BOTTER Designs

HIGH VOLTAGE INSULATION METERS

APPLICATION NOTE 2

by Jacques Botte V1.00

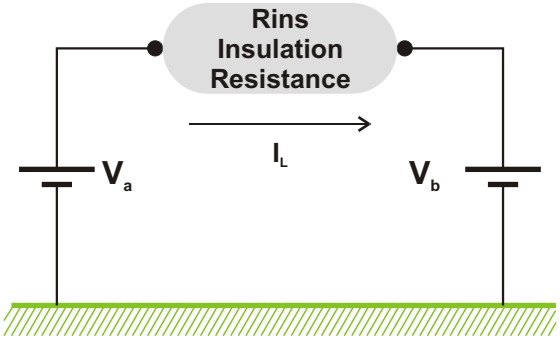
USE THE GUARD - IT'S BETTER !

When using the guard of your instruments it is important to have some basic concepts of High Voltage behavior and the knowledge of the principle of operation of your instrument. Without those, interpretation of the results can be misleading.

BASIC CONCEPTS

VOLTAGE Vs VOLTAGE

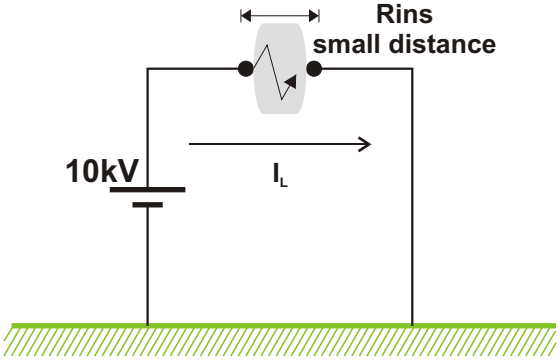
A voltage difference between two points will create a leakage current circulating between those two points. This current is equal to the ratio of the difference of those two voltages divided by the insulation resistance between those two points.



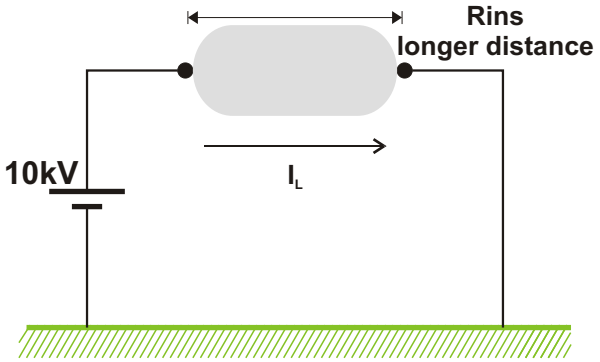
$$I_L = \frac{V_a - V_b}{Rins}$$

HIGH VOLTAGE Vs DISTANCE

More Voltage per Meter will give you more leakage current.
High Voltage between two points near each other increase leakage current and can arc.



Less voltage per meter decrease the leakage current.
High Voltage between two points far away from each other is unlikely to arc.



HIGH VOLTAGE Vs SURFACE RESISTANCE

The coating or the surface resistance is not the same as the material resistance. The surface resistance is in parallel with the ambient resistance on one side and in parallel with the material on the other side.
Surface resistance is a very important factor to take into account when connecting the guard and interpreting the results.

If the material to test is coated with a paint or any other kind of coating, the specification of that coating will interfere with the insulation resistance and the surface leakage between the points where the insulation test is made.
Coatings can be epoxy or silicone based (good insulating properties) or conductive paint.
The material can be very conductive (metal sheeting of a washing machine) or very insulating (glass or porcelain).
The coating can be absorbing (retain humidity) or not.

When testing insulation resistance, it is recommended to sketch the electrical equivalent for analysis.

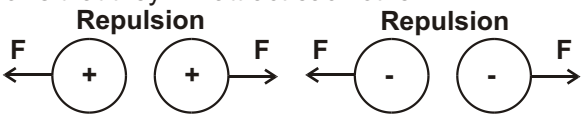
HIGH VOLTAGE Vs ATTRACTION

Attraction and repulsion force depend of the charges between points

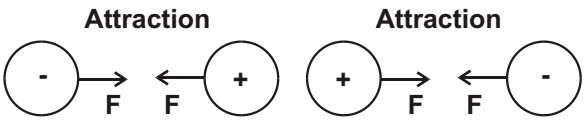
$$F = \frac{Q_1 * Q_2}{k * D^2}$$

Q_1 and Q_2 are the charges
D is the distance separating the charges
k is the dielectric constant of the material between the charges

If the charges are of equal sign, the positive product indicates a force of repulsion.
The force between two charged bodies varies as a function of the medium in which they are imbedded.
These forces are greatest in a vacuum.
The reduction in force is a measure of the dielectric constant of the media.
Experimentation with oppositely charged bodies shows that they will attract each other.



