CREATING AN AUTOMATED CELL CULTURING MACHINE

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BACKGROUND

Cancer is a leading cause of death worldwide. [1]

American patients diagnosed with this disease are faced with

- Costs exceeding $100k [2]
- Multiple cycles of treatment that can increase drug resistance

There is an imminent need to accurately identify an appropriate treatment on the first test to increase the chance of survival. Encapsulate develops tumour-on-chip technology with cells from patient biopsies and uses them to test different chemotherapy treatments, determining which is most effective for each patient.

DESIGN CHOICES

Material Selection

Material	Use
PLA	Exterior
Polyisocyanurate	Insulation
Stainless Steel 304	Interior

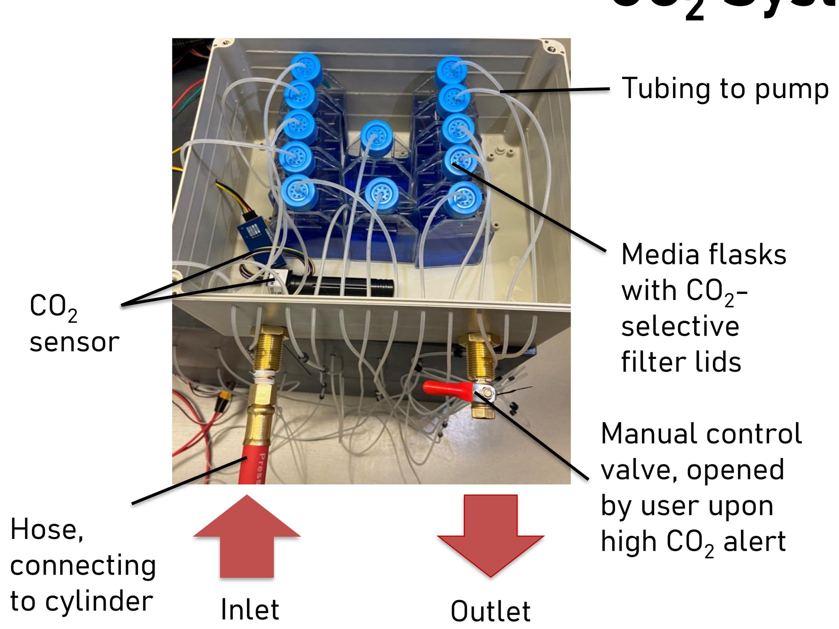
Enclosure Design

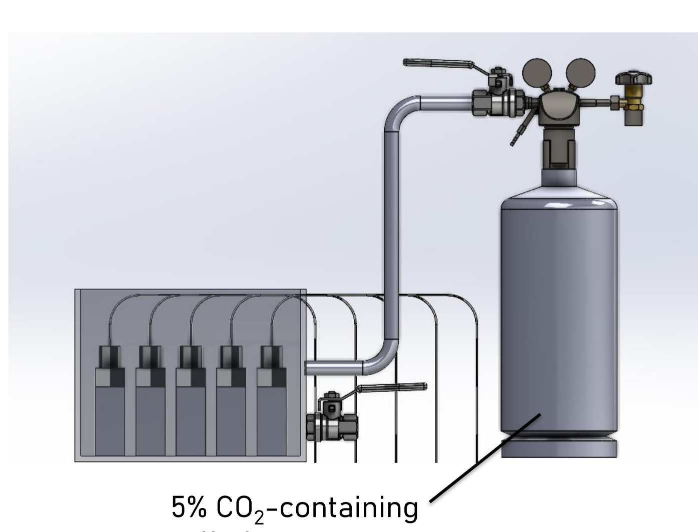
- Double-paned acrylic door to reduce heat loss by 87%
- Storage space for electrical parts and CO_2 System
- Compact dimensions: 41.2cm (L), 40.3cm (W), 58.1cm (H)

Number of Patients Treated & Number of Drugs Tested

- Maximizing the number of patients treated & drug combinations
- Minimizing the space taken up by the manifolds

