VANIER
CÉGEP / COLLEGE

Project Proposal

243-611-VA THE SMART FACTORY

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Process Description

This project outlines the engineering, technical, and operational process for the development of our miniature Slime Making Factory. This scaled-down version will serve as a prototype for an actual slime production plant, utilizing materials such as cardboards, illustration boards, chopping boards, containers, and other needed components to build the structure of the plant along with other functional key equipment including a Mixing Machine, Peristaltic Pump, Robotic Arm, and Control Sensors to simulate the industrial operations.

Overview

At the end of our project, our miniature Slime-Making Factory was only able to have a production process that involves precise **Ingredient Dispensing** of the raw materials and **Mixing System** that will run for 2-3 different times for each process (1^{st} run for Water and Borax (Powder) to dissolve the powder properly, 2^{nd} for the mixture with glue). The **Optional Glitter Addition** and the **Controlled Slime Dispensing** were not implemented for we faced a lot of problems making the system works.

To ensure consistency and quality, we will be monitoring our system's **Process Variable** which is the slime's consistency, achieved through accurate ingredient ratios and optimized mixing time, our **Measured Variable** which is the Torque of the Motor captured by ***supposedly*** a ***Current Sensor*** which we then changed to a ***Speed Encoder*** and our **Manipulated Variable** which is the Flow (Amount) of the Water to ensure uniformity and proper consistency. For us, this will ensure a controlled and repeatable slime production process, minimizing defects and maintaining high product quality.

Table 1. *Input and Output Materials*

Input (Raw Materials)	Water	Glue	Borax (Powder)
Output (Final Product)	Fully mixed slime with optional glitter		
Optional	Glitter (Three color for choices)		

Table 2. *Input/Outputs/Specs*

Specifications	Inputs	Outputs
1.5A Max	Weight Sensor *(Broken)*	Borax Open & Close
120 VAC/12VDC/5VDC/3.3VDC	Speed Encoder *(From CS)*	Water Pump (PWM)
Mixer:120V, 0.6A	Temperature Sensor	Mixer
	Flow Sensor	Heating Element
		Glue Pump
		Slime/Purge-Reset Pump

Key Equipment and Systems

Ingredient Dispensing System (Peristaltic Pumps, Pumps, Tanks and Valve):

- Consists of a water tank with a temperature sensor and a glue tank
- Pumps will dispense measured amounts of water and glue through small tubes into a transparent container
- Borax powder will be added by a Hopper that would only open when the weight sensor is triggered
- Operates until the raw materials reaches a predefined level (for each), detected by a weight sensor

Mixing System (Mixer and Transparent Container):

- Once the sensor confirms the required volume, the mixer is activated
- Mixer will run for 2-3 times: 1st for warm water & borax mixture & 2nd for the addition of glue & more water
- The mixer runs for a preset duration to achieve the desired slime consistency

Features Supposed to be Added…

- **Glitter Addition System - Optional Feature (Robotic Arm and Boxes)**
- **Slime Dispensing System**
- **Optional Conveyor System (Time-Permitting Feature)**

Evaluating Product Quality & Defects

To determine if the slime product is defective or fails to meet quality standards, verify checklist:

Quality Slime Checklist			
Batch #:	Time:	Date:	Inspected by:

Quality Item	Yes	No	Comments
Does the slime have smooth, homogeneous texture w/out clumps of undissolved borax or glue?			
Does the slime have exhibited the desired stretch and elasticity w/out being too runny/too stiff?			
Are the sensors monitoring correctly the exact amounts of water, glue, and borax dispensed?			
Was the slime mixed thoroughly for the set duration?			
If not, do some additional mixing cycles are added?			
If glitter is added, was it evenly dispersed throughout rather than clumping in certain areas?			
Signature of the Inspector:			

Along the process of producing our Slime, we would be continuously referring to this checklist to maintain product consistency and to also have a better perspective on how and where our product is.