F=Electrostatic Force



HIGH VOLTAGE Vs MATERIAL

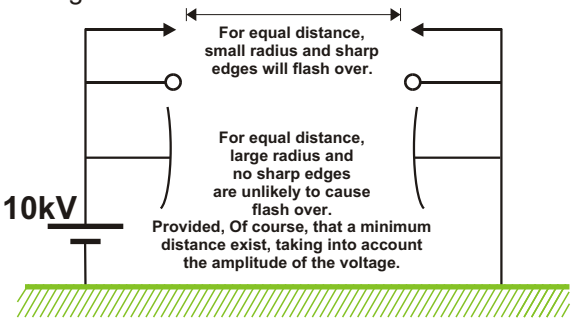
Each material has a different insulation resistance and different dielectric factors.
For example; the maximum dielectric strength that a certain material can take would be the maximum field strength that it can sustain without breakdown.
The dielectric strength of material is expressed in V/M or kV/mm...
For example; High-Voltage Porcelain is used for power-line insulators because of it's high V/mm and good thermal shock resistance.

	Glass	R>>>>
	Copper	R<<<<
	Porcelain	R>>>>>>
	Ceramic	R>>>>>

Many materials can have a very high insulation resistance at low voltage. It does not mean that their insulation resistance at high voltage is high.
The choice of high voltage insulation material must take into account the maximum Volts/Meter, mechanical, chemical, and time constraints.
Some materials are susceptible to U.V. exposure, others to humidity absorption, etc...

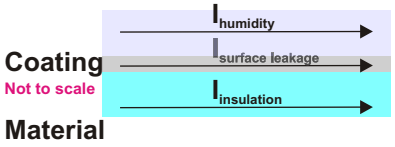
HIGH VOLTAGE Vs SHAPE

The shape of material influence the way the High Voltage behave.
Remember, with High Voltage, ionization is a very big problem. Once ionization occurs, this is like having a short circuit for the high voltage. Ouch!!!
With very high voltage air-insulated points, it is necessary to ensure that spacing is high enough, so that the electromagnetic stress in the air surrounding the conductors is low enough not to cause corona discharge.
Corona discharge is to be avoided where possible as it creates ionized gas which can cause flash-over. Should flash-over occur, this will in many cases lead to a short-circuit.
Corona discharge can also cause radio interference.
To avoid these conditions, ***the conductors or insulators, should be free from sharp edges or small radius.***
Barometric pressure and temperature also influence the formation of corona discharge.
In bad weather, discharge may appear at a lower voltage.



HIGH VOLTAGE Vs HUMIDITY

The Humidity influence the materials and particularly the coating. The humidity is in parallel with the coating (when coating exist) and therefore, the leakage current is higher than without humidity.



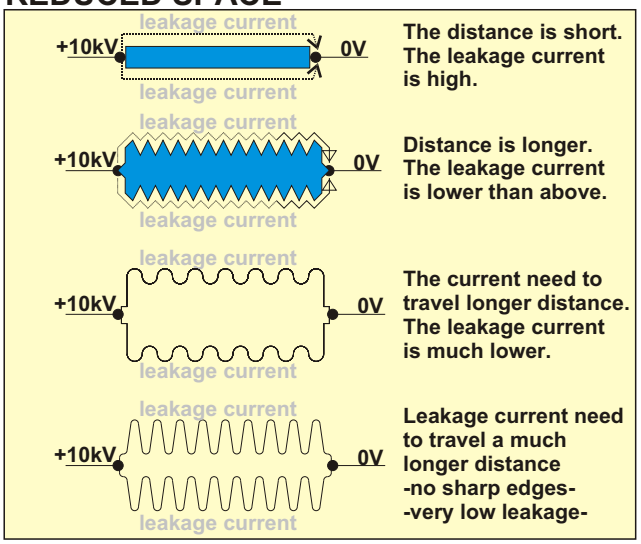
Humidity has the same effect as increased surface leakage current.
With good insulating materials, the Insulation current is generally lower than the surface leakage current and the humidity current.
The added error of the surface leakage and the humidity make the insulation resistance looking as if it was very low.
By removing the surface current and the humidity current, the real insulation resistance is read.

On our Insulation Meters, ***the guard wire is used to take away the unwanted currents*** (surface leakage, humidity, dust, etc...) ***from the measuring circuit***.

BOTTER Safer

HELPING YOU MAKING OUR WORLD SAFER, EVERYDAY, DAY AFTER DAY.
TOGETHER,
WE CAN MAKE THE DIFFERENCE

INCREASING CREEPAGE DISTANCE IN REDUCED SPACE



The distance is short. The leakage current is high.

