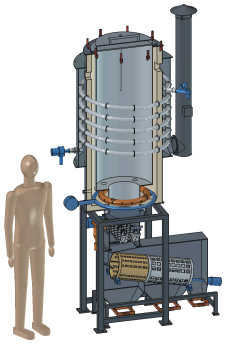
TimberVolt

STAGE 1 R&D · FIELD MANUAL

STEP-BY-STEP ILLUSTRATED OPERATOR'S GUIDE

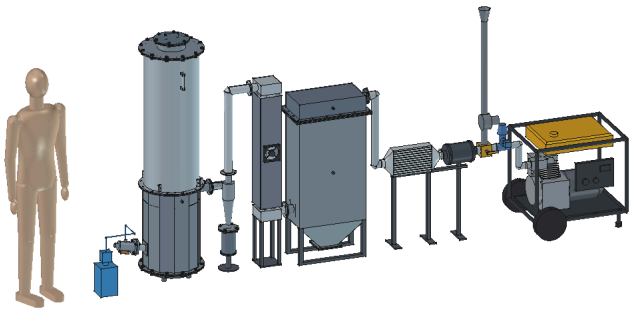
Field Operating Manual for **TimberKiln 25** (Hydronic Cordwood Pyrolysis Retort & Sealed Mini-Crusher) and **TimberGen 5** (5.0 kW Charcoal 48V DC Resilience Charger)

100-120 kg	70-90 kWh_{th}	25-30 kg Char	5.0 kW Net DC
Split Cordwood per TimberKiln 25 Batch (15-25% MC)	Hydronic Heat Harvested (18-25 kW_{th} Peak)	~24 kg 6-15 mm Fuel + ~3 kg <2 mm Biochar	96 A @ 52 V DC (~6.0-7.5 hrs per Batch)



TIMBERKILN 25: CORDWOOD PYROLYSIS RETORT & SEALED MINI-CRUSHER

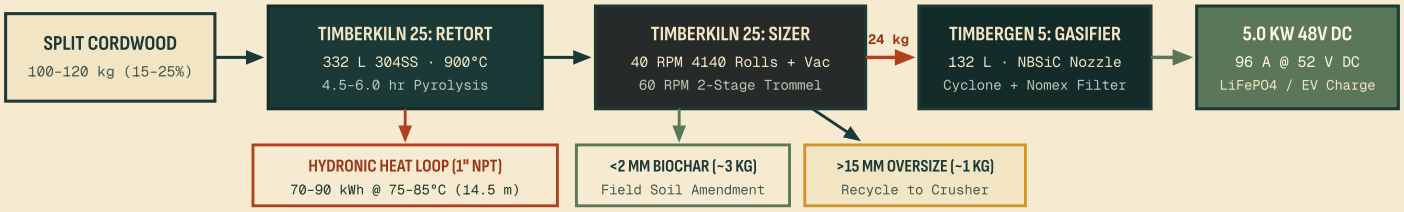
332 L Retort (2.70 m top rim) · 14.5 m Finned HX · Shown w/ 5'10" (1.78 m) scale figure



TIMBERGEN 5: 5.0 KW CHARCOAL 48V DC RESILIENCE CHARGER

132 L Cartridge (1.87 m top cap) · 4.08 m train · Shown w/ 5'10" (1.78 m) scale figure

END-TO-END CORDWOOD-TO-48V-DC RESILIENCE PROCESS



CRITICAL SAFETY INTERLOCKS · READ BEFORE OPERATING EITHER UNIT

- **Outdoor Operation Only:** Site both TimberKiln 25 and TimberGen 5 outdoors or under an open-sided canopy at least **5 m (16 ft)** from windows, doors, and building air intakes.
- **Carbon Monoxide (CO) Lethal Hazard:** Producer gas contains 20–30% odorless CO. Never bypass TimberGen 5's hard-wired `CO_Loop` relay (**hard kill ≥ 35 ppm**) and always wear a calibrated personal CO monitor.
- **Anaerobic Cooldown Lockout (TimberKiln 25):** Never open the top loading lid or bottom dump slide gate while `T_retort > 100 °C`; hot charcoal spontaneously reignites in air.
- **Hydronic Pressure & Boil-Over (TimberKiln 25):** Never fire TimberKiln 25 with a dry or valved-off glycol loop. Confirm `~1.5 bar` loop pressure and an unobstructed `3.0 bar` safety relief discharge line before lighting kindling.

