

Abstract

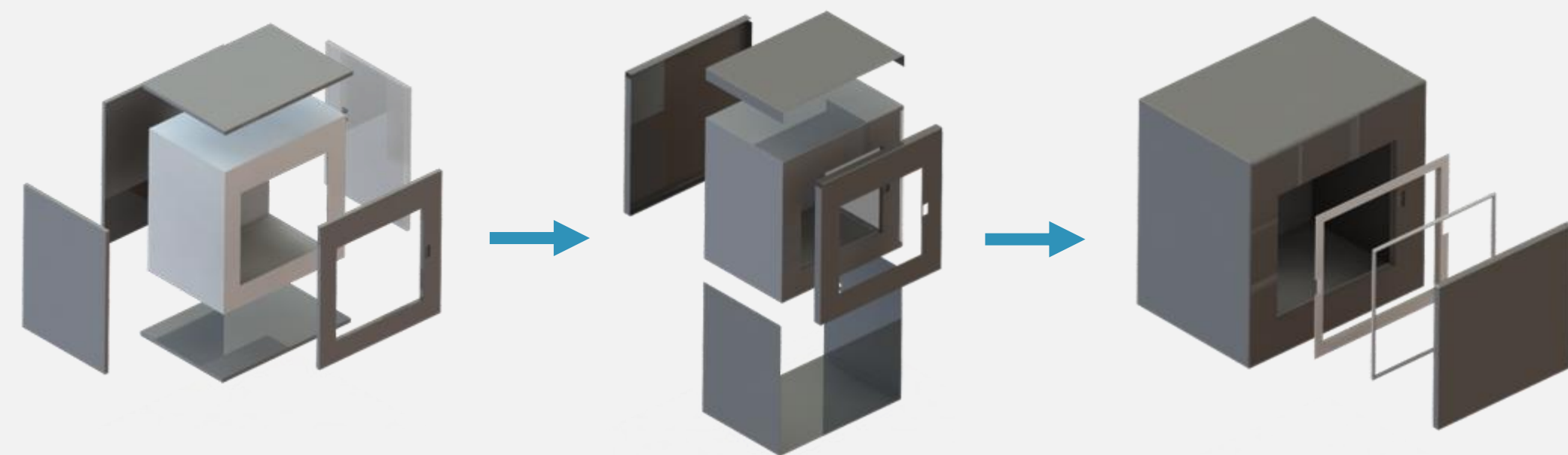
The Vitatron synergizes several typically separate processes of cell culture research into an all-in-one customizable, compact, and truly autonomous bioreactor. It combines liquid handling, cell culture monitoring, and environmental controls into one product, letting the user merely set up their desired samples and conditions and the system begins operation hands-free. The harmony of these autonomous systems allows for constant, sanitary cell culture growth and monitoring with minimal user interaction.

Product Functionality

Housed in a 3-layer composite wall for high thermal resistance, the Vitatron is capable of wide temperature ranges through an electric heater and a chiller-heat exchanger system. The liquid handling and optical measurement system move accurately and precisely due to the ball-screw setup for 3-axis motion. The pipettes consist of Opentron's open-source generation 2 P1000, including a scaled-up version to reach higher volumes. Furthermore, the optical measurement system allows for both optical density and fluorescent intensity measurements with any desired wavelength. It uses refractive grating, beam expander, and fluorescence wheel with interchangeable lenses. The Vitatron features a well tray that fits any standard well-plate size, and any combination of falcon tubes to allow the user to run eclectic and esoteric experiments alike. This universal tray sits on top of an agitator system capable of linear, orbital, and double orbital shake patterns.

