

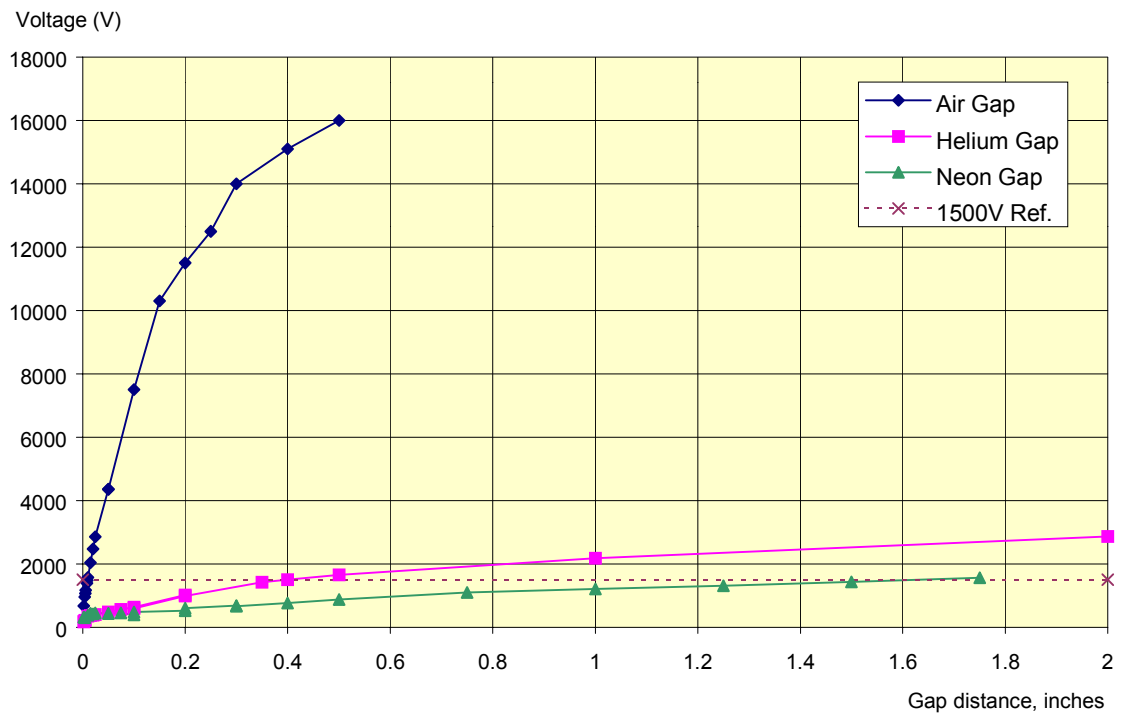
**USING INERT GAS
TO ENHANCE
ELECTRICAL
WIRING
INSPECTION**

Electricity arcs greater distances in inert gas than in air

How It Works (Theory)

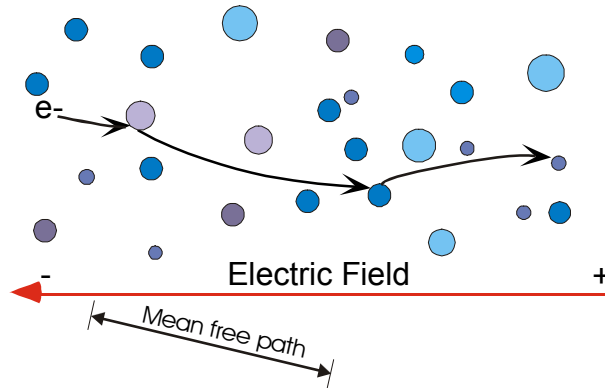
Filling the space around wires to be tested with inert gas significantly enhances hipot testing while reducing the voltage and energy required to find insulation defects.

Test Voltage Required to find Insulation Defects vs. Distance Between Defects



Why Testing in Inert Gas is More Effective Than Testing in Air

Mean free path illustrated for air. Air has a variety of atoms and molecules.



