The Operation Manual of

Pagani & Lamborghini

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1 Important

Authorized operating personal only.
If at any point you are uncomfortable or do not know what you are doing, find someone who does.

The manual provided by Bluefors is a helpful reference, but **DO NOT** follow the procedures for cooldown and warm-up given in that manual - you risk the destruction of valuable equipment! Operate the fridge only as described in this document.

Contents

2 General Notes

- The scroll pumps SCROLL1 and SCROLL2 take about 10 seconds to run up. After turning them on, wait until you hear a relay click and give them a few seconds to get up to speed before continuing. SCROLL1 has mixture on both sides and will slowly leak gas back from the P_4 manifold to the $\overline{V10V11}$ manifold as well as internal spaces inside the pump. This is normal. It takes about 20 minuites to fully recover a quoted P_4 value.
- Do not leave the fridge in LOCAL mode. Otherwise you are left powerless when logging in remotely in case of emergency.
- Since we rarely have a need to control T_{MC}, we usually use the “sample heater” output of the LakeShore for controlling the still temperature. The correct wiring is thus: Heater-Still attached to “Sample heater” and Heater-MC not attached.
- This is a living document and is updated to reflex the best known operating procedures. If you spot a mistake or think of an improvement contact MJS or BT.

3 Procedures

3.1 Starting Software

Usually the software is kept running, so you might not have to start the programs. Ensure that all the following are running

- ValveControl. Check that is does not report communication errors with any device, except the Pulse tube compressors (when they are powered off). Make sure it is correctly reading the status of valves, the pressures, and the flow.
- LakeShore Reader. Make sure it reads the temperatures from the LakeShore correctly.
- TeamViewer. Record the ID so you can log in later.
- Fridge tracking. The webpage of the fridge is updated by the Python script `fridge_tracker3.py`. Stop it if it is running in a terminal window (Ctrl+C). Open the script in an editor and set the startdate value (line 13) to the current date (or whenever you want the data displayed on the web to start). Then restart the script by running `python fridge_tracker3.py`.

3.2 Pump on dilution unit

The fridge is warm, the mix is recovered, and the manual dump valve is closed. All valves on the control panel are closed. Around SCROLL1 and the compressor, a small amount of mixture remains, and these valves should thus never be opened when the fridge is warm. Do not proceed if they were open!

1. Open V2. Monitor P_2, it should settle at not more than 5mBar.
2. After P_2 has settled, open the gate valve V1.
3. Start SCROLL2, open V21 to evacuate the auxiliary unit, then open V18 to start pumping on the dilution unit.
4. When $P_2 < 5$mBar, turn on TURBO1.
5. Open V3, V4 to the condensing side, and V7 to the trap.
6. Pump for at least 30 minutes.
7. Close all valves and turn off TURBO1.

3.3 Check thermometers and heaters

The patch panel is located on the right side of the control panel.

1. Check the thermometers. The LakeShore should display around 290 K for T_1, T_2, T_5. T_6 should be over range ("T. OVER"). For Pagani the resistance should read 1.024 kΩ. For Lamborghini the resistance should be around 10 kΩ.
2. Check the resistance of the heaters according to the table:

Heater	Channel	Resistance at RT (Ω)	Resistance Cold (Ω)
Heatswitch still HS-ST	1	30	?
Heatswitch MC HS-MC	2	50	?
Still heater EXT	3	155	90
MC heater	4	170	?
4K Power Heater	n/a	12	?

3. Turn on HS-MC, HS-ST and EXT on the control panel and use a voltmeter to measure the voltages across the connectors.

3.4 Button up the fridge

The samples are mounted in the fridge and the thermometers and heaters are checked. The state of the inside of the fridge has been documented with photographs and documented in the fridge logbook.

- Close all shields. This requires two people. The shields have a bayonet mechanism, so that no forklift is needed. Pagani has a cold plate shield, while Lamborghini does not.
- Make sure to use the shields belonging to the fridge. Each shield is marked with an "L" or a "P" on the flange, above the seam.
- Make sure all seams are aligned:
  - Due to the bayonets, for most shields, only two orientations are possible:

Lamborghini: orient all seams towards the hallway.
Pagani: orient all seams towards the window.

