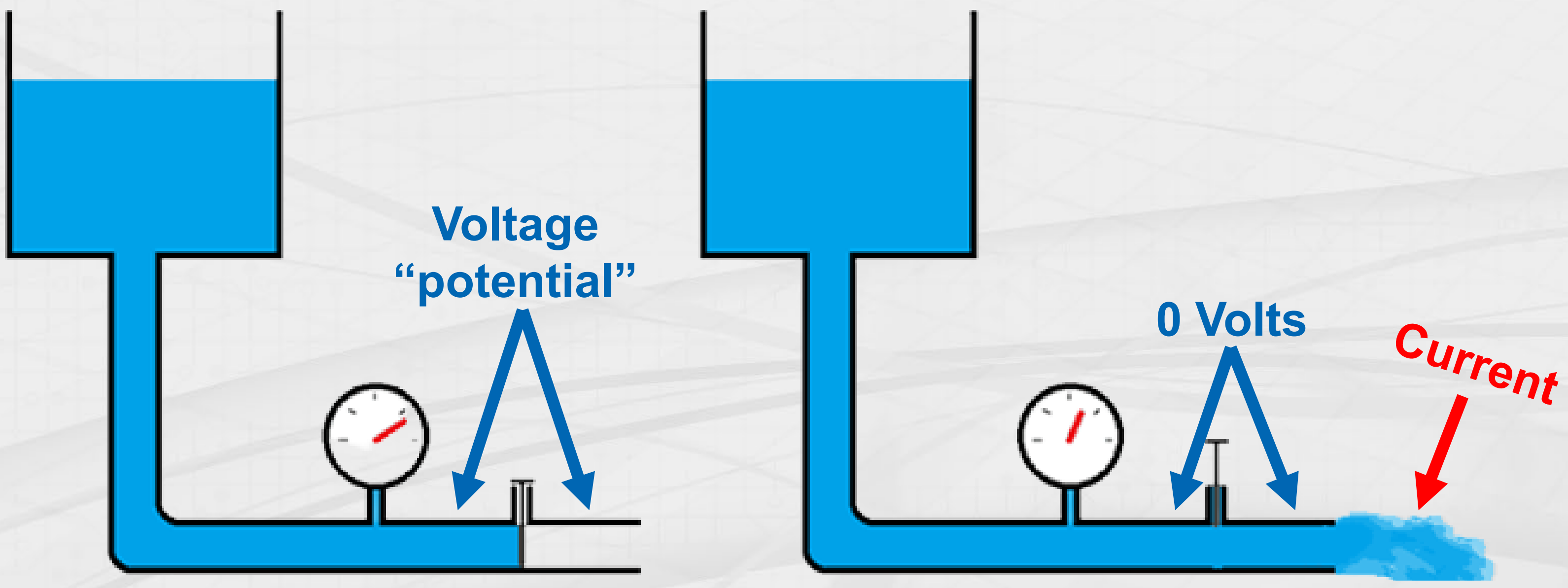
Understanding Insulation Testing

INSULATION RESISTANCE

IEEE 43-2000 defines insulation resistance as:

- **Insulation Resistance (*IR_t*)**
  “The capability of the electrical insulation of a winding to resist direct current”
- **Resistance is not impedance!**

VOLTAGE AND CURRENT



Pressure (Voltage)
No Current

Pressure (Voltage)
And Current

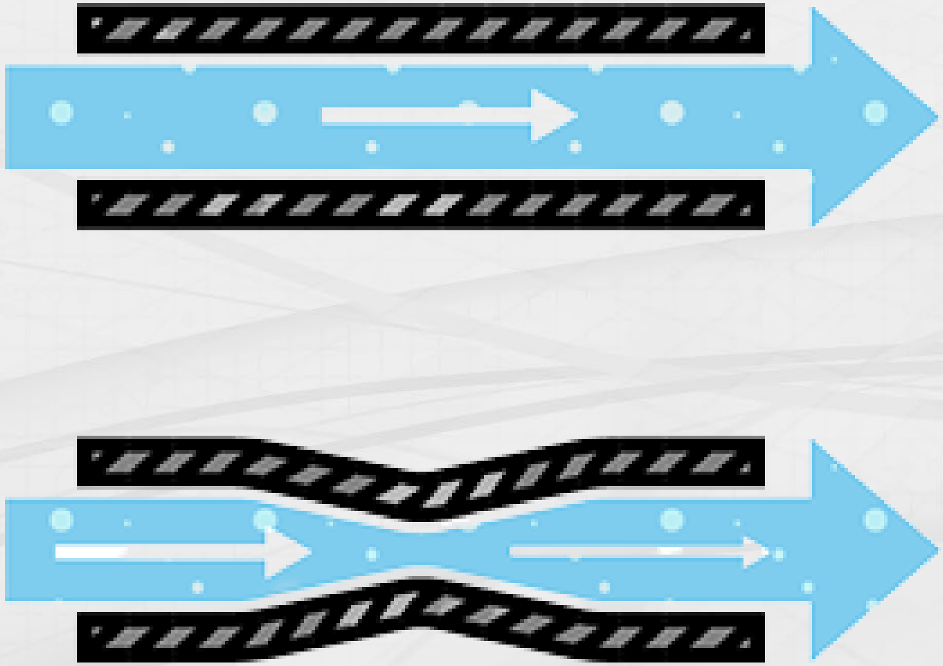
Voltage: The pressure from an electrical circuit's power source that ***pushes*** charged electrons through a conducting loop.

Symbols Used: V, E, or U.

Current: The ***rate*** at which electrons flow past a point in a complete electrical circuit.

Symbol Used: I

Resistance Basics



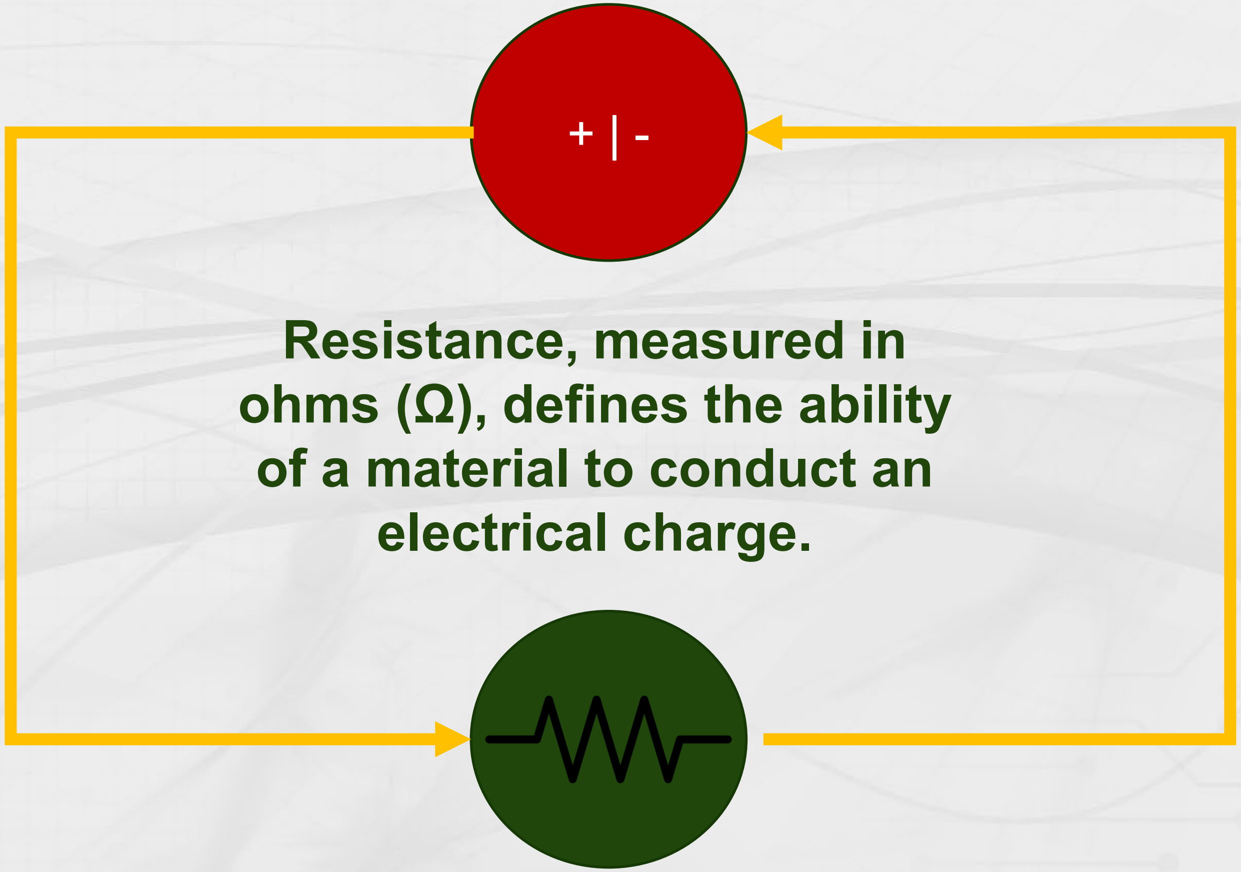
Resistance: A measure of the opposition to current flow in an electrical circuit.

Symbols Used: R, Ω

Resistance (R): The property of a circuit or element that determines, for a given current, the rate at which electrical energy is converted to heat.

Circuit Basics

Current is measured in amps (A, mA) and represents the rate of electron flow in a circuit.



Resistance, measured in ohms (Ω), defines the ability of a material to conduct an electrical charge.

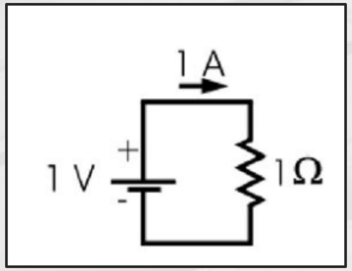
V or E: Voltage is the POTENTIAL for CURRENT to flow from one point to another.

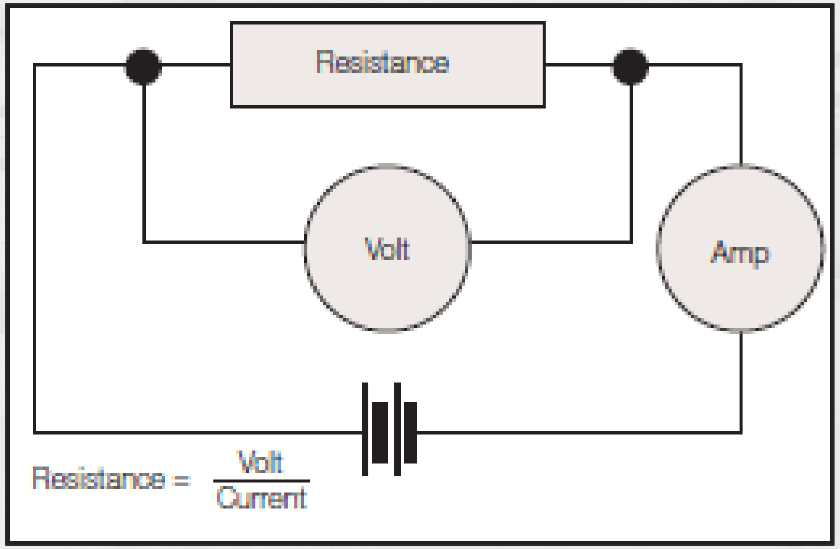
A voltage must be created first.

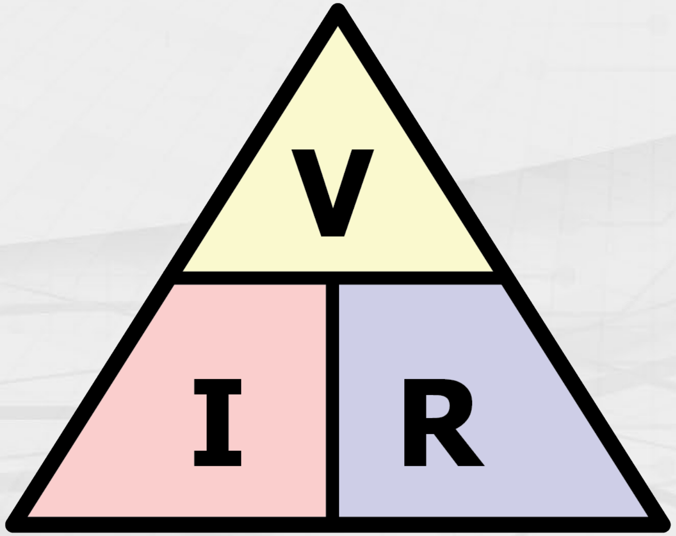
Ohms Law

Resistance (R) = Voltage (E) / Current (I)

1. **APPLY TEST CURRENT** through a sample
2. **MEASURE VOLTAGE** across the sample under test
3. **CALCULATE RESISTANCE** of the sample







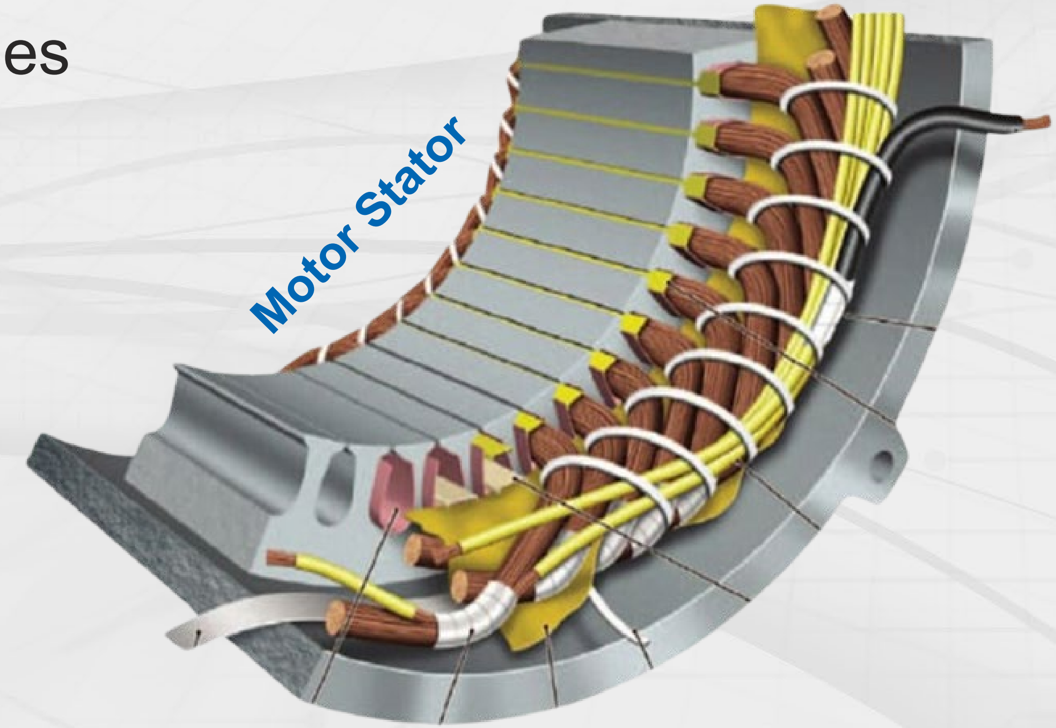
Resistance (R) = Ω

Resistance (R): **The property of a circuit or element that determines, for a given current, the rate at which electrical energy is converted to heat.**

What is a Dielectric? (Insulation)

Di-electric: Having the property of transmitting electric force without conduction.

