INTEREGR-170 Design Practicum 12/12/18
Project Title: Got Milk?
Client: Abby Jensen
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Photograph of the Final Design:

Abstract:

This project designed, evaluated, and fabricated a device to enable a dairy farmer with prosthetic leg and spina bifida to access the controls of his milk tank with more ease than the status quo. A hydraulic lift with the capacity to support the client was selected, and while it was not purchased, various modifications to the lift were fabricated over the course of the project to be installed on the selected lift once purchased by the client. A railing and gate to ensure the lift's safety was fabricated using square steel tubing, MIG welding, and low carbon hot rolled flat. Additionally, a steel-and-wood platform was created to mimic the lift's platform to accommodate the rails. This design should solve the problem of not only our client, but other farmers with similar cases.

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Introduction:

Problem Statement:

The milk tank is an indispensable component to a dairy farmer's business, and is frequently accessed. It is most common to have the pipe valve controls on top of the milk tank and a ladder to access them. This has caused problems for farmers who have medical issues that limit their ability to climb a ladder. The solution to this problem is to create a safer, more stable design that streamlines the client's access to the milk tank's controls and minimizes the need to leave the ground. In meeting the client's needs the final product will be unique to farmers with similar issues. A budget of $500 has been given to meet these requirements.

Client Information:

Abigail Jensen, a UW-Madison AgrAbility Outreach Specialist, is representing a known dairy farmer from Chilton, Wisconsin who has had problems throughout his farming career. These difficulties include a prosthetic leg and his Spina Bifida which is a birth defect that occurs when a section of spinal column forms incorrectly and causes lifelong complications [1]. The ongoing current solution is having his father go on top of the milk tank, a practice the client wants to cease. With the help of Abigail he is seeking a device that makes it comfortable for him to control the pipe valves on top of the milk tank, allowing him to become an independent farmer.

Background:

Wisconsin's dairy farms provide over 3.5 million gallons of milk to the United States annually, becoming one of the top milk-producing states in the nation [5]. In past decades small, family-owned farms provided the majority of the state's milk production. However, the number of dairy farms in Wisconsin has dramatically decreased by 81.6% in the last forty years with only 8,790 fully functioning farms as of 2017 and privately-owned farms most prominently decreasing [4]. Many farmers develop medical issues due the intensive work done daily. In a statistical survey of 1,171 farmers served by AgrAbility in 1999, 16% had amputations of either upper or lower body parts, along with 21% having a spinal cord deficiency [6]. Both of these problems greatly affect our client and many other privately-owned farmers. These issues result in farmers being unable to safely reach the control systems of the milk tank and parlor. Since family-owned farms are less financially stable, the ability to afford high end equipment is unrealistic. This is why an affordable, efficient way to safely reach the milk tank valves for efficient cleaning and transferring of raw milk is needed.

Research:

Since the mechanism will be housed in an environment that is prone to wetness and humidity, top recommendations included materials such as concrete and rubber. However, these materials were insufficient for the necessity of the rails. Steel was another recommendation, and when coated with an application to prevent corrosion it would be sustainable in the environment. Therefore, steel was chosen for the use of the rails and feet [7]. While considering the design specifications of our prototype, the Pasteurized Milk Ordinance provided additional factors to consider in the design. A milk tank delivery personnel regularly comes and retrieves the raw milk, requiring access to the milk controls. Furthermore, the elbow piece connecting the pipes for milk and cleaning fluid needs to be hand-washed and sanitized after each use, along with connector for the access point on the bottom of the milk tank. Finally, the parlor needs to have a drain and sloped floors to get rid of the access milk or leakage[2][3][8]. These factors had to considered in how frequently the lift would be used and where the lift should be placed. Currently, there are only large hydraulic lifts for personal use and safety precautions of large scale for commercial use only. There is no personal hydraulic lift of smaller and more affordable scale. There are small-scaled hydraulic lifts suited for the transportation and lift of heavy items. but these are only used for non-living objects [9]. Our project takes one of the preexisting non-personal lifts and implements safety accomodations for disabled farmers.

Design Specification:

As stated on the Design Specification Appendix, the design must:

1. Be budgeted at/under $500
2. Limit or reduce the need of a ladder
3. Composed of stainless steel and non-corrosive materials
4. Accommodate a sloped floor
5. Be easy-to-use, durable, efficient, and safe

Approach:

Each team member developed multiple sketches focusing on methods to achieve the necessary height to access the milk tank controls while eliminating the use of a stair or "stepping" mechanism. At a team meeting all ideas were presented and the top three were selected. The three designs are the renovation of pipes, a hydraulic lift, and minimized stairs. These designs were evaluated using a design matrix, focusing on the client's design requirements for safety and durability to determine the best fit. After thorough consideration, the hydraulic lift was chosen.