What We Learned

Tamer if you are reading this, the factory ended up working the day after we presented it to you, as it turns out I bought the wrong kind of borax, that's why it wasn't sliming…

Throughout this project, I gained valuable knowledge and learned several key lessons that have shaped my understanding of both hardware and software integration.

One of the first lessons I learned was the correct wiring of relays with the ESP32. Initially, I had the misconception that the power supply for the ESP32 and the relay module should be kept separate. However, after conducting further research and troubleshooting, I discovered that the relay should be directly wired and powered by the ESP32 to ensure proper functionality. This experience taught me the importance of verifying wiring configurations and understanding how components interact with each other.

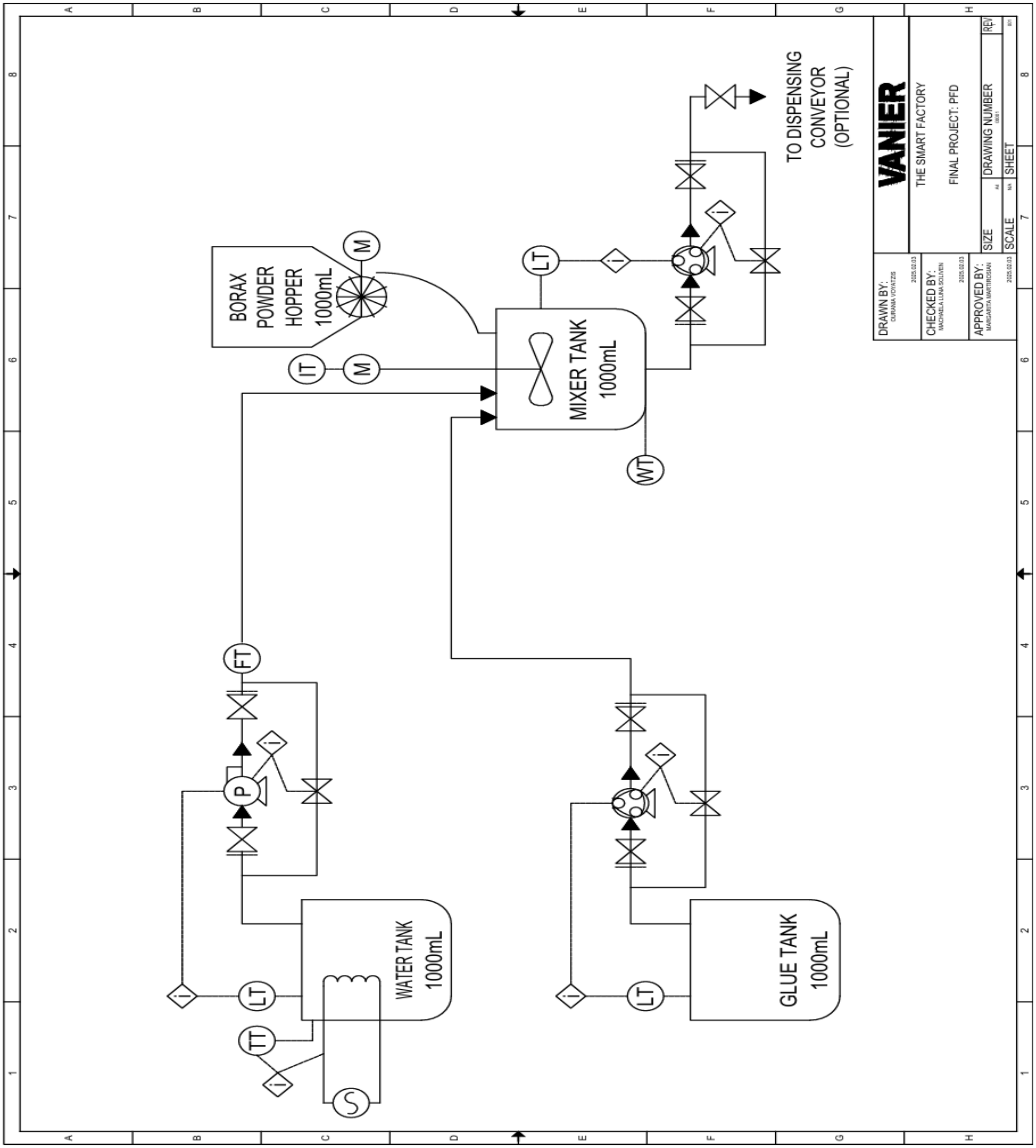
Another valuable lesson came from dealing with noise in the signals from the pulses of flow sensor. Initially, the sensor wasn't functioning properly, and no matter how I wired it, it wouldn't work. After researching, I learned that high-pass and low-pass filters were essential to reduce the noise in the signals. Applying these filters allowed the flow sensor to be detected and function properly with the ESP32, teaching me the significance of signal processing techniques in my projects.