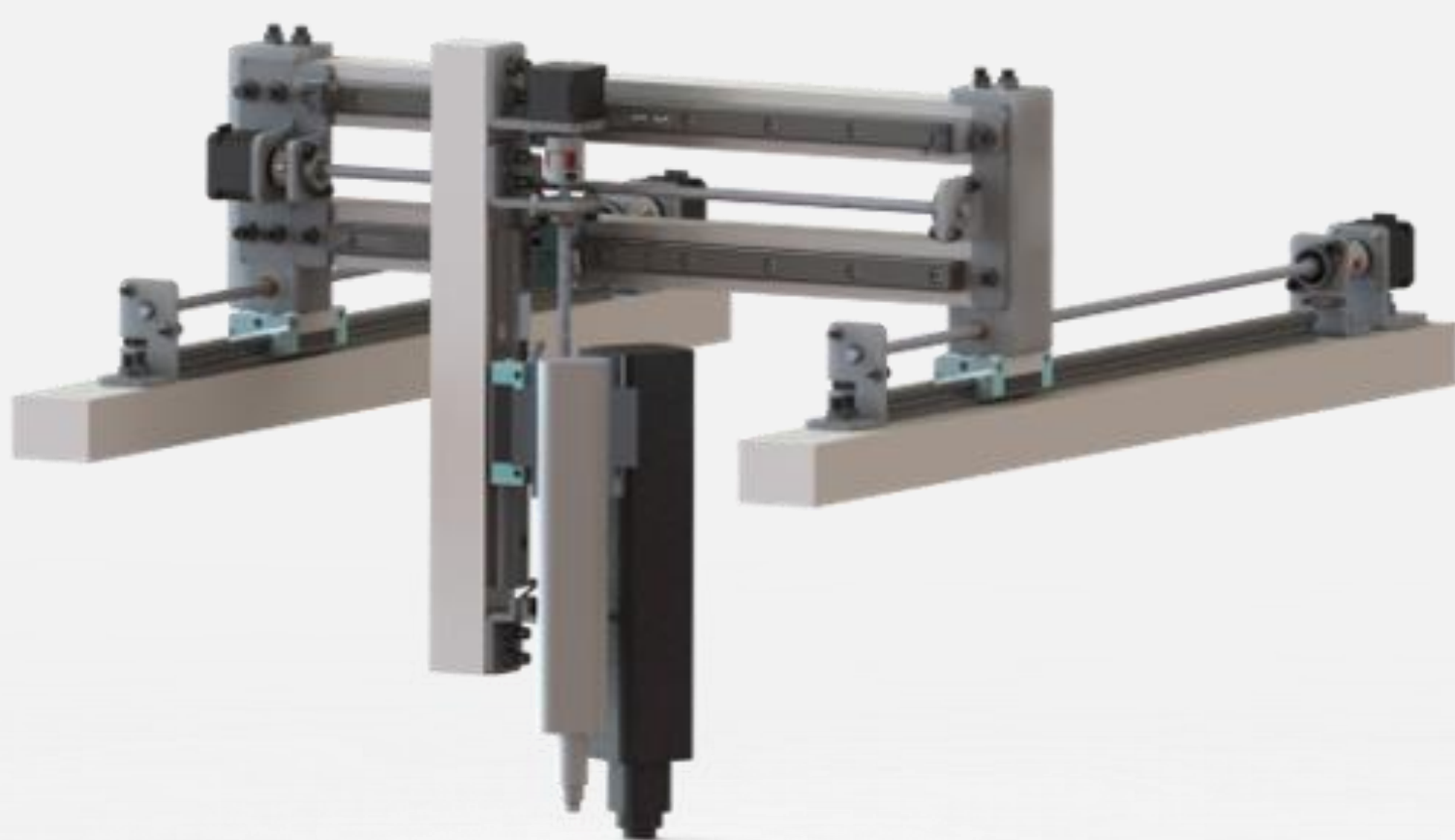
Housing

A three-layer composite wall. From the inside coming out, the first is polypropylene, a chemically resistant material. The second focuses on insulation taking advantage of polystyrene foam. The final and outside layer is stainless steel boosting the structural integrity. The composite wall boosts a high thermal resistance and will maintain the desired temperature range inside the chamber.