  - The cold-plate shield of Pagani has no bayonets. It should have its seam in the middle of the line of sight port 'AA' (towards the window, slightly towards Maserati).
- Before mounting each shield, wipe both mating surfaces with IPA to ensure good thermal contact. This is the top inside edge of each shield, and the outside surface of the plates.
- Check for dust in the bottom of the shields, and remove if present.
- The screws for the 50K and 4K shields must not be confused with the slightly longer screws that are only meant to be used for the top of the vacuum can.
- When closing the vacuum can, take each O-ring out of the groove, wipe the O-ring and groove with IPA and apply fresh high-vacuum grease to the O-ring until a thin film coats the entire ring. While doing so, you may let the individual shield parts rest on the floor, as they will sit on the bayonet screws, not on the sealing surface.
- The opposing face that mates with the o-ring also needs to be cleaned.
- Double check for any dust on the O-rings just before making the vacuum seal.

3.5 Evacuate Vacuum Can

Thermometers and heaters are checked, all shields are closed, the traps and dilution unit have been evacuated. All valves are closed and pumps are turned off. The trap has been cleaned and is in LN2.

1. Turn off P_1 on the MaxiGauge ("Sen-off"). The gauge is sensitive to fast pressure changes when active.
2. Start SCROLL2, then open V21, V16 and V14 to start evacuating the vacuum can.
3. Use an external turbo to evacuate the vacuum can further. Attach it to the AUX port, open V20, then start the external turbo immediately, the help from the turbo roughing pump makes quite a difference.
4. The vacuum can is big and roughing takes long, even with both SCROLL2 and the roughing pump of the external turbo. If the external turbo is not set to delay run-up or to idle up to a set point, it might abort run-up. In that case, just restart it.
5. Wait until $P_6 < 1$mBar.
6. Turn on the P_1 sensor. Close V21 and turn off SCROLL2.
7. Precooling can now be started. Leave the external turbo pumping until $P_1 = 10^{-5}$mBar.

3.6 Precooling

1. Open the manual valve to the mixture dump, on the left of the gas handling system.
2. Check whether P_5 reaches the value recorded after the last cooldown.
3. Turn on the main breakers of the pulse tube compressors, wait until they have loaded their firmware, then start them by turning on **PULSE TUBE**.
4. Turn on **HS-MC** and **HS-ST**.
5. The pulse tube compressors run very warm in the beginning of precooling. Monitor the compressors to make sure that they do not shut down.
6. Optional: After around 12 hours of precooling, it helps to let exchange gas into the dilution unit. For that,
   (a) Open **V13**, **V9** and **V7**, wait 10 seconds for the pressures to equalize
   (b) Close **V13**.
   (c) Open **V3** to let a shot of mix into the dilution unit.
   (d) Close all valves (**V7**, **V9**, **V3**) again.
7. When $P_1 < 10^{-5}$mBar, close **V14**, **V16**, and **V20**, then turn off and disconnect the external turbo.

3.7 Pulse precooling

When the still plate temperature T_5 falls below 15 K (after around 30 hours after start of the pulse tubes), pulse precooling, PPC, can be started. This procedure helps to thermalize the dilution unit, and also cleans the mixture. PPC can be omitted if the fridge has already settled to around 4K for more than 5 hours before condensation. PPC is controlled by a computer script, which periodically lets the mixture expand into the dilution unit from the still side, and then pumping it again.

1. Wait until $T_5 < 15$ K. After start of pulse tubes:

Lamborghini : ca. 35 hours

Pagani : ca. 45 hours

2. Ensure that the manual dump valve is opened.
3. Load and start the script "`Pulse_PreCool_v1_24`". It runs for 2 hours.
4. Monitor the peaks and dips of the dump and still pressure. They should be stable after around 30 cycles.
5. Wait about 30 minutes until T_6 falls below 4 K.

3.8 Condensation

PPC is finished and the fridge is circulating a small amount of mixture. T_6 has fallen to 4 K.