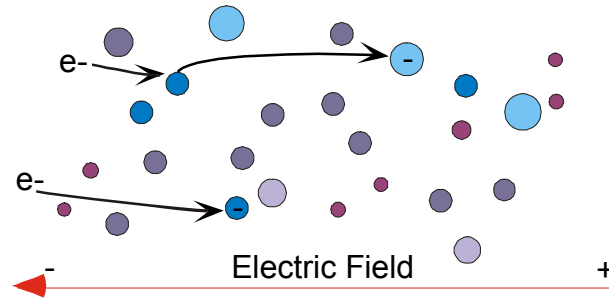
Electrons are accelerated in an electric field. In a vacuum, there is nothing for free electrons to collide with. In a gas, however, free electrons may collide with atoms or molecules (particles) in their path. The distance that an electron will travel before colliding into a particle (the electron's mean free path) depends on several factors, including the density of the gas (number of particles per unit volume) and the size of the particles.

Mean free path, molecular diameter, and 1st ionization potential of various gases.

Gas	Mean Free Path of Gases			Molecular Diameter (10 ⁻¹⁰ m)	1 st Ionization Potential (eV)
	1 mm Hg (1.3x10 ⁻³ atm) 20°C (10 ⁻⁶ m)	0.001 mm Hg (1.3x10 ⁻⁶ atm) 20°C (10 ⁻⁶ m)	760 mm Hg (1 atm) 0°C (10 ⁻⁶ m)		
Helium	133.2	133,200	0.133	1.9	24.6
Neon	94.0	94,000	0.094	(NA)	21.6
Hydrogen	88.1	88,100	0.088	2.40	15.4
Argon	47.3	47,300	0.062	2.88	15.8
Oxygen	48.2	48,200	0.063	2.98	12.1
Nitrogen	45.0	45,000	~0.045	3.15	15.6
Krypton	36.3	36,300	0.036	3.14	14.0
Xenon	26.2	26,200	~0.026	3.42	12.1

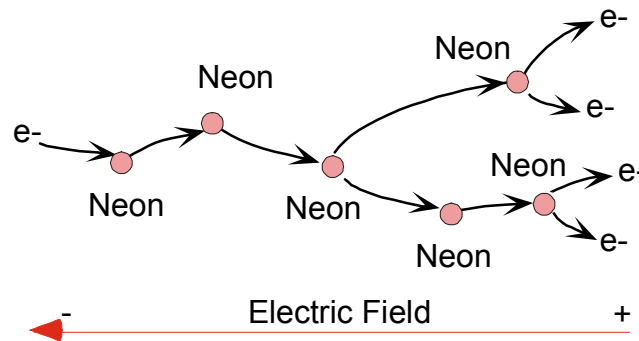
Mean free path data, like that above, gives information about the free path of a molecule in the gas, and thus gives insight into the mean free path of an electron in the gas. Note that as the gas pressure decreases (high altitude), arcs can travel farther than when at high pressure (sea level). Also note that insulation testing is performed on the ground where pressure is high and arc distance short.

Capture of free electrons by electronegative molecules in air.



Sometimes an electron is captured when it collides with particles in its path. Electronegative gases are so called because they have electron affinity and form long-lived ions after capturing electrons. These gases are used to suppress arcs in high voltage circuit breakers. Probably the best-known arc-suppressing gas is SF_6 , which has a large electron attachment cross-section and a strong electron affinity. Gases that capture electrons include SF_6 , CF_4 , CO , CO_2 , N_2O , and other gases including many commonly found in normal air. The presence of these gases suppresses arcs by capturing free electrons. Inert gases, particularly Helium and Neon, do not capture electrons.

Townsend breakdown of an inert gas.



As an electron travels in an electric field, it speeds up and gains kinetic energy. If it has gained enough kinetic energy before colliding with a particle, it can cause that particle to release (emit) an electron. This can lead to a Townsend avalanche, wherein electrons hit gas molecules, producing fresh ions and electrons. If the avalanche extends from one conductor to the other, it is called an arc.

Performing the Tests (Practical Application)

Effectively performing the test requires the use of the Cirris Touch 1™ High-voltage analyzer in conjunction with a gas containment device.

Touch 1 High-Voltage Cable Analyzer



Inert Gas Wand (for smaller wire bundles)

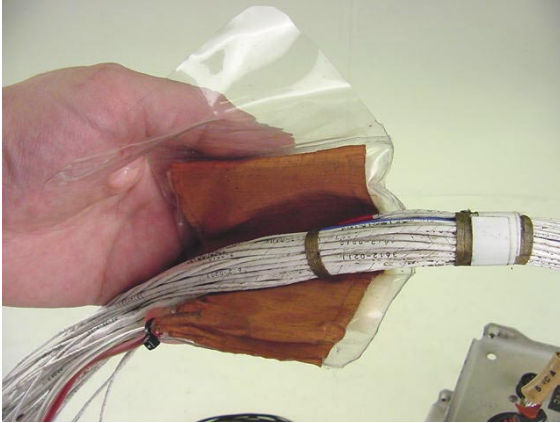


Inert Gas Wand with three rows of brushes (inside row is conductive nylon). Provides gas containment and conductive path for low-energy arcing.