Insulating: To separate from conducting bodies by means of nonconductors to present the transfer of electricity.



Three Primary Properties

1. High resistance to the flow of electrons
2. High strength against electrical stress
3. Heat-conducting properties

Purpose = Guide charge

INSULATOR MATERIALS

Solids

1. Paper
2. Rubber / PVC / Nylon
3. Mica / Teflon
4. Thermoplastics
5. Silica / Glass

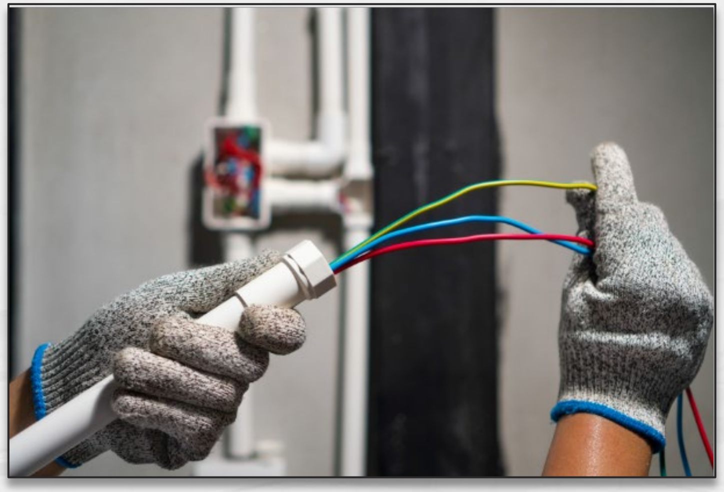
Liquids

1. Mineral Oils
2. Hydrocarbons

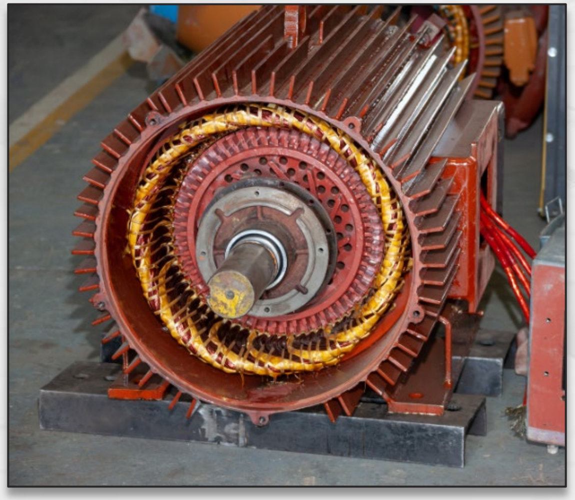
Gases

1. SF6
2. Nitrogen
3. Dry Air

Enamel coated windings



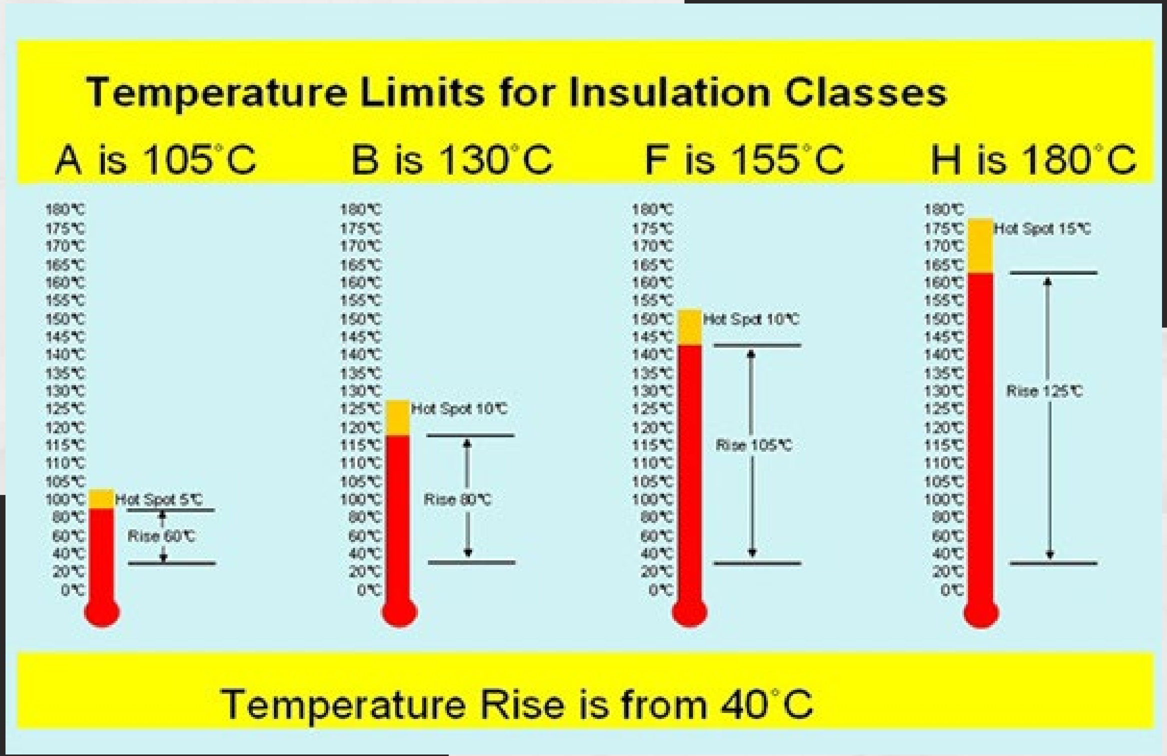
Nylon / PVC Insulator

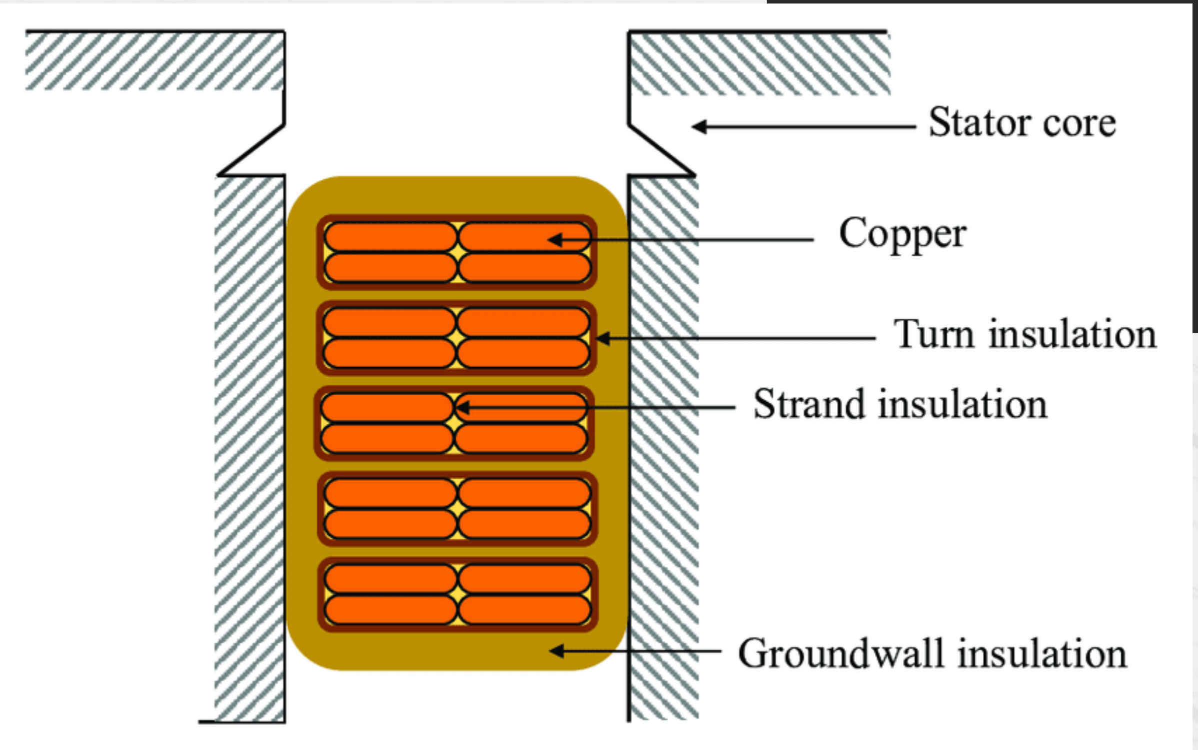


Impregnated Varnish

Important!
Know the ***Thermal Class***
of insulation under test!

NEMA Insulation Ratings - Stators

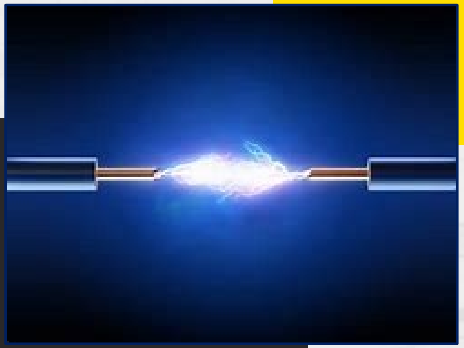




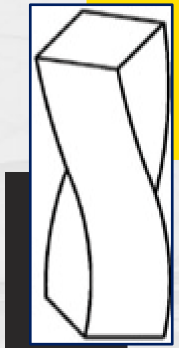
Referred to as the "ground wall"

WHAT CAUSES INSULATION TO FAIL

Five basic initiators for insulation breakdown

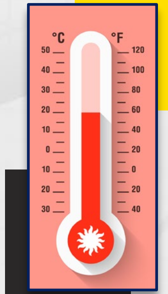


Electrical stress



Mechanical stress

Chemical stress



Thermal stress

Environmental contamination

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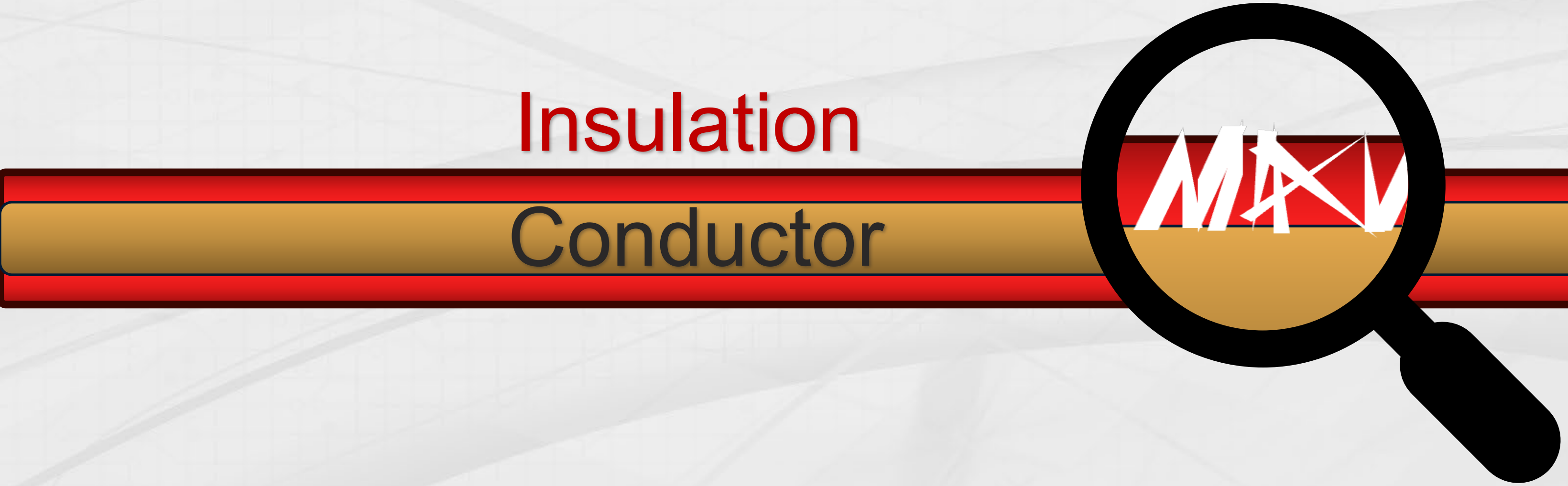
No "Perfect" Insulators

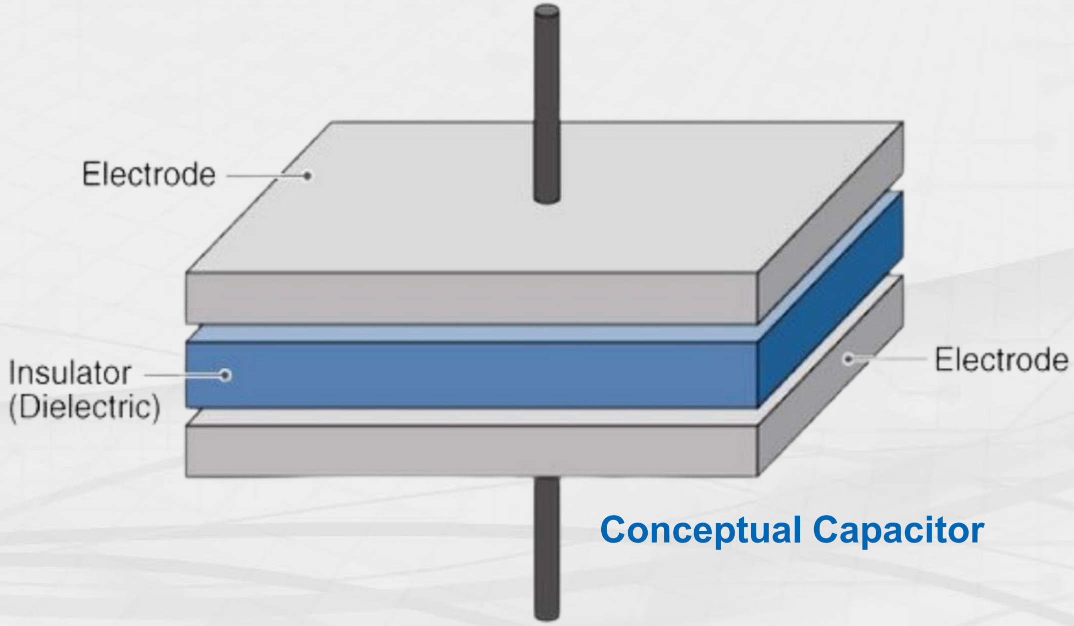


Q: What is an "ideal" insulator?

