Fully Automated Supercritical CO2 Extractor

Close Loop, Dual 3L chambers, Triple 3L separators, 2000PSI

May 2022 — February 2023

How Supercritical CO2 Extraction Works

CO2 extraction uses the high solubility of lipophilic molecules in liquid or supercritical carbon dioxide. First, pressurized CO2 dissolves lipophilic molecules (e.g., essential oils) in the extraction columns. The solution then flows to separators, where pressure drop and heating evaporates the CO2, allowing the extract to drain through bottom valves. The CO2 gas is re-condensed, re-pressurized, and recycled—closing the loop. The CO2 extraction method is environmentally safe and efficient, with no residues in the final extract, though it's engineering-wise complicated.

This state-of-the-art CO2 extractor was designed for fast, efficient cannabis and hop extraction. What distinguishes it is full automation, high extraction speed and control over the final product profile, letting operators obtain high-quality products with a tap of a button.

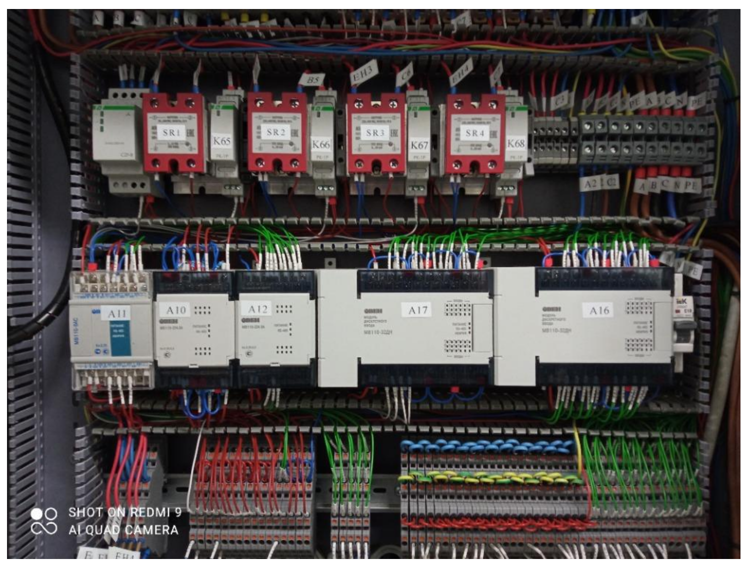
Key Innovations:

- **Process Optimization**: Using Python ML tools on previously accumulated data, we identified CO2 flow rate and pressure as the main drivers of extraction speed. Since heightening pressure would significantly increase the cost of the machine, we increased flow rates by more than 200%. In combination with quick frame locks on the column lids, we achieved doubling extraction efficiency, cutting cycle time by more than **50%** compared to industry standards.

- **Dynamic Temperature Control**: Unlike standard systems, this machine can both heat and cool extraction columns and **separators**. By controlling pressure and temperature—key factors in supercritical CO_2 solubility—we selectively "crash out" specific compounds, fractioning the extracts (e.g., isolating CBD in the first separator to increase THC concentration in the second one, which gives us high CBD extract in one separator and high THC extract in another one).

- **Heat/Cold Regeneration**: Typically, a chiller's compressor heat is dissipated through cooling fans. We diverted it to evaporate CO_2 from the final separator (the system's largest thermal load). This eliminated the need for electric heaters on the final separator and reduced fan loads, achieving up to 30% lower power consumption through energy recovery. Even though this practice is becoming more common, it is still rare.

Project Challenges & Solutions:



Full automation was our main goal, complicated by high pressure gradients, rapid flows, phase transitions, and compressibility of supercritical CO_2. Achieving stable pressure setpoints despite these variables was especially challenging. We succeeded by upgrading the needle valves with stepper motors modified for position control feedback and by using three precisely tuned PID controllers for pressure regulation.

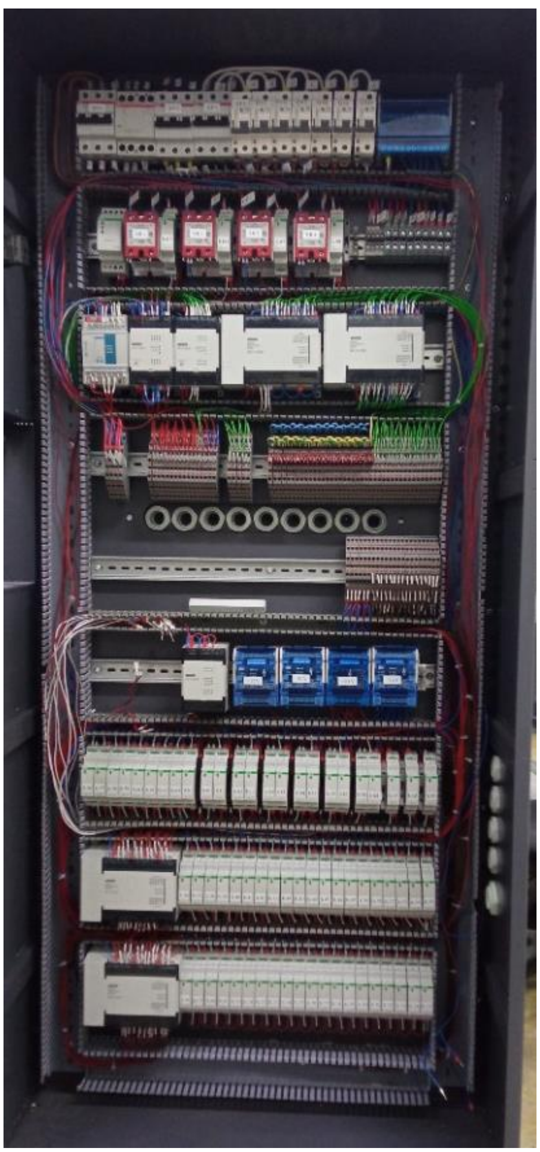
Another significant challenge involved purging air from the lines before charging the system with CO_2. Standard procedures would include vacuuming down whole system, which was not viable for us as the time required would diminish the progress we had already made. Instead, we developed a 'CO_2 blow-out' method to clear the lines and vessels. The primary difficulty was managing high pressure gradients (700+ PSI), which risked freezing the lines, making a lot of noise, and creating hazardous CO_2 level in the workspace. By installing quick-discharge heated valves and implementing whole system pressure monitoring, we achieved a full air purge in less than 20 seconds in full auto mode.