Preliminary Designs:

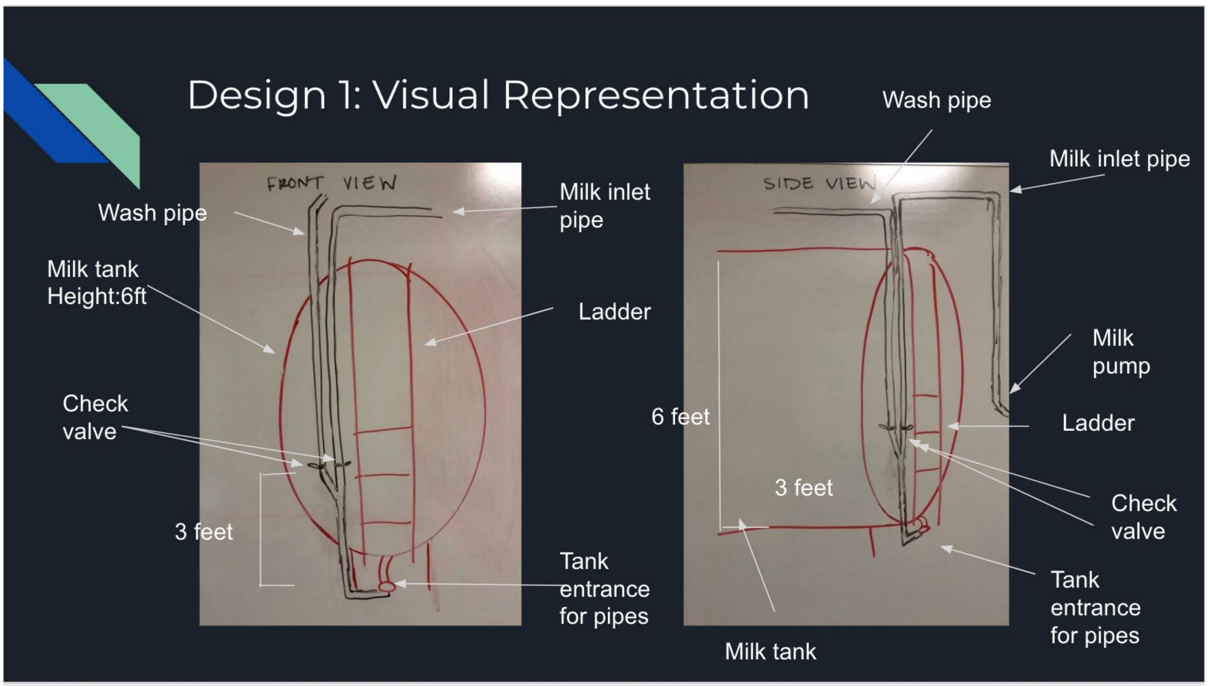

Figure 1 Pipes: This design involves a pipe system renovation, rerouting the pipe valve down to waist height with a removable pipe piece connected to the bottom entrance point.

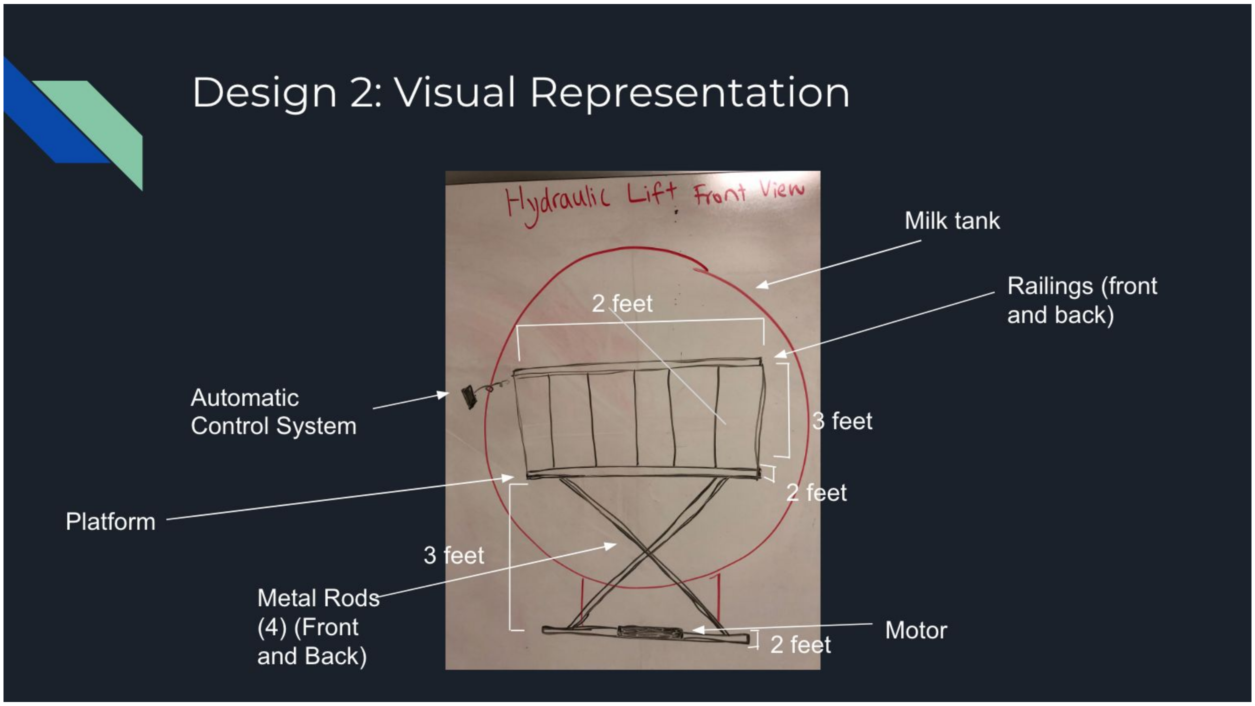

Figure 2 Hydraulic Lift: This design implements a hydraulic lift. Rails will be fabricated onto the lift to ensure personal safety.

