Innovative Soft Wash System

Senior Design Proposal submitted to the

Department of Mechanical and Materials Engineering

College of Engineering and Applied Science

University of Cincinnati

in partial fulfillment of the

requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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Problem Statement

Current soft wash systems on the market come with an exceedingly high price tag, little versatility, and poor mobility. Most soft wash systems are geared towards commercial use but the ones for the average homeowner are not ideal for a new user from a usability and cost standpoint.

Research

Background of the Problem

Soft wash systems have been around for quite some time now and the performance of them varies depending on the system that you desire to use. With all soft wash systems for the average homeowners to purchase, they all tend to use the same method of mixing the chemicals, which is in the form of batch mixing. Batch mixing may get the job done, but the user could have a more productive system with increased efficiency.(4)

Batch mixing is one of the most common ways of preparing chemicals to conduct a soft wash on a residential property. This type of mixing chemical uses calculated ratios dependent on the strength that you are looking to get out of the wash. With batch mixing you are pre-mixing your water, Sodium Hypochlorite, and a surfactant which is also known as soap. The use of this method is fine if you know the exact mixture you are looking to get, but that is almost always not going to be the case. You may need a stronger mix, or you may even need a lighter mix if you are working with a sensitive mixture. Either way, if you are batch mixing you cannot change that mixture without completing wasting the mix that you have already prepared. (11)

The magnitude of the problem is that homeowners need to precisely measure out each of their chemicals and water ratios. If the ratios are not correct then you are stuck with a batch that you cannot use and are wasting time, chemical, and money. From a safety standpoint with a proportioner you can be in constant control of the amount of SH you are putting onto the surface that you are cleaning and will not risk damaging anything, but if your mix is too hot with a batch mix set you can run the risk of damage to your property. An example of this would be if you are cleaning a surface near a pool. You would not want your mix to be as hot to protect the water and if you had a proportioner you could lower the mix for that area, instead of mixing a brand-new batch. (11)

If the user of the system had a way to control the exact amount of chemical to be input for the specific cleaning being done it could not only cut down on cost, but also improve the effectiveness of the system itself. The standard batch mixing system can be extremely costly and still not produce the desired output. The focus of this design and problem will be to decrease the cost, improve effectiveness, improve efficiency output, control the chemical input, and satisfy the customer.

Applicable Standards

The standards that will put restrictions on our design will be as follows, AWWA B300-2018 and 29 CFR 1910.1200. The standard AWWA B300-2018 states that the chemical when not mixed into a solution must be stored in a cool and dry area for no more than 9 months. Also, it states that upon receiving a hypochlorite it must first be diluted before its arrival for individual use. As for the standard of 29 CFR 1910.1200 it states to be cautious when handling the hypochlorite chemicals and to wear gloves and immediately rinse or remove any clothing that the chemical you might meet. (6)

The user also must wear the PPE of safety glasses and long pants/shirts when handling the hypochlorite solution. Once the chlorite is mixed within its given solution though it becomes even more diluted and is less of a hazard. With the two standards being stated above in the design process we will have to ensure that there is an easy chemical deposit point so that the user is at the least amount of harm as possible. The flow of the chemical solution will also have to be sealed without any leaks present to eliminate the corroding of equipment or harm to the user. There will also need to be airtight storage containers for the chemicals to be placed in to ensure they are stored properly without any other issues arising. (10)

State of the Art

We split the design of the overall project into 3 major parts, the frame, plumbing, and the drivetrain. I will be focused on creating a proportioner system that can pull water, a surfactant, and sodium hypochlorite in the desired amounts, as the user seems fit. We will both take part in designing the frame of the soft wash system.

We will start by looking at some frames that exist that are currently on the market. There are several different sized frames, but as you will see. They come in different sizes of trailers and are

way larger and heavier than what we are looking to make. These frames are made for softwash systems that are based around a commercial consumer who is going to be running a business and not our target user, a residential homeowner.