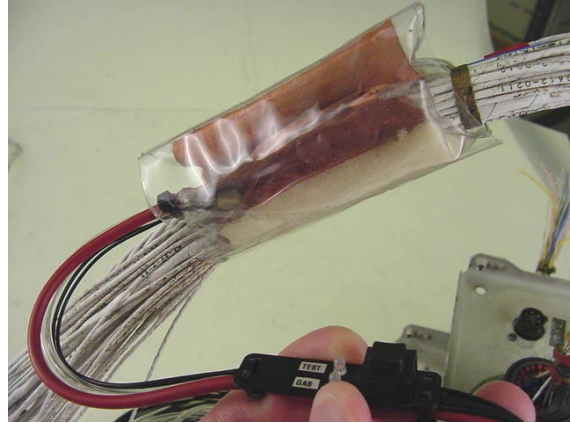


Inert Gas Wand shown clamped over the cable to be tested. Wand provides remote "Start Test" and pass/fail indicator LED's.

Inert Gas Cuff (for larger wire bundles)



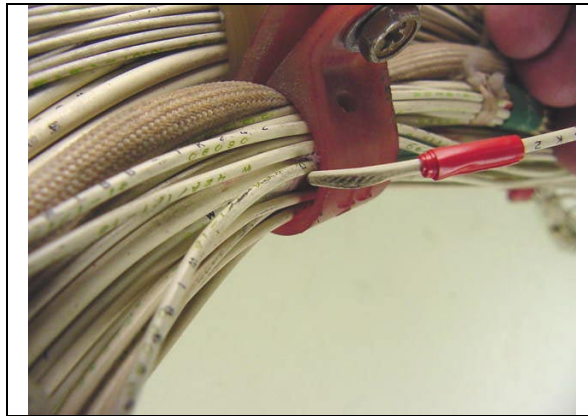
Inert Gas Cuff positioned over a bundle of wires to be tested. Provides gas containment and conductive path for low-energy arcing.



Inert Gas Cuff wrapped around wiring harness to be tested. Cuff provides remote "Start Test" and pass/fail indicator LED's.

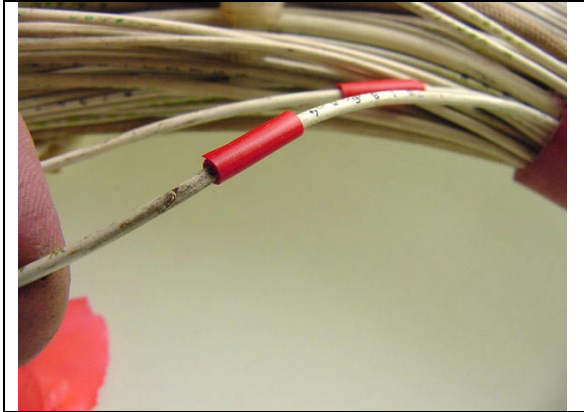
Sample Test Results Performed On Actual Aircraft Cables

The following photos highlight the results of high-voltage tests performed on sample cables from an FAA test site using the inert gas test system. (For the full report see Smith, P.; 2002; Inert-Gas and Low-Energy HV Tests Performed on FAA Test Samples; <ftp://www.cirris.com/AircraftTesting/FAASampleCables.pdf>)



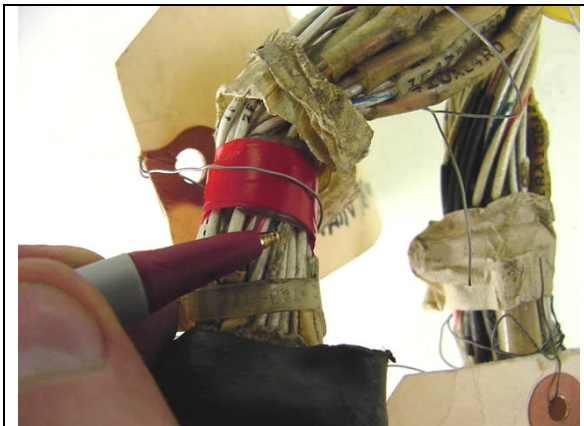
Close view of crushed insulation by a bracket. Note the diagonal lines on the wire to the left of the red tape.

