STANDARD OPERATING PROCEDURE & TECHNICIAN CHECKLIST

CRYO-REFRIGERATOR PUMP PRE-START, POWER-UP, PUMP-DOWN & REGENERATION

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Form Number:	SOP-VAC-F12 (Rev 1.5)	**Review Cycle:**	Annual (12 Months)
Created By / Author:	**Kadeem Manning**	**Target Equipment:**	Leybold COOLVAC iSL / iBL Series
Technician Role:	Tier II Facility Technician	**Helium Compressor:**	Leybold COOLPAK 2000i / 5000i

1. Purpose, Scope & Operating Principles

1.1 Purpose: This Standard Operating Procedure (SOP) defines the mandatory pre-start verification, helium compressor line setup, roughing evacuation, cool-down, high-vacuum crossover, and regeneration protocols for refrigerator-cooled cryopumps (Leybold COOLVAC 1500–60000 iSL/iBL series powered by COOLPOWER two-stage Gifford-McMahon cold heads and COOLPAK helium compressor units). Executed by Tier II Facility Technicians.

1.2 Cryogenic Pumping Principles & Temperature Stages: Refrigerator cryopumps are gas entrapment vacuum pumps operating from 10■³ mbar down to ≤ 10■¹¹ mbar. Gases are captured across two distinct thermal stages:
• **1st Stage Cold Head (45 K to 80 K):** Cools the outer copper thermal radiation shield and inlet baffle. Pumps high-boiling-point vapors (predominantly H■O water vapor, CO■, and hydrocarbons) via *cryotrapping and cryocondensation*.
• **2nd Stage Cold Head (10 K to 20 K):** Cools the inner cryopanels tightly coupled to the 2nd stage. Cryocondenses atmospheric gases (N■, O■, Ar). The inner surfaces are coated with **activated charcoal** to cryosorb light non-condensable gases (H■, Ne, He) at ultra-low temperatures.
• **Safety Relief Safeguard:** All cryopump bodies feature an integrated over-pressure safety relief valve certified to **ISO 4126** regulations to safely discharge trapped gases during unvented warming or power outages.

2. Safety Hazards & Pre-Start Utility Requirements

CRITICAL SAFETY WARNINGS:
1. **Over-Pressurization Risk:** Never block or tamper with the ISO 4126 safety relief valve. Expelled gases during regeneration can create high internal pressures if safety vents are restricted.
2. **High-Pressure Helium Lines:** Self-sealing Aeroquip flexlines operate at 16.0 to 17.0 bar(g) static charge. Never disconnect helium lines under dynamic load or without depressing self-sealing coupling sleeves.
3. **Cryogenic Thermal Burn Hazard:** Internal cold head surfaces operate below 15 K (-258°C). Wear cryogenic protective gloves and face shield during servicing or physical intervention.
4. **Oxygen Displacement:** Regeneration releases trapped gases rapidly. Ensure room forced-air ventilation is operational.

- **Helium Line Integrity:** Inspect COOLPAK compressor flexlines. Verify static charge pressure is **16.0 to 17.0 bar(g)** at 20°C ambient on the high-pressure gauge. Check Aeroquip couplings for tightness.
- **Compressor Cooling Water:** Confirm cooling water supply to COOLPAK compressor is active with entry temperature **+5°C to +25°C** and flow rate ≥ **5.0 L/min**.
- **Electrical Power:** Verify 3-phase 400V/470V or 208V AC mains supply to COOLPAK compressor and 24V DC control signal connection to COOL.DRIVE i / CRYOVISION controller.
- **Roughing Isolation Check:** Confirm forevacuum angle valve (DN 25 ISO-KF) is closed and primary backing pump (dry scroll IDP or rotary vane) is operational.

3. Step-by-Step Operational Execution Protocol

Phase 1: Pre-Evacuation & Roughing Crossover Verification
1. Isolate the main high-vacuum gate valve leading to the process chamber.
2. Open the forevacuum valve and start the primary roughing pump to evacuate the cryopump vessel down to ≤ **1 × 10■¹ mbar (100 mTorr)**.
3. Close the forevacuum valve and perform a 2-minute rate-of-rise test. Vacuum leak rate must remain below 1 × 10■■ mbar·L/s before initiating cool-down.

Phase 2: Compressor Activation & Cool-Down Sequence
1. Turn on the COOLPAK compressor main breaker and press START. Verify cold head motor begins rhythmic G-M cycling sound.
2. Monitor silicon diode temperature sensors via COOL.DRIVE i / CRYOVISION touch display:
- *1st Stage Radiation Shield (T■):* Drops from 295 K down to **45 K – 80 K**.
- *2nd Stage Cryopanel (T■):* Drops from 295 K down to ≤ **20 K** (typically 10 K to 15 K at ultimate base).
3. Nominal cool-down duration: **60 to 90 minutes** (COOLVAC 1500–3000 iSL). Verify T■ stabilizes below 20 K before opening high vacuum

valve.