I also realized the limitations of using current sensors to measure torque in the mixing machine. The sensor was unable to detect torque accurately because its internal components couldn't handle the rapid changes in current. As a result, it wasn't suitable for our PID control system. After revisiting the design, we decided to switch to a speed encoder, which allowed us to measure torque effectively. This taught me the importance of selecting the right sensor for the application and being flexible when problems arise.

Another key takeaway was the complexity of writing Python code for hardware integration. I learned that understanding the specific requirements of embedded components is crucial before coding. I also found that debugging hardware-software integration issues requires patience and a methodical approach.

Lastly, I learned the importance of proper grounding connections in electronic systems. Without proper grounding, we experienced static shocks and interference, which negatively impacted the performance of several components. This made me realize that grounding is essential for minimizing noise and ensuring reliable operation, even though I am still learning the best practices for implementing it. The learning was not limited to these experiences however, to detail all the things that I learned would be very long. I have also edited the document with strike throughs to show how the scope and specifications changed from when we first submitted the proposal.

Process Flow Diagram (PFD)



Sequence of Operation

In our ***Slime Factory***, there would be two buttons available: **Start** and **Reset** Buttons

1. If temperature sensor inside the Tank for water is the same as the set temperature for the system, Pump for water will start to pump to the mixing container until flow sensor value is reached, then Pump will stop
2. When the pump stops, the Rotary Valve for the Borax Powder will open for certain, then closes, stopping the distribution of powder to the mixing container
3. After the Valve stops, the relay contact in the motor of the mixer closes, starting the mixer 1st round of mix
4. 1st mix will go for certain seconds, then stops, then 2nd pump pushes certain amount of glue to the container
5. It will pump for certain seconds THEN
6. 2nd run of mix and water pump will go until desired consistency is reached (PID)
7. When the mixer stops, the Speed Encoder will be verifying if the product meets the set viscosity for the Slime by checking the speed
8. If the Speed sensor's set value is not met, it will add the necessary material (e.g. water)
9. If met, it will continue the process and us, the operators, will verify if the product complies with the checklist provided to assure quality of product
10. Once set weight is achieved (no slime left), system would wait for the Start button to be triggered again

***** *This system will continue its process as long as* ***Reset*** *button is not triggered* *****

Control Strategy

The Slime Factory's process is divided into **2 parts**: **The Slime Making** and **The Slime Dispensing Process**
The entire process is automated and monitored using sensors, actuators, a PLC-based control system, and alarm/safety systems to ensure efficiency and reliability.

Slime Making Process

This involves mixing raw materials in a container to produce slime, process is monitored and controlled using:

- PID Control Strategy to adjust slime consistency
- PLC to automate the process, control pumps, mixers & sensors to maintain desired slime consistency
- Temperature Sensor to monitor and regulate water temperature
- Weight sensor to measure weight of materials and trigger alarms if values are too low or too high
- Speed Encoder Sensor to detect how fast the mixer is going (to measure slime's consistency)
- Level Sensors in water and glue tanks to ensure system has enough for the process
- Pump and Peristaltic Pump Actuator to control the flow of water, glue and the final Slime
- Weight Alarm in the mixing container to prevent overloading
- No Current Draw Alarm to know if the mixer doesn't start, indicating a motor failure
- Pump Failure Alarm to know if materials aren't flowing
- Low and High Weight Alarm to ensure correct ingredient levels
- Borax Powder Alarm to see if the Rotary Valve have opened and placed some powder

