

ROUGHING VACUUM PUMP TROUBLESHOOTING & DIAGNOSTIC MANUAL

Systematic Decision Trees, Failure Root Cause Analysis & Data-Quality Isolation Protocols

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1. Purpose & Diagnostic Methodology

This Standard Operating Procedure (SOP) provides a rigorous, step-by-step diagnostic decision framework for identifying, isolating, and resolving mechanical, electrical, and vacuum performance anomalies in dual-stage oil-sealed rotary vane and dry roughing pumps. Operating in accordance with EPA QA/QC guidelines and OSHA safety standards, technicians must execute systematic isolation tests to distinguish between internal pump degradation and external vacuum chamber issues before replacing hardware.

CRITICAL SAFETY WARNING: Before performing electrical or internal mechanical diagnostics, verify Lockout/Tagout (LOTO) per OSHA 29 CFR 1910.147. Operating pumps reach temperatures of 60°C–80°C; allow 20 minutes cooling before draining fluids or dismantling exhaust fittings.

2. Master Troubleshooting & Diagnostic Matrix

Symptom / Issue	Likely Root Cause	Step-by-Step Diagnostic & Corrective Action	Target Acceptance Threshold
1. Vacuum Stalls at Rough Range (~1 Torr)	- Gross external flange/O-ring leak - Failing roughing pump vanes/seals - Gas ballast valve left open	- Check chamber door O-ring for hair/dust/flattening. - Close inline isolation valve directly at pump inlet. - Measure standalone pump base pressure with Pirani gauge. - Verify gas ballast valve is tightly closed.	Standalone base pressure < 100 mTorr (10–20 microns)
2. System Stalls at \$10^{-4}\$ Torr Range	- Absorbed moisture outgassing - Minor seal or fitting leak - Hydrocarbon backstreaming	- Execute mild chamber bake-out (100°C–150°C). - Monitor Residual Gas Analyzer (RGA) \$m/z=18\$ (\$H_2O\$) vs \$m/z=28\$ (\$N_2\$) / \$m/z=32\$ (\$O_2\$) peak ratio. - If \$N_2/O_2\$ ratio is 4:1, execute Helium Leak Check with mass spec detector.	Helium leak rate < \$5 \times 10^{-9} \text{ ext{mbar}\cdot ext{L/s}}\$
3. Excessive Operating Noise & Vibration	- Cavitation (marbles sound) - Hydraulic groaning (water overload) - Foreign object trapped in vanes - Worn bearings/coupling misalignment	- If rattling/cavitation, open gas ballast briefly to de-aerate. - If groaning, inspect oil sight glass for water emulsification; drain liquid slugs. - If metallic knocking, perform LOTO, inspect coupling and vane height. - Check V-belt tension and motor mounting bolts.	Vibration < ISO 10816-3 baseline; Amperage within $\pm 5\%$ nameplate
4. Hydrocarbon Backstreaming Film	- Improper shutdown sequence - Anti-suckback valve failure - Operating below \$10^{-1}\$ Torr without gas sweep	- Inspect foreline interior for rainbow sheen/yellow film. - Monitor RGA cracking peaks at \$m/z=41, 43, 55, 57\$. - Verify electro-pneumatic safety valve shuts in < 20 ms upon power loss. - Install alumina molecular sieve or LN2 cold trap.	Zero oil film in viewports; RGA hydrocarbon peaks at noise floor
5. Motor Overheating / Trips Circuit	- Blocked motor cooling fins - Clogged exhaust mist filter - High inlet gas load/pressure - Seized internal mechanism	- Measure motor current draw under load. - Inspect exhaust filter differential pressure; replace clogged element. - Clean dust from motor cooling fins and shroud. - Verify voltage supply matches 115V $\pm$ 10%.	Motor temperature < 70°C; Amperage \$le\$ Nameplate FLA

6. Rapid Oil Darkening / Discoloration	- Process gas chemical attack - High operating temperature - Particulate/moisture ingress	- Check sight glass color against ISO scale. - If milky/foamy, open gas ballast for 30 min to purge moisture. - If dark brown/black, execute full oil drain and TKO-FF flush. - Inspect intake dust filter element.	Oil clarity clear to light-amber; Change interval $\leq$ 500 hrs
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3. Specialized Diagnostic Workflows

A. Standalone Base Pressure Isolation Workflow

When system pressure stalls above specification, technicians must perform an isolation test to identify whether the issue originates in the roughing pump or the connected vacuum chamber:

- Install a calibrated convection/Pirani gauge directly onto the pump inlet flange using an KF-25 isolation valve.
- Start the pump with the isolation valve closed and gas ballast turned off.
- Record ultimate base pressure after 5 minutes of operation.
 - Result A** ($\leq 100 \text{ mTorr}$ / $10^{-20} \mu\text{m}$): Roughing pump is healthy. Problem lies in foreline connections or chamber door seals.
 - Result B** ($> 100 \text{ mTorr}$): Pump performance is degraded. Proceed to Oil Inspection & Vane Audit.

B. Hydrocarbon Backstreaming Prevention Protocol

Oil backstreaming occurs when roughing pump oil vapors migrate upstream into the vacuum chamber during shutdown or low-pressure operation ($< 10^{-1} \text{ Torr}$). To eliminate backstreaming:

- Proper Shutdown Sequence:** Always close the foreline isolation valve *before* turning off pump power.
- Anti-Suckback Protection:** Verify automatic fast-closing safety valves spring shut in $< 20 \text{ ms}$ upon power loss.
- Gas Ballast Sweep:** Introduce a dry N_2 purge ($> 10^{-1} \text{ Torr}$) to maintain viscous gas flow toward the pump.
- RGA Tracking:** Confirm backstreaming by monitoring hydrocarbon cracking mass peaks at $m/z = 41, 43, 55, 57$.

C. Vacuum Decay & Leak-Down Rate Protocol

To verify vacuum boundary integrity following servicing, perform a 5-minute isolation decay test:

- Evacuate system to base pressure, isolate the pump, and measure rate of pressure rise ($\Delta P / \Delta t$).
- Acceptance Criterion:** Leak-down rate must be $< 5\%$ of total system volume per minute.

4. Authorization & Sign-Off Block

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