FRAMES

Southeast Soft Wash Trailer Build

Southeast company builds a soft wash framing system that is completely contained on a towable trailer. This system is built to hold a commercial size soft wash system with the size of the trailer being 6’ x 12’. This trailer will hold all aspects of your system but has many downfalls when it comes to portability and the everyday household user. This trailer is highly priced with the cost of a dual axle trailer and custom-built framing it comes out to $27,000.00 but this also includes the price of the entire soft wash system as well. The next aspect is the size, this system is very large, and it requires a vehicle with a hitch to be able to tow the system to its location and then the system is not easily movable while in use. This system is targeting commercial use and is not very suitable for the average homeowner. (2)

Southeast Mini Soft Wash Skid

Southeast manufactures another type of soft wash support system called the mini skid. This system allows for enough space to contain all the needed equipment on a smaller scale using a 48” x 40” skid. With this system it is designed to either be placed in the bed of a truck or remain stationary in one position with a long hose designed to reach wherever the user needs to go. This system still has a high price tag for the average user coming in at $7,000.00. With this being said the system still targets the commercial use due to it being a larger soft wash system and the mobility of it is still lacking requiring a truck or a pallet jack to be able to be moved from one destination to the next. (2)

NorthStar Soft Wash and Disinfectant System with 4.0 GPM Bleach Pump Cart

As discussed above NorthStar manufactures a soft wash system that is all contained on a small steel cart with the dimensions of 47” x 20” x 25”. This system is much smaller than the two frames discussed above and holds less with only a 13-gallon holding tank. This

smaller design though makes the system much lighter and a lot more user friendly when it comes to mobility. The user will lift the handle and be able to drag the chassis anywhere they desire without having to use the aid of another system to assist. This system size also brings down the price significantly coming in at $550.00, which targets the everyday user. This system size is ideal for the average user the only issue is the limit to the batch mixing system and once all the solution is added to the tank the system becomes quite heavy meaning it can be difficult to transport. (4)

Next we will dive into some of the different types of blend manifolds or proportioner systems that are currently on the market. With a combination of these designs, we can achieve a more efficient, cheaper, and user-friendly system that any homeowner would be able to use.

Figure (01)

The first state of the art is a valved manifold that allows for you to pull 4 different liquids from different areas. This design appears to only have the options for on an off when controlling the valve which would not allow for the user to have complete control over the levels of chemicals they are trying to mix. This design also comes with a high price tag and may be a little overkill with a pressure rating of 150 psi. This is using a metal ball valve which you need to be careful with because you are going to be using a highly corrosive chemical though the proportioner itself. We are going to want to stay away from metal ball valves, unless they are stainless steel. (7)

Figure (02)

This manifold made by FilmCo is a fitting proportioner system for the application that we are using. Although, you are also not able to fully know how much chemical you are pulling, as there are no markings on the valves themselves. This option has a much more appealing price tag, coming in around 30$. This option is using a plastic style ball valve which will be beneficial, as we will be using a corrosive chemical and do not want the proportioner to rust and not be able to be used. (8)

Figure (03)

This last state of the art design we are going to look at on the plumbing side of the project is an option produced by adaptive reef. This design is one of the better designs as you can meter the amount of chemical that you would be pulling, but are only able to pull 2 different liquids, where we would need to pull 3 liquids. This design also comes with a relatively high price tag at just under 100$. This design appears to be using plastic ball valves which is what we will be looking to use, as we will be running a corrosive liquid through them. (9)

End User

The focus of interest will be on those who are impacted by this problem are homeowners. Many of whom may think they need a new roof, new siding, or even a new driveway. All of these can

be expensive to replace but can also be rejuvenated by using a soft wash system to get rid of algicides and other forms of natural occurrences that can affect the curb appeal of your home. Many people do not realize the harm of taking a high pressure, pressure washer to the side of their home can severely damage and even go against your roof or siding warranty.

Many of the companies that provide these services charge large amounts of money to come out and do the services of soft washing for you. With an innovative design, homeowners can take the problem into their own hands and be able to complete the service themselves

Summary of Research

The need for a residential use soft wash system has started to become more prevalent over the past few years and more homeowners begin to realize that it is not safe for them to be using high pressure on the sides of their house as well as other parts too. We need to create a system that allow the user who will most times than not, be an amateur when it comes to soft washing. This system needs to be easy to use, but also allow for the user to have the ability to change the amount of chemical that is coming out during use. This will allow for the user to step away from one of the only residential soft wash units on the market that only allows for batch mixing and be able to step in to a more affordable, environmentally friendly, and easy to use option. The system needs to be light weight enough to be moved around on a yard with chemical and water on board, but also needs to be built to withstand unforeseen forces when being used. The user is going to want something that seems easy to use, but also makes sense to make purchase and will have a return on investment in a short time.