Slime Dispensing Process

This involves dispensing the produced slime into containers, process is monitored and controlled using:

- PLC that manages the dispensing process, ensuring precise filling and preventing waste
- Pump State alarm to know the peristaltic pump's state
- End of Process Alarm to indicate successful slime dispensing
- Mixing Container alarm indicator to know if the system is ready for dispensing

Hazardous Materials & Safety Considerations

Hazardous Materials Used in the Process

Material	Potential Hazard	Safety Measures
Borax (Sodium Borate Powder)	- Skin and eye irritation can lead to allergic reactions - Inhalation can cause respiratory issues - Ingesting borax can cause Gastrointestinal issues	- Personal Protection: Use gloves, goggles and masks - Ventilate the area
Glue (Polyvinyl Acetate – PVA)	- Prolonged skin contact may cause irritation, blisters, and corrosion - Eye irritation: Causes reddening & burning sensations - Respiratory Irritation: Causes coughing, nose & throat irritation - Fire & Explosion: Flammable and reactive	- Personal Protection: Use gloves, goggles and masks - Ventilate the area. - Fire prevention: Store away from heat sources and use flame-resistant storage
Clay Sprinkles (Small Colored Clay Pieces)	- Inhalation risk: Small dust particles from the sprinkles may become airborne and cause respiratory irritation - Ingestion risk: Accidental swallowing may be a choking hazard if not properly handled and stored - Contamination: Loose sprinkles may mix into different batches which can affect product quality	- Work in ventilated areas: reduce airborne dust particles - Use protective gear: Wear Masks - Automate handling: Use robotic dispenser to minimize manual contact
Water (Warm for Mixing)	- High temperature water can cause burns if mishandled - Slips and falls: Wet floors from spills or leaks can cause workers to slip and fall - Electrical Shock: Contact with exposed electrical components near water can lead to severe electric shock - Drowning: Accidental falls into the large tank can lead to drowning - Flooding: Sudden flooding can inundate machinery and create unsafe working conditions	- Burn Protection: Use efficient temperature sensors to regulate the heat - Slip Prevention: Install anti-slip mats and ensure regular cleanup of spills. Regular cleaning and maintenance is necessary - Electrical Safety: Keep the components insulated and away from water sources

Environmental Risk Evaluation

***Table 1.1**. Temperature Hazards*

Potential Risk	Description	Measures
Overheating of Equipment	- Motors, pumps and the mixer may overheat due to prolonged operation - This can lead to breakdowns of equipment or fire risks	- Install temperature sensors to monitor equipment heat levels - Implement automatic shutoff mechanisms if the overheating occurs
Water Heating Risks	- Process requires warm water for dissolving borax - If water is overheated, it can cause burns, pressure and uncontrolled steam	- Use temperature-controlled heating for water - Limit max temperature setting to prevent any burns or pressure - Install Pressure Relief Valves
Effect on Slime Quality	- If there are extreme environmental temperatures, it can affect the slime consistency	- Keep the temperature-controlled storage for the raw materials - Ensure ambient consistent temperature during production time

***Table 1.2.** Radiation Risks*

Potential Risk	Description	Measures
UV Radiation from lights	- Extended exposure to high intensity UV lighting can degrade raw materials	- Use UV blocking enclosures around UV light sources
Electromagnetic Radiation (EMF exposure)	- Motors, pumps, and control systems generate low levels of electromagnetic fields (EMF) - This can lead to interference with other equipment	- Use shielded cables for electrical Wiring - Maintain proper grounding of electrical systems - Keep electronic sensors away from high EMF areas

Table 1.3. *Air Quality & Ventilation Risks*

Potential Risk	Description	Measures
Dust and Powder Inhalation	- The fine particles can become airborne which can lead to asthma, respiratory infections and chronic obstructive pulmonary disease.	- Work in ventilated areas - Use dust extraction systems. - Wear PPE when handling powders - Regularly clean work areas
Volatile Organic Compounds (VOC)	- Glue fumes can release VOCs - It can cause dizziness, headaches and long-term health effects	- Use low VOC or non-toxic glue - Ensure airflow w/ exhaust fans - Use PPE