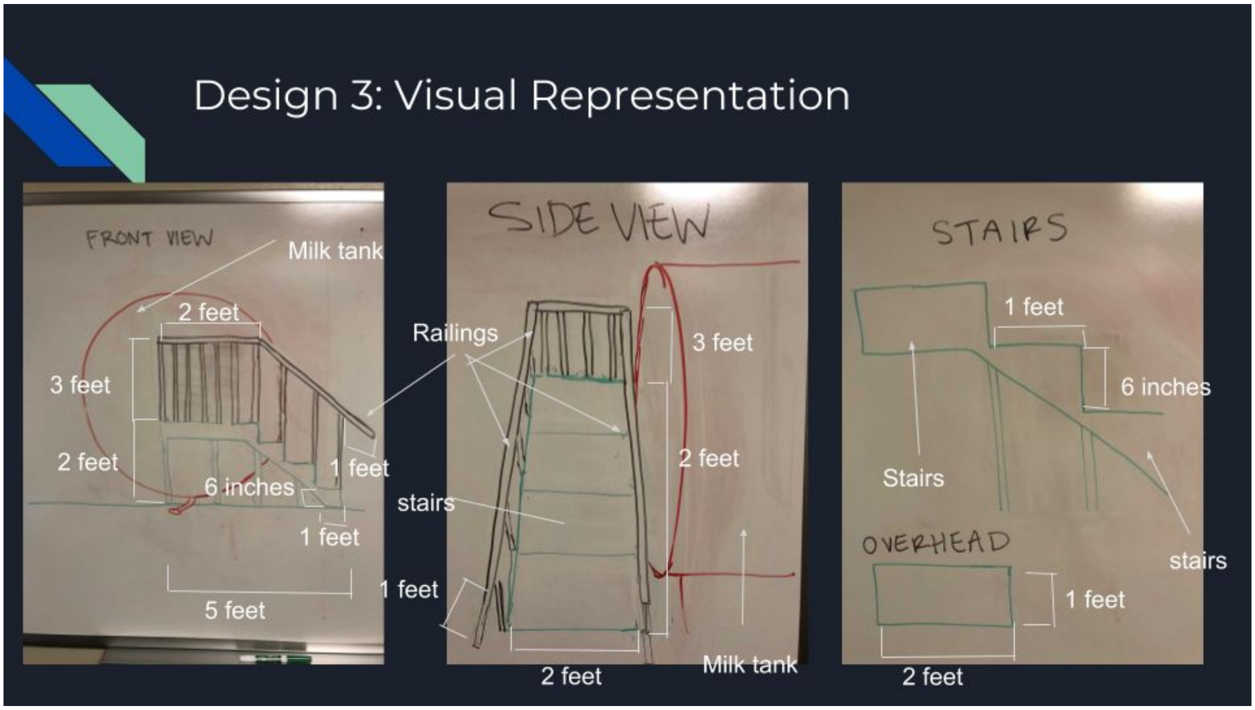

Figure 3 The Staircase: This design is a traditional staircase with an exposed bottom to ensure no obstruction at the access point. Inclined stairs with a platform in the center provide access to controls.

Preliminary Design Evaluation:

Design Matrix:

To select the best design to meet the client's requirement, a design matrix was used with the following factors ranked from most to least important.

1. Safety: The most important factor due to the client's needs to be stable and safe while working with controls.
2. Space Usage: Due to the milk parlor restraints, the space usage of the design was non-negotiable.
3. Food Safety: Our client runs a diary farmers for public consumers, which means there are food safety requirements outlined in the Milk Coordinates. This was highly considered to ensure that there would be no issues with our client's business.
4. Ease of Fabrication: Due to the timeline of the project and the restraints on our team members' knowledge and fabrication skills, ease of fabrication was considered to ensure that the project was achievable and possible to produce.
5. Effectiveness: Since our client is having a major issue with the current system, effectiveness is needed to ensure that the mechanism solves the problem.
6. Comfort/Access: Comfort of the mechanism was considered, but was assessed lower than others since our client would only use the mechanism shortly each day.
7. Durability: The client will be using the mechanism each day, so the design must have durability.
8. Cost: The cost was valued less because having a quality, secure design was worth the additional monetary investments. Abby, our representative, also approved for the cost to exceed the $500 budget.

			Concept 1: The Pipes		Concept 2: The Lift		Concept 3: The Stairs	
Rank	Criteria	Weight	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score
1	Personal safety	20	9.1	18.3	8.5	17.0	5.5	11.0
2	Space usage	20	8.9	17.8	6.5	13.0	3.3	6.5
3	Food safety	15	2.6	3.9	9.6	14.4	9.6	14.4
4	Ease of fabrication	10	2.0	2.0	2.9	2.9	8.4	8.4
5	Effectiveness	10	8.9	8.9	6.5	6.5	7.8	7.8
6	Comfort/access	10	7.3	7.3	7.1	7.1	7.4	7.4
7	Durability	10	7.9	7.9	7.0	7.0	8.5	8.5
8	Cost	5	5.4	2.7	2.0	1.0	8.0	4.0
		100	52.0	68.6	50.1	68.9	58.4	67.9

Figure 4 Design Matrix: Analyzing eight weighted criteria, the pipe scored highest in personal safety, space usage, and effectiveness: the most important categories, giving it the highest overall score of the three. Thus, the pipe design was selected.

