



# Hermetic Leak Rate Testing Limits and Qualification for Connectors Used in Military and Aerospace Applications

Hermetic sealing is central to the long-term reliability of military and aerospace electronics. Hermeticity—defined simply as the condition of being airtight—prevents the ingress of moisture, outgassing products, and contaminants that can degrade electronics or lead to failure over the life of a mission. While interconnect engineers can partially mitigate moisture risks through conformal coatings, backpotting, environmental cable-to-connector sealing, and other protective design strategies, the most robust approach remains the use of true hermetically-sealed interconnects. Glass-to-metal sealed connectors, including rectangular, circular, and RF coaxial styles, ensure that internal cavity moisture remains below the threshold at which condensation can occur, even after decades of thermal cycling and pressure variations. These same attributes make hermetic connectors indispensable in vacuum chambers, cryogenic assemblies, high-altitude payloads, and enclosures filled with inert gases.

Moisture management is a persistent challenge in sealed electronics. Even modest levels of water vapor can condense during variations in temperature and altitude, causing corrosion, dielectric breakdown, and electrical shorts. High-frequency systems can be particularly sensitive: small changes in dielectric environment or corrosion at contact interfaces can alter insertion loss or return loss performance. Glass-to-metal seals provide a stable, impermeable barrier that is far more resistant to moisture diffusion than polymeric sealing compounds. This extremely low permeability is essential not only for aircraft-borne equipment with 20- to 30-year service expectations but also for spacecraft assemblies where maintenance is impossible after launch.

Because hermeticity is integral to performance, every aerospace-qualified hermetic connector is verified through helium leak testing prior to shipment. Helium is used because its atomic size allows it to pass through extremely fine defects in a seal, its inert nature prevents interaction with connector materials, and its scarcity in the atmosphere makes it easy to detect with a mass spectrometer. A typical test applies a one-atmosphere vacuum to one side of the connector while helium surrounds the opposite side. If helium penetrates the seal, the mass spectrometer will register the leakage rate. Depending on connector configuration, fine-leak testing may be performed using either a vacuum method or a “bombing” technique, both of which are described in MIL-STD-883, Method 1014. Gross-leak testing is also performed to screen out catastrophic sealing failures, employing the overpressure or fluorocarbon-immersion methods outlined in the same standard.

A variety of U.S. military, NASA, and international standards govern hermeticity requirements and test methods. MIL-STD-883, Method 1014 remains the most widely referenced specification and defines the acceptable leak-rate limits and procedures for fine and gross leak testing. Although originally written for microelectronics, its methods are routinely applied to hermetic connectors. MIL-STD-202, Method 112 provides an additional framework for sealing tests on passive components and connector assemblies, especially under mechanical or environmental stress. Many connector detail specifications—including MIL-DTL-38999, MIL-DTL-24308, and MIL-DTL-32139—reference hermeticity verification as part of qualification. NASA workmanship and reliability standards, such as NASA-STD-8739.14 and NASA-HDBK-8739.23, reinforce similar requirements for spaceflight hardware. International programs often rely on ECSS-Q-ST-70-02, which incorporates hermetic leak limitations into broader thermal-vacuum qualification guidance.



Leak-rate limits vary depending on connector style, internal free volume, and expected mission duration, but typical aerospace practice calls for fine-leak thresholds of  $1 \times 10^{-7}$  atm-cc/sec helium or better. Space-flight hardware and high-reliability avionics assemblies often require even lower values—on the order of  $1 \times 10^{-8}$  atm-cc/sec—to ensure negligible moisture accumulation over many years. Gross-leak failures are not permissible under any conditions; a connector must demonstrate an absence of detectable leakage when subjected to gross-test procedures. Designers sometimes apply volume-based moisture-ingress models such as the Airborne Moisture Content (AMC) method to confirm that the total water vapor entering a sealed cavity over the system's lifetime remains below condensation limits.

Qualification of hermetic connectors for military and aerospace platforms involves more than a single leak test. Mechanical and environmental stresses—thermal cycling, vibration, shock, altitude exposure, and corrosive atmospheres—are typically applied before and after hermeticity testing to verify that seals remain stable under mission-representative conditions. For RF coaxial connectors such as SMA, TNC, and BNC, qualification also incorporates return-loss and insertion-loss verification, shielding-effectiveness measurements, and performance checks after thermal shock or mechanical load. The stability of glass-to-metal seals depends heavily on compatible coefficients of thermal expansion among the shell, glass, and conductor materials. Qualification programs therefore pay close attention to metallurgical factors, glass chemistry, plating thickness, and the torque or clamping loads applied during assembly.

Despite the robustness of hermetic connectors, failures can occur when processes or materials deviate from specification. Common issues include micro-cracks in glass resulting from thermal mismatch, voids or inclusions within the seal, plating porosity that enables moisture migration, or shell deformation caused by excessive installation torque. Manufacturers typically address these issues through improved process control—better furnace profiles, tighter material certification, enhanced optical inspection methods, and 100% leak testing for all production products.

Hermetic connectors remain one of the most effective tools for protecting mission-critical electronics from moisture and contamination. Helium leak testing, grounded in well-established military and NASA standards, provides a reliable and repeatable means of certifying hermetic performance. For aerospace system engineers, selecting connectors built to stringent leak-rate thresholds and ensuring that they are qualified under relevant environmental conditions is essential for achieving the long-term reliability demanded of modern aircraft, spacecraft, and high-reliability defense systems.