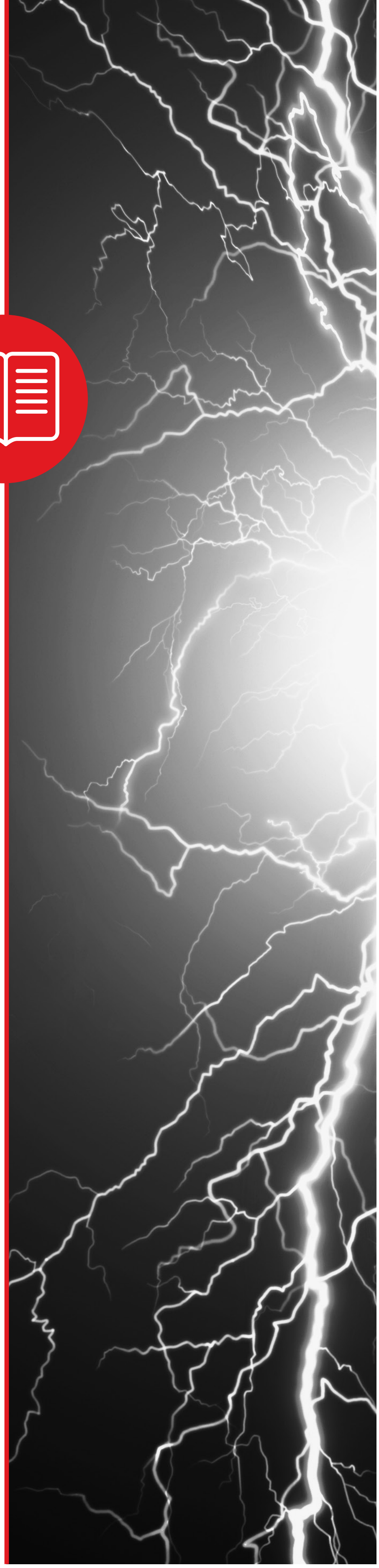
WHITE PAPER



CONNECTOR OPERATING VOLTAGE

EDITION 3.1 | MARCH 2019

fischer CONNECTORS®

REIMAGINING CONNECTIVITY TOGETHER

CONNECTOR OPERATING VOLTAGE

Unlike most product specifications, operating voltage is not an intrinsic characteristic of a connector. Because voltage is affected by environmental conditions such as humidity and air pressure, and is subject to safety requirements that are often field-specific, it is often difficult to determine the actual voltage that the connector can safely carry.

This paper walks engineers through the conditions that impact operating voltage so that they can be better informed to specify connectors that will work as expected in their unique rugged environments.

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INTRODUCTION

Question

When does the weather impact the design of your device?

Answer

When you are determining the operating voltage of your connector solution.

Voltage ratings are often of crucial importance because they are safety-related. But accommodating the proper voltage is not always a straight-forward determination when it comes to connectors in rugged environments. Unlike most product specifications, operating voltage is not an intrinsic characteristic of a connector because voltage is affected by environmental conditions such as humidity and air pressure, as well as safety requirements that are often field-specific.

In addition to weather conditions, an engineer must plan for materials to degrade over time in tough conditions. The guidelines in this paper will help equipment manufacturers identify considerations for selecting an adequate connector solution based on general guidelines. Before you begin, however, it is important that you identify whether specific regulations or standards exist for the equipment being designed, as they must be considered and incorporated into the device and connector solution as a priority.

1. DEFINITIONS

1.1 Breakdown voltage

Breakdown voltage is a characteristic that defines the maximum voltage difference that can be applied before a disruptive discharge occurs between mutually insulated portions of a connector, or between insulated portions and ground. Breakdown voltage is measured in a destructive test.

1.2 Test voltage

Test or withstanding voltage is the voltage level at which the connector is tested during a qualification test. According to IEC 60512-4-1, the test shall last 1 minute and no flashover or breakdown is allowed. This value represents the upper physical limit, and is sometimes used as a basis to calculate operating levels when predefined safety factors are established.

In theory, test voltage may be stated as high as it is tested, provided the conditions of the standard are met. Practically, however, test voltage is usually set at 75% of breakdown value (as defined for examples in EIA- 364-20 and former MIL-STD-1344 method 3001).

Fischer Connectors always applies this 75% ratio; so the resulting test voltage values cited are reliable even when breakdown values exhibit the large scatter typical in high-voltage testing (See Fig.1).

