Project Definition

Date: 8 June 2022

Project Name: Block Sight not Heat, Hinman ver.

Client: Quarantine and Isolation Housing Team of Northwestern

Project Team Member: Paul Kim

Mission Statement:

Design a cost-saving implement for people who live in 1835 Hinman that provides low-maintenance temperature control.

Project Deliverables:

- Sketch of prototype which will effectively demonstrate how the idea will be applied in the real world
- Short report

Constraints:

- **Budget:** The budget for this project is USD $100. I must stay under budget in buying resources to construct prototypes and final product.
- **Time/Due Date:** I have less than two weeks to work on this project. Although building off of an existing solution, this limits me because I must successfully adjust the solution to fix the new context within the time frame.

Users and Stakeholders:

- Northwestern undergraduates who are living on campus and tested positive for COVID-19 will be temporarily residing in 1835 Hinman and use this product to maintain temperature control in their rooms so that they remain comfortable throughout the day.
- Northwestern Quarantine & Isolation Housing office that maintains 1835 Hinman and its use as a quarantine facility are also stakeholders, as they are responsible for dealing with feedback and possible complaints from the Hinman residents and covering costs for maintenance systems.

User's profile

I will be designing for myself, a Northwestern sophomore who currently lives in 1835 Hinman after testing positive for COVID-19. I have experience living in tropical weather in the Philippines as well as living in the largely cooler weather of Evanston.

User scenario:

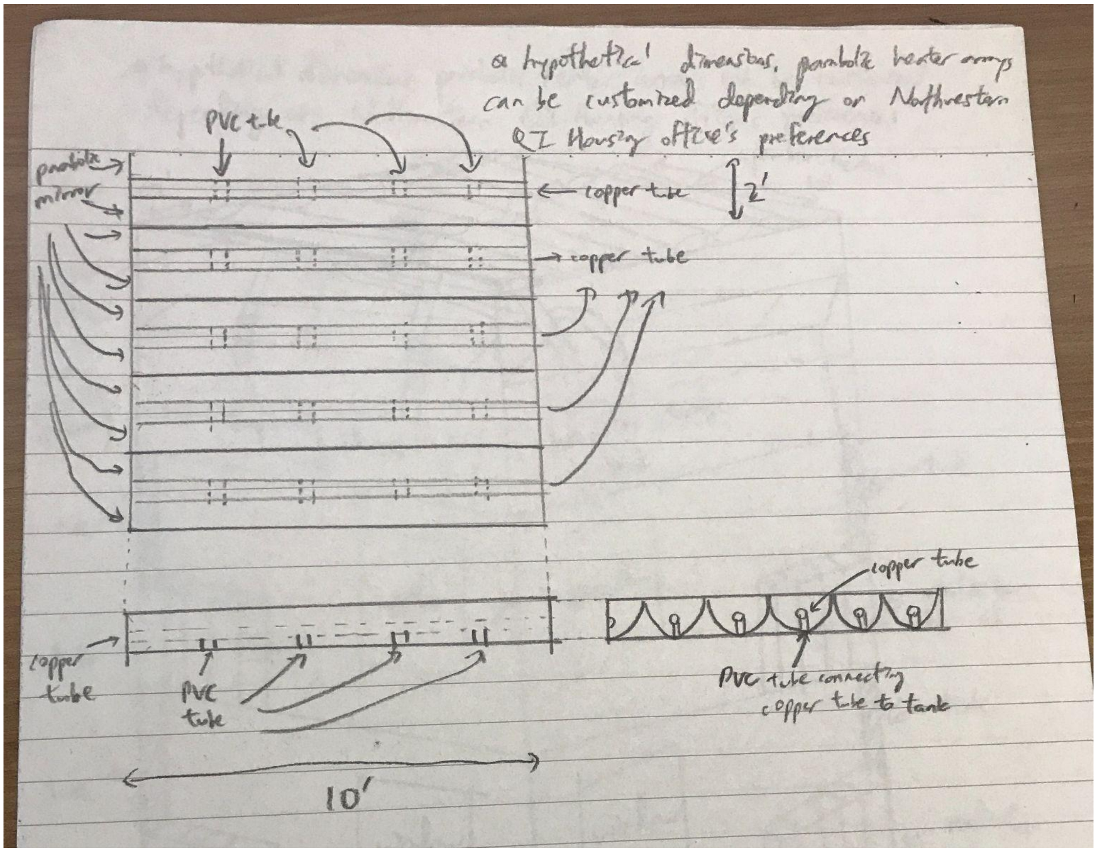
Currently in Hinman, I have no control over the temperature setting in my room, as the AC system is malfunctioning. The only way I can attempt to control temperature is by opening or closing the window. Temperatures can often reach the 70s or even 80s in the afternoon and fall to 50-60s at night. However, one of the symptoms of COVID-19 is chills, so I often feel colder than it actually is at nighttime. This means that I am often cold in the morning and too hot in the afternoon, affecting my comfort and productivity. Sunlight and privacy are not too much of a concern due to being surrounded by tall trees. The inconvenience of having abundant heat in the afternoon when it is unneeded, combined with the lack of heat in the morning when it is needed, merits a solution.