PART I: TIMBERKILN 25 · PYROLYSIS RETORT & MINI-CRUSHER

Fuel Production & Hydronic Thermal Harvest

`4.5-6.0 hr Burn + 4-6 hr Cooldown`

PRE-FLIGHT CHECKLIST (VERIFY BEFORE EVERY TIMBERKILN 25 BATCH)

- ☐ **Hydronic Loop Primed:** Dual `1" NPT` hoses connected to thermal storage, `P_glycol ≈ 1.5 bar`, `T_glycol_out < 40 °C`, `3.0 bar` PRV unobstructed.
- ☐ **Gates & Totes Ready:** Bottom dump slide gate **CLOSED**; all 3 hopper slide gates **OPEN**; empty Green, Blue, and Amber wheeled totes docked beneath Hoppers 1–3.
- ☐ **Auxiliary Batteries Charged:** `12V` bus (controls, `V_air_sec`, `Pump_glycol`, stack solenoid) and `48V` bus (crusher, trommel, micro-cyclone).
- ☐ **Cordwood Staged:** `100-120 kg` split cordwood (`300-500 mm` length, `15-25%` moisture, 30% max) plus dry kindling bundle.

STEP 1 LOAD CORDWOOD & CLAMP LID AIRTIGHT

`STATE: 1. LOAD_AND_SEAL`



1. Release all **8 red over-center toggle latches** around the `640 mm OD` upper clamp flange.
2. Lift the insulated 304SS lid clear using the twin-post top handle, taking care not to bend the `480 mm` `T_retort` Type-K Inconel thermowell hanging beneath the dome.
3. Stack **100–120 kg** of split cordwood densely into the `550 mm ID × 1,400 mm H` (`332 L`) 304SS retort core, leaving ~50 mm headspace below the top rim.
4. Brush any bark or splinters off the **braided 650 °C graphite seal gasket** seated in the top groove.
5. Seat the insulated lid squarely and clamp all **8 toggle latches** in an opposing star pattern until airtight.

WHY AIRTIGHT MATTERS

Any air leak at the top flange admits oxygen into the hot wood bed, turning your charcoal yield into ash instead of forcing pyrolytic wood gas downward through the `4× 2"` stainless downcomers.

STEP 2 WOOD-FIRE START & MOISTURE DRYING

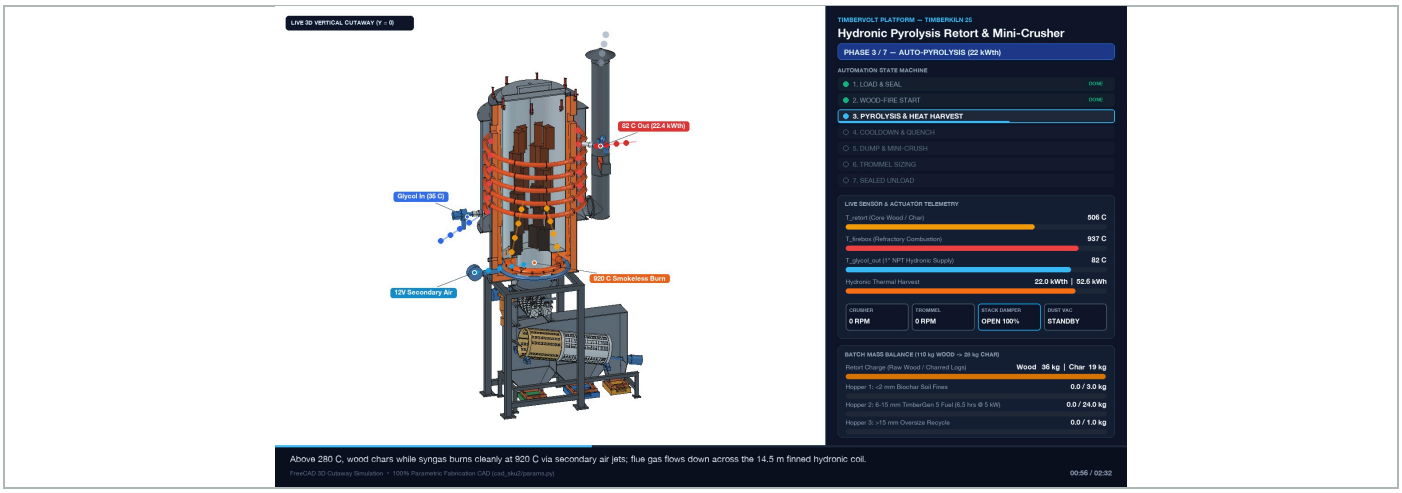
`STATE: 2. WOOD_FIRE_START · ~1.0 hr`



1. Select **START BATCH** on the controller and verify the motorized `150 mm` stack butterfly damper rotates to **100% OPEN**.
2. Open the front `-Y` **Kindling Start Door** on the `750 mm OD` outer firebox, place dry kindling and small splits on the lower `50 mm` refractory floor, light cleanly, and close the door with its rotary draft wheel open.
3. As the firebox climbs toward `600-700 °C`, `T_retort` rises through **150–280 °C** while moisture steams off through the `4× 2"` downcomers and vents up the stack. `Pump_glycol` starts low-speed circulation above `45 °C`.