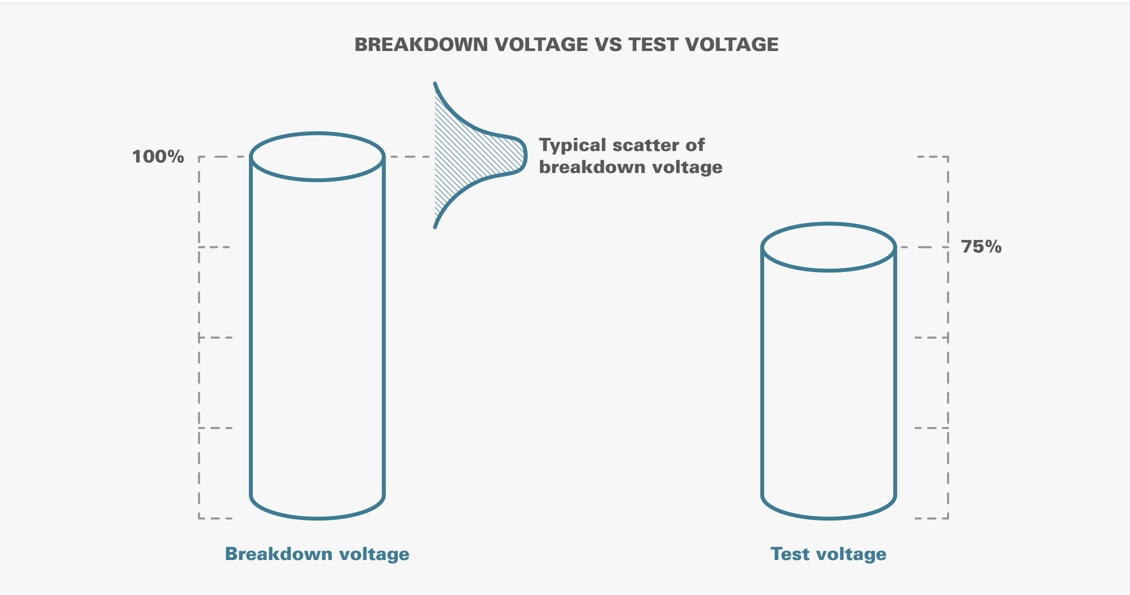
1.3 Operating voltage

Operating voltage is the voltage under which the connector will actually work in the equipment over the normal expected lifetime and in typical environmental conditions. As we will see, this value depends both on connector design and on the specific operating environment.

Often, significant scatter is observed in breakdown testing, because the breakdown mechanism is naturally triggered by instabilities. Breakdown voltages determined at various locations with different equipment frequently result in up to 10% differences. Such differences in breakdown voltage do not show evidence of differences between the test samples.

The overall performance of any electrical connector is typically determined by the spacing of the contacts (air gap), the distance along insulating components (creepage distance), and of course, by the choice of the insulating material. In most general-purpose connector designs, the short term performance is driven by the insulating performance of the surrounding air. In the long term, the physical properties of the insulating material are important.

FIG.1



2. DETERMINATION OF OPERATING VOLTAGE

For connectors in common applications, IEC60664 is in particular recommended. This specification uses creepage distance instead of test voltage as a calculation basis for the operating voltage, taking into account the above mentioned long-term effects. It is similar to German VDE 0110; typical applications are classifid in insulation groups depending on their exposure to pollution.

Fischer Connectors recommends the use of IEC60664 in general multipole connector specifications, unless other more specific standards or regulations are applicable to the design. For example, IEC 60601 provides adequate special guidelines for medical devices.

All values given here are valid for mated connectors, provided that termination of connectors has been completed with adequate cable and following correct termination procedures. Other standards recommend a calculation using the test voltage as a basis with the application of a safety factor. For example, BS 9520 recommends setting the operating voltage at:

$$\frac{\text{Test Voltage}}{3} \quad \text{for} \quad 500V < \text{Test Voltage} < 3kV$$

$$\frac{\text{Test Voltage}}{1.5} \quad \text{for} \quad \text{Test Voltage} \geq 3kV$$

Similar recommendations are provided in EIA-364-20 and former MIL-STD-1344 method 3001. This method takes into account the measured test voltage of the connector; however, it does not take into consideration either long-term environmental effects or the specific behavior of different insulator materials. This method can be recommended for cases where the connector “on-time” or duty cycle is low, combined with little exposure to environmental factors, for example, scientific instruments or similar equipment. Fischer Connectors provides test voltage values in the general catalog and in some product specifications.