Distance is longer. The leakage current is lower than above.

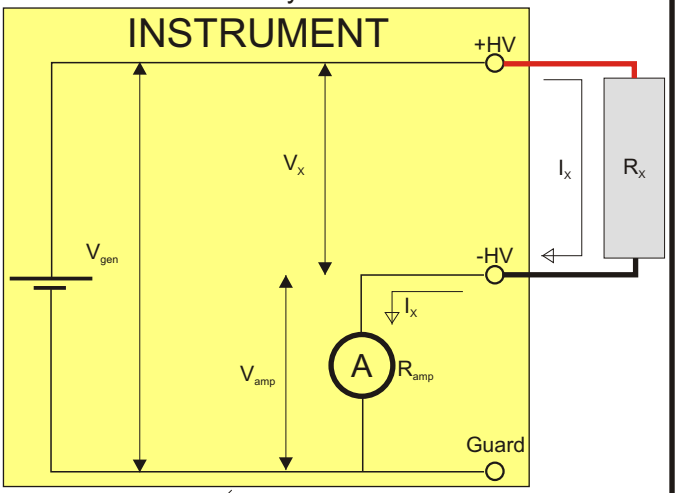
The current need to travel longer distance. The leakage current is much lower.

Leakage current need to travel a much longer distance -no sharp edges- -very low leakage-

MEASURING PRINCIPLE

The Insulation Meter:

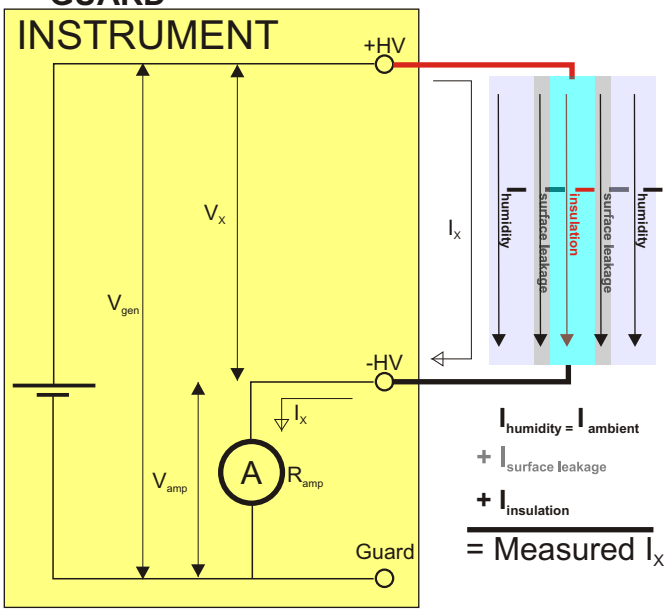
1- measures the voltage generated (Vx) on the unknown insulation resistor Rx.
2- measures the current (Ix) going through the insulation resistor Rx.
3- Computes the result: Rx is the ratio of Vx divided by Ix.



$$R_x = \frac{V_x}{I_x} \rightarrow \begin{cases} V_x = V_{gen} - V_{amp} \\ I_x = \frac{V_{amp}}{R_{amp}} \end{cases} \rightarrow R_x = \frac{V_{gen} - V_{amp}}{\frac{V_{amp}}{R_{amp}}}$$

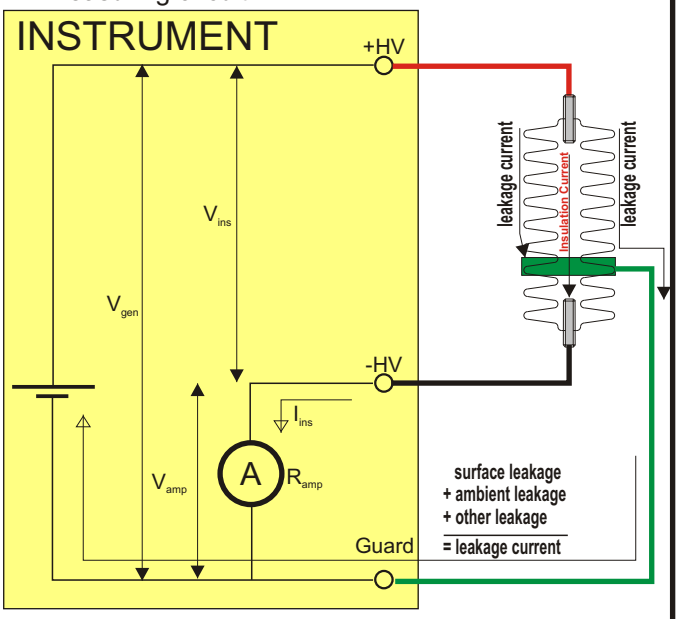
$$R_x = \frac{(V_{gen} - V_{amp})}{V_{amp}} * R_{amp} \rightarrow R_x = \{ (\frac{V_{gen}}{V_{amp}}) - 1 \} * R_{amp}$$