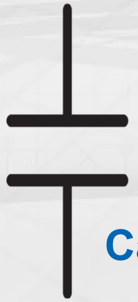
A: Vacuum

CAPACITORS

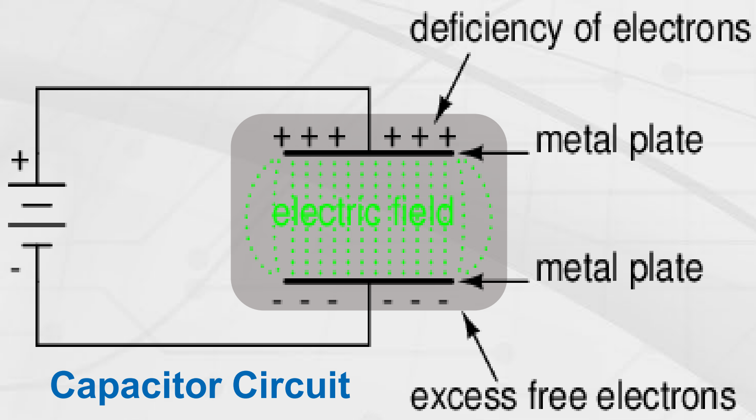
1. Stores an **electric field** when voltage is applied to one plate
2. Purpose-built capacitors are used to **regulate voltage**
3. “Accidental” capacitors create **leakage currents**, and **interference,** and can **hold a charge** when deenergized
4. Measured in **farads**



Conceptual Capacitor



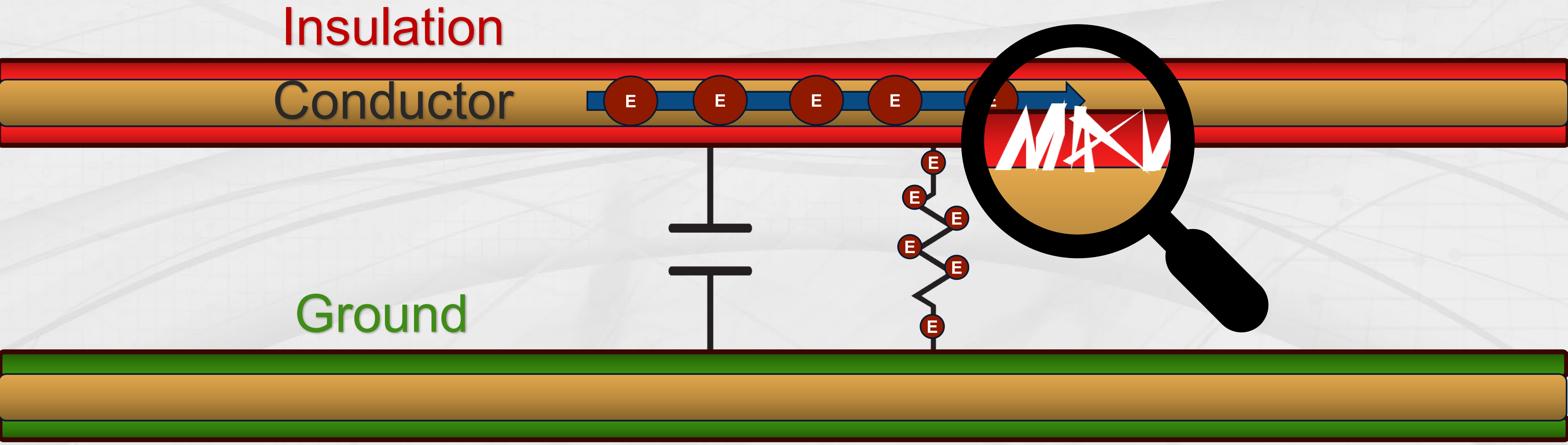
Capacitor Symbol



Capacitor Circuit

$$F = \frac{Q}{V}$$

INSULATORS AS CAPACITORS



DIELECTRIC DEFINITIONS

Dielectric constant: is known as specific inductive capacitance, or permittivity. The dielectric constant of any medium or material is defined as the ratio of the capacitance of a given configuration of electrodes with the medium as a dielectric, to the capacitance of the same configuration with a vacuum (or air) as the dielectric between the electrodes.

Dielectric strength: of a material is the potential gradient (voltage) at which breakdown (electrical failure) occurs and is a function of the material's thickness and its electrical properties.

Dielectric absorption: occurs in dielectrics whereby positive and negative charges are separated to respective polarity when a DC voltage is applied to the dielectric. This phenomenon is time-dependent and usually manifests itself as a gradually decreasing current with time after the application of DC voltage.

Dielectric Constant of Insulating Materials			
Vacuum	1.0	Fiber	2.5-5.0
Air	1.0	Glass	5.4-9-9
Paper	2-2.6	Mica	2.5-7.7
Rubber	2-3.5	Wood	2.5-7.7
Oil	2.2	Porcelain	5.7-6.8
Bakelite	4.5-5.5	Polyethylene	2.3

Source: Electrical Power Equipment Maintenance and Testing 2nd edition – Paul Gill

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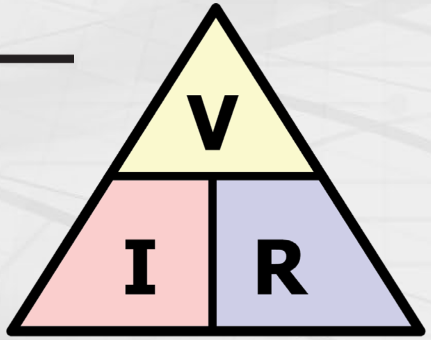
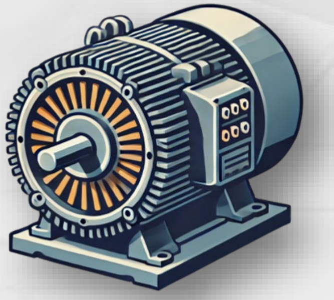
RECAP: SECTION 1

- Resistance = **V/I(A)**
- Voltage is the **pressure** in an IR test
- Current is the flow of an **electrical charge** in a circuit
- Insulators are dielectrics, **they *resist*, not <u>prevent</u>** the conduction of charge
- **Insulation Resistance Testing** attempts to create a circuit *though* insulators to *quantify* the *quality* of the insulation system ability to resist a charge

"Despite great strides in electrical equipment design in recent years, the weak link in the chain is still the insulation system." – Paul Gill





Section 2:

Megohmmeters & Testing Theory

Understanding Insulation Testing

1 kV Megohmmeters: Introduction

- **Megohmmeter:** Also known as an insulation resistance (IR) tester, measures the electrical resistance of insulation materials around conductors.
- Megohmmeters are **high-range resistance ohmmeters** with a built-in direct-current (**DC**) **generator**. They can accurately measure very low quantity test currents "leaking" through insulation.
- The instrument creates a high voltage across the insulation, allowing a direct current in the mA range to **measure** the "***Insulation Quality***" quantified in resistance in the millions (**M**eg), billions (**G**ig), or (**T**era) trillions of ohms (**Ω**).
- 1 kV Megohmmeters can apply up to 1 thousand (**K**ilo) volts (kV) over a **known period of time** to continually measure resistance.

Model 6503
1 kV Hand-Crank Megohmmeter

Model 6526
1 kV Megohmmeter & Multimeter

Model 1060
1 kV Megohmmeter

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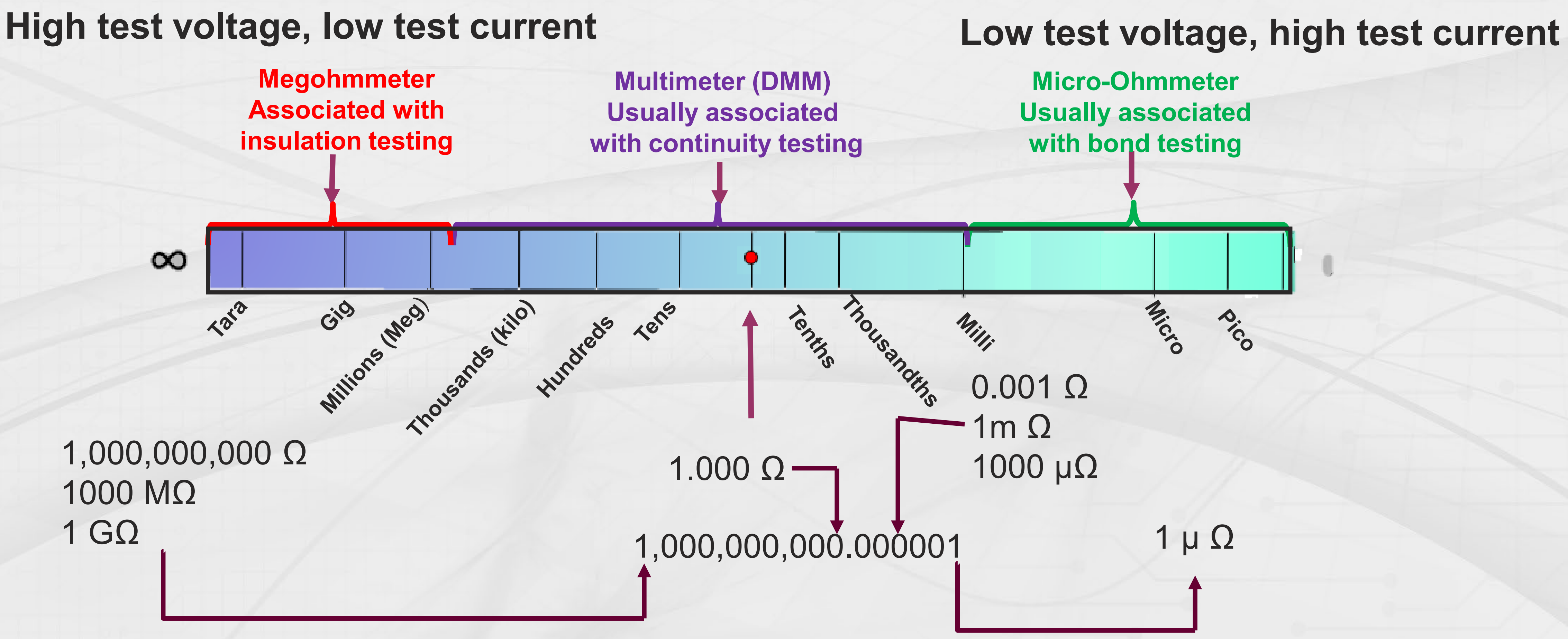
Resistance Measurement Scale



WHY DC?

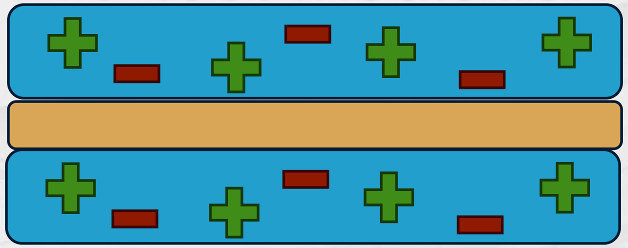
For an Insulation ***Resistance*** test

- **Stability**
  DC is easier to supply, regulate, and accurately measure in a portable, lightweight battery-powered package.

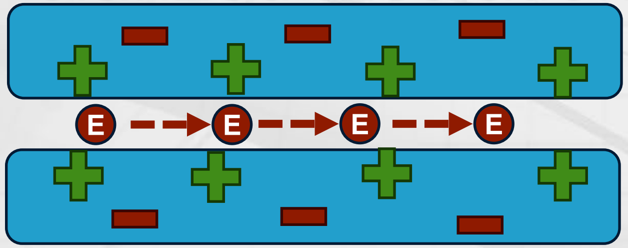
- **Polarization - Capacitance**
  AC voltage does easily not polarize materials, increasing impedance (resistance) test times.

- **Sensitivity**
  DC measurements more accurately detect the presence of contaminants and phase-to-ground failures.

Pre-test Insulation



Polarized Insulation



Why Low Current?

Megohmmeters

Low current – 1 to 6 mA

- Less destructive testing method
- Fast test time
- Portable, low-cost, without sacrificing accuracy – field capable
- Resistance measurement only – not a "full picture"

DC / AC – Withstand Tests

High current test methods

- Potentially destructive
- Less field-friendly, large and expensive
- Longer test times
- Go / No Go results

IR Testing Role in Motor Maintenance

- Motors are insulated well with materials like mica that have **HIGH** resistivities.

- Motors fail prematurely when foreign materials contaminate them. Dirt, oil, and water have **LOW** resistivity.

- IR Testing using DC is used to detect the premature failure of motors ***primarily due to contamination***.

MEGOHMMETERS: 1 kV CONSIDERATIONS

1. Range: Max value in Ωs that can be measured

- How will results be used?

2. Test modes

- Test voltage
- Spot test
- Timed test
- DAR / PI – Ratio tests
- Test result plotting / Graphical display

3. Other functions

- Pass / Fail indicator
- Accessories
- Multi-meter features
- Guard terminal

Model 6529
1 kV Megohmmeter & Multimeter

1 kV Instrument Selection

1 kV Insulation Tester

- **11 GΩ** Max IR Range
- DAR / PI
- Ohmmeter / Voltmeter
- Timed Test

Model 6529

$350.00

Model 6526

$945.00

1 kV Insulation and Multi-function tester

- **200 GΩ** Max IR Range
- DAR / PI
- Timed Test
- 1300 Measurement Storage
- Bluetooth & DataView®