STEP 3 AUTO-PYROLYSIS & HYDRONIC HEAT HARVEST

`STATE: 3. AUTO_PYROLYSIS_HARVEST · 2.5-3.5 hrs`



1. Above **`T_retort > 280 °C`**, pyrolytic wood gas and tars surge downward through the `4× 2"` downcomers into the slotted toroidal burner ring. Confirm `Flame_UV` reads active flame (auto-igniter triggers automatically if flame drops) and close the kindling door's primary draft wheel.
2. The controller modulates the **`V_air_sec`** **12V PWM secondary air blower** to hold **`T_firebox = 800-1,000 °C`** for complete, smokeless tar destruction.
3. Hot exhaust exits 4 upper transfer ports and flows **counter-current downward** across the **`14.5 m`** **spiral-finned 304SS coil (`2.8 m²`)**, cooling to `~140 °C` at the stack while `Pump_glycol` (`15-35 L/min`) holds **`ΔT = 20 K`** and **`75-85 °C`** supply (**18–25 kW_{th}, 70–90 kWh** per batch).

> **HYDRONIC HIGH-TEMP INTERLOCK (> 92 °C)**
>
> If `T_glycol_out > 92 °C`, the controller forces `Pump_glycol` to 100% into the thermal dump loop and throttles `V_air_sec`. Mechanical brass PRV relieves at `3.0 bar`.

STEP 4 ANAEROBIC COOLDOWN & RESIDUAL HEAT RECOVERY

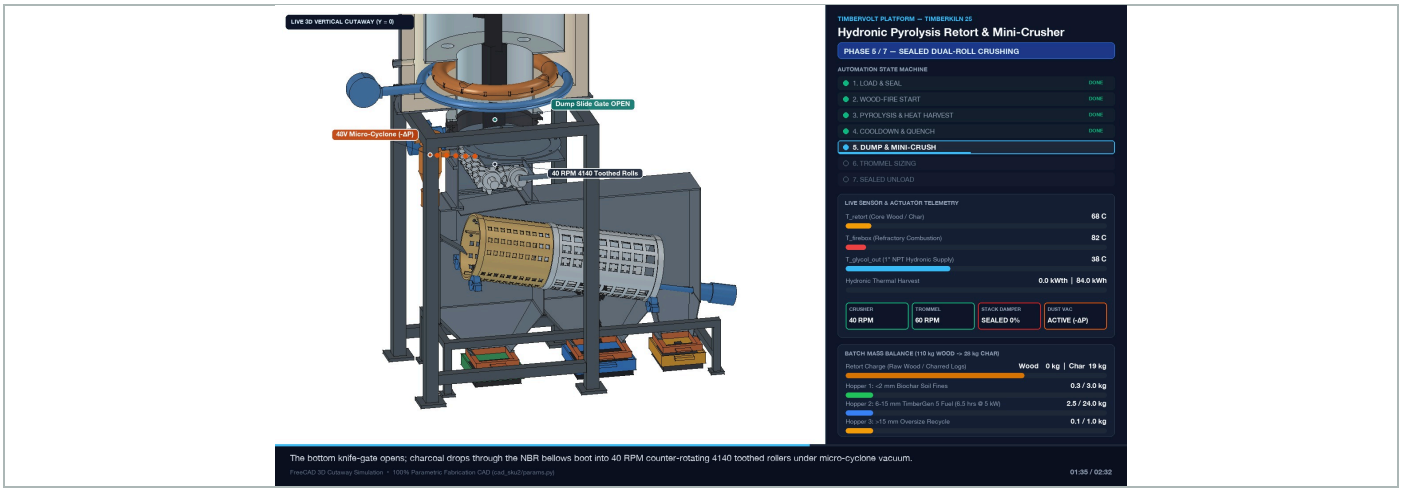
`STATE: 4. COOLDOWN_QUENCH · 4.0-6.0 hrs`



1. Once wood volatiles exhaust (`T_retort` peaks at `550-650 °C`) and `T_firebox` falls below `450 °C` , the controller transitions automatically to **COOLDOWN_QUENCH**.
2. The **`150 mm` motorized butterfly damper rotates to 0% SEALED** and `V_air_sec` shuts off, starving the firebox of oxygen while keeping the `25-30 kg` charcoal charge fully anaerobic.
3. Keep `Pump_glycol` circulating to harvest stored refractory heat until **`T_retort < 100 °C`** (target `< 70 °C` before dumping). **Never open the dump gate above 100 °C.**