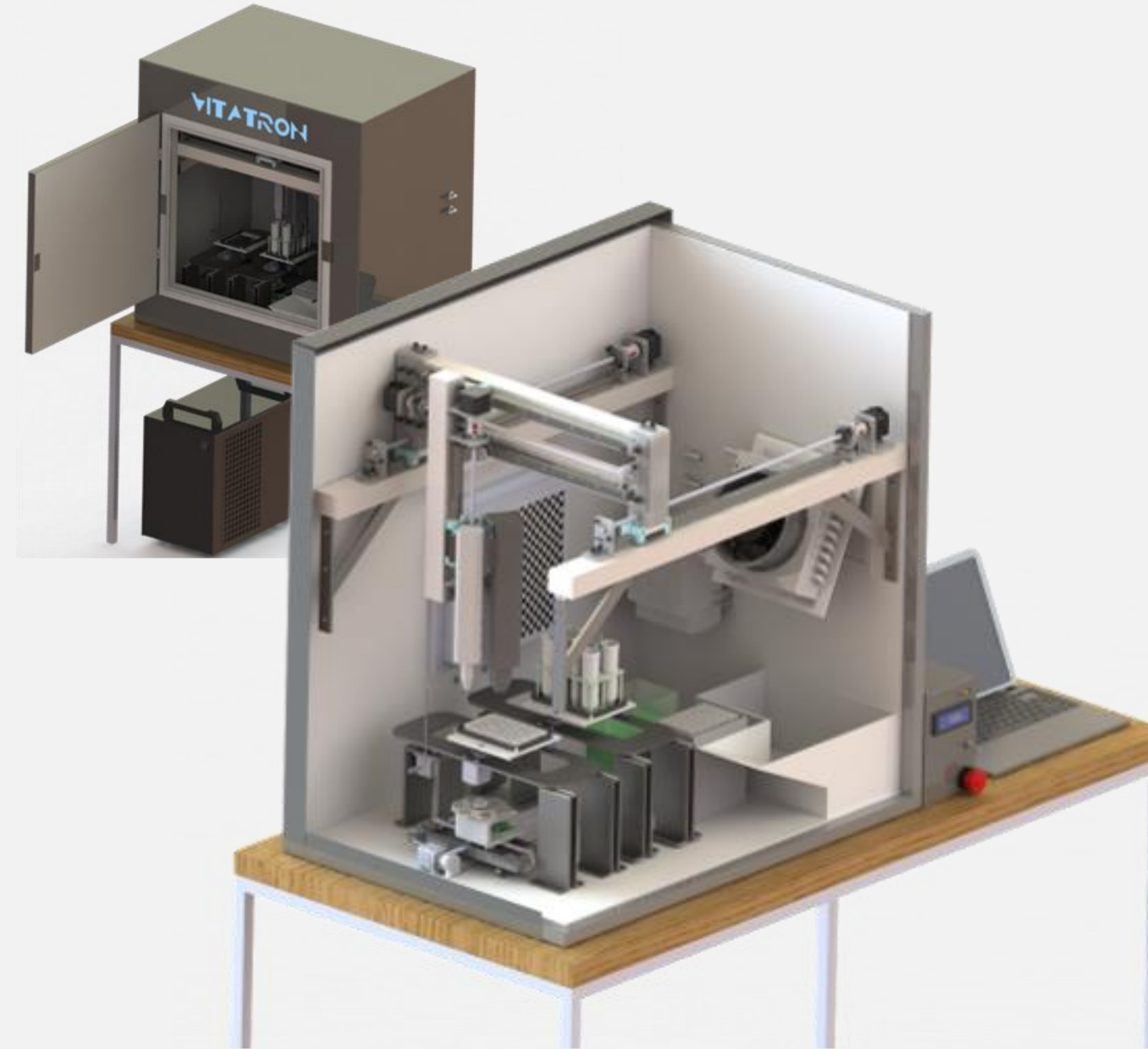
Liquid Handling

The XYZ-movement is a gantry system that maintains precision and accuracy with ball screws. The liquid will be handled by the Opentron's GEN2 P1000 for smaller volumes and a scaled-up version made inhouse as the product is open-source.