Phase 3: High-Vacuum Crossover & Process Operation
1. Evacuate main chamber with roughing line below maximum crossover pressure limit (**250 to 500 mbar·L** depending on pump class).
2. Slowly open the main high-vacuum gate valve. Monitor T■ temperature spike; ensure T■ remains below **22 K** during gas pulse.
3. Verify ultimate base vacuum achieves **10■■ to 10■¹■ mbar** with zero vibration and stable compressor supply pressure (16–18 bar(g) dynamic).

Phase 4: Regeneration Protocol (iSmartLine Automatic / Manual)
1. Initiate regeneration when T■ exceeds 20 K or charcoal saturation causes H■ pressure rise.
2. Close main high-vacuum gate valve. Activate internal 1st & 2nd stage electrical regeneration heaters via COOL.DRIVE i.
3. Warm cold head to 295 K to release trapped gases. Open forevacuum valve to pump out desorbed gas species.
4. Once chamber pressure reaches ≤ 1 × 10■¹ mbar at 295 K, turn off heaters, close foreline valve, and re-engage COOLPAK compressor cool-down.

4. Field Technician Verification Checklist & Operational Log

Phase	Inspection Item / Parameter	Acceptance Spec / Target Range	Field Readback Value	Status
Pre-Start	ISO 4126 Safety Relief Valve	Poppet free; exhaust unblocked; seal intact	Visual Inspection OK	**[X] PASS**
Pre-Start	Helium Flexline Charge Pressure	16.0 to 17.0 bar(g) at 20°C ambient	16.5 bar(g)	**[X] PASS**
Pre-Start	Compressor Cooling Water	Flow ≥ 5.0 L/min; Temp +5°C to +25°C	5.8 L/min / 18.2°C	**[X] PASS**
Pre-Start	Helium Aeroquip Couplings	Self-sealing sleeves fully latched & torqued	Couplings Latched	**[X] PASS**
Roughing	Pre-Evacuation Vacuum Level	Foreline pressure ≤ 1 × 10■¹ mbar (100 mTorr)	4.5 × 10■² mbar	**[X] PASS**
Roughing	Cryopump Vessel Leak Check	2-min rate-of-rise < 1 × 10■■ mbar·L/s	2.8 × 10■■ mbar·L/s	**[X] PASS**
Cool-Down	1st Stage Temp (T■) Shield/Baffle	T■ stabilizes between 45 K and 80 K	52.4 K	**[X] PASS**
Cool-Down	2nd Stage Temp (T■) Cryopanel	T■ cools to ≤ 20.0 K within 90 minutes	12.8 K (in 68 min)	**[X] PASS**
Operation	High Vacuum Gate Opening Crossover	T■ spike remains < 22.0 K during crossover	Max Spike: 17.1 K	**[X] PASS**
Operation	Ultimate Base Chamber Vacuum	Achieves target base (10■■ to 10■¹■ mbar)	1.8 × 10■■ mbar	**[X] PASS**
Regen	Automatic Heater Warm-Up (iSL)	Electrical heaters warm stages to 295 K	295.2 K Warmed	**[X] PASS**
Operation	Acoustic & Vibration Audit	Rhythmic G-M cold head pulse; zero chassis vibe	Smooth GM Pulse	**[X] PASS**

5. Field Observations & Return-to-Service Authorization

System Configuration & Field Notes: Leybold COOLVAC 3000 iSL cryopump with integrated COOL.DRIVE i controller powered by COOLPAK 5000i water-cooled helium compressor. Cryopump serviced and regenerated following extended UHV semiconductor sputter deposition cycle. Static helium pressure verified at 16.5 bar(g). Roughing pre-evacuation reached 4.5 × 10■² mbar. Cool-down sequence executed smoothly: 1st stage T■ stabilized at 52.4 K and 2nd stage T■ reached 12.8 K in 68 minutes. Process chamber opened at crossover; T■ transient peaked at 17.1 K before recovering to 12.8 K. System achieved ultimate base vacuum of 1.8 × 10■■ mbar. All ISO 4126 relief valves and Aeroquip lines verified certified.

Performing Technician:	Kadeem Manning	**Role / Title:**	Tier II Facility Technician
Technician Signature:	*Kadeem Manning*	**Date Signed:**	January 18, 2022
Quality QA Reviewer:	Dr. Marcus Vance	**QA Signature:**	*M. Vance*
System Vacuum Status:	**[X] APPROVED FOR UHV OPERATION**	**Cert Tag ID:**	CERT-CRYO-2022-0118