Needs	**Metrics**	**Units**	**Ideal Value**	**Allowable Value**	**Notes**
Temperature control	Temperature (A range)	Fahrenheit	70-75	64-76 New World Encyclopedia	Ranges chosen by proxy user testing of different ambient temperature in dorm rooms
Easily installable	Installability, on a scale of 1 to 5 (5 being the easiest to install, 1 being the hardest)	N/A	5	4	Method of installation must not impose additional monetary or temporal costs for

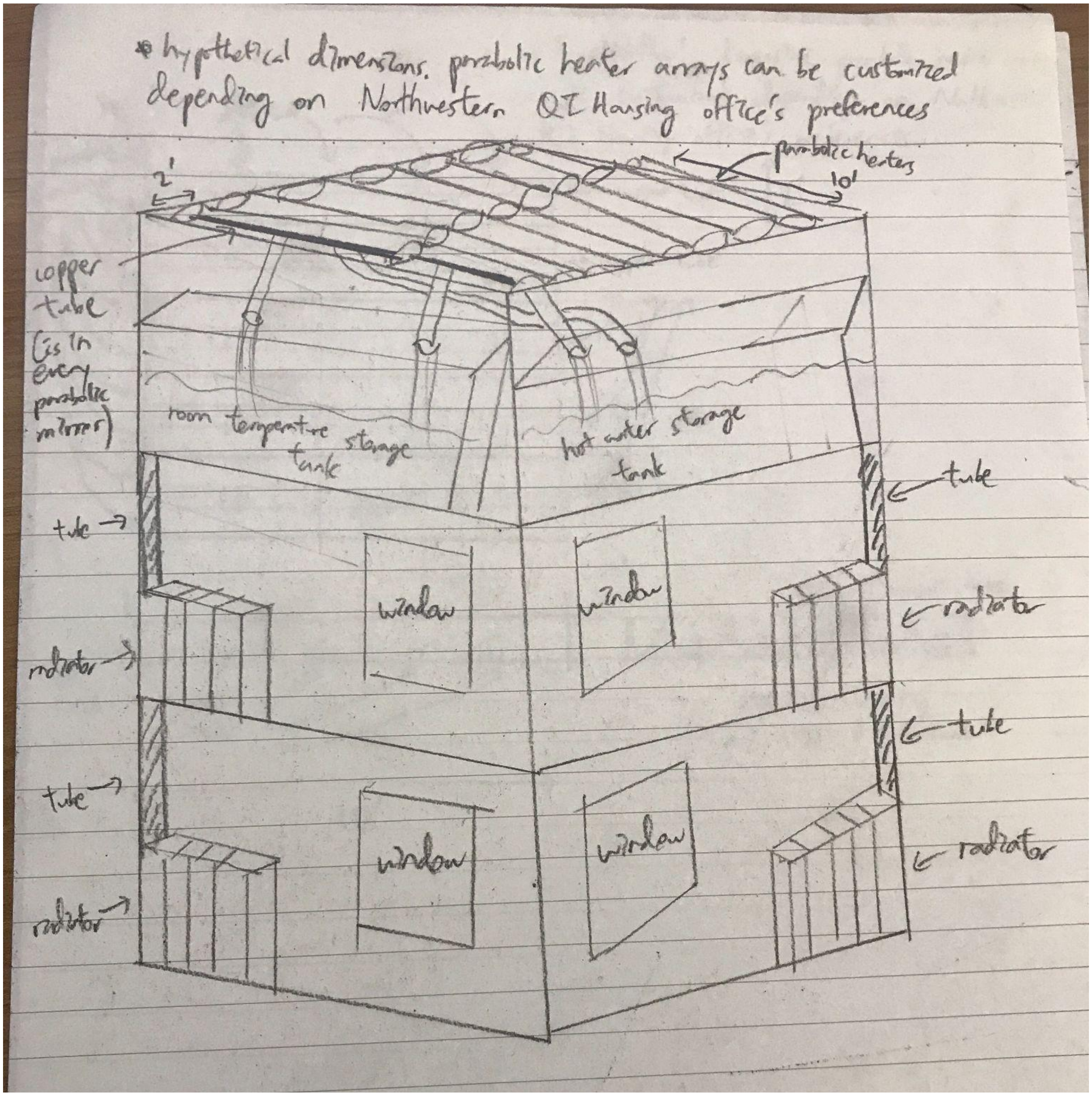
					user
Worthwhile value proposition	Worth, on a scale of 1 to 5 (5 being the most worthwhile, 1 being the least)	N/A	5	4	
Environmentally friendly	Environmental impact on a scale of 1-10, with 10 having the most positive impact and 1 being the most negative impact, and 5-6 being in the neutral range	N/A	10		"Environmental friendliness" is subjective depending. Need to solicit input from project partner and perform additional research.