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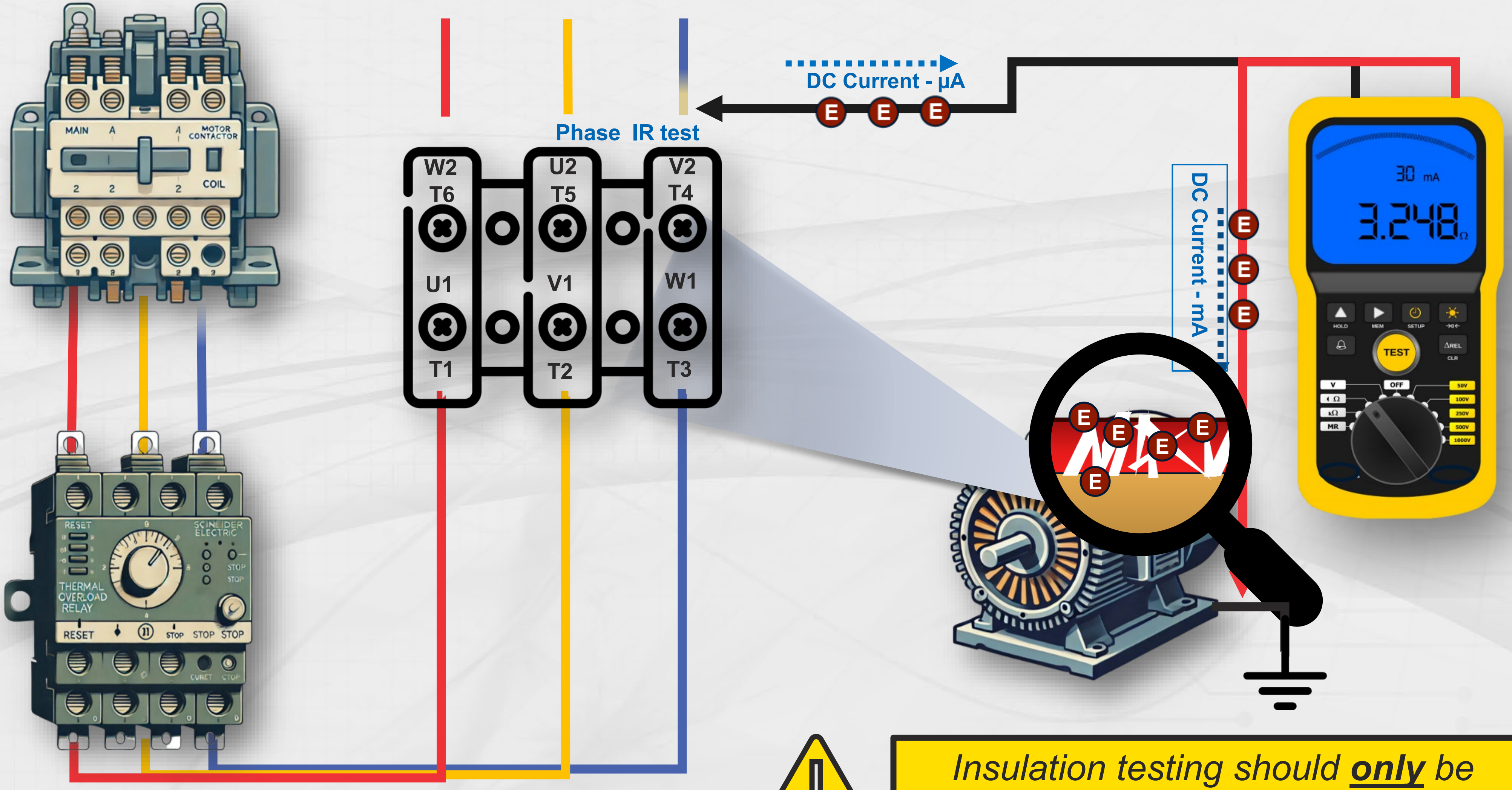
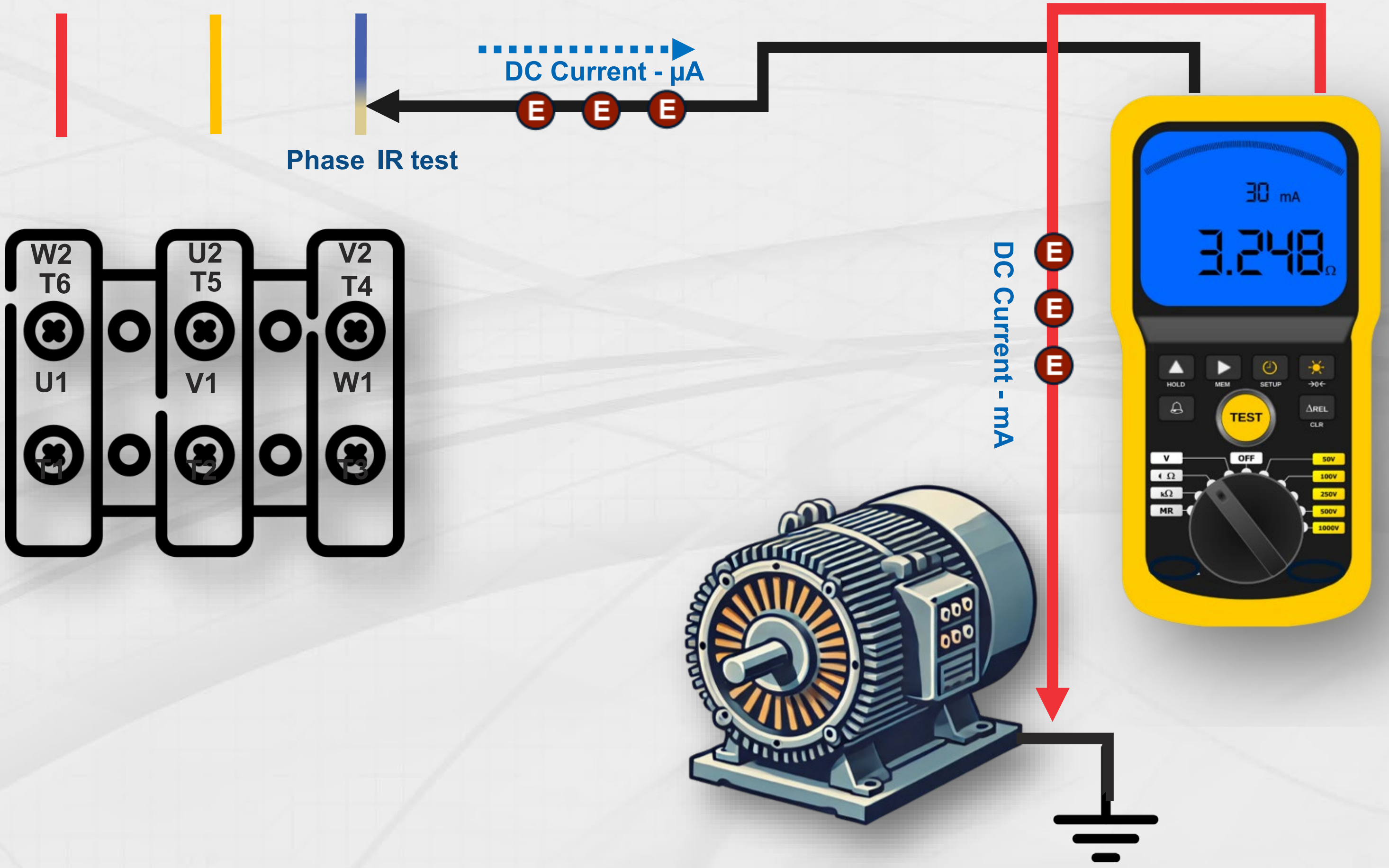
MEGOHMMETERS: PRINCIPAL CONCEPT



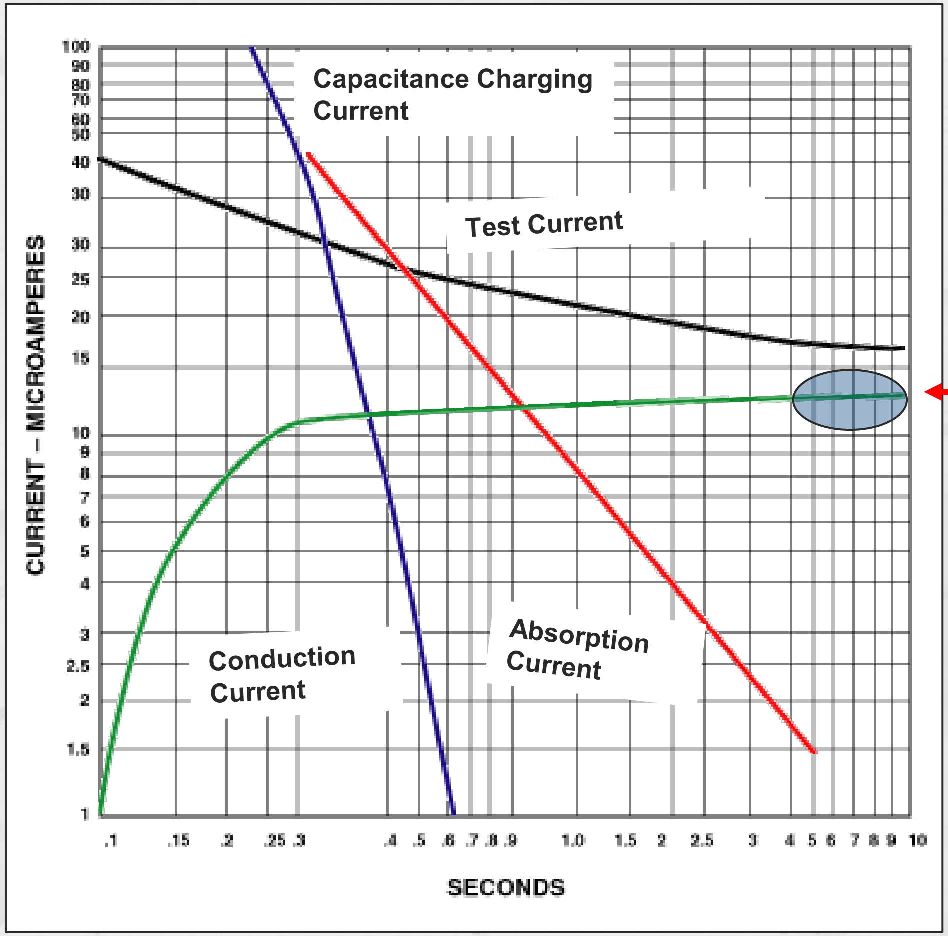
Insulation testing should **only** be done on de-energized equipment.

POLARITY FOR IR TESTING…..

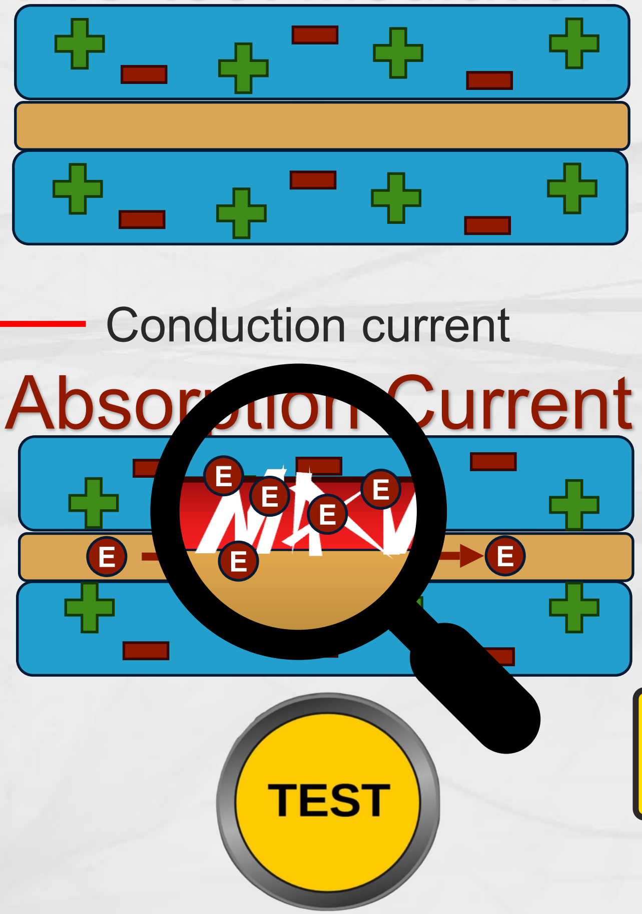


IEEE 43-2013 5.3
"Insulation resistance tests are conducted with a negative polarity to accommodate for the phenomenon of ***electroendosmosis.***"

Time Requirement for Insulation Testing

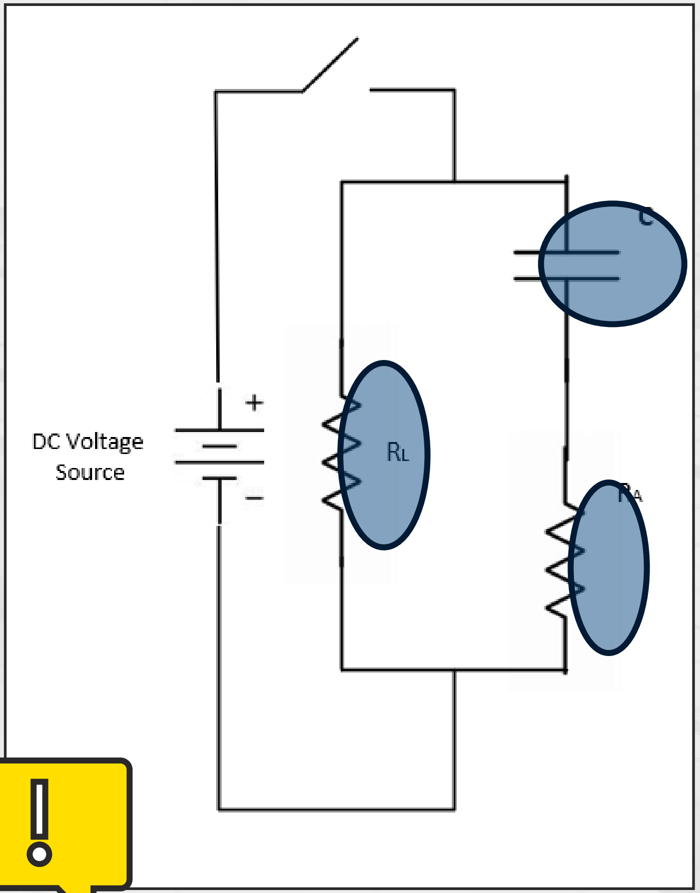


Pre-test Insulation



Conduction current

Absorption Current



Important!
Absorption Current should decrease in a linear fashion

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Test Types: Short Spot Testing

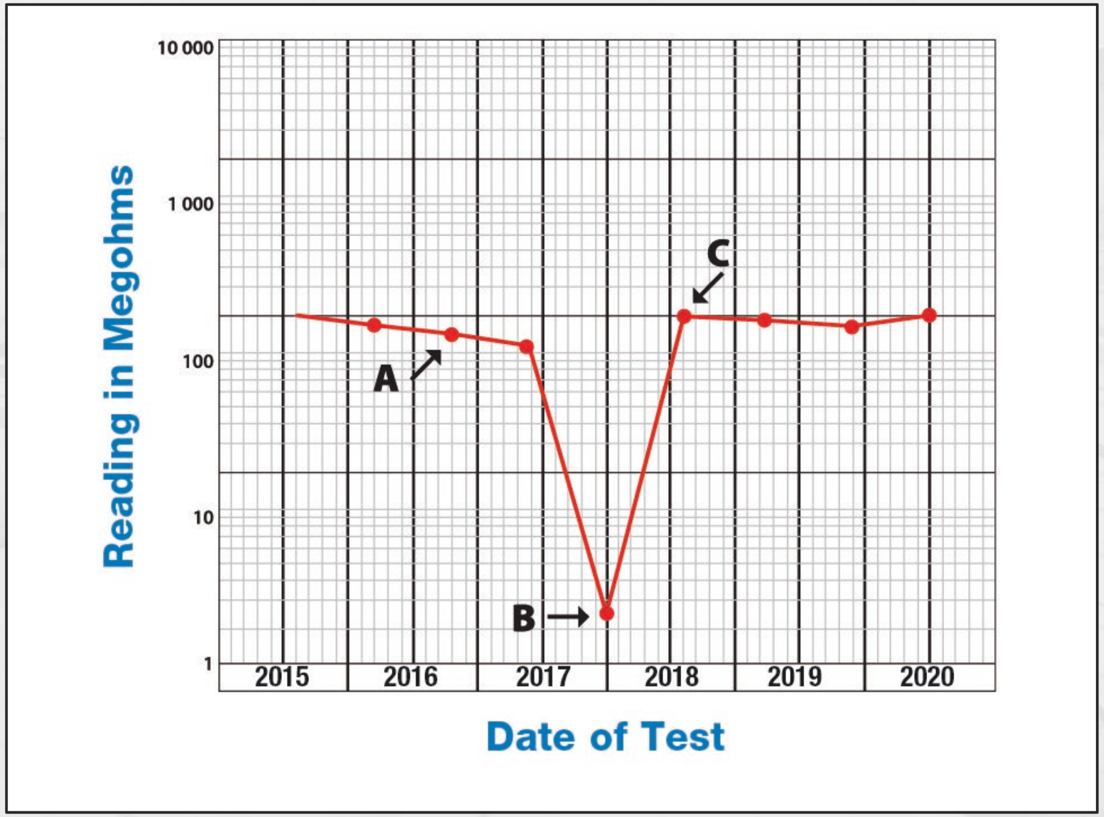
30 to 60 s Timed Tests

Advantages

- Simplest option
- Short time – 30 s to1 min
- Quick "go/no-go" test

Disadvantages

- Inaccurate results
  - Must adjust for temperature & humidity
- 1 IR value only
- Machine (windings) size may not allow for full conducting current to be established
- Shorter tests increase the margin of error between technicians