VITATRON

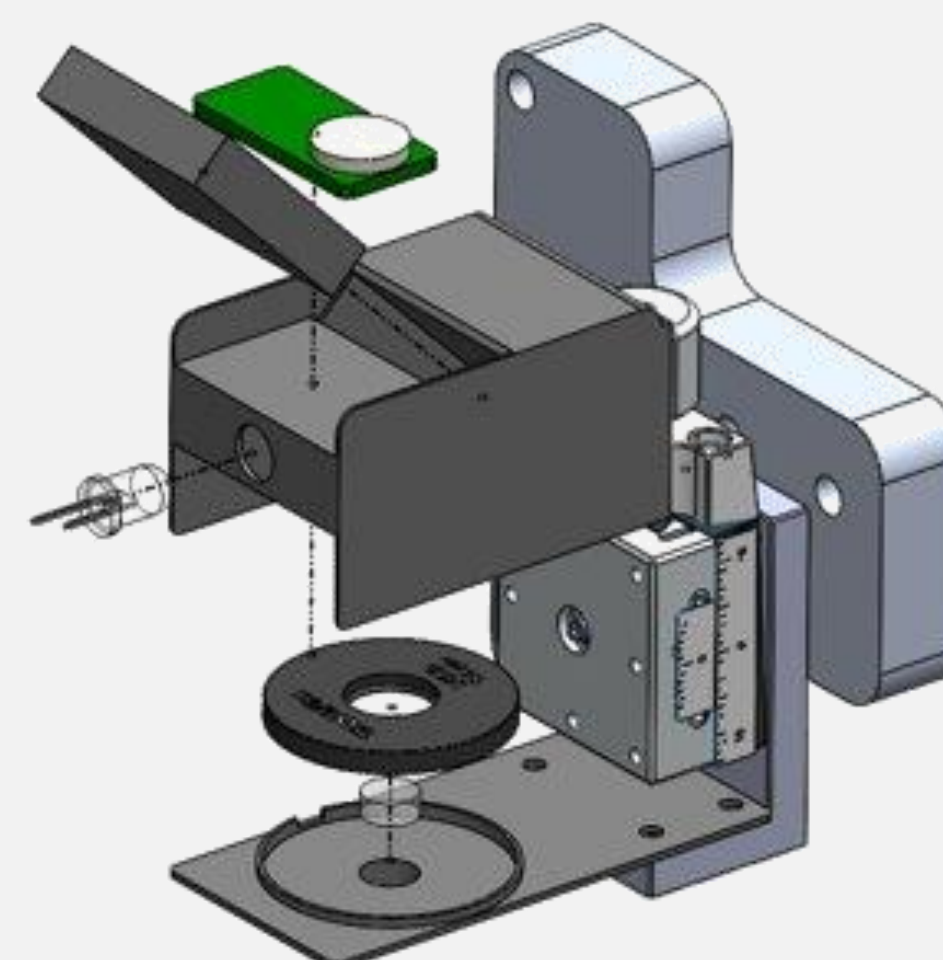
Group 4: Adam Ellenbogen, Cindy Long, Daniel Espinoza, Guillermo Aceves, Katherine Gonzalez, Nicolo Woodward, Rachel Pleitez, Sagar Das, Zakaria Bennouna



Cost Overview

OTS Parts	\$7914.83
Raw Materials	\$1915.00
Manufacturing and Assembly Labor	\$442.18
Energy Consumption	\$424.75
Total	\$10696.76

OD/FI System



Through the exit slit and adjustable height, the wavelength can be customized through a range of desired values. Both optical density (OD) and fluorescence intensity (FI) measurements are achieved. Integrated into the system is a beam expander, amplifying the beam diameter to accommodate reading of different well sizes and falcon tubes. A fluorescence wheel allows the customer to select a specific fluorescence filter lens based on the emission light hitting the cell cultures. The wheel comes with three filter lenses for standard FI measurements, but the customer can integrate up to five filter lenses in the wheel. The light is then diffracted and captured by a linear CCD sensor.