STEP 5 DUST-FREE CHAR DUMP & DUAL-ROLL CRUSHING

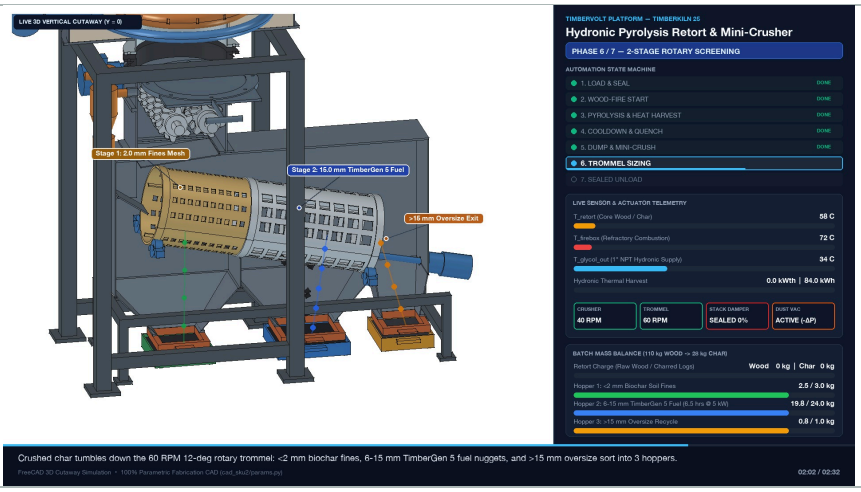
`STATE: 5. CRUSH_AND_SIZE (PART A)`



1. Verify `T_retort < 100 °C` , check the **corrugated NBR sealing boot** clamps, and confirm the crusher bearing slide locks are set to **`14 mm` nominal nip gap** (`8-20 mm` adjustable range).
2. Switch ON the **`48V` Micro-Cyclone Dust Extractor** first (pulls negative pressure `-ΔP` via the `Ø25 mm` port to eliminate fugitive carbon dust).
3. Start the **`60 RPM` Rotary Trommel** and the **`0.75 kW` 48V DC Dual-Roll Crusher** (`30-45 RPM` , `160 Nm` torque; low RPM shears char cleanly with minimal dust).
4. Pull the front `-Y` T-handle of the **Bottom Dump Slide Gate** fully open (`280 mm` stroke); cooled char logs drop by gravity through the NBR boot into the interlocking `Ø120 mm` 4140 steel cutter teeth.

STEP 6 2-STAGE ROTARY TROMMEL SIZING

`STATE: 5. CRUSH_AND_SIZE (PART B) · 60 RPM`



1. Crushed charcoal discharges onto the internal gravity feed chute and tumbles down the `Ø250 × 750 mm` **drum inclined at 12°** (`60 RPM`), automatically separating into three dust-sealed bottom hoppers:

HOPPER 1: <2 MM BIOCHAR (~3 KG)
Stage 1 (`300 mm`, `2.0 mm` brass mesh) drops pure soil-replenishing biochar fines into the Green Tote.

HOPPER 2: 6–15 MM FUEL (~24 KG)
Stage 2 (`450 mm`, `15.0 mm` steel mesh) passes uniform TimberGen 5 engine nuggets into the Blue Fuel Tote.

HOPPER 3: >15 MM OVERSIZE (~1 KG)
Oversize chunks exit the open `+X` drum end into the Amber Return Bin for re-crushing on the next batch.

2. Allow the crusher and trommel to spin **15–20 seconds after tumbling stops** so all chutes clear completely.

STEP 7 SEALED CONTAINER UNLOADING

`STATE: 6. UNLOAD · READY FOR NEXT BATCH`



1. Push the **Bottom Dump Slide Gate** firmly closed until the `-Y` handle seats flush.
2. Switch OFF the crusher and trommel, wait **10 seconds** for suspended fines to clear into the micro-cyclone catch jar, then switch OFF the `48V` Micro-Cyclone.
3. Close all **3 copper hopper slide gates** dust-tight to seal the trommel enclosure.
4. Roll all **3 filled wheeled totes** forward out from underneath the stand: store the **Blue** `6–15 mm` **Fuel** dry in a sealed 55-gal drum or load it straight into **TimberGen 5** for `~6.0–6.5 hours` of `5.0 kW` DC power.