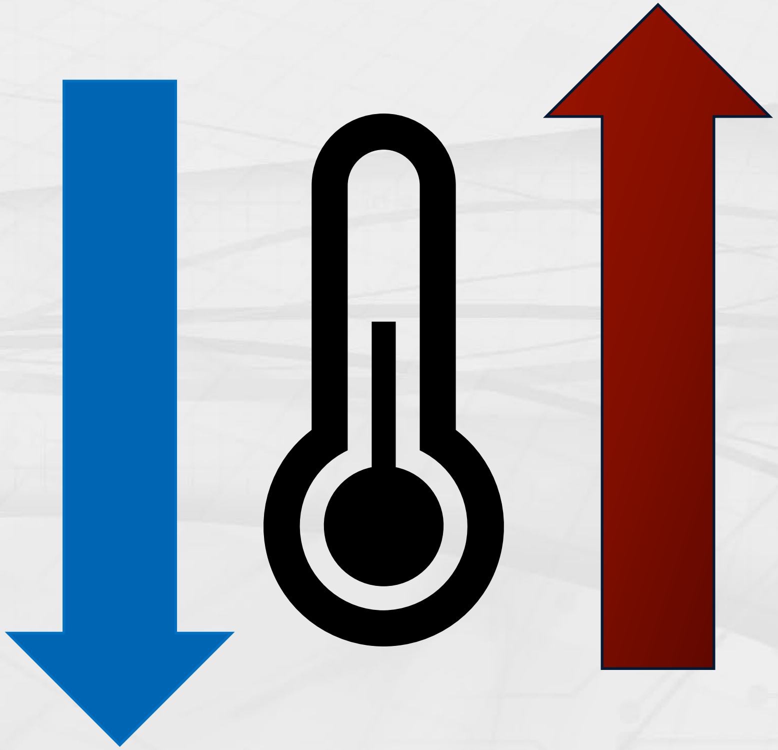
Temperature Correction

As the temperature **rises,** insulators lose **dielectric strength**

Resistance should be corrected for **operating temperature (104 °F)**

Options

- Sample stator temp, if probe is installed
- Run motor for 10 minutes with no mechanical load, deenergize, discharge, test
- Correct for ambient
- Temperature on cold motor (1 hour out of service)



Model 6526
1 kV Megohmmeter
& Multimeter

Temperature Correction For IR Testing - Motors - 104 °F

Solid Insulation Winding Temperature - Correction to 104 °F	
Winding Temp (°F)	**Correction Factor**
14	0.1
23	0.13
32	0.16
41	0.2
50	0.25
59	0.31
68	0.4
77	0.5
86	0.63
95	0.79
104	1
113	1.26
122	1.59
131	2
140	2.52
149	3.17
158	4
167	5.04
176	6.35
185	8
194	10.08
203	12.7
212	16
221	20.16
230	25.4

Available as a hand-out

TEST TYPES: INSULATION RESISTANCE PROFILING (IR_P)

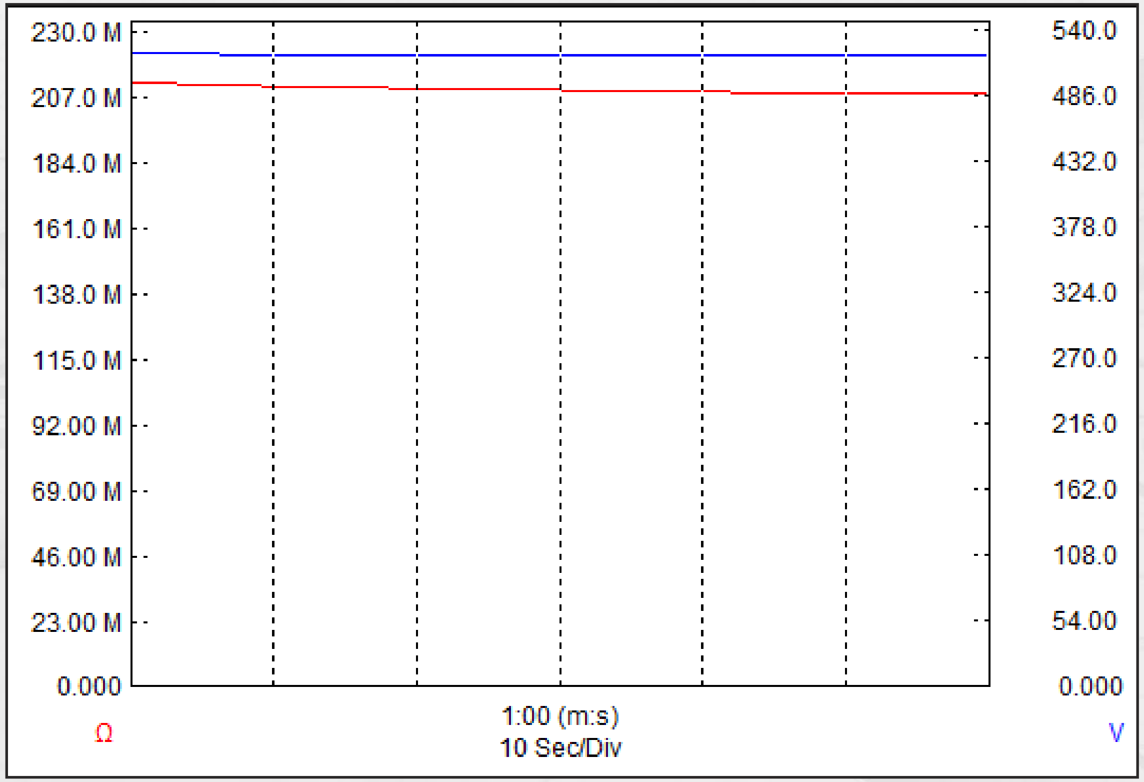
5 to 10 Minute Timed Tests
(Resistance Profiling)

Advantages

- Most comprehensive method
- IR_p – Resistance Profiling
- Plot **multiple values** for a single IR test
- Best for maintenance trending over time
- Reveals the majority of detectable problems

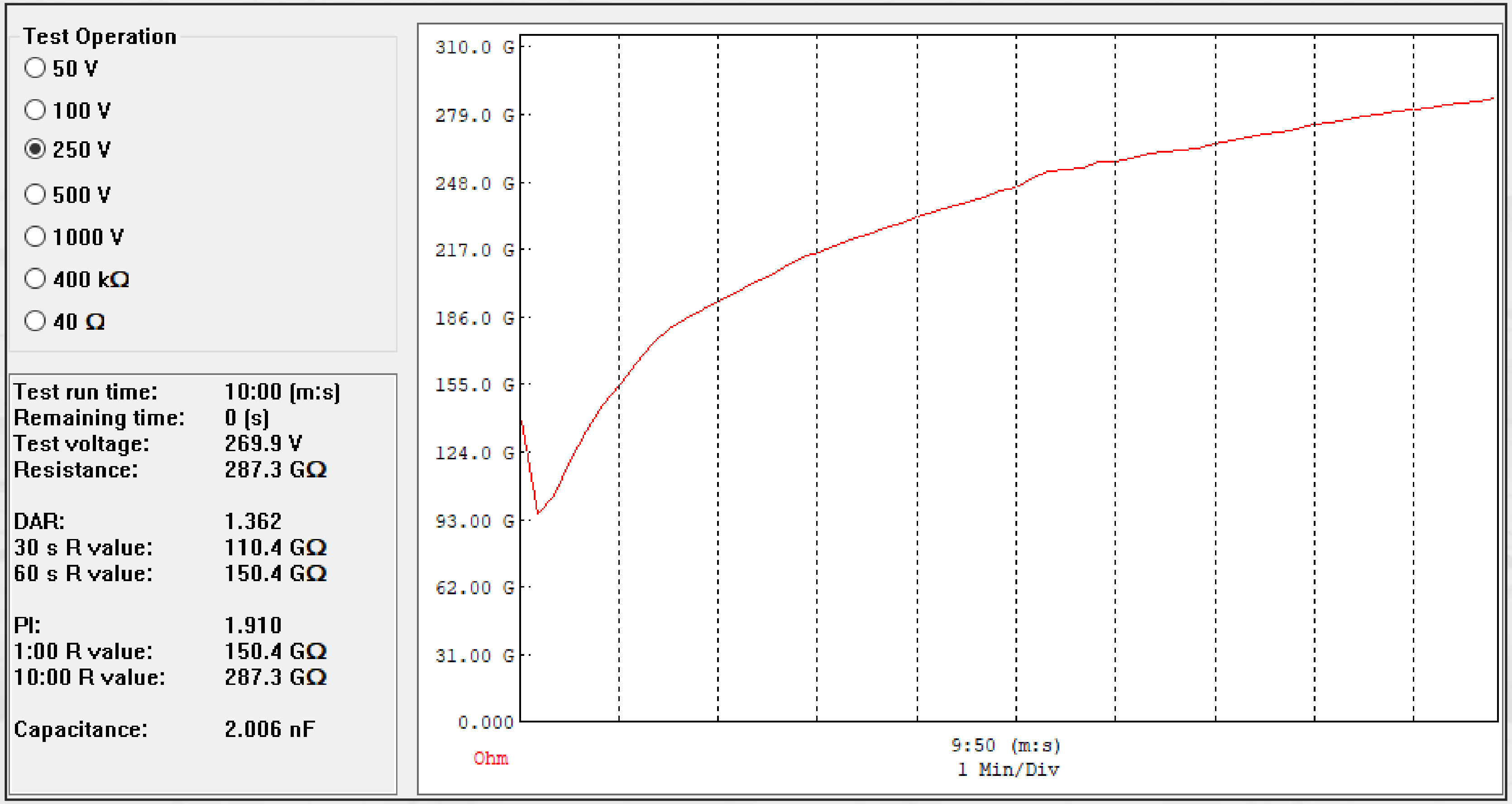
Disadvantages

- ***Less*** reliant on humidity and temp*
  - Below 50 °F and above 85 °F should be adjusted*
- Longer test time
- More data points
- Reliant on technicians unless plotted by an instrument



***Assumes temperatures fluctuate—if trending and motors stay in a controlled temperature environment, this step may be skipped.**

Test Types: Insulation Resistance Profiling



IEEE 43 – 2013 Annex B. "…Another variation is to record the insulation resistance every minute and discontinue the test when a **stable (<u>three consecutive readings</u>)** ***IR*** has been measured."

Insulation Resistance Results

Interpreting Results

IEEE-43-2013 Machines rated < 1 kV built after 1970…

IR_{1min} = 5 MΩ

- IEEE acknowledges that these values may be too low
- Preference on trending data
- Temperature compensation

Better option

- Acceptance test – Record value
- Maintenance test – Trend against previous values
- **Major deviations** = possible failure

Minimum Insulation Resistance	TEST SPECIMEN
$R_{1\ min}$ = kV+1	For most windings made before about 1970, all field windings, and others not described below
$R_{1\ min}$ = 100	For most dc armature and ac windings built after about 1970 (form wound coils)
$R_{1\ min}$ = 5	For most machines with random-wound stator coils and form-wound coils rated below 1kV

Notes

1 - IR 1 min is the recommended minimum insulation resistance, in megohms, at 40 °C entire machine winding
2 - kV is the rated machine terminal to terminal voltage, in rms kV

Test Types: Ratio Tests – DAR

DAR – Dielectric Absorption Ratio

For use on machines 200 h.p. | 150 kW or less

DAR Concept

- **“Poor” insulation**
  Absorption current is inconsistent and/or does not decrease – Resistance remains relatively stable
- **“Good” insulation**
  Absorption current decreases over time

Advantages

- **Easy operation – Pre-set instrument mode**
- Pre-set “good/bad” limits
- Mostly independent of temp/humidity

Disadvantages

- Not comprehensive – Single data point
- Smaller machines
- Outdated

$$DAR: \frac{60\ Seconds}{30\ Seconds}$$

DAR Values - 1 m / 30 s	
Value	**State of the Insulation**
Less than 1.25	Inadequate
1.25 - <1.6	Acceptable
Greater than 1.6	Excellent

Test Types: Ratio Tests – P.I.

P.I. – Polarization Index

For use on machines 200 h.p. | 150 kW or greater

$$P.I.: \frac{10\ Minutes}{60\ Seconds}$$

P.I. Concept

- **“Poor” insulation**
  Absorption current is inconsistent and/or does not decrease – Resistance remains relatively stable
- **“Good” insulation**
  Absorption current decreases over time

Advantages

- **Easy operation – Pre-set instrument mode**
- Pre-set “good/bad” limits
- Mostly independent of temp/humidity

Disadvantages

- Larger machines only
- Cannot use if IR value is > 5 GΩ within 1st minute of test
- 1 Data point

PI Values - 10 m / 60 s	
Value	**State of the Insulation**
<1	Hazardous
1-1.5	Bad
1.5* – 2.0	Doubtful
2.0	Adequate
3.0-4.0	Acceptable
> 4.0	Excellent

*** Class A is Adequate at 1.5**

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RECAP: SECTION 1-2

- **Megohmmeters** apply a **HIGH** test voltage and **LOW** test current

- Test **voltage = pressure** – remains constant

- Test **current = electron flow**
  MORE flow – less resistance
  = potential insulation failure

Model 6526
1 kV Megohmmeter
& Multimeter

Model 1060
1 kV Megohmmeter

Recap: Section 1-2

Two Different Test Options

Timed IR Test

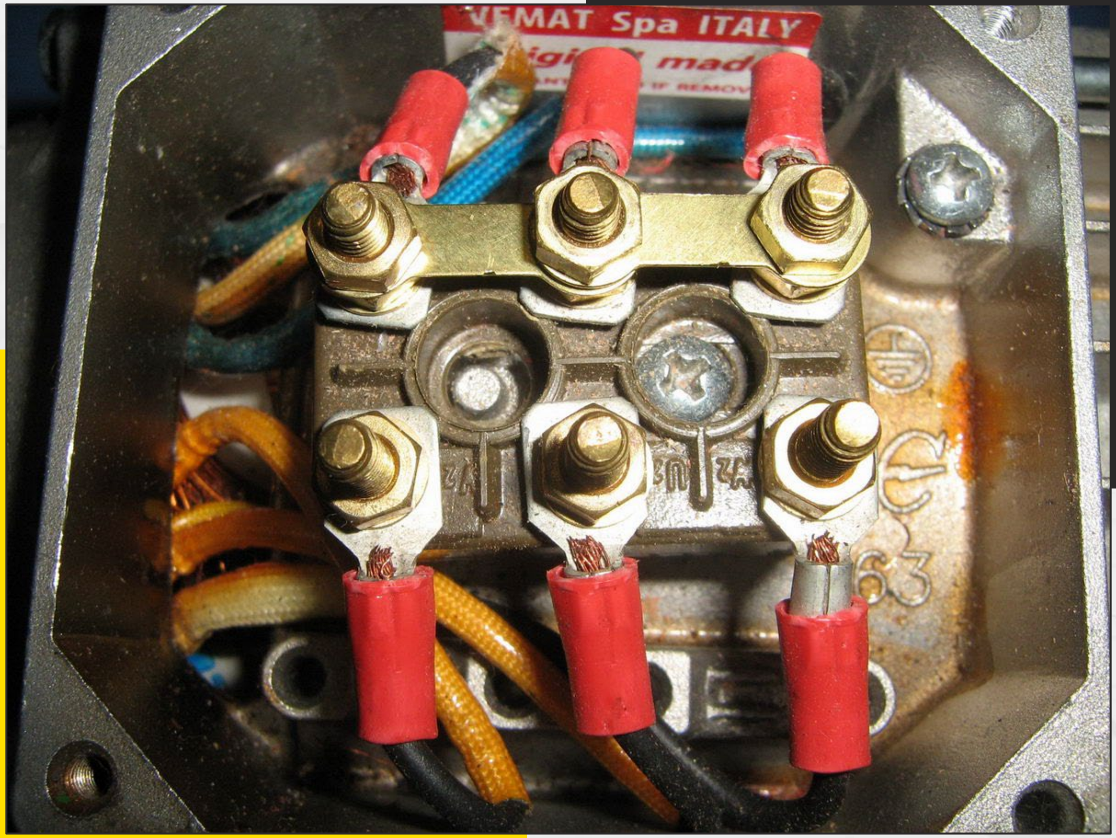
- IR_t – Short Insulation Resistance
- IR_p – Timed Resistance Profile

Ratio Tests

- **DAR** – 200 kW and less
- **PI** – 200 kW and more

Temperature Correction

Use chart to correct insulation resistance based on stator temperature



Section 3:
Testing Application

Understanding Insulation Testing

Testing Procedures – Safety

This is NOT a SAFETY presentation!

