MPF PRODUCTS, INC.

MANUFACTURING PRECISION
FEEDTHROUGH PRODUCTS

# Breakdown in Electrical Feedthroughs – Effects of Gases, Vacuum, Dielectric Surfaces and Gap Spacings on the Dielectric Withstanding Voltage

Vacuum feedthrough connectors are designed to pass current, impress voltage or connect power across a sealed boundary. These electrical products provide an insulated connection between atmospheric pressure on the air-side and high and ultrahigh vacuum on the other.

Most common gases and vacuum are insulating. The breakdown voltage in air is approximately 3MV/m. The maximum field strength without breakdown in vacuum is approximately ten times that or approximately 30MV/m. These limits are as measured through space – electrode to electrode and are used to ensure the safe high-voltage design of electrical feedthroughs.

If there is any material besides air or high vacuum between the electrode surfaces, the limits are not the same. A few examples are illustrative: Fused Silica has a dielectric strength of around 600MV/m.

Theoretically, a fused silica plate 0.1mm thick could withstand 60kV. And Teflon film has a dielectric strength of over 150MV/m, so a .01mm thick Teflon coating could withstand 1.5kV.

In contrast, the dielectric strengths of many gases are much lower than that of air. Consequently, if one is attempting to make electrical connections within gas-filled chambers, the high voltage standoff can be much lower. In some arrangements, both electrodes are in contact with lower dielectric strength material. The dielectric strength in Argon at one-atmosphere pressure is only 0.6MV/m and in Neon is only 0.06MV/m. The electrode gap spacing in Neon at one-atmosphere would need to be 50 times that in air to hold off the same voltage! Similarly, the electrode spacing in Argon would require five times that in the air.

The condition “gas-filled” includes partial vacuum (p > 10 -4 Torr) which can lead to a breakdown condition in gases known as “glow discharge” that can occur at relatively low voltages. The dielectric strength of air at the Paschen minimum 327 V. This low voltage breakdown condition corresponds with the reduced pressure-gap minimum of 0.567 Torr-cm. If the residual gas is air, the spacing would need to be much greater than 0.567 m at 0.01 Torr in order to hold off 327V. Compare this very large spacing to the 10 micron gap required to hold off 327 V at in high vacuum (p < 10 -4 Torr). At this partial pressure of 0.01 Torr the spacing is 50,000 to 100,000 times greater to hold off the same voltage. The breakdown voltage of other gases like helium, argon, neon, and nitrogen are all a little lower than in residual air alone under the glow discharge condition. Glow discharge breakdown can occur during vacuum system roughing. During pump down, the pressure of the vacuum vessel will drop to the Paschen minimum voltage limit sometime in the process of achieving high-vacuum. Disconnecting all high voltage sources during vacuum system pump down will avoid this surprisingly frequent problem.