1. Point a blow dryer (with a timer set to 2 h) at the top of the external trap, right below the O-rings. This is to prevent ice forming on the O-rings during the high load of condensation.
2. Condensation is controlled by the script "`Condense_wLN2_v1_24`". Load and run it in the ValveControl Programming tab. Condensation takes around three hours.
3. Wait until condensation is finished.
4. Turn off the blow dryer.
5. With lots of mass in the fridge (especially Pagani with extra CP shield), the fridge might enter a phase of lumpy He-3. This leads to large oscillations in P_2, P_4 and flow rate. It might happen that $P_4 > 1200$mBar; then the safety valve BPV3 should break and let a bit of the mixture back in the tank.
   (a) If you observe a small increase of P_5 (no more than 50mBar), wait until the fridge is stable and then pump the dump empty again by opening **V11**.

(b) If P_5 increses above 1 Bar after normal condensation, the condensing lines might be blocked, or the fridge is still too hot. You might wish to wait until the fridge is cooled a bit further, and then run the condensation script again. If normal circulation can not be reached, contact an experienced user.

6. When dilution cooling sets in, T_{MC} below 1 K and falling fast. turn on the still heater by setting the Sample heater range to 120 mW and Setpoint to 1.05 K (Lamborghini) or 1.22 K (Pagani).

3.9 Warm-up

Warm up is performed manually. **Do not** use the Bluefors-supplied warm-up scripts; they let *nasty wet* room air in the VC as exchange gas while the fridge is cold! The fridge is circulating normally, all room-temperature electronics and HEMT biases are off.

1. Record the current temperatures and pressures in the fridge logbook.
2. Turn off sensor P_1 on the MaxiGauge ("Sen-off").
3. Check that the manual valve to the mixture dump is open.
4. Open V13, close V9.
5. Turn off TURBO1.
6. Turn on HS-ST and HS-MC.
7. Apply 90 mW to the MC plate using the LakeShore:
   (a) Select "Output setup" (button "4").
   (b) Select "Sample heater".
   (c) Set "Heater Range" to 100 mA, then "Manual output" to 90 mW.
8. Prepare the first of two additions of helium exchange gas. Flush and pump the volume $\overline{V14V16V21}$:
   (a) Turn on SCROLL1, open V16 and V21.
   (b) Open a helium bottle and regulate to a gentle flow. Attach the helium line to the TEST port (adapter is kept in drawer of Pagani control panel).
   (c) Close V21, open TEST manual valve and *slowly* let about P_6 = 1000mBar of helium in the volume. Watch out: the high pressure connectors can not be pumped under 1 atm. The helium line must always be over atmosphere to prevent sucking in air through the connector.
   (d) Close the TEST manual valve, then open V21 to evacuate the volume.
   (e) Flush the volume two more times, then close V21.
9. Prepare the first shot of exchange gas: Let P_6 = 15mBar of helium in the volume $\overline{V14V16V21}$ through the TEST manual valve.
10. Wait until TURBO1 is spun down.
11. Open V3 and V2.
12. Open V14 to let the exchange gas into the vacuum can. Wait 5 seconds, then close V14 again. The still, P_2 should increase as the mix begins to evaporate fast.
13. Wait until $P_2 < 10$mBar (ca. 10 minutes).
14. Turn on TURBO1 .
15. Wait until $P_2 < 5 \times 10^{-4}$mBar and $T_6 > 20\ K$. Then an additional 30 minutes to ensure full recovey of the mixture.
16. Record the final values of P_4 and P_5 in the fridge logbook.
17. Close the manual dump valve, then close all other valves
18. Turn off all small heaters (HS-ST, HS-MC and "All Off" on the LakeShore), and pumps SCROLL1 and TURBO1.
19. Add more exchange gas:

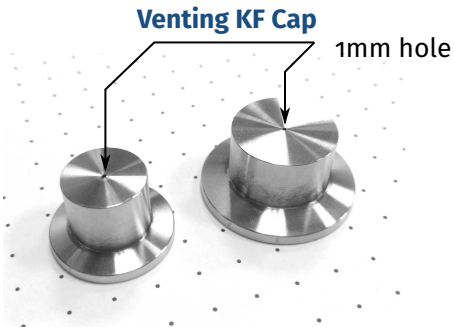

Figure 1: **A cap for venting fridge** This cap has a small hole, about 1 mm diameter, that limits the inrush of air.