Always follow company-issued safety directives, NFPA 70E guidelines, and common sense when working on or near live voltages. If you're not sure if it's live, **test it**. If you think it is dead, **test it**. If someone told you it's dead, **test it anyway**.

CA 773 (Cat. #2121.15)
Contact Voltage Detector

SAFETY AND ACCURACY: TEST SETUP & HYGIENE

Test setup for Machines

1. **LOTO / barricade – Safety Protocols**
2. **Discharge**
   - Windings should read 0 V
   - Verify discharge after each test
3. **Isolate motor under test**
   - VFDs, Cables, heaters, surge arresters, etc. will influence the measurement and could be damaged during testing
4. **Low-resistance chassis connection**
   - Identify low resistance connection to ground
5. **Clean machine under test**
   - Surface contaminants will lower IR
6. **Temperature / Dew-point**
   - Ideal testing temp for stator – 40 °C Otherwise, correct for temperature

Safety and Accuracy: Test Setup & Hygiene

Test setup for Instrument

1. Avoid intertwined leads
- Magnets
- Velcro ties

2. Isolate leads
- Choose well-insulated leads!
  - Only use leads approved for insulation testing
- Avoid contact with the ground
- Hands off leads during testing
- Avoid running leads parallel for distances more than 1 ft

3. Use clean leads, probes, and clips
- Use rubbing alcohol or appropriate cleaner

Avoid IR testing with a Probe!

Introduces additional leakage pathways

Test Method Selection

Why are we testing?

Insulation Resistance Test Types		
Test	**Voltage**	**Purpose**
Timed Step Voltage Resistance Profiling	Rated Voltage x1 Rated Voltage x2	Proof / Acceptance Testing Comprehensive maintenance programs
Spot Test 30 to 60 s	Rated Voltage x1	Maintenance Trending Test
Resistance Profiling 3 to10 m	Rated Voltage x1	Maintenance Trending Test
Ratio Test (DAR / PI)	Nominal x1	Maintenance Trending Test

Test Voltage: Nominal "Rating" Voltage	
3 Phase Machines *1000 V or less*	Phase-to-phase Voltage
Single Phase Machines	Phase-to-ground Voltage
DC Machines	Direct Voltage

Suggested Testing Steps - Quick Test Option

Step 1: Machine & Instrument Preparation
Terminals stay connected in "HV"

Step 2: Coil resistance check
T1,2,3 to ground – (Y 7/8/9 to grnd) – T1-T2-T3, T2-T3

Step 3: Coil-to-Ground Insulation Resistance (IR) test. Short T1-T3

IEEE 43-2013: No recommendation to verify phase-to-phase IR on 2300 V or less

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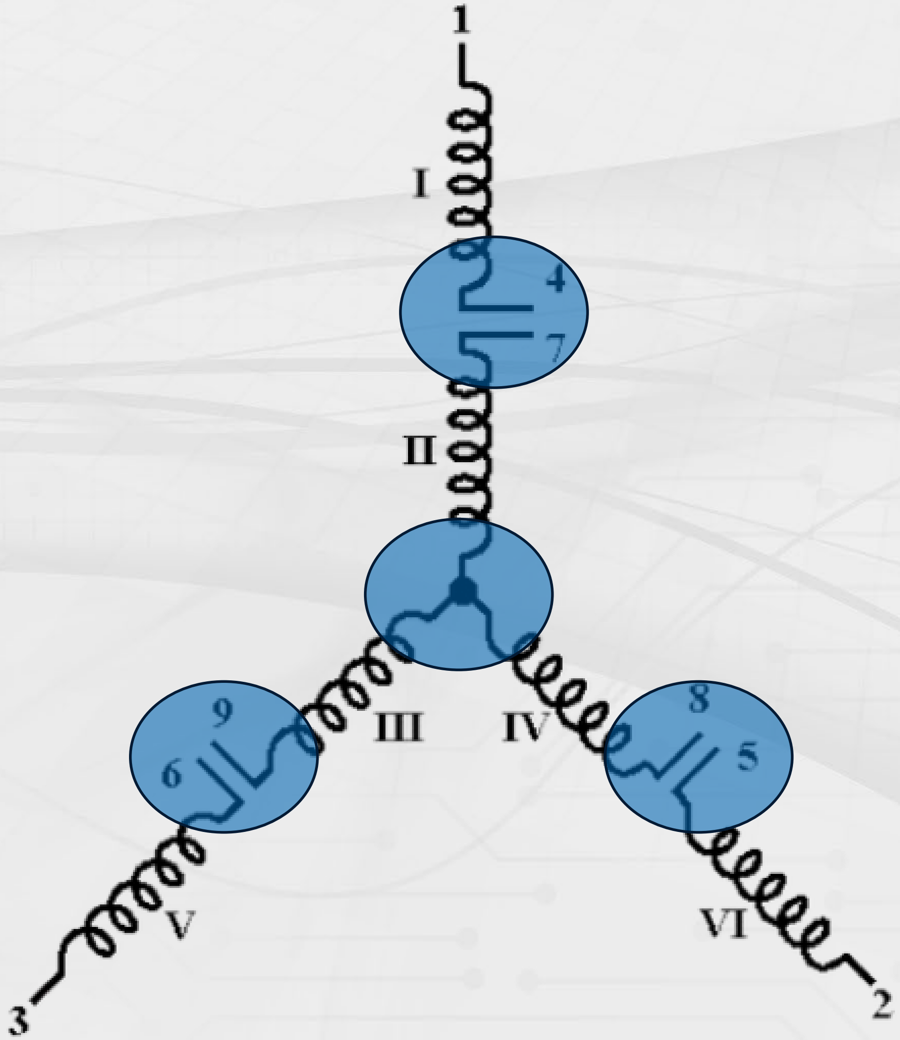
Quick: 9 Lead Wye Arrangement – Coil Check

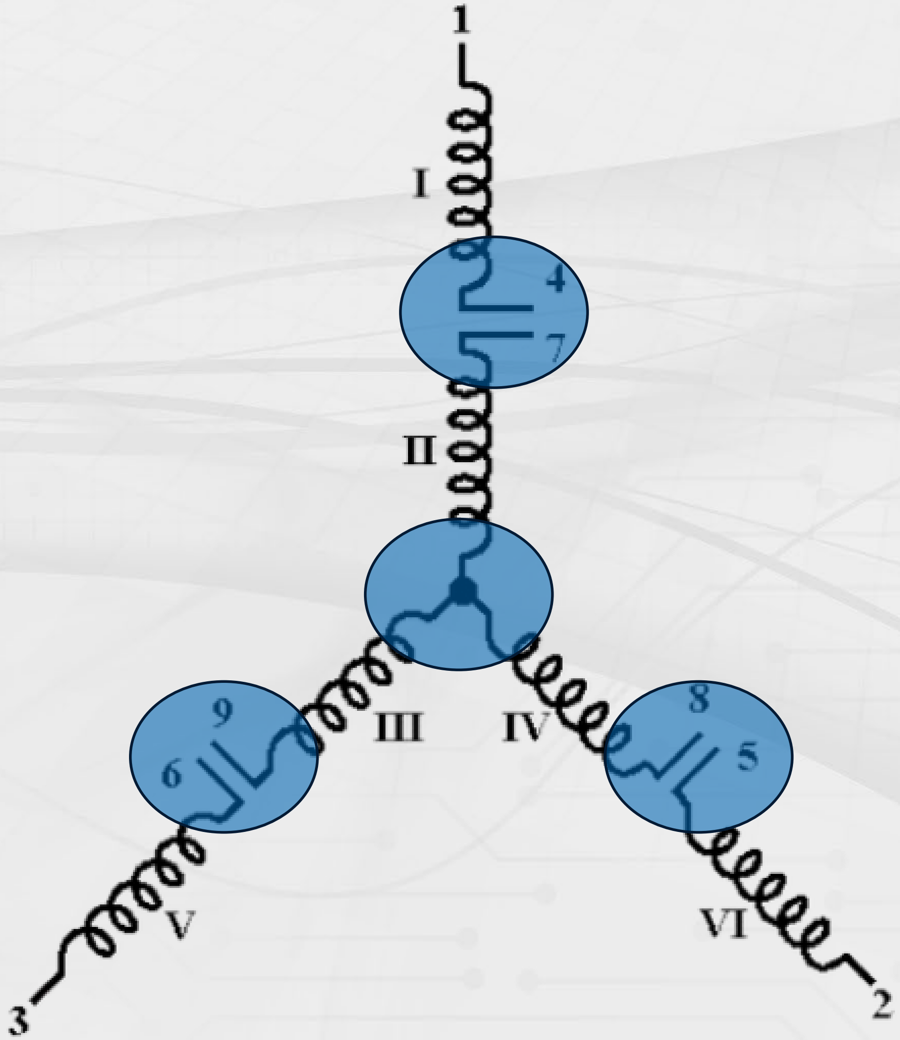
- **7-8-9** are joined internally and not accessible
- **4-7, 5-8 & 6-9** are joined in HV configuration
- Coil resistance check **1,2,3 & 7** to ground
- Check - **1-2-3, 2-3**



QUICK: 9 LEAD WYE ARRANGEMENT – IR TEST

- **7-8-9** are joined internally and not accessible
- **4-7, 5-8 & 6-9** are joined in HV configuration
- Short **1-2-3**
- IR_t test / 2 = Approximate resistance per winding
- Correct for temp

*Check the Instrument for voltage after every IR Test! **DISCHARGE** coils to ground per **IEEE 43** recommendations*



Suggested Testing Steps – Comprehensive Test Option "wye" Example – Use Worksheet!

Step 1: Machine & Instrument Preparation *(Terminals Open)*

Step 2: Coil resistance check

Step 3: Coil-to-Ground Insulation *Resistance (IR) test*

IEEE 43-2013: No recommendation to verify phase-to-phase IR on 2300V or less

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Motor Example Test Form - 9 Terminal Wye Comprehensive Test

Date: ____________

Asset: ____________

Tempatures:

Ambient: ____________

Winding: ____________

Instrument Model: ____________

Calibration Date: ____________

EXAMPLE

Motor Information	
Power - (kW)	Voltage ph-ph:
kW	V

Coil Resistance Checks - Wye

Meter in "Ω" - Verify coil resistance

	T1- T2	T1-T3	T2-T3	T1-T4	T2-T5	T3-T6	T7-T8	T7-T9	T8-T9
Ω:	Ω	Ω	Ω	Ω	Ω	Ω	Ω	Ω	Ω

	T1-grnd	T2-grnd	T3-grnd	T7/8/9 - Grnd	
Ω:	Ω	Ω	Ω	Ω	<- This line should be open!

Insulation Resistance Tests

Complete Insulation Resistance Measurements From Ph1,2,3 & 7-8-9 to ground until resistance is similar (less than 10% change) for 3 consecutive minutes

Insulation Resistance Measurements - Wye Wired - Open Terminals / wire nuts

Test Voltage: V

Test - Wye:

Time Ω:	T1- gnd	T2-gnd	T3-gnd	T7-gnd
Minute 1 Ω:	Ω	Ω	Ω	Ω
Minute 2 Ω:	Ω	Ω	Ω	Ω
Minute 3 Ω:	Ω	Ω	Ω	Ω
Minute 4 Ω:	Ω	Ω	Ω	Ω
Minute 5 Ω:	Ω	Ω	Ω	Ω
Minute 6 Ω:	Ω	Ω	Ω	Ω
Minute 7 Ω:	Ω	Ω	Ω	Ω
Minute 8 Ω:	Ω	Ω	Ω	Ω
Minute 9 Ω:	Ω	Ω	Ω	Ω
Minute 10Ω:	Ω	Ω	Ω	Ω

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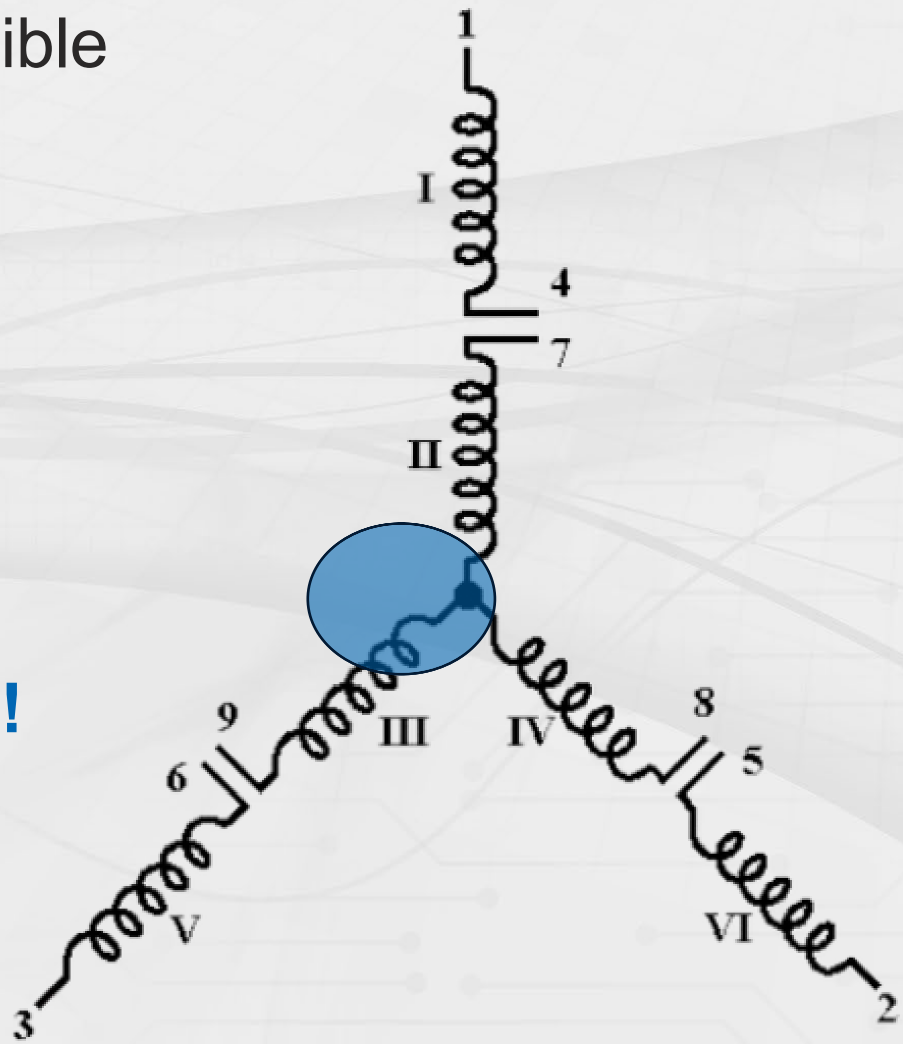
Comprehensive: 9 Lead Wye Arrangement – Coil / IR