Agitator

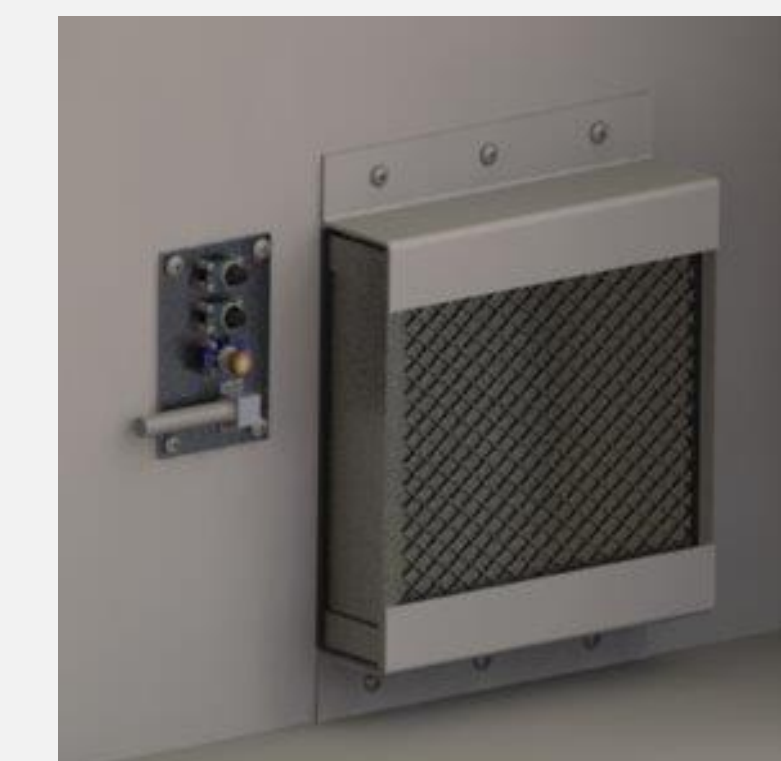
Employing the abilities of a scotch-yoke mechanism, each agitator achieves all three shaking patterns: linear, orbital, and double orbital. The seating tray can fit any well plate, as well as many falcon tubes due to the removable tube rack. Additionally, it achieves speeds from 50 to 300 RPM and easily accommodates for OD, as well as FI.