PART II: TIMBERGEN 5 · 5.0 KW CHARCOAL RESILIENCE CHARGER

Off-Grid 48V DC Battery & EV Charging

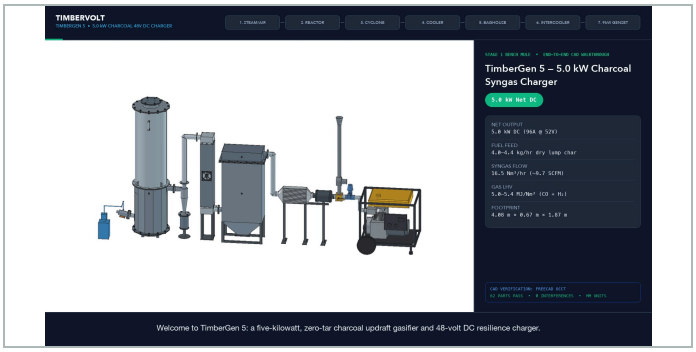
`96 A @ 52 V DC · ~6.0 hrs / Cartridge`

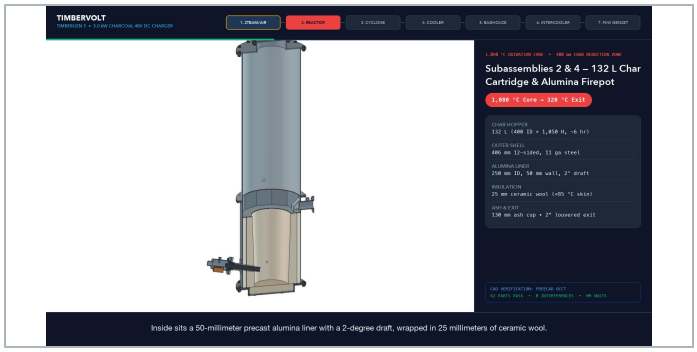
PRE-FLIGHT CHECKLIST (VERIFY BEFORE EVERY TIMBERGEN 5 RUN · `1. IDLE / PRE_CHECK`)

- ☐ **CO Safety Loop Armed:** Wear clip-on CO detector and verify hard-wired `CO_Loop` NC relay reads **OK (< 35 ppm)** on ESP32-S3 display.
- ☐ **Distilled Water Filled:** Fill `P_h2o` peristaltic tank with clean/distilled water (`~6 L` for a 6 hr run) to prevent evaporator scaling.
- ☐ **Cleanup Train Ready:** Confirm `T_bag_in < 100 °C`, cyclone catch pot empty & sealed, Stage 2 intercooler `1/4" NPT` drain drained & **CLOSED**.
- ☐ **DC Load Disconnected:** Confirm EG4 Chargeverter GC is **OFF (0 A)** and wired to your `48V` LiFePO4 battery bank (`< 95%` SOC).

STEP 1 LOAD 6–15 MM CHARCOAL CARTRIDGE & VERIFY VACUUM SEAL

`STATE: 1. IDLE / PRE_CHECK`

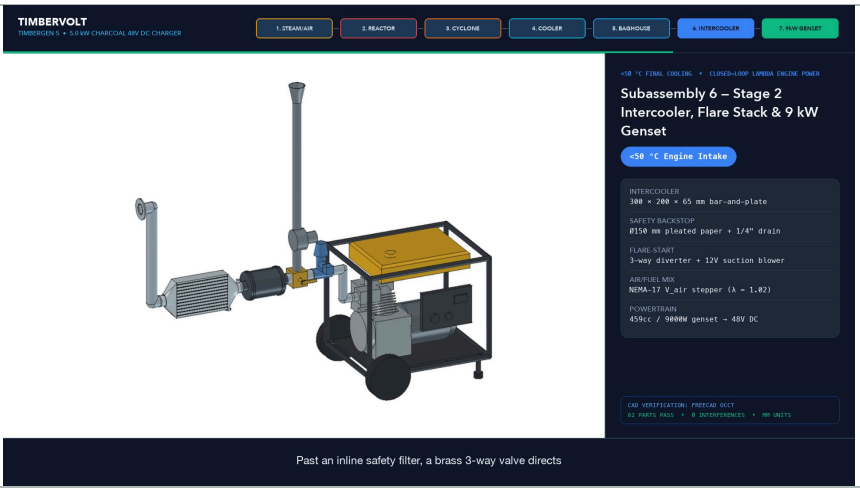




1. Unclamp the quick-release toggle latches on top of the `132 L` **304SS Char Cartridge** (`400 mm ID × 1,050 mm H`).
2. Pour **24–26 kg** of dry, sized `6-15 mm` **charcoal nuggets** from TimberKiln 25 into the hopper, filling both the `250 mm ID` precast alumina firepot and upper cartridge (delivers **~6.0 hours** at `4.0-4.4 kg/hr`).
3. Wipe the high-temp silicone top flange gasket clean and clamp the lid tight. *Because TimberGen 5 runs under negative engine suction, every flange from top cap to intake must be vacuum-tight.*
4. Power ON the ESP32-S3 controller; confirm the `V_air` NEMA 17 stepper homes cleanly to `0°` and the cartridge level switch shows **FULL**.

STEP 2 FLARE-START IGNITION

`STATE: 2. FLARE_START · 3-5 min`



1. Rotate the **brass 3-way diverter valve** to **FLARE STACK** (isolating the `459cc` engine intake).
2. Select **FLARE_START** on the ESP32-S3 controller: the flare pilot spark energizes and the `12V` **suction start blower** ramps up, pulling air inward through the `12°` `16 mm ID` NBSiC ceramic nozzle.
3. Hold a propane/butane lighting torch briefly at the steam pre-chamber air inlet for **15–20 seconds** until the char bed at the `45 mm` protruding nozzle tip glows bright orange.
4. Maintain blower draft until `T_noz > 650 °C` and `Flare Temp > 450 °C`, confirming a crisp, self-sustaining pale-blue/orange producer-gas flame atop the flare stack.