Table 1.4. *Water & Moisture Hazards*

Potential Risk	Description	Measures
Humidity Affecting Raw Materials	- High humidity can cause borax powder to clump; - This can affect proper mixing and slime consistency	- Store borax in airtight containers - Maintain stable humidity levels, monitor with sensors
Leakage and Water Damage	- Leaks from pumps, tanks and pipes can cause electrical hazards, equipment failure or floor hazards	- Regularly inspect pipes and seals for leaks - Install leak sensor near the water tanks - Ensure proper draining to prevent the water accumulation

Table 1.5. *Noise Pollution Risks*

Potential Risk	Description	Measures
Loud Mixing or Pumping Equipment	- Continuous operations of Mixers, Robotic Arms and pumps can cause hearing discomfort	- Use sound dampening enclosures around the noisy equipment - Maintain proper lubrication to reduce mechanical noise - Provide hearing protection for operators

Energy Efficiency & Environmental Sustainability Risks

Potential Risk	Description	Measures
High Power Consumption	- Excessive energy use from motors, heaters and control systems increase operational costs and carbon production	- Use energy efficient motors and LED lighting - Implement automated shutdown when the equipment is not used
Waste Generation	The improper disposal of slime waste, glue residue and the excess of water can contribute to pollution.	- Implement waste recycling strategies - Minimize water waste with controlled dispensing systems