Gas Control



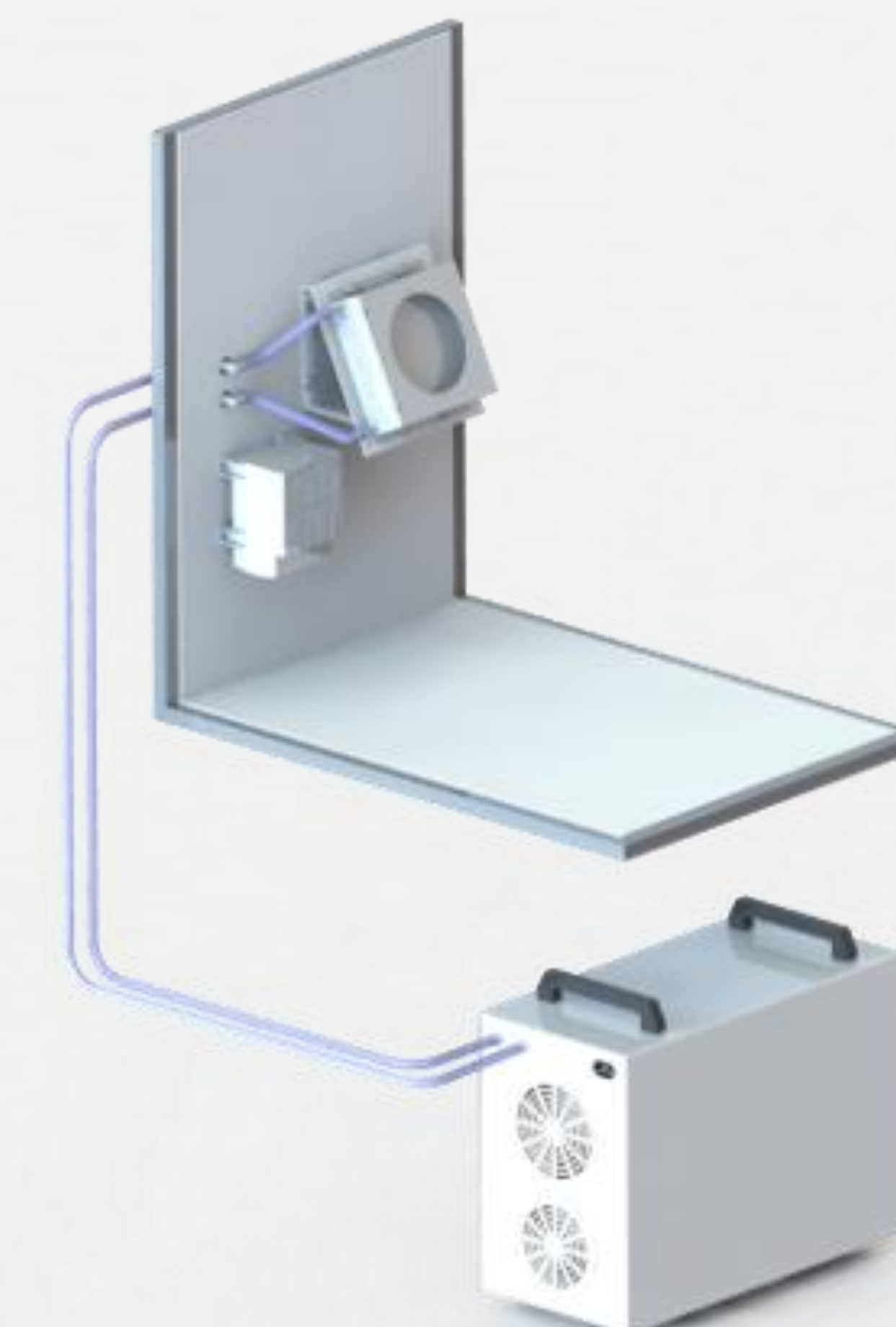
Exterior Gas Valves



Interior HEPA filter

With five inlets, the user may use up to five different gases at a time. Within this box are five solenoid valves, controlling the amount of the incoming gas for the chamber to ensure desired distribution is met. Furthermore, a composition and pressure sensor are placed inside the environment to monitor said values. A HEPA filter was added to mitigate airborne contamination.

Temperature Control



Using the density and specific heat for each gas, the minimum heat rate was found to achieve the desired temperature in the worst conditions in under 15 minutes. The performance and mass flow rate were used to find the heat flux needed to provide the heat transfer rate for the gases. The chiller cools a mixture of water and ethylene glycol which then goes through the heat exchanger to cool the system. An electric heater heats the system.

