METROLOGY & VACUUM TROUBLESHOOTING PROTOCOL

ION GETTER PUMP LEAK HUNTING, VACUUM INTEGRITY & FAULT DIAGNOSTICS

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Target Pumps: Gamma Vacuum TiTan / Agilent VacIon	**Target Controllers:** DIGITEL SPCe/QPC & Agilent 4UHV/IPCMini	**Facility Location:** UHV Cleanroom Bay 3

1. High-Voltage Safety Precautions & Testing Principles

Ion pumps operate at lethal bias potential (**+3,000 V to +7,000 V DC** for Diode/Differential; **-7,000 V DC** for Triode/StarCell). Prior to open-flange inspection, cable disconnecting, or internal service, complete Lockout/Tagout (LOTO) and zero-energy verification. Always confirm the 10kV SHV cable ground braid is securely clamped to earth ground. Maintain awareness of external permanent magnets (stray field ≤ **150 mT**).

> **CRITICAL SAFETY RULE:** Never energize an ion pump at pressures above **1×10^{-4} mbar (100 μTorr)**. Starting at elevated pressures causes continuous glow discharge, severe cathode sputtering, insulator contamination, and instantaneous high-voltage controller overload trips.

2. Primary Leak Hunting Methodologies for Ion Pumped Systems

Method / Technique	Operating Principle & Sensitivity	Application & Detection Procedure
Ion Pump Current Response (Internal Gauge Method)	Uses ion pump current draw as a gas indicator. Helium entering a leak alters local ion current due to gas ionization differences. **Sensitivity:** ~10^{-8} mbar·l/s	Monitor DIGITEL / 4UHV current readout while spraying fine helium jets around CF flanges and feedthroughs. Look for sharp current spikes (ΔI).
Helium Leak Detector (Counterflow / Spray Method)	Connects portable MS leak detector (Leybold PHOENIX / Agilent HLD C15) to roughing manifold. **Sensitivity:** < 5×10^{-12} mbar·l/s	Evacuate chamber with dry scroll / turbomolecular backing system. Spray helium systematically starting from top to bottom over seals and welds.
Pressure Rise Test (Rate of Rise: dp/dt)	Isolates chamber and logs pressure rise over fixed time interval (Δt). Calculates total leak rate: $Q = V \times (dp/dt)$.	Distinguishes real physical leaks (constant linear slope dp/dt) from surface outgassing (asymptotic flattening curve).
RGA Gas Analysis (Residual Gas Analyzer)	Quadrupole mass spectrometer (Leybold LEYSPEC RGA) scans m/z 1 to 200. **Detection Limit:** 10^{-11} mbar partial pressure	Monitor Mass 28 (N_2) vs Mass 32 (O_2). A **4:1 ratio** confirms an atmospheric air leak; dominant Mass 18 (H_2O) indicates outgassing.

3. Step-by-Step Executable Leak Hunting Protocol

Step 3.1 — Setup: Rough chamber down below 1×10^{-5} mbar using a dry scroll pump. Energize ion pump at nominal bias (+7.0 kV DC). Connect MS leak detector to foreline manifold.

Step 3.2 — Reference Check: Zero leak detector against a DAkkS-certified helium reference leak (Leybold TL 6, nominal 1×10^{-7} mbar·l/s). Verify response time t_A < 2 sec.

Step 3.3 — Systematic Spray: Apply helium gas via needle valve spray gun. Begin at highest elevation and work downward over OFHC copper CF gaskets, feedthrough insulators, and pinch-off tubes.

Step 3.4 — Verification: When helium response occurs, pause spray for 30s to clear signal. Re-spray localized spot with minimal flow to isolate leak. Log peak leak rate Q_{He}.

