Executive Summary

Our design aims to provide an engaging experience for the audience of a video art projection by alternately revealing and hiding the projected images. The purpose of this project is to design a controllable fluid screen which is capable of changing its state repeatedly between transparent an opaque as it receives an input from the audience.

We have converted the user requirements set by our sponsor into quantifiable engineering specifications. Relative weight and correlations of user requirements and engineering specifications are shown in QFD.

From our primary concept generation, only chemical solutions can achieve the sponsor's desired visual effect. We generated 12 specifications to evaluate the top five sub-concepts. The design using a supersaturated solution has the highest weighted score with the advantages of best visual performance and repeatable transparency changing, and with incorporate a heating element and circulation of cooling liquid.

The chosen design consists of four subsystems: chemical, heating, cooling, and the corresponding control system. Chemical experiments was carried out and determined the heating temperature is 70℃. From our engineering analysis, the required heating to achieve our desired temperature in 5 minutes is 3.35kW and our pump must operate at 2L/min with an output pressure ≥ 1.378 psi.

After determining the parameters, the final design of both physical and control components are introduced. For physical part, heating is done by two immersion heaters placed in sealed heating compartments, to protect from potential damage, through conduction and by passing steam boiled off through the solution. The cooling system flows cold water underneath the solution tray and then will be chilled using an ice. Our control design utilizes an Arduino Uno microprocessor to control the heating element, the pump, and the valve. The Arduino takes inputs from the sensors of our physical system to determine the corresponding required operation: precipitation, heating, or cooling.
All polycarbonate parts were manufactured in the machine shop using the mill, and subsequently glue together with plastic solvent. The pump, water reservoir, and radiator are laid in series with the flow compartment using plastic tubing barbed fittings and hose clamps. The heater are screwed into the fluid container.

We conducted several validation tests to verify our design. For the physical part, the size is 15”×18”× 3.5” compared with 15”×18”× 2” required by our sponsor. The weight of the tray with solution inside is 21.2±0.1 pounds, which is less than the maximum limit 40 pounds. Currently we are not able to conduct display quality test since we have not attained the opaque state. The acetic acid in vapor is about 3ppm, which is less than the limit of 10 ppm. For the control part, the solution was heated from 25℃ to 70℃ in 15-20 minutes and cooled down from 70℃ to 25℃ in 25 minutes. The temperature sensor triggered and stopped each process accurately when it sensed the preset temperature in the Arduino program. However, the temperature sensor sensed 6 to 8℃ slower than real temperature change.

We have provided some recommendations improve the performance of our design. We recommend a concentration of 6.8 kg sodium acetate in about 1.2L deionized water to achieve the instantaneous crystallization effect. For the heating system, we recommend incorporating a magnetic stirrer and circulation system to accelerate the propagation of heat. An automated water level control system is also recommended to replace the water inside the heating compartment. For the cooling system, we recommend redesigning the cooling compartment to include an extension for an outlet capable of removing trapped air. We also recommend replacing the current pump with a self-priming pump so that it can still run with an air/liquid mixture. For the control design, we recommend an offset temperature of 7℃, since the thermal sensor sensed the temperature 6-8℃ slower than the real temperature.