Preliminary Final Design:

The team's recommendation was to re-route the pipes but due to requests from the client and instructor as well as the lack of fabrication opportunities offered by this design, the lift design was selected. Since ordering a lift was highly expensive, a prototype of the railing design was created on a wooden platform to mimic the lift platform.

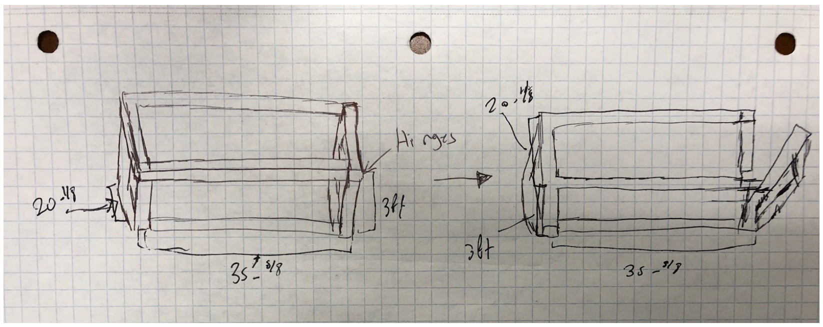

Figure 5 Gate: The 23.5" side farthest away from the ladder will house the gate, having hinges on the left side to open away from the milk tank.

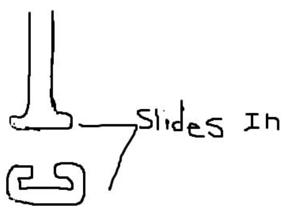

Figure 6 Slide-In Rails: Mechanism would include slide-in rails to allow for easier removal and storage.

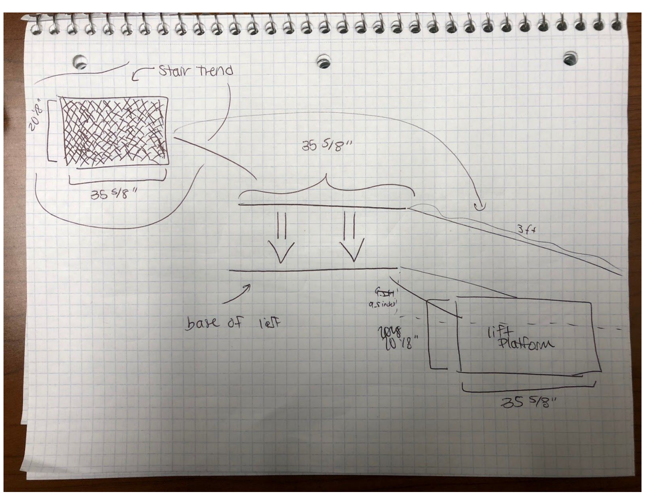

Figure 7: Installation of the stair tread.

The hydraulic lift selected uses an external air compressor to pump the manual lift up, with the client being supported by the rails. Along the bottom sides of the lift platform are hot rolled steel sheets 4” wide that surrounds all sides to protect against slipping. To assist with the potentially slippery surface, a stair tread covers the platform. To allow easy removal of the rails. each side of the platform will contain a slide-in mechanism. The lift’s wheels will also be removed, so the lift can be situated on the ground, with the platform at floor height. To accommodate to the sloped floor, a steel wedge will be created so that the lift sits perpendicular to the ground. There will be a ramp leading up to the platform to accommodate the height difference from the ground up to the platform. Finally, the lift (on the short side farthest away from the access point) will have a gate for the client to get in and out of the lift.

Fabrication:

Due to inabilities to obtain the desired hydraulic lift, our team opted to fabricate the safety features that would be implemented on top of the lift. Therefore, only the carbon steel tubing and low carbon hot rolled flat were purchased with the wooden platform, hinges, and screws/bolts being salvaged. Without the purchase of the lift, the total cost was below the $500 budget.

Total Cost: $3161.89
Total Cost without the Lift: $357.49

Material	Quantity	Cost
23.5” x 40” Steel Hydraulic Lift	1	$2,886.50
12.75” x 4’ Rubber Stair Tread	4	$256.6
Gorilla Glue	1	$7.97
24’ 1” x 1” Carbon Square Steel Tubing	6	$67.40
Screws/Bolts/Washers		Salvaged
2½” Steel Surface Hinge	2	$12
10ga 4” x 48” Low Carbon Hot Rolled Flat	10	$93

Figure 8: List of materials used and predicted in use, the quantity and cost of each.

Construction methods:
Using a drop saw, the steel square tubing was cut and sanded down. The following was fabricated:

Steel Square Tubing (railings):
- 42” posts: 6
- 10.5” posts: 4
- 38” posts: 2

Steel Square Tubing (gate):
- 14.5” posts: 3
- 41.5” posts: 2

Low Carbon Hot Rolled Flat:
- 3.5” x 3.5” posts: 6
- 40” posts: 1
- 23.5” posts: 1
- 11.5” posts: 2

Using a table saw, the plywood was cut to 23.5” x 40”. All railing and gate components were attached to each other and the square flats using MIG welding. Two hinges were drilled into the pieces of tubing that would serve as gate-posts, and a latch was drilled into the gate itself.