FIG.2

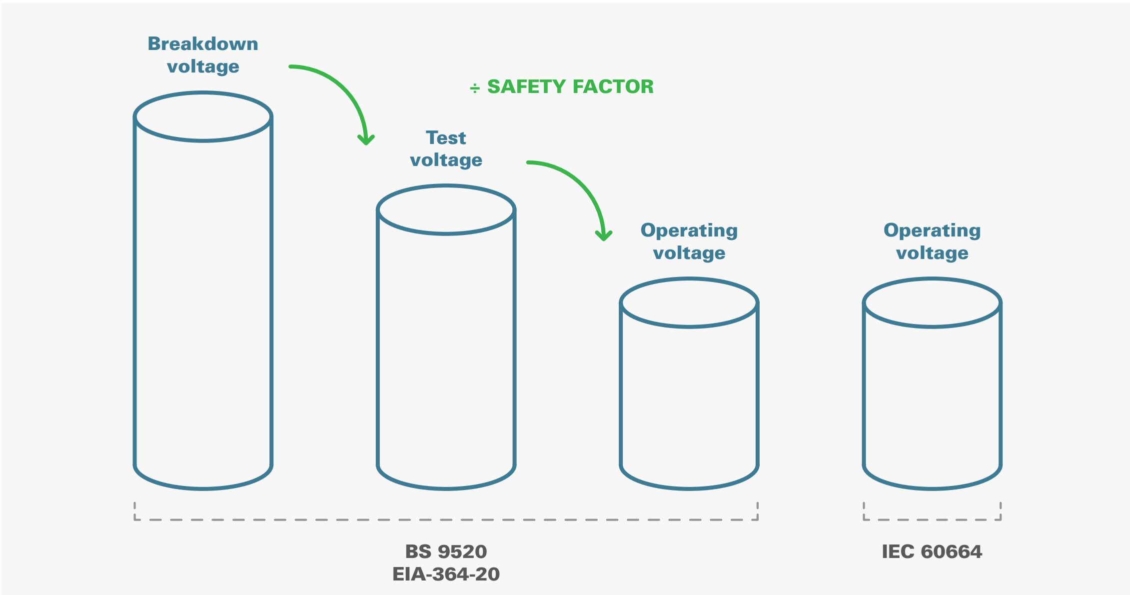


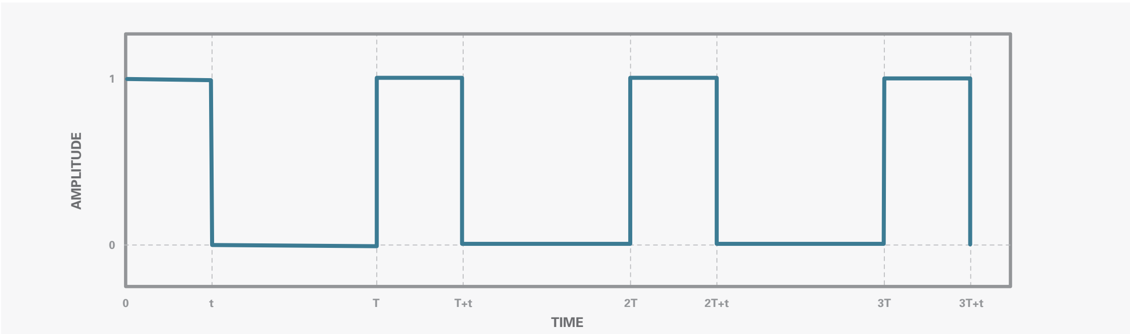
Fig. 2 shows a comparison of both design methods. No precise rule can be given for the selection of the best method to determine operating voltage. Thorough study of the specific application, the operating conditions and relevant safety rules is essential for the designer.

3. FREQUENCY EFFECTS

Both methods described in Figure 2 are valid for conventional DC or low-frequency AC conditions. At high frequencies, additional physical effects in the insulating material may significantly affect the performance of the connector. Of course, the connector cannot be considered as an isolated element; in such critical situations, the response of the entire system including cables and other devices should be evaluated.

At low frequencies, electrical charges on the insulator surface will move according to their relative freedom of movement; time within a cycle is sufficient to relax the local accumulated charges. At high frequencies (typically above the kHz range), the simultaneous displacement of these charges leads to the well-known corona effect or partial discharge, accelerating the breakdown.