Machine & Operators Risks

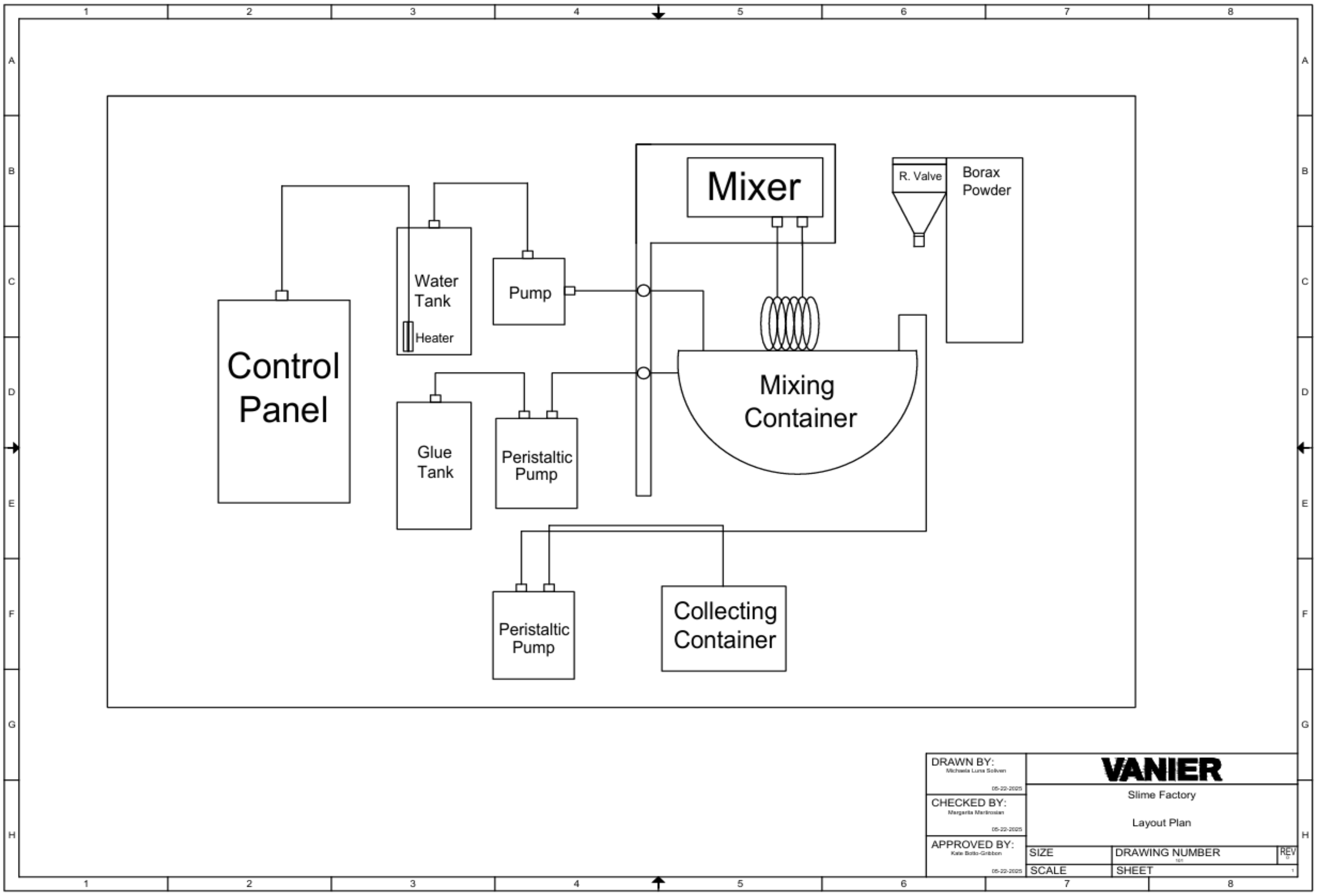
Table 1.1. *Machine Risks*

Potential Risk	Description	Measures
Mixer Overload & Jamming	- The mixer may jam or overload if materials are improperly added - This will cause a motor failure or Mechanical damage	- Install Overload Protection AND - Install Current Sensor to shut down the mixer if it exceeds safe limits - Use proper material sequencing to prevent jams
Pump Malfunction & Pressure Build-up	- A failed pump could cause pressure buildup - This leads to sudden bursts or leaks	- Install Pressure Relief Valves AND - Real-time Pump Monitoring with Alarms for malfunctions
Hopper Blockage & Material Overflow	- Materials may clog the hopper, causing an overflow or uneven material flow into the mixer	- Use vibration mechanisms or flow sensors to prevent blockages - Install an overflow alarm to stop the feeding process - Manually & consistently check Hopper to see if there are blockages
Robot Arm Unexpected Movement due to Malfunction	- Software bugs or sensor failures can cause the robotic arm to move unpredictably	- Use fail-safe programming and redundancy in control systems - Conduct routine maintenance and sensor calibration - Install override/manual control in case of emergency

Table 1.2. *Operator Risks*

Potential Risk	Description	Measures
Chemical Exposure (Borax & Glue Fumes)	- Prolonged exposure to borax dust or glue fumes can cause skin irritation or respiratory issues	- Install proper ventilation and require the use of gloves and masks - Implement sealed dispensing system for borax powder
Slippery Floors from Spills	- Spilled slime, glue, or water can create a slip hazard for operators	- Place non-slip mats, ensure quick spill cleanup procedures - Install floor drains to manage excess liquid
Hand Injury from Moving Parts	- Operators may accidentally place their hands near moving parts of the mixer, hopper, arm robot or conveyor	- Use safety interlocks to prevent the mixer from running when the lid is open - Provide machine guarding on rotating parts
Electric Shock	- Faulty wiring or moisture exposure can lead to electrical hazards.	- Ensure use of waterproof electrical enclosures - Do regular maintenance checks - Use ground fault circuit interrupters (GFCI)
Robot Arm Collision with Operator	- Robotic Arm may accidentally hit an operator during movement - This could cause severe injuries	- Install safety cages or barriers around the robot's operating area - Use Motion Sensors and Emergency Stop buttons - Implement Light Curtains to pause the robot if an operator enters the workspace
Robot Arm Pinch & Crush Hazard	- Moving parts of the robotic arm can trap hands or fingers	- Design the robotic arm with rounded edges and protective covers - Train operators to stay clear of moving parts - Use force-limiting technology to stop movement if resistance is detected
Arm Robot High-Speed Movement	- Fast robotic arm motions can cause sudden impacts	- Set speed limits and soft-stop zones in programming - Use adjustable speed control based on proximity to humans