7-8-9 are joined internally and not accessible

Coil test:
T1-2-3-4-7 | T2-3-5-7
T3-6-7 | T1,2,3,7 - Grnd

Ground T2-3-7
Test T1 - Grnd
Repeat for other phases – Include **T7-8-9!**

*Check the Instrument for voltage after every IR Test! **DISCHARGE** coils to ground per **IEEE 43** recommendations*



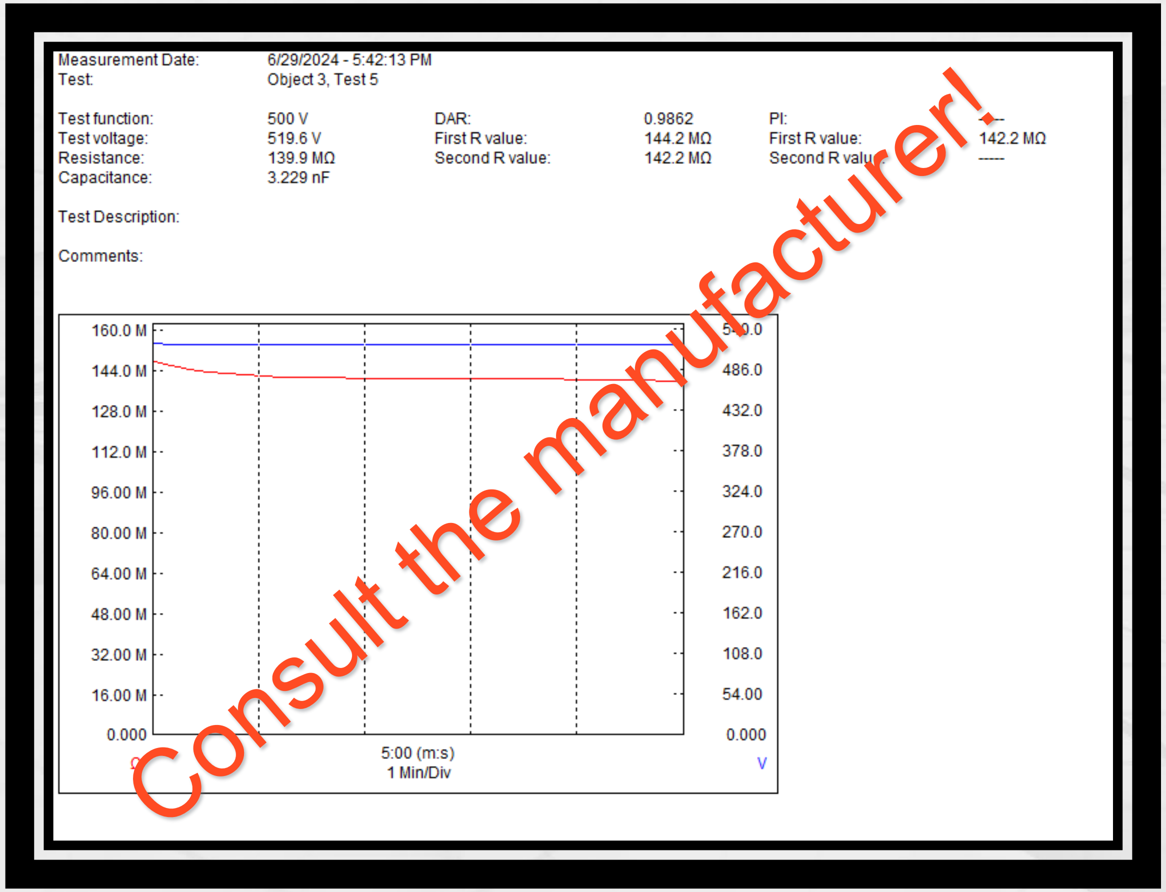
Testing Results

Good IEEE 43-2013

- 1 kV and less rated machines – **5 MΩ**
- DAR – **1.25 or better**
- PI – **2.0 or better**

Better

- New motor Ir_t = **250 MΩ**
- 3 Year Maintenance Ir_t = **224 MΩ**
- 4 Year Condition Ir_t = **150 MΩ**



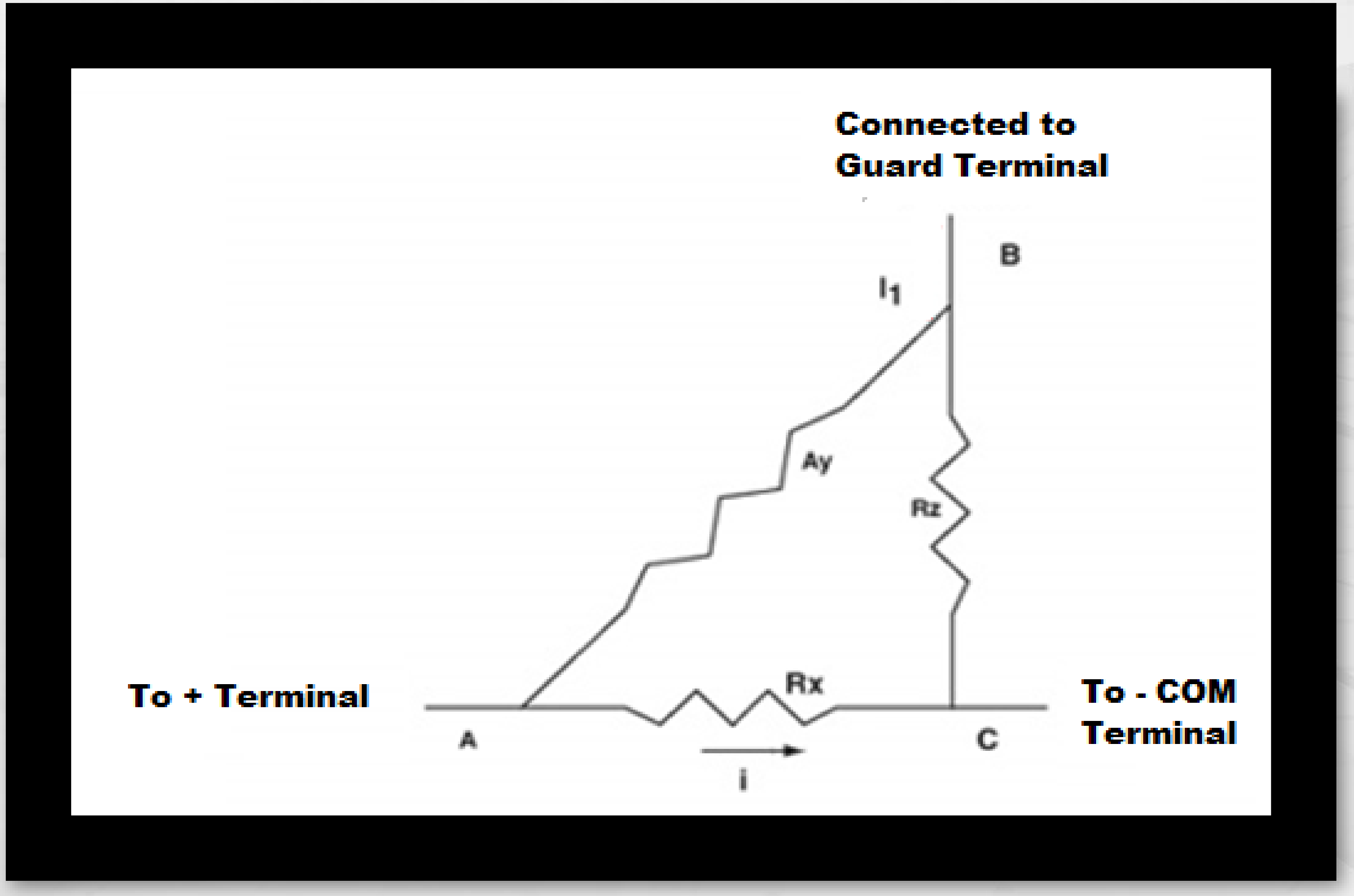
IR Testing Limitations

IEEE 43-2013

- Insulation Resistance of a winding is not directly related to its dielectric strength.
  - It is impossible to specify the value at which failure will occur.
- Large windings, slow machines, or machines with commutators.
  - May have lower insulation values than recommended. Historical trending is key.
- A single insulation resistance measurement at one voltage does not indicate a potential issue exists.
- Direct Current measurements do not detect internal insulation voids.
  - There is an extent to which failures in a DC test can measure insulation breakdown.

Troubleshooting with a Guard Lead

- A "**Guard**" is a 3rd terminal used to better isolate a test
- Not heavily used in motor testing
- However, "guarding out" can be used for advanced troubleshooting



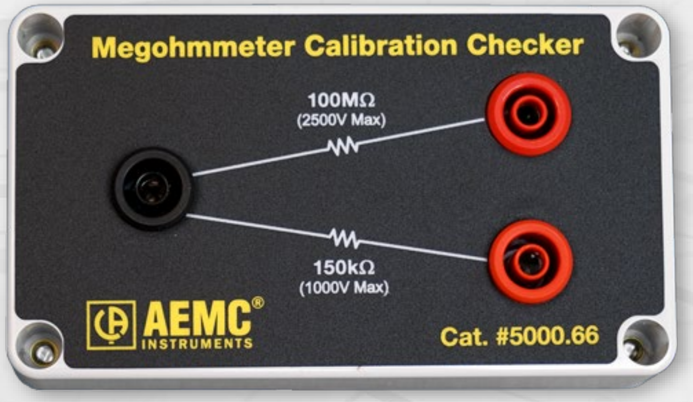
MEGOHMMETER FUNCTION TEST

Lead Continuity

- Continuity setting
- Clip leads together

Megohmmeter function test

- Use against a known resistance
- Use against a multimeter



AEMC® Instruments recommends annual calibration

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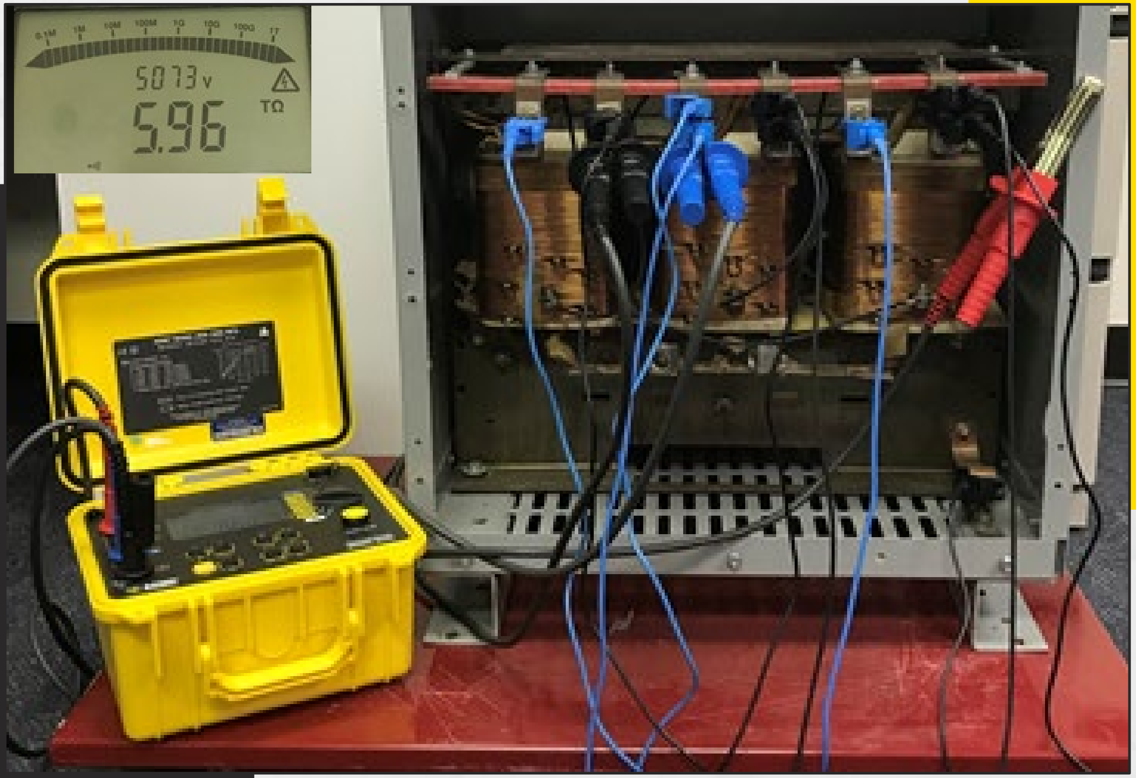
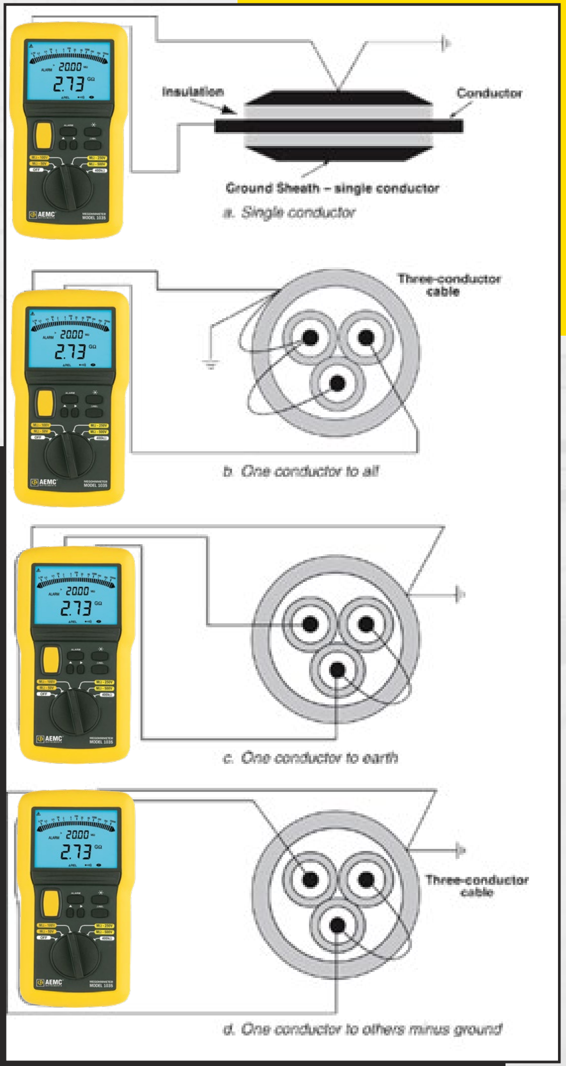
Other IR Tests – 3 phase Transformer



Low voltage winding to ground and high voltage winding to guard

- High voltage windings shorted together
- Guard blue **(G)** lead connected to high voltage windings
- Low voltage windings shorted together and connected to ground
- Megohmmeter **red +** lead connected to case
- Megohmmeter **black -** lead connected to the low voltage windings