Results:
- Stability of rails:
    - Testing 150 and 300 lb loads directly on top and at angles determined all sides of railings except gate corner to be stable
    - Gate corner is unstable due to lack of support
- Gate functionality:
    - Hinges could have been put on other side to increase stability of structure
    - Opens and closes completely

Prototype Evaluations:
By the fabrication of our prototype are team discovered some areas that could be improved for future models. Firstly, the stability of the rails could be improved with better drilling techniques, such as the use of screws instead of bolts. The steel plates along the sides are currently drilled into the platform; however, welding the plates onto the steel posts would create better stability. Through our testing, the side of access point failed the weight test due to instability of the two sides, requiring additional support. Finally, the gate opens in both directions which can be potentially unsafe for users and adding a stopper would be considered.

Final Design:

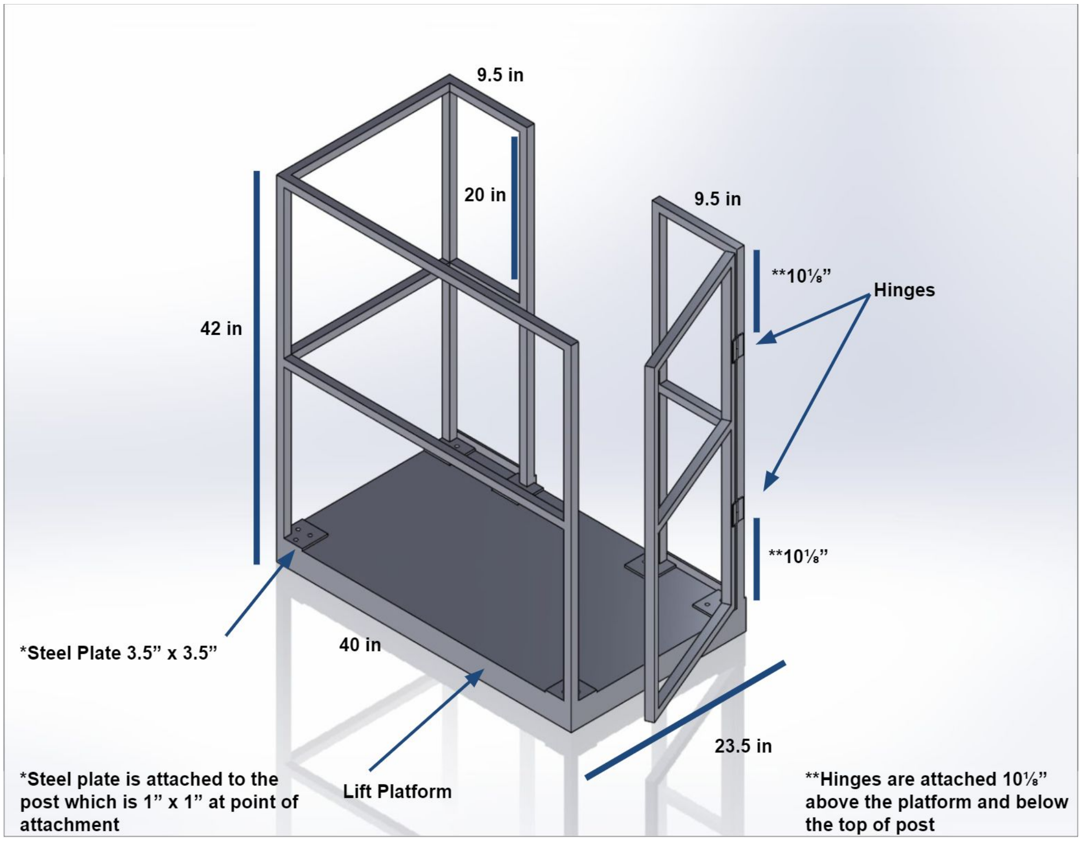

Figure 9: SolidWorks Model of Lift

Figure 10: Completed Design

Wrench Design (for pipe rerouting alternative to lift design):

Ratchet (bottom right) sits in between two fastened rectangular wrench handles (bottom left) in circular housing. Internal switch (top right) is placed between handles pressed close to the ratchet piece. External switch (top left) is located on external area of wrench while fastened to the internal switch so that both turn when one is turned. Internal switch restricts motion of the ratchet to one direction; direction may be switched by switching the external switch. Switch may be locked to one direction by multiple methods (possible method explored was through small magnets on either side of internal switch).

Handle length of wrench to be made optimal for client to operate from a standing position while fastening or loosening a nut close to the ground.