CO_2 System

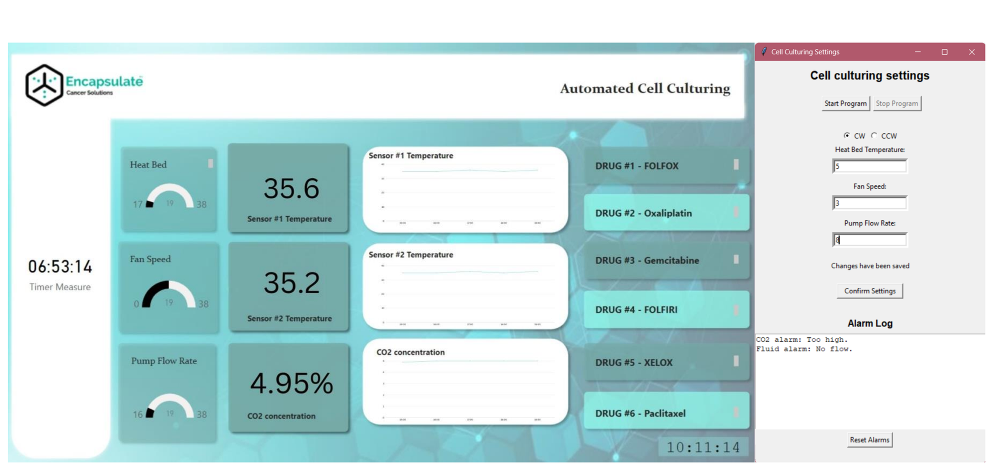




Fan & Heat Bed Placement

- Heat bed based on ANSYS thermal simulations
- Fans based on SolidWorks flow simulations

User Interface



OUR SOLUTION

A low-cost automated device that integrates with Encapsulate's on-chip technology and simulates human body conditions to grow, maintain, and drug-test cancerous micro-tumours.

Methods

SolidWorks Design → Simulation Testing → Sub-system Development → Assembly & Physical Testing

SUB-SYSTEMS

1 Thermal Regulation

Requirement: Maintain 37°C

Components: 3D printer heat bed, 4 fans

2 Pump Control

Requirement: Control the fluid pump through a Raspberry Pi interface using the Modbus protocol, allowing for pump routine automation

Components: Pump, Raspberry Pi, serial cable, RS485-USB adapter

3 Physical Enclosure

Requirement: Aesthetic appearance, compact size

Components: PLA exterior, insulation, stainless steel 304 interior, acrylic

4 CO_2 Regulation

Requirement: Maintain 5% CO_2

Components: Carbogen cylinder (5% CO_2, 95% O_2), hose, manual inlet and outlet ball valves, CO_2 sensor, media flasks with CO_2-permeable lids, airtight "media chamber", silicone tubing

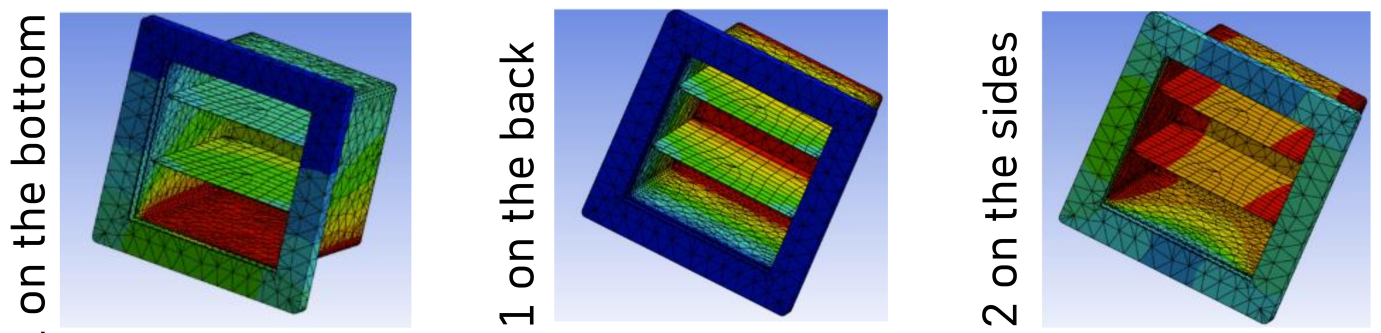
5 Fluid Circulation

Requirement: Maximize number of patients treated and drugs tested

Components: 24 biochips, 4 acrylic manifolds, silicone tubing, waste collection vials