STEP 3 ENGINE CRANK & SYNGAS SWITCHOVER

`STATE: 3. CRANK_SYNC`

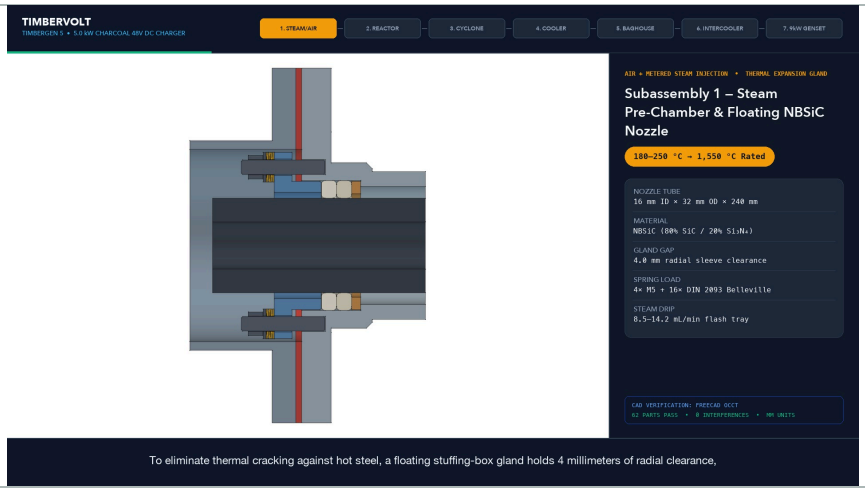
1. Confirm steady flare flame (`> 450 °C`) and clean reactor vacuum (`dP_rx = 2.0-3.5 inH20`).
2. Select **CRANK_SYNC**: the controller pre-positions the `V_air` **secondary air butterfly valve to** `42%` **open** for stoichiometric startup air/syngas mixing.
3. Swing the **brass 3-way diverter valve** smoothly from **FLARE → ENGINE**, stop the `12V` start blower, and crank the genset starter (**maximum 5 seconds** per crank attempt).
4. Once the `459cc` genset catches and stabilizes at `3,600 RPM`, verify steady vacuum (`dP_rx = 2.8-4.0 inH20`) and cool engine intake temperature (`T_eng_in < 55 °C`).

NO-START RECOVERY

If the engine does not catch within 5 seconds, switch the 3-way valve back to **FLARE STACK**, re-run the start blower for 60 seconds to restore rich gas quality (`Flare Temp > 450 °C`), verify `V_air = 42%` , and retry.

STEP 4 WARMUP RAMP & METERED STEAM INJECTION

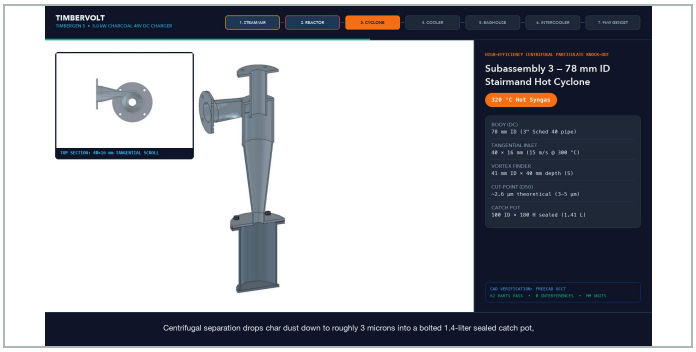
`STATE: 4. WARMUP_RAMP · 5-8 min`

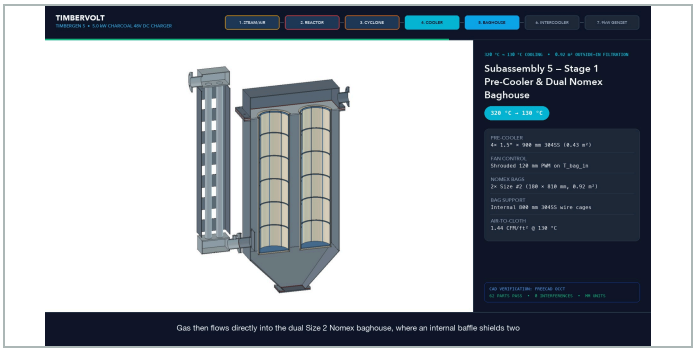


1. Enable closed-loop **Bosch LSU 4.9** `Lambda` **PID**; the controller automatically trims the `V_air` stepper to hold `λ = 1.02` (slightly lean for high brake thermal efficiency and ultra-low exhaust CO).
2. Switch ON the **EG4 Chargeverter GC** at `30 A` **(~1.5 kW)** warmup load until `T_noz > 900 °C` and the Steam Pre-Chamber evaporator plate exceeds `160 °C` (`180-250 °C` nominal via exhaust heat or 60 W 48 V cartridge).
3. The controller automatically starts `P_h2o` **metered water drip** (`8.5-14.2 mL/min`), flashing liquid water into dry steam inside the pre-chamber before entering the `16 mm` NBSiC nozzle, boosting H_2 energy content (`5.0-5.4 MJ/Nm³`) while holding core temperature cleanly at `1,000-1,150 °C` without ash slagging.