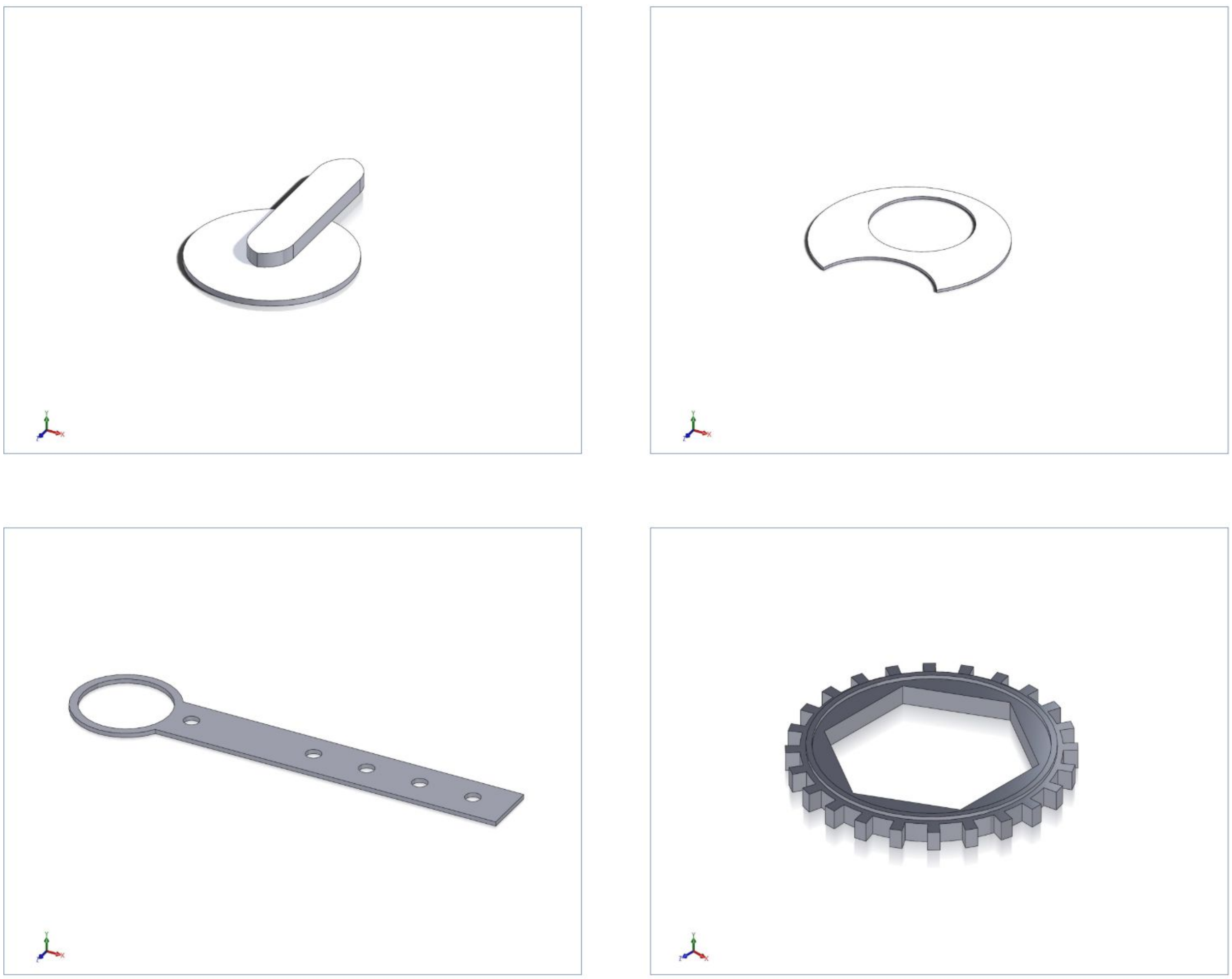

Figure 11: SolidWorks models of ratcheting wrench parts

Final Design and Prototype:

The structure of the railings was adjusted from the multiple vertical railings to a design with 3 horizontal rails. The steel pipes were welded together into railings and then welded onto steel sheets which were screwed into a 23.5” x40” wooden platform to simulate the body of the lift platform. A gate was also added.

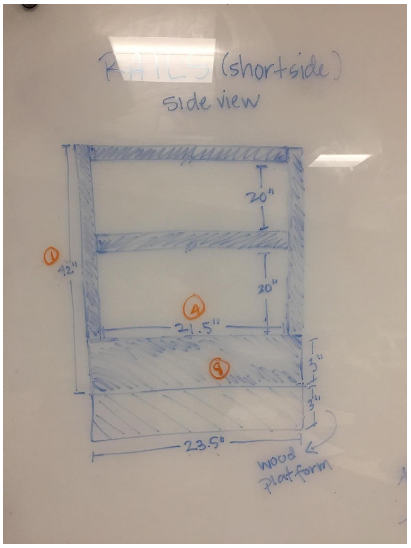

Figure 12: Dimensions of short side (23.5”) without gate.

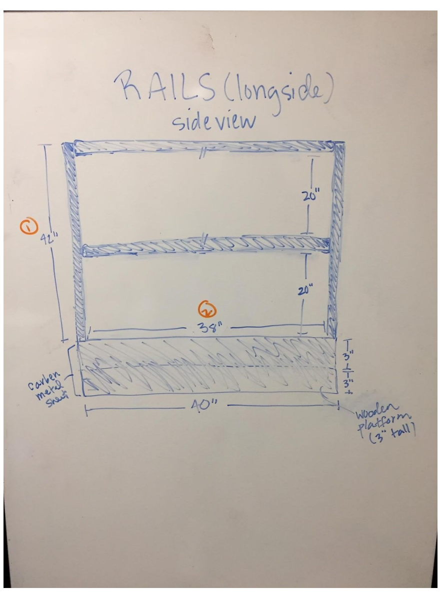

Figure 13: Dimensions of long side (40”) on opposite side of access point.