Main Specifications:

- **Columns**: 2 × 3L
- **Separators**: 3 × 3L
- **Pressure Range**: 800–2400 PSI
- **Liquid CO2 Flow Rate**: 1–4 lbs/min
- **Cycle Time**: 60 minutes
- **Power**: 3-phase, 210V, 14 kW

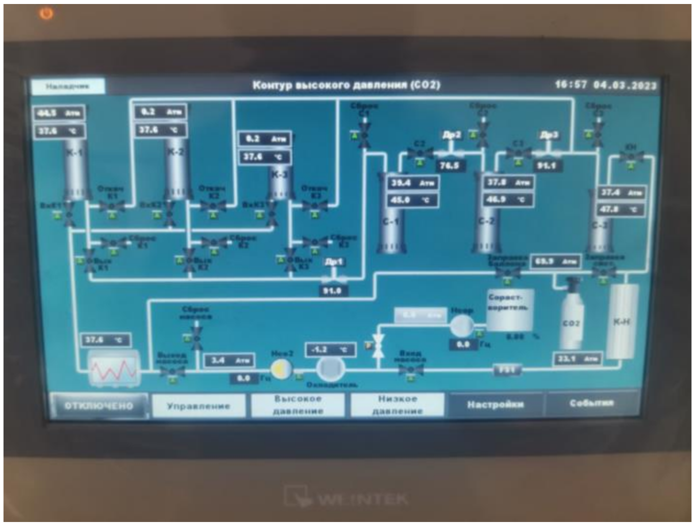
System Modules:

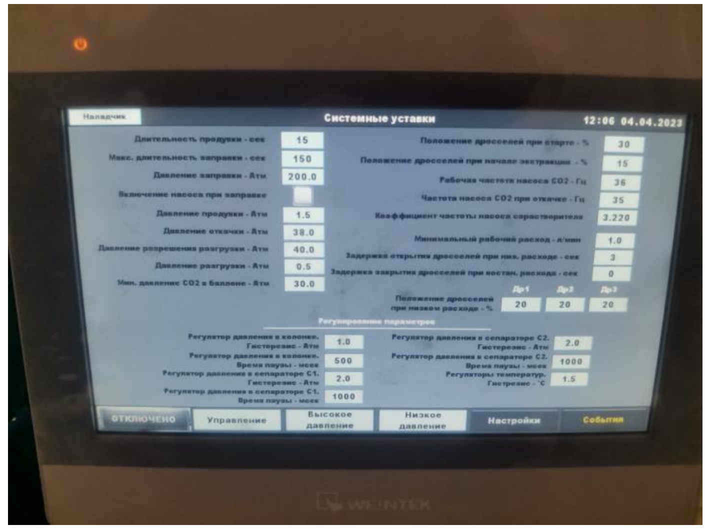
- Extraction Module
- Pump Station
- Chiller
- Control Panel
- Voltage Transformer



Controls & Automation Equipment:

- 23 motorized valves with position feedback (12V)
- 3 needle valves driven by stepper motors with position feedback
- 8 × 12V "fuel" pumps + 4 three-way valves for heating/cooling loops switching
- 8 pressure sensors (0–3000 PSI, 4–20 mA) with mechanical backups
- 12 Type K thermocouples
- High-pressure 3-plunger CO2 pump
- Breakers, relays, stepper motor drivers, contactors, 12V/24V DC power supplies, PLC and I/O modules, HMI display





The system was programmed in CODESYS with ladder logic. Heat exchange and strength calculations were done by hand firstly, then verified by SolidWorks simulations. All components and final assembly were modeled in SolidWorks. Additionally, a voltage transformer was installed to adapt the machine from Russia's 380V to Canada's 210V grid.

Key Achievements:

1. Full extraction cycle from start to finish with a single button tap.
2. Doubled extraction efficiency, cutting time by more than 50% vs. industry standards.
3. Up to 30% energy savings through heat/cold regeneration
4. Stable pressure across three vessels (800–2400 PSI) with 20 PSI accuracy.
5. Enabled heating and cooling of extraction vessels for product fractioning.

My Role: *Process Control/Automation Engineer*, transitioning to *Head Engineer* midway through.

As Process Control/Automation Engineer, I led the automation side of the project—including electrical schematics, process logic development, PLC programming, and HMI creation—along with theoretical calculations and SolidWorks simulations. As Head Engineer, I continued leading automation and theoretical aspects while overseeing the entire project: leading the team, selecting and purchasing equipment, managing the budget, and engaging directly with the client.

Based on 3+ years of CO2 extractors design experience, a team of five built this machine from scratch in 8 months in Moscow, Russia.

Equipment installation and staff training was handled by me. It's now operating in Ontario, Canada, producing **0.5–1 kg of THC/CBD crude oil per 8-hour shift**.

Watch a quick demo (Russian audio)

Thank you for your time , for more details or questions, feel free to contact me:
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Sincerely, Andrei Kuznetsov