MEASURING INSULATOR WITHOUT GUARD



WITHOUT GUARD Rx IS LOWER

The voltage stressing the insulation, create multiples currents (Humidity, Surface, Insulation,..). If you are measuring the Insulation Resistance of the material only, the current going through the Insulation is the only current you want to measure. The current collected by the guard lead, bypass the measuring circuit.



WITH GUARD Rins IS CORRECT

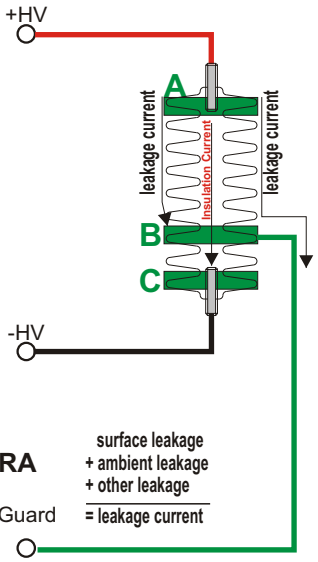
SEW® STANDARD

STANDARD ELECTRIC WORKS CO. LTD

HOW TO CONNECT THE GUARD?

The guard lead is connected to a conductive ring made of conductive copper wires, or something similar which can collect the current from all around the material.
Do not connect the guard too close to the +HV lead (**A**) connection, because you will have the proximity effect, maybe even flash-over, depending of the testing voltage.
Connect as per (**B**) or (**C**) will give better results.
Keep in mind that the guard is at the lowest possible voltage compared to +HV lead.
The guard can be seen as a voltage divider between (**A**) and (**C**).

LEAKAGE CURRENT ALWAYS TAKES THE SHORTER PATH or LEAST RESISTIVE PATH.



GUARD CAN BE USED AS AN EXTRA LEAD WHICH CAN GIVE EXTRA INFOs AND DETAILS.

It's not always necessary to use the guard!
First, defines what you want to do, analyses the problem and the circuit.

Consider the following :

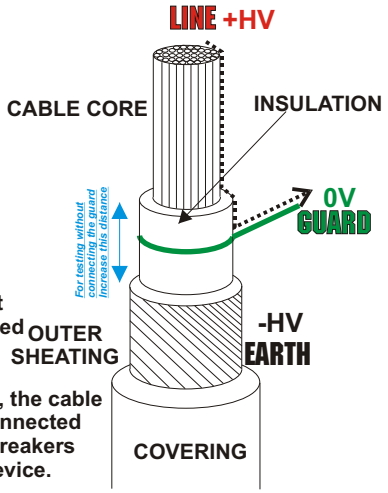
a- Volts per Meter or Volts per Cm.
b- Insulation Resistance (M or G
c- Proximity. (Inv. prop. to square of distance)
d- Humidity and Temperature.
e- Altitude.
f- Ionization Build-up.
g- Material type.

TESTING ARMED CABLE

Only one side of the cable is shown here. For optimal results, other side must be inspected and connected to the guard lead.

The cable must not be connected to it's load.

During Testing, the cable must not be connected to any circuit breakers or switching device.



With Guard Connected,Surface Leakage Current is eliminated by the Guard Test Lead. Therefore eliminating measurement error. The result will be correct.

Should it be impossible to connect the guard lead on both sides of the cable, the distance of the insulating material separating the core of the cable and the outer sheating must be increased, in order to reduce the surface leakage.

Think about the following:

In Real Life:

- **There is no guard.**
- **The weather changes.**
- **The mechanical forces changes.**
- **Leakage, other than insulation, is always present.**
- **The voltage fluctuates.**
- **The faults currents are variables.**

So, testing insulation with the guard is a "component test", not a field test.
Once connected to others circuits, the component may behave differently in the field, due to the other factors.

When testing insulation resistance, it is recommended to sketch the electrical equivalent for analysis.
Don't comes too quickly to the wrong conclusion. Analyses before taking dramatic actions.

READ APPLICATION NOTE # 3
AL-50: A BETTER H.V. TEST LEAD !

In a next application note, we will discuss the testing of:

- **spark plugs.**
- **transformers.**
- **insulators.**
- **single phase motors.**
- **three phases motors**
- **contactors.**
- **H.V. capacitors.**