There is interest in finding damaged insulation. Damage appears to have been caused during maintenance or cable extraction.



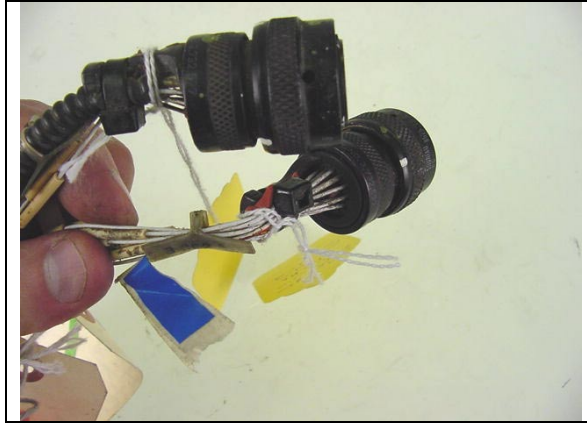
Nicked insulation by bracket. The nick can be seen to the left of the red tape.

With this sample, the insulation has been nicked, and the conductor is exposed.



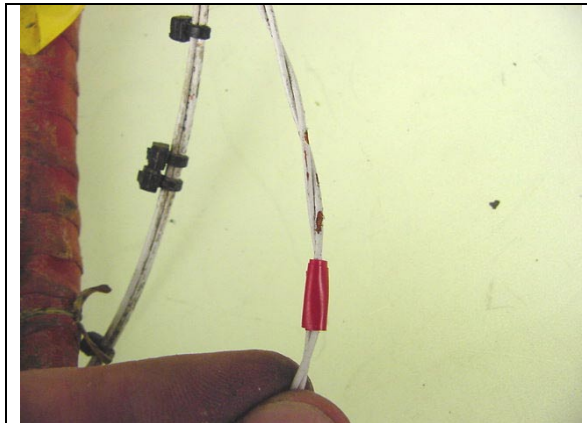
Chafed insulation at edge of label. The wire is not visibly exposed, but appears to have rubbed against something. Insulation has been compromised. The conductor IS exposed (test failed), although it can't be seen with the naked eye.

Sometimes there is damage near a wiring label due to chafing or tightening of the cable strap associated with the label.



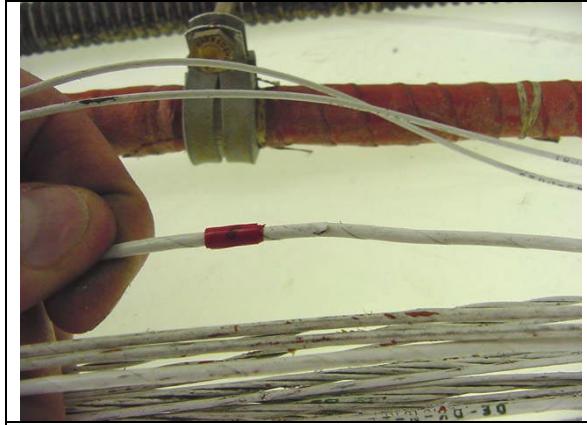
Paint rubbed off wires near backshell. The insulation is not compromised.

Here is a cable that “looks” bad, but it is intact. All tests passed, there is no damage to insulation.



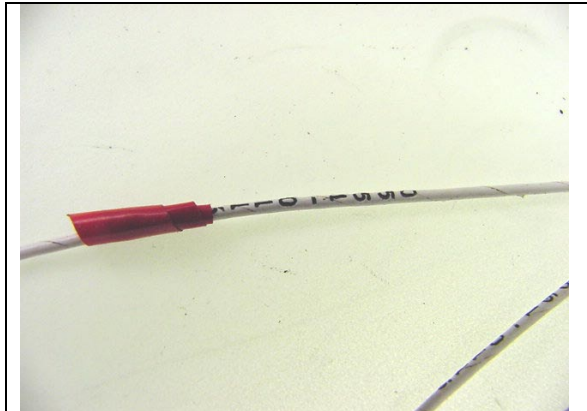
Chafed insulation. Insulation compromised.

This picture shows chafing damage, probably caused by a cable clamp rubbing the wires in question.