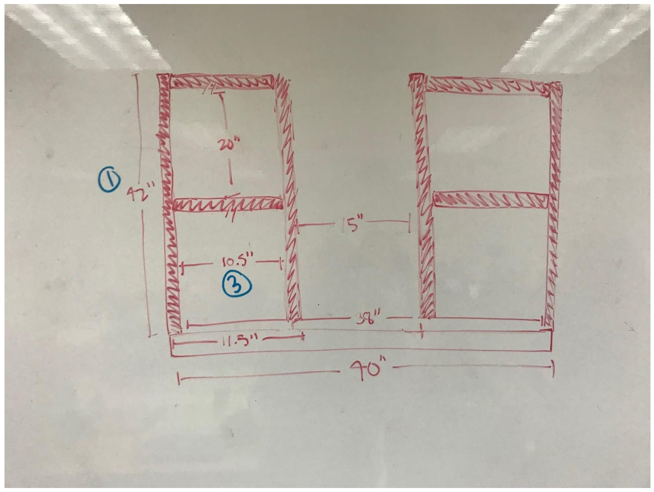

Figure 14: Dimensions of long side (40") with accommodations for access point.

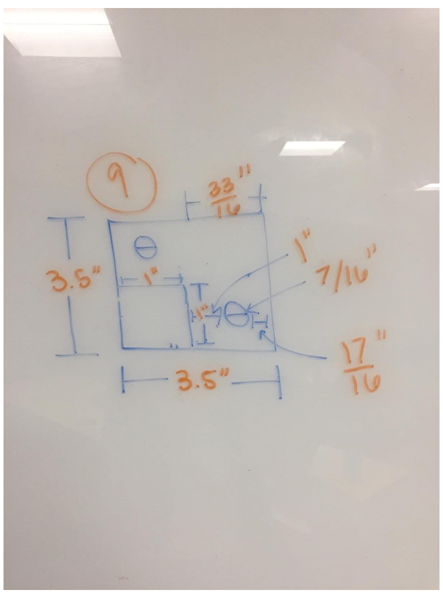

Figure 15: Dimensions of the four corner feet platforms. The additional due have same measurements, but with the 1" x 1" rod in the center bottom.

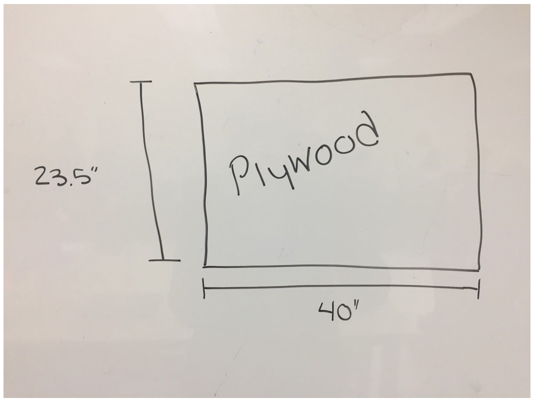

Figure 16: Dimensions of plywood to mimic the lift platform.

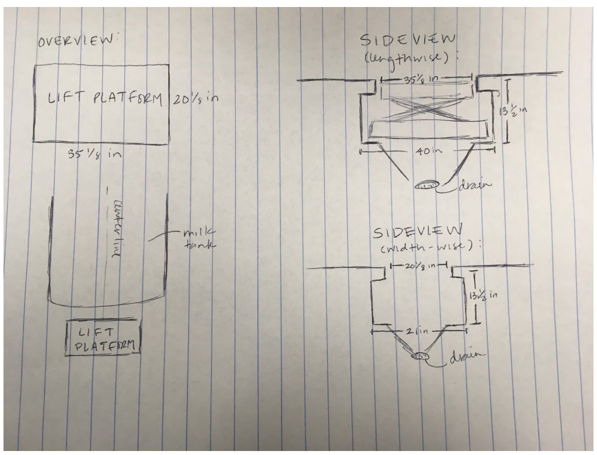

Figure 17: Dimensions and design for implementing lift into ground with drainage.

Since the preliminary final design presentation, changes were made to the design. A major alteration was the decision to refrain from purchasing a hydraulic lift, using a piece of plywood as a substitute in order for us to fabricate the railings. The railing configuration has also changed substantially in order to be more efficient in terms of material usage. They were originally designed like a cage with the seven bars on the long side and four on the short side standing vertically. To save materials, this design was heavily simplified into four corner posts with two horizontal bars, one in the middle and one on the top. This still satisfies the safety requirements while minimizing material usage. The choice of material for the railings also changed from solid round steel rods to hollow square steel tubing. This was to make calculations easier for determining spacing of the railings and dimensions, as well as make the material easier to cut and reduce the weight of entire mechanism. The lift will be implemented into the ground instead of above the ground, allowing our client to walk directly on the lift without having to take a step. This will be located in the middle of the milk tank, where the stairs currently are. The rail design was accommodated to incorporate the access point by adding an opening into the railing side facing the milk tank. The prototype had a total weight of approximately 381 lbs.

Conclusion:

A dairy farmer had trouble accessing the top of his milk tank due to balance issues with his ladder, so this project aimed to design a safer and more stable way for the farmer to access the top of his milk tank. The final design consists of railings with a gate to be attached to the top of a lift. The rails are welded onto square sheets which are screwed into the lift.

