Team 27

Purdue Horticulture

Instrumented Greenhouse Growth Chamber

Purdue Students: Ed Warner, Dexter Porsi, Jacob Kosiba, Cameron Westerman
Purdue Mentors / Customers: Dr. Kashchandra Raghothama, Nathan Deppe
Purdue Professors: Dr. Fred Berry & Dr. Suranjan Panigrahi

Team 27

PURDUE POLYTECHNIC

Customer Background

The Horticulture and Landscape Architecture department at Purdue University, under the direction of Dr. Kashchandra Raghothama, is studying the effects of increased carbon-dioxide levels and elevated temperatures on the growth of crop plants. These studies attempt to capture the changing climate in anticipation of future environmental conditions.

Problem Statement / Scope of Work

Our client, Professor Raghothama and the Purdue Horticulture and Landscape Architecture Department desire a growth chamber that utilizes natural light and regulates humidity, temperature, and carbon-dioxide levels. The growth chamber will be used to study the effects of anticipated future environmental conditions of elevated temperature and carbon-dioxide levels on the growing of food producing crop plants such as tomatoes.

Requirements Matrix

Requirement	Description	Test to Verify
	Electrical Requirements	
C02 Sensor	The sensor needs to have an error of ±5ppm	Expose the sensor to a known concentration of CO2 and check measurements.
Humidity Sensor	This sensor must be able to measure relative humidity within ±2%.	Expose the sensor to a known humidity level and verify measurements.
Control System for tuning.	Chamber controller must be able to regulate temperature, humidity, and CO2 based on user inputs	Create parameter set points and let the PID loop close the difference
	Mechanical Requirements	
C02 Supply	The chamber needs a CO2 source and a way to regulate it	Create a chamber controller set point and make sure the system can meet it
Frame Size	The frame bust be able to accommodate plants of the size of "strawberries to tomatoes"	Measure the chamber to make sure it is at least 4" in all directions

Experimentation / Concepts Exploration

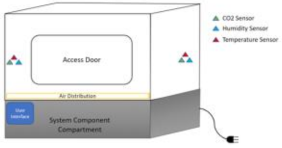


Figure 1: Conceptual Design of Chamber Prototype with Internal Systems

Strengths:
- Good utilization of light
- Easy concept
- Parts are easily obtainable

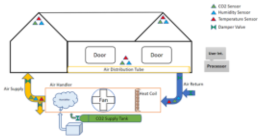
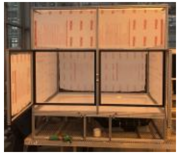
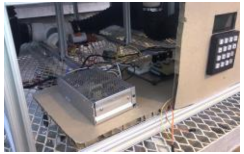


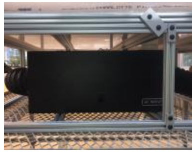
Figure 2 Conceptual Design of Chamber Prototype with External System Components

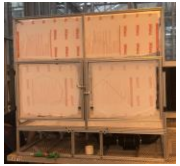
Strengths:
- Good use of air circulation
- Smaller footprint
- Easy to fix parts

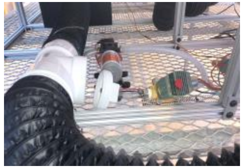
Final Design

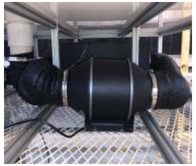












Failure Mode and Effect Analysis

FMEA - Failure Modes and Effective Analysis									
Key Process Step	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Taken
Automation/Controls									
Microcontroller	Communication Loss	Total loss of system control	1	Power Loss	3	Robust Power Supply System	1	3	Power supply system provides adequate energy needs
Solenoid Control	Control Valve Failure	Unable to regulate CO2/Humidity	1	Power Loss, Transistor failure	2	Flyback diode	3	6	Schottky diode to protect transistor
Heater Coils	Loss of Heat Control	Unable to regulate temperature	1	Power Loss, Coil Failure	2	Redundant coil system	3	6	Heat coils easily replaced
Inline Duct Fan	Loss of control signal	Unable to regulate airflow	1	Power Loss, Digital Signal loss	1	PWM Control Signal	3	3	Fan operates at 100% in absence of PWM signal
Mechanical									
Sealed Enclosure	Loss of Chamber seal	Unable to maintain temperature/ humidity/ CO2 setpoints	1	Door seal/Chamber seal	1	Inspect Chamber/Door seals	3	3	Silicone sealant applied to all chamber mating surfaces. Foam door seals provide tight fit
General									
Safety	Electrical Overcurrent	Electrical Shock hazard, equipment loss	2	Exposed wiring, failed transistors	1	System power switch	1	2	Install fuses to mitigate runaway current

Testing

General Automation and Mechanical Testing			
Step	Test	Details	Outcome
1	Sensor Inputs	The microcontroller reads all sensor inputs (CO2, Temperature, Humidity)	All of the sensor data inputs are valid
2	LCD Screen	LCD screen operation and control	The LCD is able to display desired data
3	Inline Duct Fan	The microcontroller provides PWM control signal to inline duct fan	Inline duct fan is able to provide airflow from 0 to 100% of product capabilities
4	Heat Coils	The microcontroller provides PWM control signal to the 120VAC control circuit via opto-isolator and triac	Heat coils provide heating commensurate with duty cycle of PWM control signal
5	Solenoid Valves	The microcontroller provides control signals to open/close solenoid valves	The solenoid valves open/close as needed via control circuitry
6	Water pressure pump	Water pump connected to 12VDC supply	Water pump self-regulates to maintain 100psi
7	Keypad	User input to keypad read by microcontroller	Keypad input is read and displayed on LCD