4. Comprehensive Ion Pump Troubleshooting Diagnostic Matrix

Fault / Symptom	Probable Root Cause	Diagnostic Verification Check	Corrective Maintenance Action
High Leakage Current / Field Emission (Current reads high, vacuum is good)	Titanium whisker growth or conductive sputtered film across ceramic insulator.	500V DC Megger test (< 10 GΩ = breakdown). HV in blanked UHV (> 10 nA leakage).	Perform controlled HV hi-potting / voltage pulsing to burn off whiskers. If shorted, replace ceramic insulator assembly.
Argon Instability / Pressure Fluctuation (Periodic pressure bursts)	Saturated Conventional Diode (CV) cathodes re-emitting trapped noble gases.	RGA spectrum shows periodic Mass 40 (Argon) spikes during steady operation.	Replace Diode elements with Differential (DI) or Triode (TR/StarCell) elements designed for noble gas stability.
Controller HV Trip / Over-Current Stall (HV trips immediately on start)	Excessive starting pressure (> 1×10^{-4} mbar) causing continuous glow discharge.	Controller current saturates at > 40 mA for > 120 sec before tripping.	Evacuate chamber with dry scroll / turbomolecular backing pump down to < 1×10^{-5} mbar before re-energizing HV.
HV Cable / Connector Arcing (Audible snapping, voltage drop)	Damaged 10kV SHV cable, moisture ingress, or broken ground braid connection.	Visual check shows carbon tracking on SHV teflon insulator; ground continuity > 0.1 Ω.	Clean feedthrough teflon with isopropyl alcohol; dry thoroughly. Replace damaged SHV cable harness; torque ground clamp.
Outgassing / Virtual Leak (Pressure plateaus at 10^{-6} mbar)	Trapped gas in blind screw holes or heavy water vapor absorbed on chamber walls.	Pressure rise curve (dp/dt) shows asymptotic curve. RGA shows dominant Mass 18 (H_2O).	Install vented screws in blind tapped holes. Perform 200°C system bakeout for 24 hours under active roughing/ion pumping.

5. Technician Verification Checklist & Field Test Readback Log

Phase	Inspection Point / Parameter	Acceptance Criteria / Target Spec	Field Readback Value	Status
Pre-Test	Ground Braid & SHV Cable	Ground resistance < 0.1 Ω; SHV latch locked	R = 0.04 Ω / Locked	[X] PASS
Pre-Test	Roughing Vacuum Threshold	Pressure ≤ 1×10^{-5} mbar before HV ON	2.1×10^{-5} mbar	[X] PASS
Leak Test	MS Leak Detector Calibration	Zeroed to Leybold TL 6 leak (1×10^{-7} mbar·l/s)	Ref Response: 1.05×10^{-7}	[X] PASS
Leak Test	System Spray Inspection	No helium signal > 1×10^{-10} mbar·l/s	Max Background: 2×10^{-11}	[X] PASS
Leak Test	RGA Air Leak Audit	Mass 28 / Mass 32 ratio < 4:1 (No N_2 air leak)	N_2/O_2 Ratio: 1.2:1 (Clean)	[X] PASS
Diagnostic	Insulator Megger Resistance	Resistance > 10 GΩ at 500V DC Megger	> 50 GΩ (No Whisker)	[X] PASS
Diagnostic	HV Field Emission Leakage	Leakage current < 10 nA in blanked UHV	3.2 nA at +7.0 kV DC	[X] PASS
Final UHV	Ultimate Base Vacuum Check	System achieves target UHV base (< 1×10^{-9} mbar)	4.2×10^{-10} mbar	[X] PASS

6. Technician Field Observations & Sign-Off Authorization

Field Notes: Helium spray leak check performed on Gamma Vacuum TiTan 75S ion pump attached to UHV Chamber 4. Initial rate of rise test indicated micro-leak at CF-40 bypass valve flange ($Q_{He} = 3.4 \times 10^{-8}$ mbar·l/s). Replaced gasket with silver-plated OFHC copper seal; re-torqued bolts to 16 N·m. Post-repair spray test confirmed leak-tight seal (< 2×10^{-11} mbar·l/s). High voltage leakage current verified clean at 3.2 nA. System achieved ultimate base vacuum of 4.2×10^{-10} mbar following 12-hour 180°C bakeout.

Performing Technician: Kadeem Manning	**Role / Title:** Tier II Facility Technician
Technician Signature: Kadeem Manning	**Date Signed:** March 15, 2022
Quality QA Reviewer: Dr. Marcus Vance	**QA Signature:** M. Vance
System Vacuum Status: [X] CERTIFIED LEAK-TIGHT	**Certificate Tag ID:** CERT-LEAK-2022-0315