The simple and obvious alternatives to a ladder, such as stairs and ramps, seemed like a quick fix but the stairs were found to be almost as physically taxing for the client as a ladder and a ramp did not fit in the space provided. The team learned to be creative and seek more complex, but safer options. These more detailed and inventive designs required consideration of many unexpected aspects, such as how to keep the design from blocking the milk tank's access point. Complex designs also led to in-depth research on FDA regulations for pipe systems, how a scissor lift system works, and OSHA and ADA requirements. The team has learned about the unexpectedly tedious research involved in the design process, which could only be achieved by meeting outside of class for hours almost every week. Future work includes purchasing the hydraulic lift and adhering the rails to it, and contacting the pipe company to drill into the floors.

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FA: Nick
Client: Abigail Jensen

Appendices:

A: Additional Hydraulic Lift Specifications:

When the lift is obtained, the following additions should be added:

1. The railings, attached at the feet, should be unscrewed and reattached onto the platform of the lift.
2. Using Gorilla Glue or another form of strong adhesive substance, attach the stair tread onto the platform.
3. Create a placement in the ground to accommodate the 23.5” x 40” lift with 1” all around and 6” deep for the drainage.
4. Lift will be positioned in front of the ladder with the side accommodating the access point.

The following tests should be performed:

1. Ensure that the stability of the lift with the air pump reaches the required height of 40” by placing 500+ lbs of weight on the lift (max cap. = 1100lbs).
2. Once desired height is obtained, test the release handle and confirm the lift goes down at an appropriate speed.
3. Use a copper sulfate solution on the hydraulic lift and rails to confirm the materials is non corrosive.

B: Product Design Specification

Design requirements:

1. Budget: $500* (exclusions apply due to partnering with AgrAbility)
2. Work around space constraints of the layout of the milk house
   -Must be within 2.5 ft. of the milk tank

-Sloped floor
3. Must comply with food safety regulations (only if design comes into contact with milk products), using materials such as aluminum or stainless steel
4. Minimize need to leave the ground.
5. Safe, sturdy, and accessible

1. Physical and Operational Characteristics

a. *Performance requirements*:

- Will be used at least twice a day.
- Must be securely attached to the ground to ensure stability.
- Must be at least 3.0’ tall to access the top of the milk tank.
- Must eliminate the need for client to bend down if pipes were rerouted

b. *Safety*: The safety aspects and standards that the device must comply with are as follows.

- If a new ladder, lift method, or staircase is constructed, there must be railings
- Must be securely attached to the floor due to the sloped floor.
- The client must be able to clean tank with same effectiveness as previous system.
- All materials used must follow food safety regulations and be non-toxic, odorless, and corrosion resistant.
- Any device that elevates the client to the top of the milk tank must be in compliance with OSHA standards.

c. *Accuracy and Reliability*:

- Dimensions of pipe and milk tank:
  - Tank height: 77” (79” to the top of the pipe)
  - Tank width: 86”
  - Tank depth (stops at wall): 42”
  - Tallest ladder step height: 40”
  - Milk tank to wall: 49.5”

d. *Life in Service*:

- Ladder and hydraulic lifts are used twice a day, seven days a week
- Cleaned every other day
- Ideal life span of 10+ years

e. *Shelf Life*:

- Inside a constantly heated building
- Walls and floors are whitewashed concrete
- Sloped floor

- Restricted space usage around tank
- Hydraulic lift lasts up to 15 years, operated by air compressor

f. *Operating Environment*:
- Clean, heated room
- Possible liquid spillage (cleaning fluid, water, raw milk)
- Rust and corrosion due to heat of environment and drain location
- Client-operated

g. *Ergonomics*:
- Interaction with client and milk delivery person
- Height requirement of 3 feet (in order to reach top of tank)
- OSHA rail height regulation of 42”
- 450 lbs weight capacity (client and material weight)
- Eliminates client’s need to bend down

h. *Size*:
- Restricted to 49.5” between milk tank and pump system
- The milk tank is 77” tall, with a needed mechanism height of 40” (height of tallest ladder step)
- The device must not restrict access to the check valve

i. *Weight*:
- Unknown weight of client: budgeting 300 lbs
- Hydraulic lift selected holds up 1100 lbs (actual weight = 277 lbs.)

j. *Materials*:
- Must use materials that are safe, non-corrosive, non-toxic, and odorless according to the Pasteurized Milk Ordinance
- Possible materials: stainless steel, steel, aluminum, plastic and/or rubber

k. *Aesthetics*, *Appearance, and Finish*:
- Smooth finish on materials, no rigid edges for client comfort

2. Production Characteristics

a. *Quantity*:
- Hydraulic lift (1)
- Air compressor (1)

- Controller (1)

b. *Target Product Cost*:
- Hydraulic lift is $2,866.50
- Other materials are $357.49

3. Miscellaneous

a. *Standards and Specifications*:
- The PMO states that all access points of milk tank need to be readily accessible by the operator, as well as the room in general, providing an aisle at least 76 cm (30 in) wide
- OSHA requires that all handrails must be at least 42” above ground

b. *Customer*:
- Prefers to be secured to the ground
- Mechanism must be stable and safe to operate
- Prefers no ladders

c. *Patient-related concerns*:
- Mechanism will need to be cleaned at least twice a year