Final Layout



Materials

This will be the table of all the materials we are going be using for this project:

Table 2. *Project's Materials*

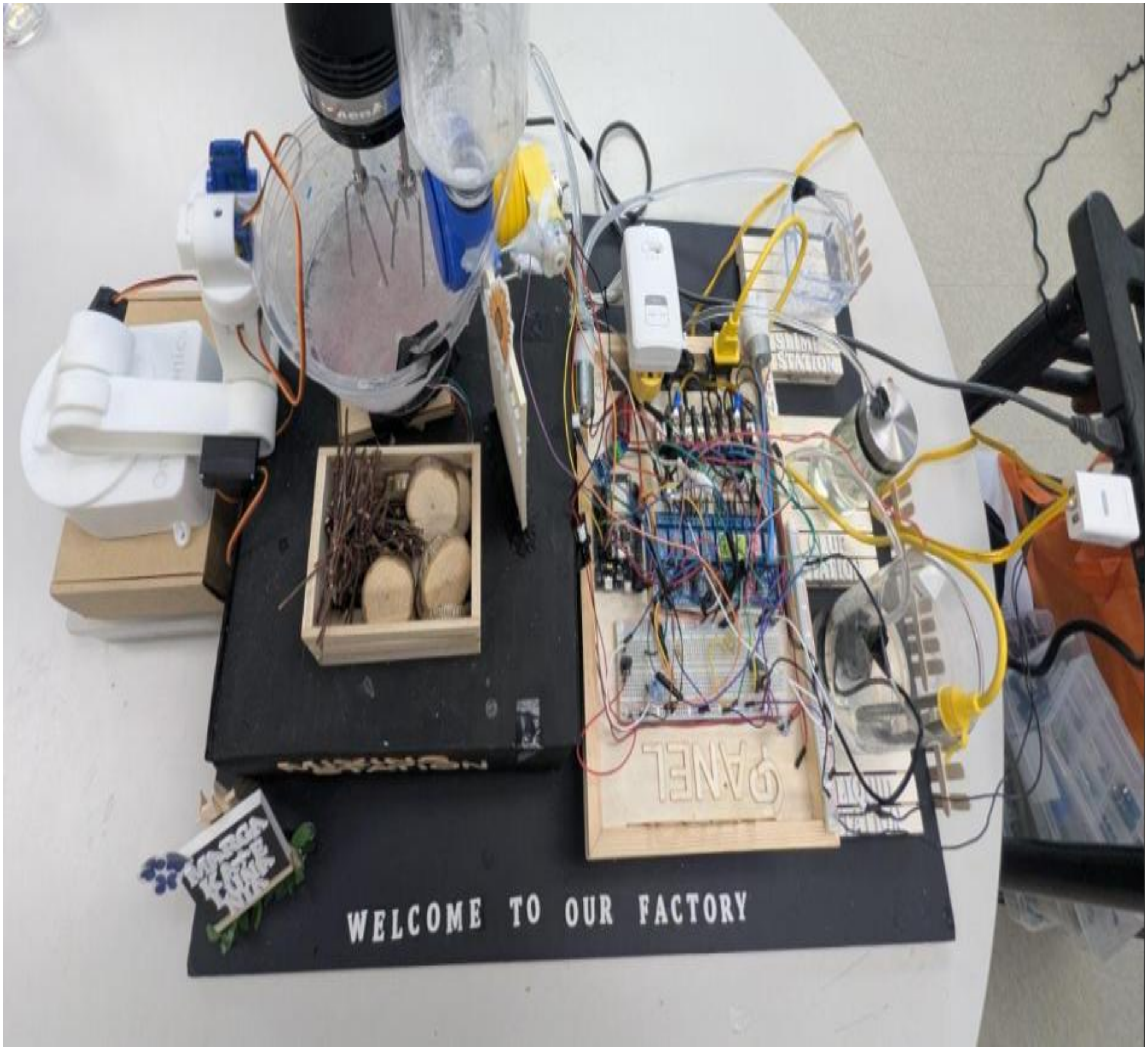
Ingredient Dispensing System	Mixing System	Slime Dispensing System	Glitter Addition System	Optional Conveyor System
Normal Pump	Mixing Container	Electromechanical Valve	Arm Robot (3D + Motor + Scoop)	Conveyor (Self-Made)
Big Peristaltic Pump (Glue)	Speed Encoder Sensor	Small Diaphragm Pump (Slime)	Glitter Containers (3x)	Optic OR Ultrasonic Sensor
Tubes	Mixer	Collecting Container	Push Buttons (4x)	Containers (3x)
Glue & Water Tanks	Relays	Weight Sensor		
Rotary Valve (3D + Motor)				