STEP 5 STEADY 5.0 KW DC CHARGING & GAS CLEANUP

`STATE: 5. STEADY_CHARGE · 96 A @ 52 V DC`

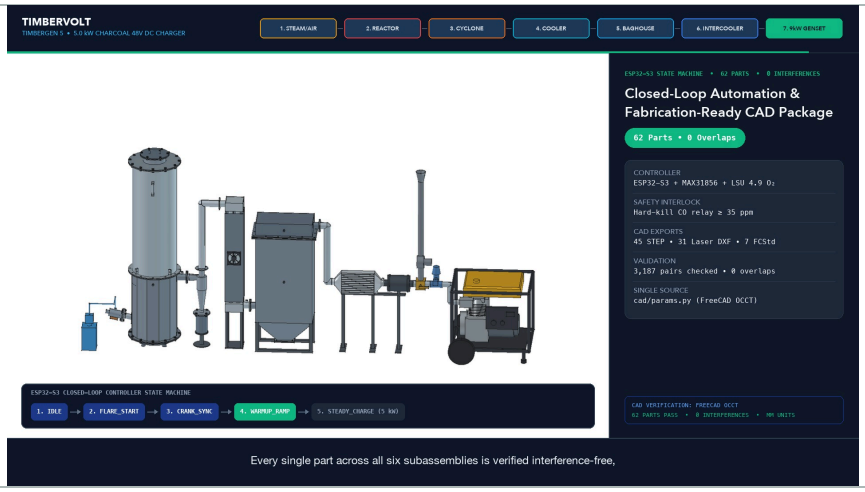




1. Ramp the EG4 Chargeverter smoothly up to `95-96 A @ 52 V DC` **(`5.0 kW` net electrical output)**.
2. Verify smooth cleanup performance across all 4 stages: `78 mm` **Stairmand Hot Cyclone** (`d50 ≈ 2.6 µm`), **Stage 1 4-Tube PWM Cooler** (`320 → 130 °C`), **Dual Size #2 Nomex Baghouse** (`120-140 °C`, above dew point & below scorch), and **Stage 2 Bar-and-Plate Intercooler** (`< 50 °C` engine intake).
3. The ESP32-S3 executes closed-loop Lambda, Steam Temp, and Cooler Fan PWM PIDs automatically while logging 1 Hz telemetry to microSD. Expect **~6.0 hours** per full `132 L` cartridge (`~30 kWh`$_e$ net DC delivered).

TELEMETRY TIMBERGEN 5 LIVE OPERATING TARGETS & SAFETY INTERLOCKS

ESP32-S3 CLOSED-LOOP CONTROLLER



SENSOR / ACTUATOR	NOMINAL TARGET	HARD TRIP LIMIT	OPERATIONAL MEANING & CONTROL ACTION
`T_noz` (Core)	**1,000 - 1,150 °C**	**> 1,350 °C**	Regulated via `P_h2o` water drip (`8.5-14.2 mL/min`) to prevent clinkering.
`T_rx_out` (Exit)	**250 - 350 °C**	**> 420 °C**	Steady climb above `370 °C` indicates low charcoal bed; prepare to refuel.
`T_bag_in` (Filter)	**120 - 140 °C**	**> 185 °C**	Held by Stage 1 PWM fan (avoids wet condensation `<110 °C` & Nomex scorch).
`T_eng_in` (Intake)	**35 - 55 °C**	**> 75 °C**	Dense, cool syngas leaving Stage 2 intercooler & pleated safety filter.
`dP_rx` / `dP_bag`	**2.8-4.0 / 0.5-3.5 inH_2O**	**dP_bag > 14 inH_2O**	Measures bed permeability and Nomex filter dust cake buildup.
`Lambda` (LSU 4.9)	**λ = 1.02**	**Open-Loop Fault**	Auto-tracked by `V_air` NEMA 17 stepper + 5:1 planetary gearbox.
`CO_Loop` (Ambient)	**0 ppm**	**≥ 35 ppm**	Hard-wired NC safety relay: instant magneto kill & intake isolation.

STEP 6 CONTROLLED COOLDOWN SHUTDOWN

STATE: 6. COOLDOWN · DRY PURGE

1. Ramp the **EG4 Chargeverter GC** down to `0 A` and switch the DC load breaker **OFF**.
2. Select **COOLDOWN** on the ESP32-S3 controller: `P_h2o` **water drip stops immediately** while the engine idles unloaded for a **30-second dry purge** to clear moisture from the steam pre-chamber, NBSiC nozzle, and char bed.
3. The controller automatically grounds the genset magneto ignition (stopping the engine cleanly) and seals the **primary air intake solenoid** to snuff the firepot anaerobically, preserving unburned charcoal for the next run.
4. Leave all flanges, cyclone catch pot, and bottom ash door sealed until `T_rx_out < 60 °C` before servicing or refilling.