TESTS & VALIDATION RESULTS

Thermal Simulations

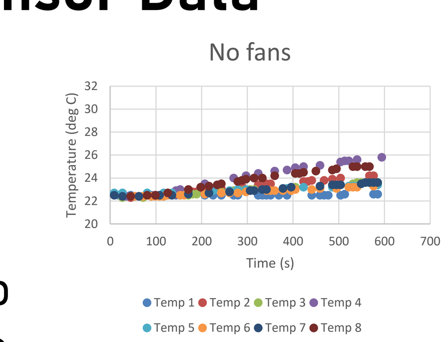


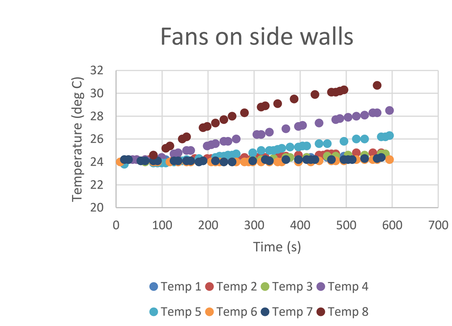
Results: 1 heater on the bottom gave the smallest temperature change.

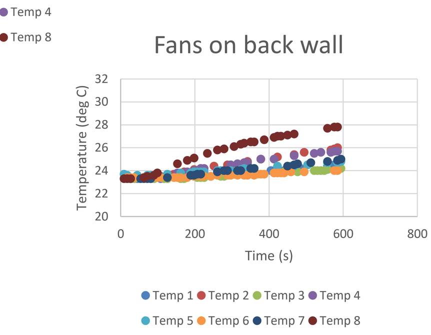
Thermal Tests and Sensor Data

Goal: Determine the heat distribution in the enclosure

Results: The fans speed up the heat distribution in the enclosure; more circulation is needed at the enclosure ceiling



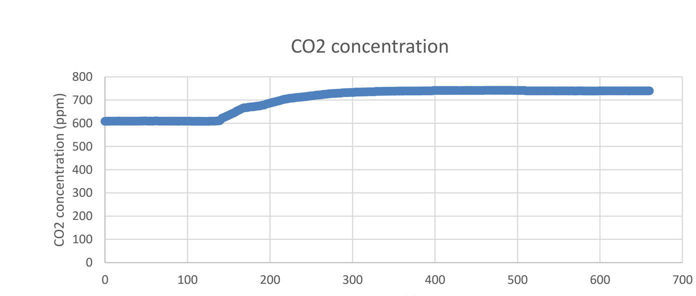




Media Chamber Airtightness

Goal: Determine if the media chamber CO_2 levels remain constant

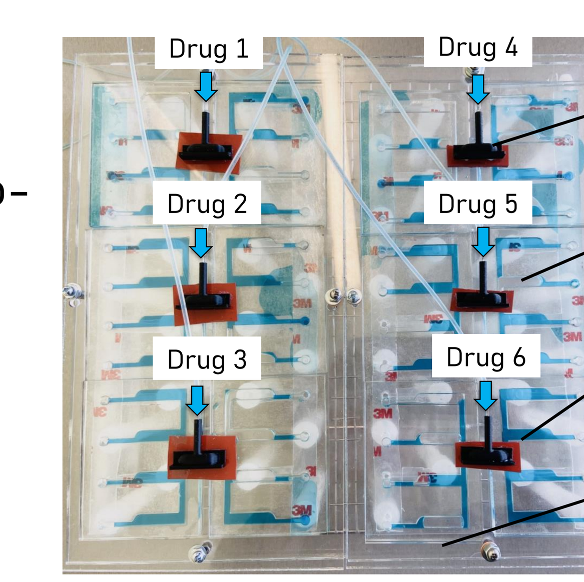
Results: After increasing the CO_2 concentration in the chamber, the level remains constant



Manifold Tests

Goal: Prevent leaks & flow drugs through bio-chip

Results: Dyed water successfully ran through 20 out of 24 biochips; minimal leaking was observed



FUTURE IMPROVEMENTS

As with any engineering project, we have identified areas for improvement, including:

- Smaller components that can be concealed within the device
- Telescoping shelves to make manifolds and biochips easier to access and remove
- Narrowing the manifold and biochip channels, allowing for higher-pressure flow to eliminate leaks
- Optimizing air circulation for even heating

[1] n.a., "ISS National Lab-sponsored research aims to grow tumors in microgravity to test chemotherapy effectiveness," ISS National Laboratory, https://www.issnationallab.org/release-spxcrs30-encapsulate-cancer-research/ (accessed Mar. 24, 2024).

[2] M. Siddiqui and S. V. Rajkumar, "The high cost of cancer drugs and what we can do about it," Mayo Clinic proceedings, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3538397/ (accessed Mar. 25, 2024).