   (a) Add P_6 = 200mBar helium through the manual TEST valve.
   (b) Close TEST, then open V14 to let the additional change gas in the vacuum can.
   (c) Wait 5 seconds, then close V14.
   (d) Detach and close the helium bottle.

20. Turn off the PULSE TUBE on the control panel, then switch off the compressors' main breakers.
21. Set up a fan (better two) pointed at the vacuum can to prevent condensation. Do not place the fans directly under the vacuum can.
22. Optional: turn on the 4K heater in the software. Set for maximum power for 15 hours.
23. Clean the external trap now. If it is forgotten and warms up when the dewar runs dry, you risk forming an accidental cryobomb.
24. The fridge also has an internal trap inside the cryostat. When T_2 crosses above 80 K, check if P_3 reaches $>$ 1000mBar (normally, it should stay below 10mBar). If so, you should also start cleaning this trap immediately by turning on SCROLL2 and opening V4, V17, V21.

3.10 Clean External Trap

The mix is recovered, and the manual dump valve is closed. All valves on the control panel are closed.

1. Start SCROLL2, then open V21 to evacuate the manifold until $P_6 < 10^{-2}$mBar.
2. Close V21 and open V17. Monitor P_6 to make sure that the path to the trap was evacuated (it should drop further).
3. Open V7 and then take the trap out of the dewar, secure it with Velcro tape or a cable tie.
4. Observe P_6, in only a minute or two it should start rising. It should not rise above 1 Bar, only if it does: open V21 and record "overfull" in the logbook.
5. Heat the trap with a blow dryer.
6. Monitor P_6 until the trap is all warmed up. Record P_6 in the fridge logbook as an indication of the gunk that the trap has collected during the last cooldown. Typical values are 10 – 100mBar.
7. Open V21 to start pumping on the trap. Pump for at least half an hour while heating the trap. In the meantime, refill the dewar.
8. Close all valves.
9. Slowly insert the trap back into the liquid nitrogen.

3.11 Opening the fridge

The cryostat is fully warmed up (**all** temperatures around 290 K, ca. 48 hours). Note that T_6 is not calibrated above 100 K, except for a single calibration point at 292 K. All valves are closed.

1. Check that P_1 is turned off ("Sen-off").
2. Make sure that the VENT port is covered by an impedance (eather a KF25 plastic cap with hole, or the metal KF flange with the hole). Do not vent without impedance, you can crush the shields!
3. Vent by opening V14, V16, and V19.
4. Usually, you only want to access the mixing chamber. In that case you need to
   (a) Lamborghini: Only unmount the lowest segment of each shields.
   (b) Pagani: Unmount the two lower segments of the VC, and both segments of the 50 K, 4 K, and still shields, in order to unmount the CP shield.
5. Before you open the satellite or begin to change wiring and/or samples, have someone with TWPA experience disconnect and terminate all TWPAs. Only do this if you have been shown how to do it – TWPAs are priceless and very ESD-sensitive.

4 Usual Operating Conditions

4.1 Lamborghini

T_1	35 K	
T_2	2.8 K	
T_4	1.05 K (PID)	Still
T_5	11 mK	MC

P_1	3×10^{-6} mBar	VC
P_2	3×10^{-2} mBar	Still
P_3	680 mBar	Condensing
P_4	800 mBar	Trap
P_5	4.5 mBar	Dump
P_6	9 mBar	Aux

4.2 Pagani

T_1	38 K	
T_2	2.9 K	
T_4	1.15 K (PID 22 mW)	Still
T_5	11.5 mK	MC

P_1	3×10^{-6} mBar	VC
P_2	3×10^{-2} mBar	Still
P_3	580 mBar	Condensing
P_4	610 mBar	Trap
P_5	6 mBar	Dump
P_6	2 mBar	Aux

4.3 PID settings

The PID control of the Lakeshore is designed for use with the mixing chamber thermometer, T_6, and heater, however, we use it for control of the still temperature. If the setting were not messed with they will remain correct. Here is our known good settings. Using the LakeShore Reader software on the computer, in the 'Heater setup' tab set the control coefficients P : 0.01, I : 1.00, and D : 0.00. The range of 31.6 mW is sufficient. Control mode: 'closed', control channel: '5' (T_5), heater resistance: 120.