Mockup

Orthographic



Isometric


* hypothetical dimensions. parabolic heater arrays can be customized depending on Northwestern QT Housing office's preferences
parabolic heaters
2'
10'
copper tube (is in every parabolic mirror)
room temperature storage tank
hot water storage tank
tube
tube
radiator
radiator
window
window
window
window
tube
tube
radiator
radiator

Mockup testing plan

Introduction

The purpose of these tests are to determine the effectiveness of using various metals for the piping material to capture heat from the concentrated sunlight. This is extremely important, as one set of parabolic structures is going to support the heating and cooling needs of the entire Hinman building, so the material has to capture as much heat as possible.

Possible metal material choices for the pipes of the parabolic heat concentrating system are copper and aluminum, so the first two experiments will determine how copper compares to aluminium in terms of heat conductivity. The focus would be on copper because it is cheaper than aluminium (thus the cost advantage). A third test would be focused on the effectiveness of coating the metal pipes with black paint to increase heat absorption.

Methodology

Materials include two 100mL beakers, a piece of copper and a piece of aluminum with the same thickness, a coffee pot, water, a handheld infrared thermometer, and a bench shear (equipment to cut thin metal pieces).

First, use the bench shear to cut the copper and aluminium into equal 4’’ by 4’’ sizes. Then, use the coffee pot to boil the water to 100 degrees Celsius. Pour 80mL of the hot water into each beaker and place the copper piece on top of one beaker and the aluminium piece on top of the other. Use the thermometer to measure the temperature of each metal piece at the 1 minute mark, 2 minute mark, 5 minute mark, 10 minute mark, 20 minute mark, and 30 minute mark. Record the temperatures for all twelve measurements.

The second test requires a piece of copper and aluminum with 1’’ thickness, two support stands each with a metal ring, a handheld infrared thermometer, and a bench shear.

First, use the bench shear to cut the copper and aluminium into equal 4’’ by 4’’ sizes. Then, attach each metal ring to a support stand so that the ring is parallel to the ground. Place the support stands in an area where the metal ring receives direct sunlight. Place a copper piece on top of one metal ring, and, simultaneously, the aluminum piece on top of the other. Use the thermometer to measure the temperature of each metal piece at the 1 minute mark, 2 minute mark, 5 minute mark, 10 minute mark, 20 minute mark, and 30 minute mark. Record the temperatures for all twelve measurements.

The final test requires a piece of copper, two support stands each with a metal ring, a handheld infrared thermometer, black acrylic paint, a brush, and a bench shear.

First, use the bench shear to cut the copper into two equal 4’’ by 4’’ pieces. Then, use the brush and black paint to paint one of the copper pieces black on the side that faces the sun. Then, attach each metal ring to a support stand so that the ring is parallel to the ground. Place the support stands in an area where the metal ring’s area receives direct sunlight. Place a copper piece on top of each metal ring simultaneously. Use the thermometer to measure the temperature of each copper piece at the 1 minute mark, 2 minute mark, 5 minute mark, 10 minute mark, 20 minute mark, and 30 minute mark. Record the temperatures for all twelve measurements.

Design Freeze

Drawings are above

The system is a circuit consisting of a parabolic mirror (termed a “parabolic heater”), a hot water tank, a radiator per room, and a room-temperature water tank. Each element of the system is connected to the next element with a PVC tube.

The basic subunit of the parabolic heater is a long sheet of metal curved into a parabola. This metal sheet is covered with reflective film. A copper tube with water pumped through it is suspended lengthwise inside the parabola formed by the metal sheet such that a cross section of the subunit shows the copper tube at the focal point of the parabola. The overall parabolic heater will consist of multiple parabolic subunits laid side-by-side.

The key operation in the system is the heating of water in the parabolic heater. The reflective film on the parabolic subunits reflects light and heat onto the copper tubes containing the water. Because copper is a strong conductor of heat, the water warms up. The mirror will work in both sunny and overcast conditions, but less heat will be stored in overcast conditions. The use of a parabola to concentrate reflected light and heat onto a focal point means that the design is more heat efficient than leaving water in an exposed container in the sun.