CABLE TESTING

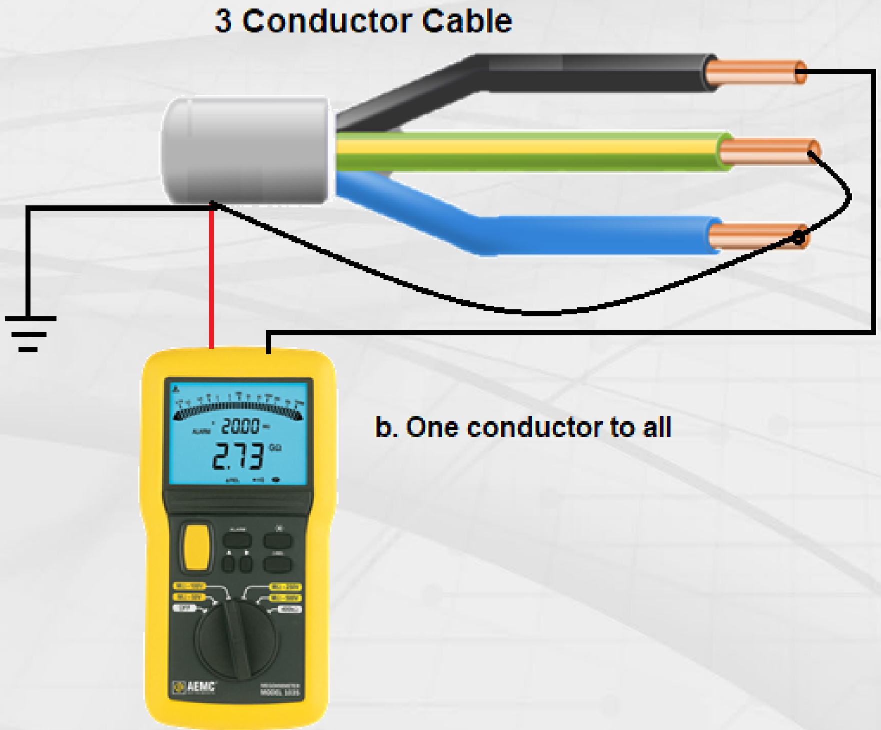


Single Conductor

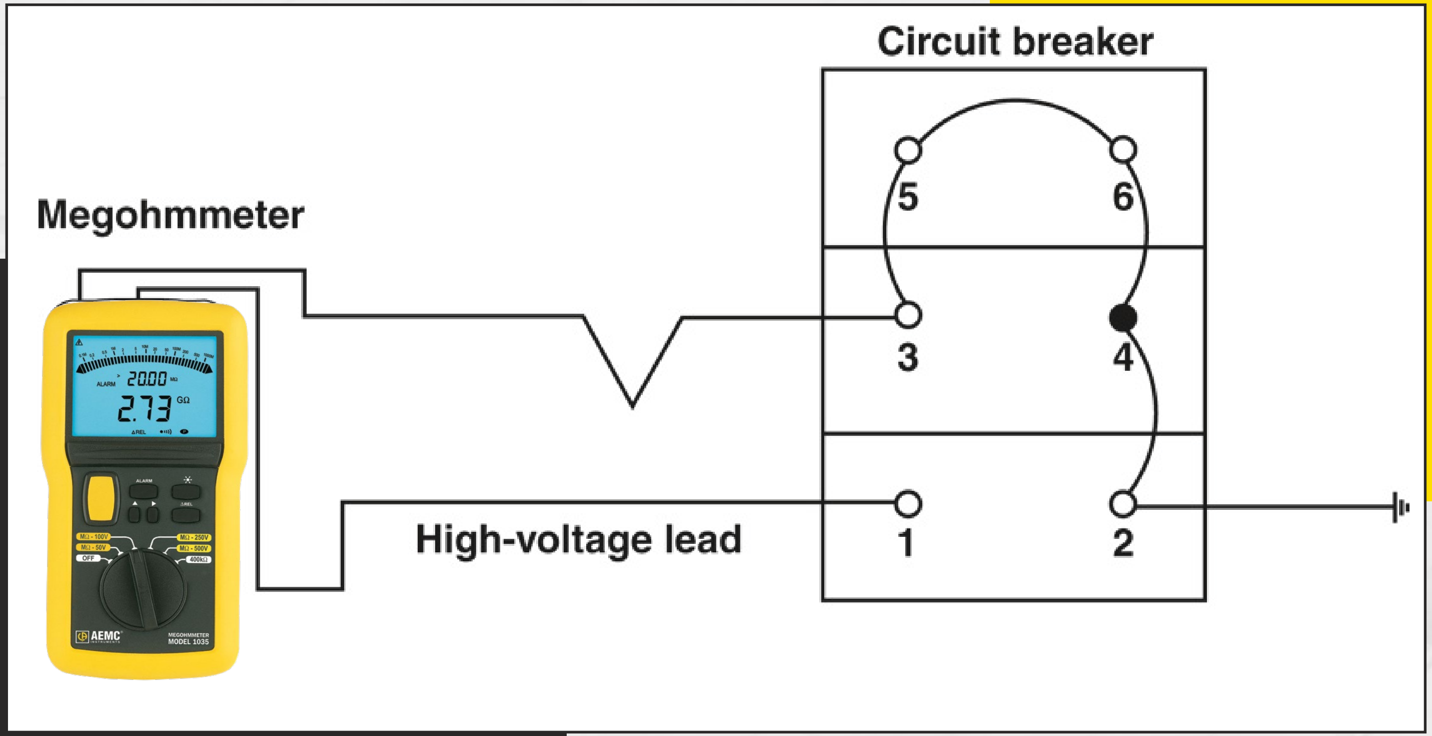
a. Conductor to Line (-) terminal and sheath to Earth (+)

Multi-Conductor

a. Single conductor
b. One conductor to all
c. One conductor to earth
d. One conductor to others minus ground



BREAKER TESTING



Circuit breaker open

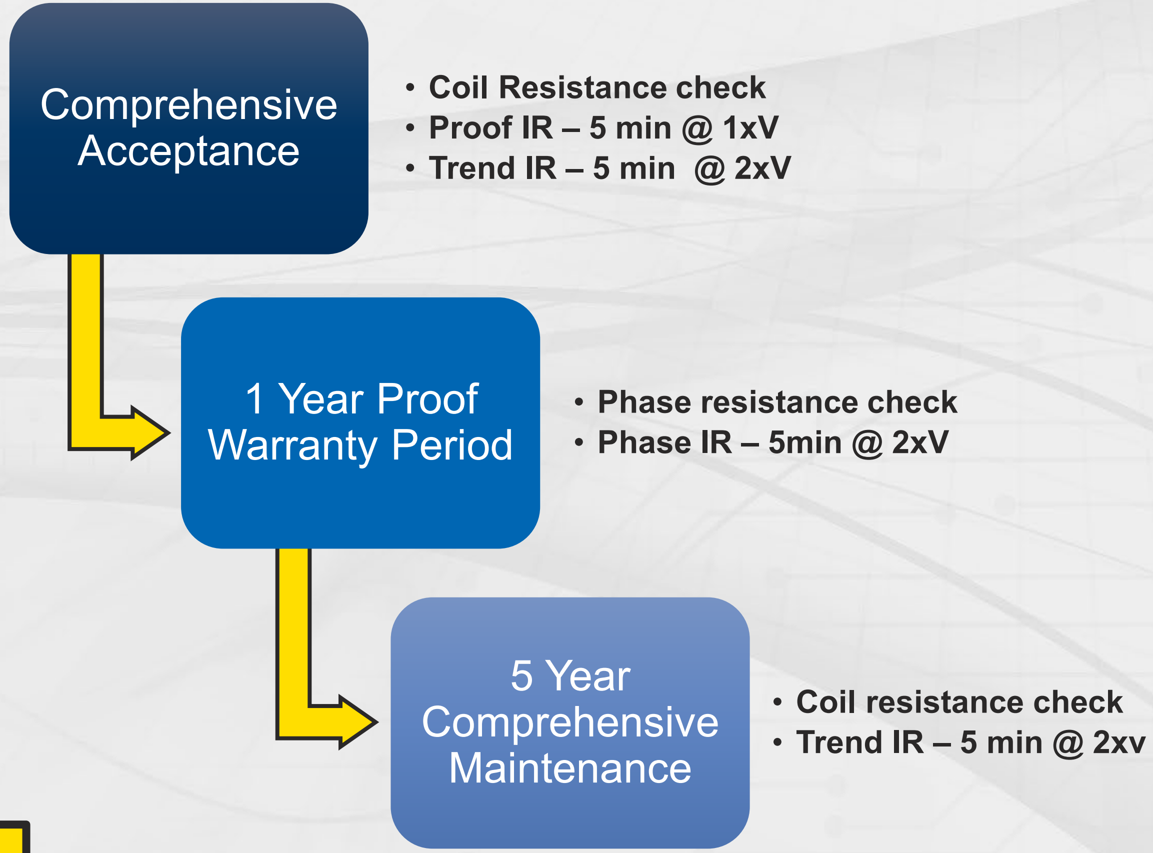
Section 4:
Testing Plans

Understanding Insulation Testing

Accuracy in Trending…Insulation Resistance

Repeatability Points for Trending

- **Test Instrument (make, model)**
  - Precision
- **Test Method & Reporting**
  - Standard Operating Procedure
    - Test method
    - Minimum test time
    - Environmental conditions
  - Standardize test reports
- **Test Specimen**
  - Order of operation
    - Clean first, then IR_t profile



Decision Makers
Reduce decision fatigue for your technicians!

TESTING INTERVALS: ACCEPTANCE

Acceptance / Proof / Commissioning Testing

- *"The systematic process to ensure that electrical power equipment and systems are operational, within applicable standards and manufacturers' tolerances…"*
- Completed upon receipt and installation but before start-up starts the **"trend"**

Insulation Resistance Acceptance Tests	
Test	**Reason**
Nominal Voltage Timed IR Test	Function Test
Insulation Resistance Profiling with trend plot	Baseline for future maintenance tests
DAR / PI Ratio with trend plot	Baseline for future maintenance tests

TESTING INTERVALS: MAINTENANCE

Maintenance / Function Testing

"Evaluate electrical equipment to ensure equipment is both functional and safe. Testing should be compared to previous acceptance and maintenance tests for analysis."

Frequency is based on the organization's maintenance program

- Preventative Maintenance
- Predictive (Condition) Maintenance
- Run-to-failure: Post-mortum

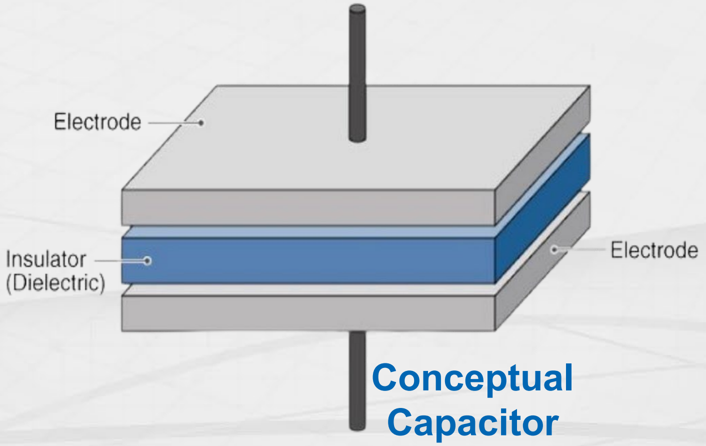
Continues the **"trend"** of data to track insulation performance, determine potential failure modes.

Insulation Resistance Maintenance Test	
Test	**Reason**
DAR / PI Ratio	Maintenance Test *Good*
Insulation Resistance Profiling with trend plot	Maintenance Test ***Better***

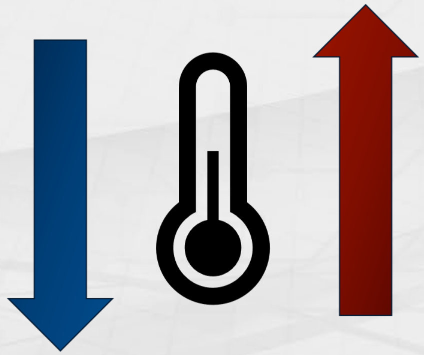
Wrapping Up

Insulation Resistance Testing Motors

- **Resistance** is a quantification of insulation integrity or performance
- **Megohmmeters** – HV current generator, voltage meter and low current measurement tool for measuring insulation resistance
- Do not follow the **2:1 Test : Rated voltage** ratio
- Motor and instrument preparation are key to **accurate trending results**
- Testing plans should be structured ahead of time



Conceptual Capacitor



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WRAPPING UP

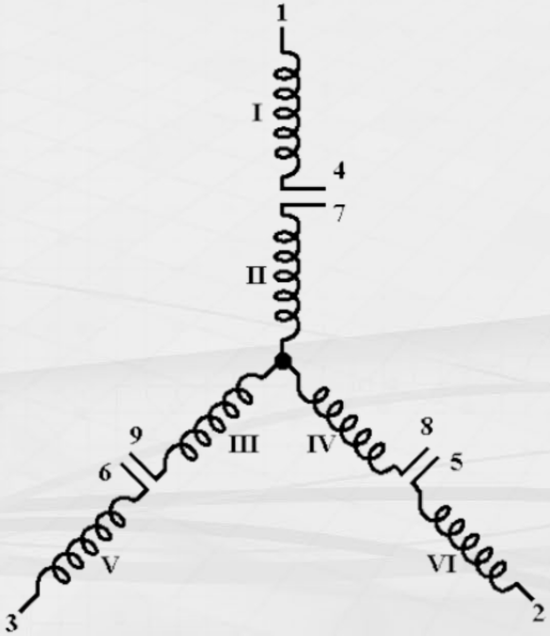
Insulation Resistance Testing

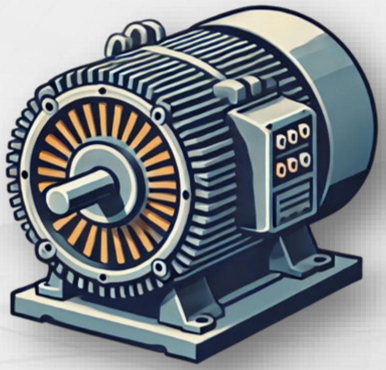
- Test voltage should be applied until the measurement "steadies"
  - 3-minute minimum for most machines

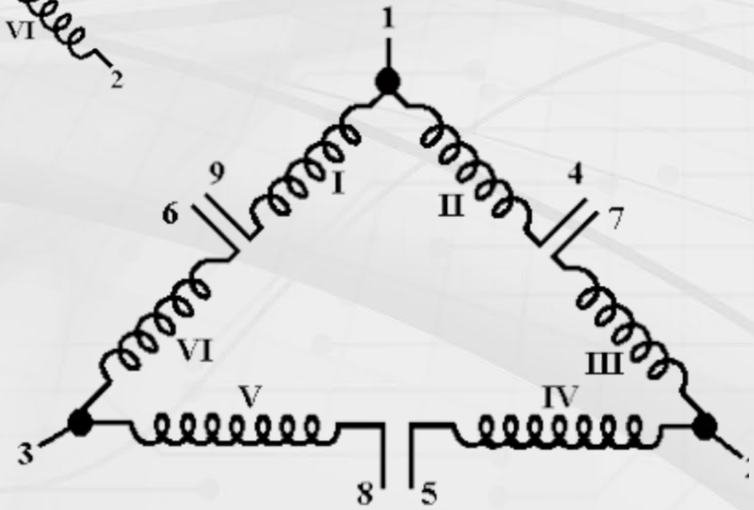
- **Temperature** has a dramatic effect on insulation performance

- 2 Types of Tests
  - **Timed IR**
  - **Ratio tests**

- 2 Approaches
  - **Quick**
  - **Comprehensive**







THANK YOU!

Understanding Insulation Testing