PART III: FAULT-LATCH RECOVERY MATRIX & ROUTINE MAINTENANCE

Printable Shop Reference Sheet · Stage 1 R&D

`TimberKiln 25 + TimberGen 5 Reference`

EMERGENCY & FAULT-LATCH TROUBLESHOOTING MATRIX (`7. FAULT_LATCH`)

FAULT / ALARM	UNIT	AUTOMATIC CONTROLLER ACTION	ROOT CAUSE & REQUIRED RECOVERY STEPS
`CO_Loop ≥ 35 ppm`	**TimberGen 5**	Instant magneto ground, `P_h2o` OFF, air solenoid closed, fault latched.	Evacuate to fresh air immediately. Once cool, vacuum-test (`-25 inH20`) all bolted flanges, floating nozzle gland, and 3-way flare diverter before restarting.
`T_noz > 1,350 °C`	**TimberGen 5**	Chargeverter load shed, fault latch shutdown.	Check empty `P_h2o` distilled water tank, kinked BPT peristaltic tubing, or clogged evaporator drip needle. Refill, prime pump, and clear latch.
`T_bag_in > 185 °C`	**TimberGen 5**	Immediate shutdown to protect PTFE-glazed Nomex filter bags.	Verify Stage 1 Pre-Cooler `120 mm` PWM fan power/RPM; check for low char level / bed channeling (`T_rx_out > 420 °C`). Inspect bags before next run.
`dP_bag > 14 inH2O`	**TimberGen 5**	Controlled shutdown & filter-blinding alert.	Cool unit, unclamp Dual Size #2 Nomex Baghouse cover, gently shake/vacuum ash cake off outside-in bags, and empty lower baghouse dust hopper.
`T_glycol_out > 92 °C`	**TimberKiln 25**	`Pump_glycol` 100% to dump loop, `V_air_sec` throttled, high-temp alarm.	Thermal storage tank saturated or trapped air in glycol loop. Verify pump flow, bleed air at top `1" NPT` tree, and confirm dump radiator fan operation.
`P_glycol > 3.0 bar`	**TimberKiln 25**	Mechanical brass PRV relieves pressure.	Check expansion tank pre-charge (`~1.5 bar` cold) and verify no shut isolation valves in the hydronic return line.
`Flame_UV Drop`	**TimberKiln 25**	Auto-igniter pulses; cuts `V_air_sec` if unlit after timeout.	Normal at end of pyrolysis (`T_firebox < 450 °C` → enters Cooldown). If mid-batch, clean UV sight lens on `-X` boss and check kindling bed temperature.

PREVENTIVE MAINTENANCE & INSPECTION SCHEDULE

SERVICE INTERVAL	UNIT	REQUIRED MAINTENANCE & INSPECTION TASKS
After Every Batch	**TimberKiln 25**	Empty `48V` micro-cyclone dust catch jar; brush top `640 mm` braided graphite lid gasket; inspect corrugated NBR boot hose clamps for dust-tight seal.
After Every Run	**TimberGen 5**	Empty `78 mm` Stairmand hot cyclone sealed catch pot (`~1 L` fine fly ash); open & close Stage 2 intercooler `1/4" NPT` condensate drain petcock; top off `P_h2o` distilled water reservoir.
Every 5 Batches	**TimberKiln 25**	Unbolt `-Y` hydronic jacket soot-cleanout inspection hatch and brush fly ash off the `14.5 m` spiral-finned 304SS coil; remove front trommel inspection cover to verify `2.0 mm` and `15.0 mm` meshes are clear.
Every 5 Runs (~25–30 hrs)	**TimberGen 5**	Unbolt reactor bottom cleanout door and empty the **`130 mm ( 6.4 L )` ash cup**; visually inspect the precast alumina liner and `16 mm` NBSiC nozzle tip for slag; shake/inspect Dual Size #2 Nomex bags and inline pleated safety backstop element.
Every 100 hrs / Seasonal	**Both**	Check **Belleville disc spring compression** & `6 mm` ceramic fiber rope in TimberGen 5's floating nozzle gland; inspect TimberKiln 25's `4140` hardened crusher teeth & `14 mm` nip-gap slide locks; change `459cc` genset engine oil & check spark plug; verify glycol freeze protection & personal CO monitor bump-test calibration.

QUICK FUEL & ENERGY CONVERSION REFERENCE (1 STANDARD CORDWOOD BATCH)

`110 kg Split Cordwood (20% MC)` → **TimberKiln 25** → **~80 kWh_{th} Hot Water/Glycol** + **~3 kg Biochar Fines** + **~24 kg Engine-Grade Charcoal (6–15 mm)** → **TimberGen 5** → **~30 kWh_e Net 48V DC** (`6.0 hrs @ 5.0 kW / 96 A`).