When the water reaches 65 degrees Celsius, detected by a temperature sensor, it is moved with a pump to a hot water storage tank. More water is then moved from the room temperature water storage tank into the copper tubes to replace the warmed water moved to the hot water tank.

For a given room, if indoor room temperature is below the minimum comfortable temperature (which is set by the user), then the water will proceed directly from the hot storage tank to the radiator in that room. The radiator used in the system will be a conventional radiator that dissipates heat from the hot water pumped into it.

After the heating, once the indoor room temperature is above the minimum comfortable temperature, the flow of water between the hot water storage tank and the radiator will be cut off. The water in the radiator is moved (either by gravity or with a pump) to the room temperature water storage tank, and thus continues to cycle through the system.

The biggest change from the original design is the fact that the structures of the system are all bigger in size. More parabolic mirrors, more radiators (one per room), larger water tanks, more copper tubes, more water, and more PVC tubes that connect the water tanks, copper tubes, and radiators. Much more pumping activity would be involved, as the amount of water flow is going to drastically increase.

Bill of Materials

Item Description	Qty	Source	Part #	Unit Cost	Total Cost
PVC Pipe 2.049" inner diameter, 2.375" outer diameter	1 (10 ft long piece)	Home Depot https://www.homedepot.com/p/JM-EAGLE-2-in-x-10-ft-280-PSI-Schedule-40-PVC-DWV-Plain-End-Pipe-531137/100161954	N/A	19.49	19.49
General Purpose Copper Tubing 3/4” outer diameter, 0.686” inner diameter	1 (3 feet long piece)	McMaster-Carr https://www.mcmaster.com/pipe/general-purpose-copper-tubing/	8967K74	34.13	34.13
Plywood/Foam core	30” width, 45” length	Shop	N/A	$0	$0
Wood glue	TBD	Shop	N/A	$0	$0
Nails	TBD	Shop	N/A	$0	$0
Black spray paint	TBD	Shop	N/A	$0	$0
Plastic or aluminum to build	TBD	Shop	N/A	$0	$0

parabolas					
Spray Adhesives	TBD	Shop	N/A	$0	$0
Hose clamps	TBD	Shop	N/A	$0	$0
Metalized Moisture-Resistant Polyester Film	1	McMaster-Carr https://www.mcmaster.com/7538T11/	7538T11	10.52	10.52
				Total Cost for the Prototype:	64.14

Ethical concerns

Engineering is meant to create products that improve the quality of life of people in one way or another, and in the engineering process this should never be neglected. At the end of the day, if the product is created under a process that violates basic safety or ethical standards, then the purpose is definitely tainted to an extent, and it is up to the engineer to decide to what extent they are going to uphold their values.

The categories of ethical concerns that are pertinent to my design are lack of expertise, social impact, and end-of-life disposal. The first one overlaps with my team's design, but the latter two are more pertinent to this specific design.

I am not sufficiently trained in chemical engineering or manufacturing to foresee any potential side effects of using certain materials. Since this design is a system that requires an overhaul of the entire Hinman building, it is concerning that I am not fully aware of the possible side effects that any of the infrastructures that are brought into the building can bring about.

The social impact aspect is mainly related to the cost that is incurred when the system is installed. Installing an entire system of heating would cost huge amounts of money, and with limited budget for remodeling, other dorms' renovation plans may be delayed, causing further discomfort in unexpected areas. In addition, during the installation process, Hinman residents and neighbors would feel discomfort due to loud noises in the construction process. There definitely are the eventual cost reduction aspect of the system's operations and environmental friendly aspects of the system's usage of solar heat. But it is hard to compare the long term benefits and short term costs prior to the implementation of the solution, and especially when long term costs in the form of end of life usage are definitely present.

The end of life usage is very important as it comes to this design. This design uses a huge number of materials in tanks, mirrors, tubes, and radiators. Thus, once the system's life has expired, or it is time to replace the equipment, disposing of the materials would be a tough process - especially while dealing with materials like copper or PVC. Careful consideration must be made to ensure that natural resource consumption and negative environmental impact is minimized. It would also cost money to dispose of huge amounts of material, so monetary concerns are also linked to this issue. While copper tubes can be recycled, it still takes effort and manpower to remove them from the existent system. Also, recycling PVC requires dealing with chlorine and other hazardous materials within PVC.

The differing aspects of ethical concerns mainly stem from the fact that my design's scale is much greater than that of the original design. With more materials and more complexities come more considerations for the environment and a longer installation and potential removal process.