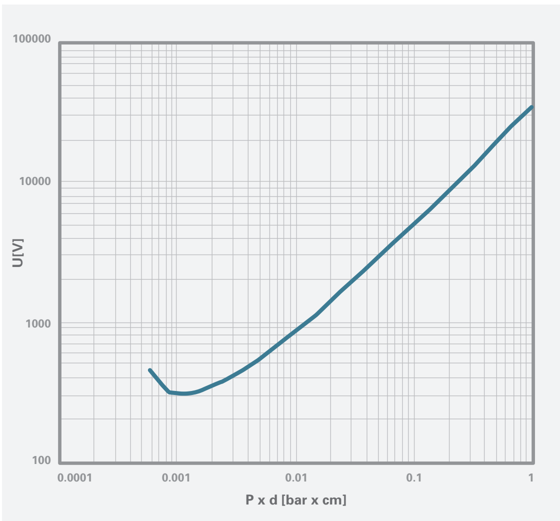
High-frequency pulsed signals are particularly critical as they exhibit very high ∂u/∂t values. No specific guidelines can be given to adapt operating voltage to these conditions, which require individual testing. But as a rule of thumb, based on IEC 60664 data, one can estimate that a derating down to 50% may be needed in critical kHz frequencies.



SUCH SIGNALS ARE KNOWN TO GENERATE DISCHARGES IN CONNECTORS WELL BELOW DC OPERATING LIMITS[1]

4. EFFECT OF AIR PRESSURE

The insulation properties of all gases, including air, are strongly influenced by their pressure. This pressure directly determines the density of the gas, and therefore the actual breakdown voltage. Connectors and other similar devices using air as an insulator must be designed to take this fact into account. Furthermore, correction factors must also be applied to the connector's normal voltage rating for those applications in which the connector is expected to operate at non-standard atmospheric pressure.



[1]*source : Wikipedia http://en.wikipedia.org/wiki/Pulse_wave*

The breakdown voltage of a connector in a gas will decrease as the pressure decreases. This phenomenon is called Paschen’s law, and the curves are of empirical origin.

Specialized high-voltage literature can provide more details and data for specific gases, for example “Traité d’Electricité XXII « Haute Tension » Swiss Federal Institute of Technology, Lausanne by Aguet and Ianovici.”

4.1 Use of a Connector in a Vacuum Application

Paschen’s law is essential in vacuum applications; the graph provided herein can assist in determining the correct parameters of the connector’s operation, but thorough testing is essential.

It is also recommended that power be switched off during the degassing phase of vacuum equipment to avoid exposure of the connector to the most critical low-insulating atmosphere.

4.2 Use of a Connector at High Altitude

Generally, the physical phenomena influencing breakdown voltage at elevated altitudes are similar to those in a partial vacuum; however, special attention should be paid to the fact that specific atmospheric parameters, like temperature and moisture, which also affect dielectric behavior, are of an uncontrolled nature.

Typical Air pressure (mbar)	Altitude (m)	Correction factor for insulation distances
800	2000	1.00
700	3000	1.14
620	4000	1.29
540	5000	1.48
470	6000	1.70
410	7000	1.95
355	8000	2.25
305	9000	2.62
265	10000	3.02
120	15000	6.67
55	20000	14.50

ADDITIONAL RESOURCES

Engineers determining the operating voltage of a connector must take the operating environment into consideration, including the impact of the environment on cables and insulating material. They must do this while maintaining all safety features and functions required by specific regulations or standards for their devices. Additional resources are available online and for purchase through various standards organizations.

Aguet, M., and Ianovici, M.: 'Phenomenes transitoires en Haute Tension' in "Traité d'Electricité Vol. XXII, Swiss Federal Institute of Technology, Lausanne, 1982

IEC regulations cited are available for purchase at *www.iec.ch*

IEC 60512-4-1 preview PDF in French and English – *http://webstore.iec.ch*

ANSI/EIA-364-20D-2008 Withstanding Voltage Test Procedure For Electrical Connectors, Sockets, And Coaxial Contacts – h*ttp://www.ec-central.org*

Pulse Wave – *http://en.wikipedia.org/wiki/Pulse_wave*

Paschen's Law – *http://en.wikipedia.org/wiki/Paschen's_law*

LIMITATIONS

The recommendations provided in this present White Paper are given only with the intention of assisting with the choice of a connector with respect to its particular application. It remains always the responsibility of the equipment manufacturer, and not the connector supplier, to determine the appropriate technical standards, as well as the necessary safety factors for a given application.

ABOUT FISCHER CONNECTORS

Fischer Connectors has been designing, manufacturing and distributing high-performance connectors and cable assembly solutions for more than 60 years. Known for their reliability, precision and resistance to demanding and harsh environments, Fischer Connectors' products are commonly used in fields requiring faultless quality, such as medical equipment, industrial instrumentation, measuring and testing devices, broadcast, telecommunication and military forces worldwide.

Primary design and manufacturing facilities are located in Saint-Prex, Switzerland, with subsidiaries and distributors located worldwide.

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