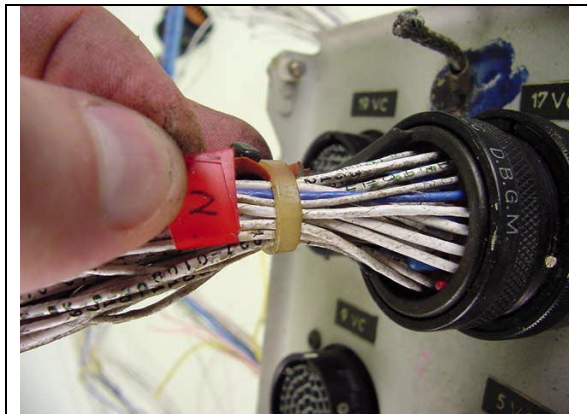
Nicked insulation. Insulation compromised.

Sometimes the damage can't be seen easily. This insulation has been nicked, as can be seen to the right of the red marking tape.



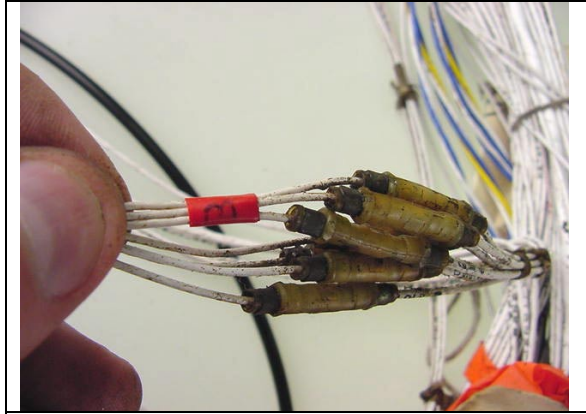
Wire marking 0551-0116 perforates insulation (multiple characters) in eight separate character groups along wire harness sample. The insulation is compromised on the following underlined characters: 0551-0116.

This is an excellent example of wire marking being the cause of damaged insulation. (Note: after a failed hipot test on this wire, a static discharge gun was used to pinpoint exactly which characters had compromised the insulation)



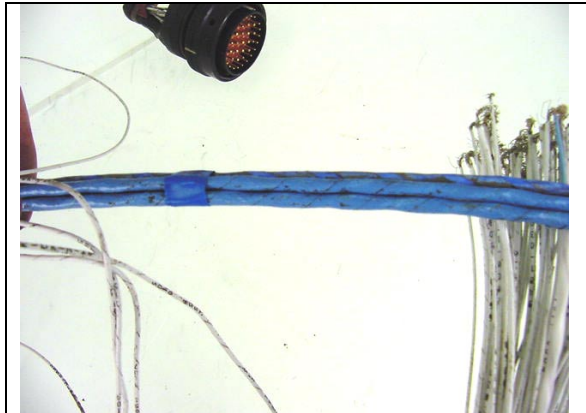
“1” wire mark perforates insulation, midway between red tape and cable clamp.

This is another excellent example of wire marking being the cause of damaged insulation. Only the character “1” perforates the insulation. The insulation is damaged by this character in several places along the length of the wire sample.



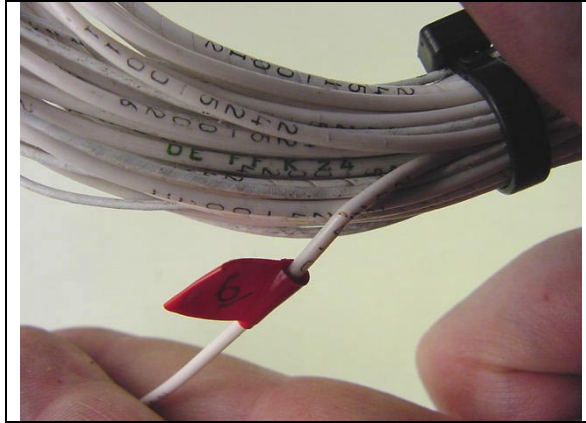
Non-environmental seal on 3 crimps (splices).

Sometimes wire repair leaves the wire harness vulnerable. In this sample, three of the wire crimps do not have an environmental seal, allowing contaminants to work their way to the conductor.



Blue shield wrap (insulating tape) does not provide an environmental seal.

Most types of wrapped insulation do not provide a good environmental seal. Although the test failed, it is probably not critical because the exposed conductor is a shield.



A crack or nick was found between the “2” and “4” printed on this wire. As with much of the damage found during these tests, this crack was first identified while still buried in the bundle of wires.

Sometimes insulation damage is not on the outermost wires in the bundle. In this example, the damaged wire is covered by two layers of wire in the bundle. None of the other wires in the bundle were damaged.