Final Project

Photo 1. *Slime Factory – Note Yet Tested*

Final Project

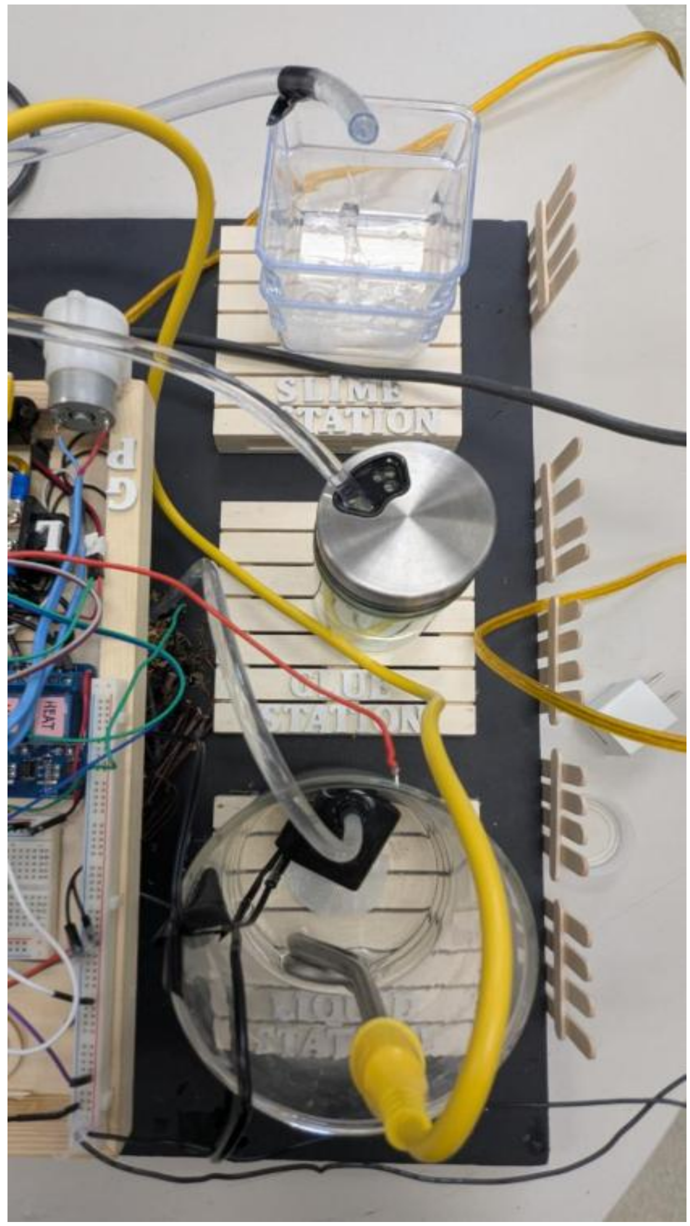
Photo 2. *Slime Factory - Working*



Final Project

Photo 3. *Mixing Station (+ Arm Robot)*

Photo 4. *Water, Glue & Slime Station*



Final Project

Photo 5. *Control Panel – After Troubleshooting*