5 Fridge Turnaround Performance

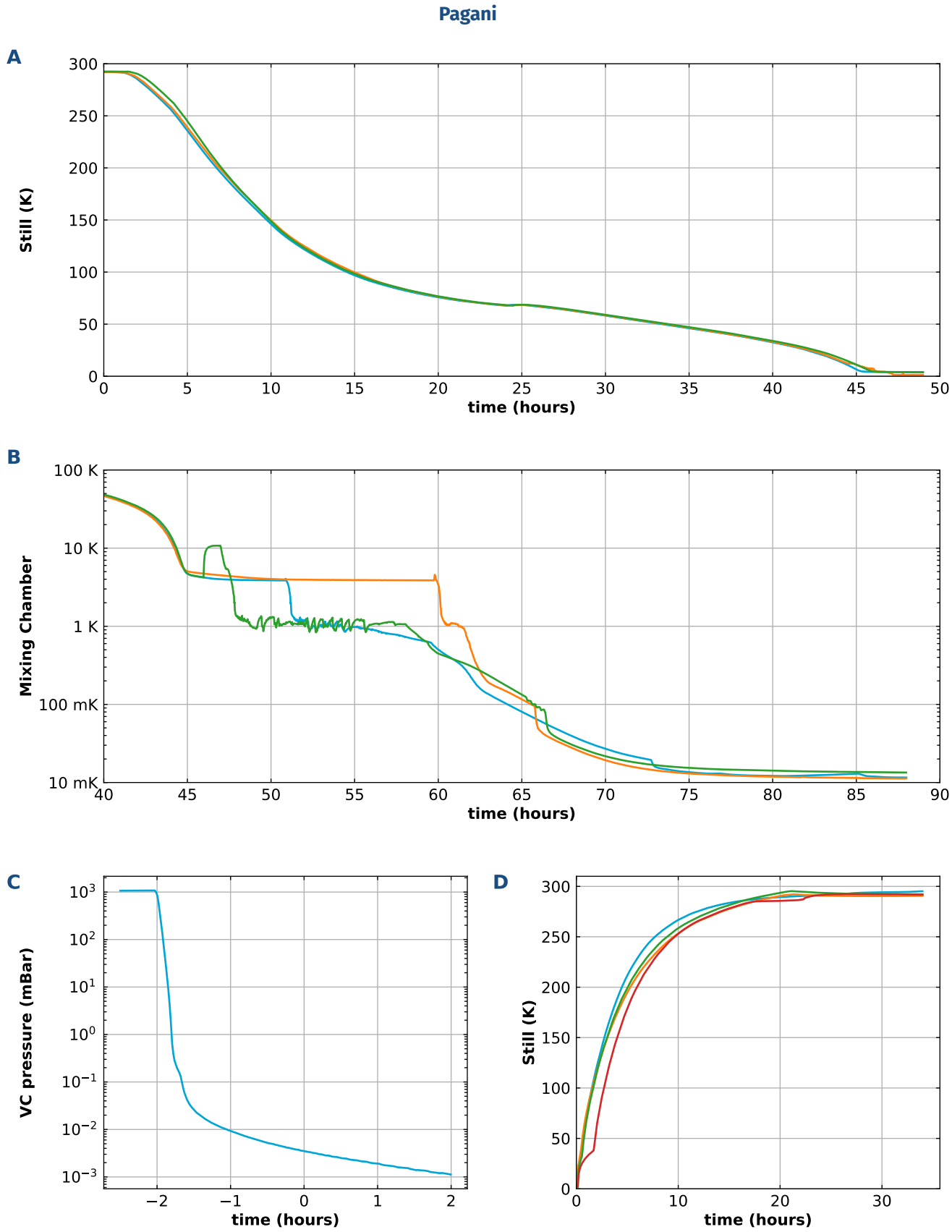

Figure 2: **Pagani Turnaround Performance** (**A**) Initial cooling of the pagani. (**B**) PPC, condensation, and cooling to base temperature. (**C**) Pumping of the VC before cooling. (**D**) Warming up when the run is over.