Customer Needs

- 1 Operational lifetime of at least 10 years
- 2 Prototype production cost does not exceed \$10,000
- 3 Moveable by one person after disassembly
- 4 Fits on a research benchtop, considering:
 - A Clearance through doors
 - B Benchtop load bearing capacity
 - C Benchtop footprint
- 5 Runs from a single standard 120 VAC outlet
- 6 Has an easily accessible interior for cleaning
- 7 Emergency shut-off that stops all functions
- 8 Has an intuitive user interface
- 9 Has a visual indicator that shows:
 - A System on/off
 - B Processing
 - C If an error occurred
- 10 Is programmable
- 11 Only nonporous materials contact cell cultures
- 12 Only nonreactive materials contact lab chemicals
- 13 Appropriate for operation in a BSL-2 space
- 14 Has an exterior surface that is safe to touch
- 15 Can handle and neutralize liquid and solid waste
- 16 Cultures in fully enclosed compartments
- 17 Maintains environmental conditions independently
- 18 Can control compartment gases
- 19 Is capable of incubation periods up to 2 weeks
- 20 Maintains cultures at a temperature from 4 - 70°C
- 21 Maintains temperature with variation less than $\pm 2.5^\circ\text{C}$
- 22 Uniformly heats and cools the cultures
- 23 Mitigates condensation on surfaces
- 24 Reaches setpoint temperature in ≤ 15 minutes
- 25 Accommodates existing culture well plates
- 26 Accommodates existing conical tubes
- 27 Photobioreactor mode to illuminate photosynthesis
- 28 Shake patterns: linear, orbital, and double orbital
- 29 Shaking patterns independent for each plate or tube
- 30 Measures optical density (OD) in all cultures
- 31 Measures fluorescent intensity (FI) in all cultures
- 32 Adequate light intensity not lethal to cells
- 33 Processes OD/FI measurements in ≤ 6.5 min
- 34 Is capable of automated liquid handling
- 35 Dispenses fluid without creating aerosols
- 36 Achieves dispense rates from 225–300 $\mu\text{L/s}$
- 37 Deposits aliquot fluid volume from 5–20,000 L
- 38 Achieves dispensing volume accuracy of $\pm 0.1\text{L}$
- 39 Achieves dispensing volume precision $\pm 0.01\text{L}$
- 40 No cross contamination between wells and tubes

Housing

- 3 Movable by one person
- 4A Clearance through doors
- 4B Benchtop load bearing capacity
- 4C Benchtop footprint
- 5 Power under 120VAC
- 6 Accessible interior for cleaning
- 7 Emergency stop button
- 8 Intuitive user interface
- 9 Time and progress indicator
- 9C Error indicator

Liquid Handling

- 12 Non-porous materials
- 13 Appropriate for BSL-2
- 15 Liquid handling & waste neutralization
- 34 Automated pipetting
- 35 No aerosols created
- 36 Dispense rates from 225–300 $\mu\text{L/s}$
- 37 Aliquot fluid volume from 5–20,000 L
- 38 Volume accuracy of $\pm 0.1\text{L}$
- 39 Volume precision of $\pm 0.1\text{L}$
- 40 No cross contamination

Gas Control

- 1 Operational lifetime ≥ 10 years
- 2 Cost $\leq \$10,000$
- 3 Movable by one person
- 17 Maintains environmental conditions
- 18 Can control compartment gases

Temperature Control

- 1 Operational lifetime ≥ 10 years
- 2 Cost $\leq \$10,000$
- 3 Movable by one person
- 17 Maintains environmental conditions
- 20 Temperature range 4°C to 70°C
- 21 Spatial variation less than $\pm 2.5^\circ\text{C}$
- 22 Uniform heating and cooling
- 23 Condensation mitigation
- 24 Set temperature reached in 15 min

OD/FI

- 1 Operational lifetime ≥ 10 years
- 2 Cost $\leq \$10,000$
- 3 Movable by one person
- 13 BSL-2 compliant
- 27 Photobioreactor mode
- 30 OD capability
- 31 FI capability
- 32 Non-lethal light intensity
- 33 OD/FI processing in ≤ 6.5 min

Agitator

- 1 Operational lifetime ≥ 10 years
- 2 Cost $\leq \$10,000$
- 3 Movable by one person
- 25 Well-plate accommodation
- 26 Falcon tube accommodation
- 28 3 shaking patterns
- 29 Independent shaking patterns