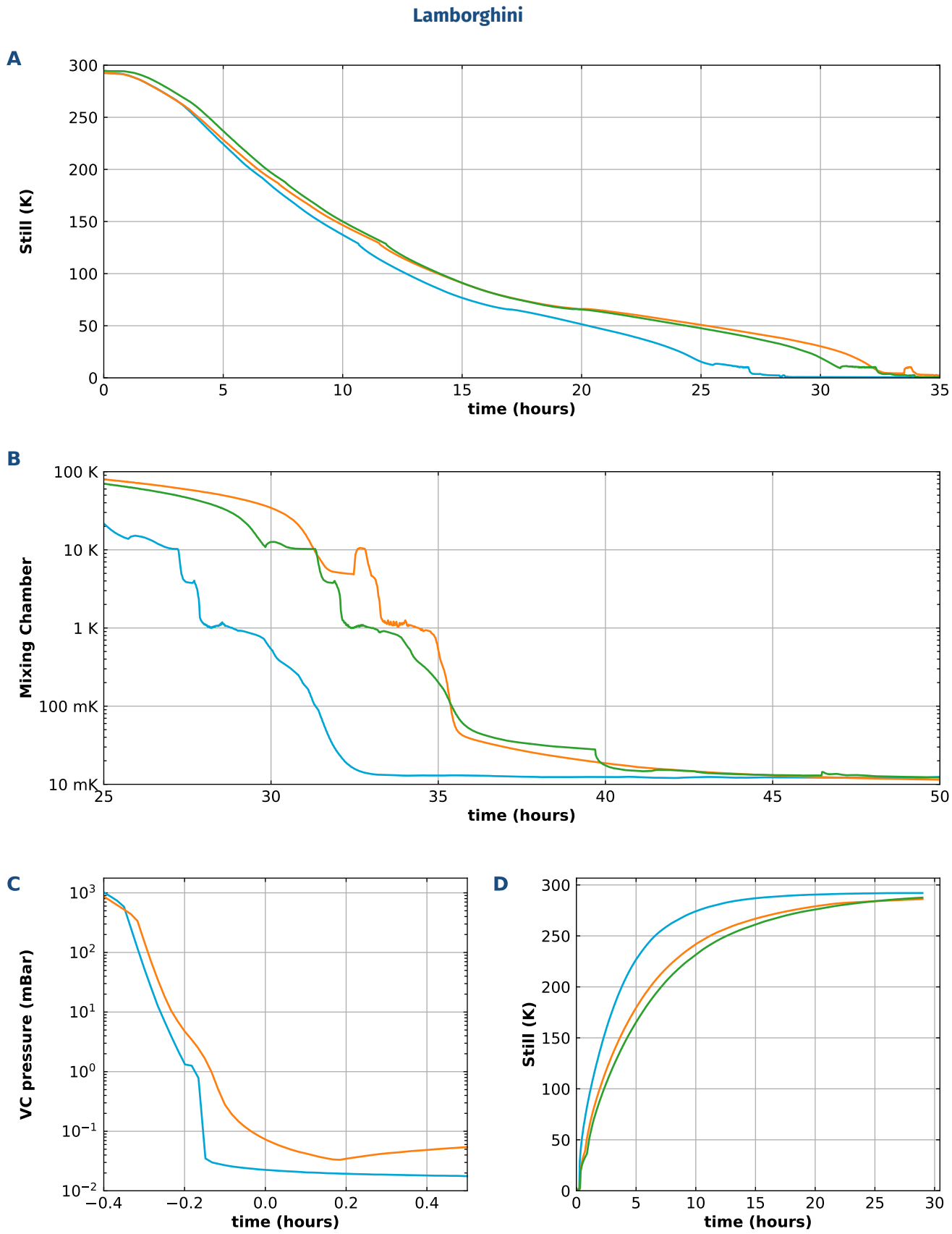

Figure 3: **Lamborghini Turnaround Performance** (**A**) Initial cooling of the Lamborghini. (**B**) PPC, condensation, and cooling to base temperature. (**C**) Pumping of the VC before cooling. (**D**) Warming up when the run is over.