Quality Function Deployment

Based on a survey conducted on the 15th of September 2022 at the University of Cincinnati, we collected data from students and residents of greater Cincinnati. From the data, opinions about cost, ability to operate, transportability were gathered. Based on the surveys collected, which a sample has been included below, project objectives have been created.

Survey Sample

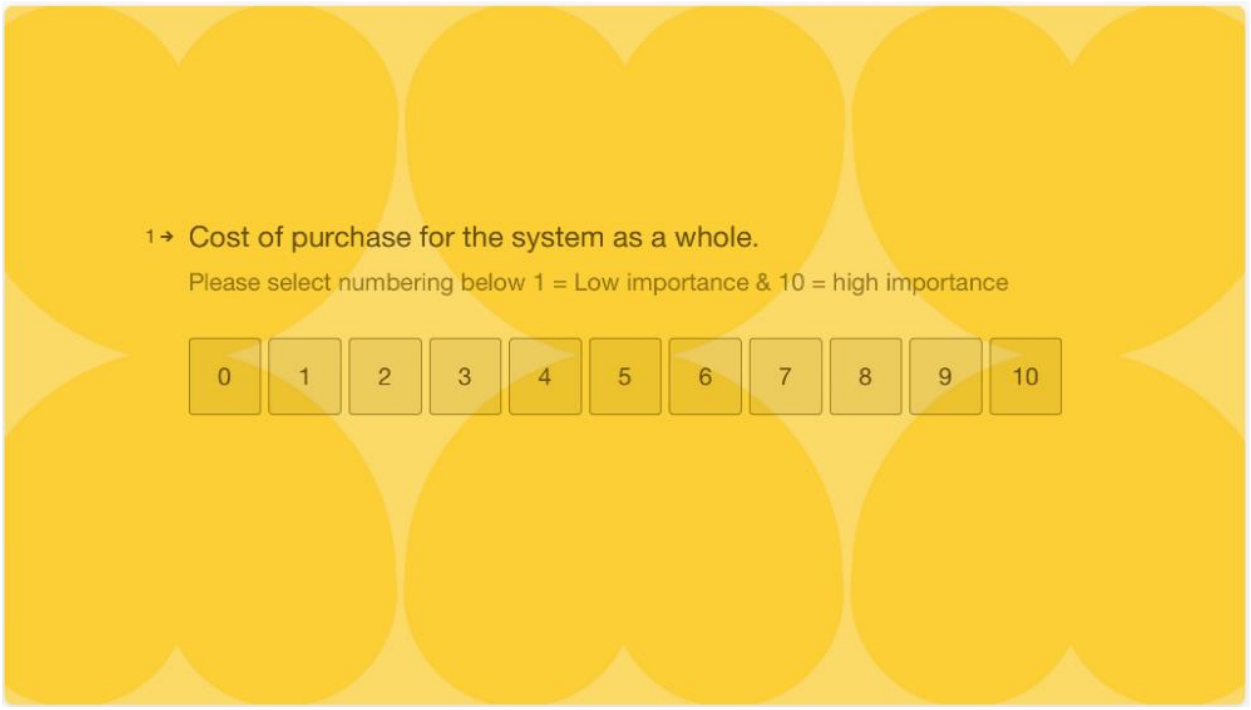
Innovative Soft Wash System

Hello, my name is Nick Juhas, a fifth year Mechanical Engineering Technology student at the University of Cincinnati. My project partner and I are conducting research to learn more about

the public's opinion on residential soft washing. We are working on designing an innovative soft wash system that will allow homeowners to clean their own houses without the need to contract an outside company. Please answer the following survey questions to help guide this project to completion.

Answer 1 to 10 in order of importance; 1 meaning least important and 10 meaning highest importance

Sample Size: 30 Residents



2 → Efficiency of the system.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

3 → User safety to ensure no possible injuries occur during operation.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

4 → Chemical combination and flow control of solutions.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

5 → System is easily operated.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

6 → Mixing and holding of solutions is easy and accessible.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

7 → System is easily transported around with little effort.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

8 → Overall size and weight of the entire system.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

9 → Tell us how you feel about the current residential soft wash systems on the Market in general.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

10 → Cost to purchase soft wash systems.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

11 → Efficiency of available systems.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

12 → User safety during operation.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

13 → Chemical mixing and flow control of system during use.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

14 → Easy operating system for all users beginner to expert.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

15 → Mixing process and holding tanks are easy to use and accessible.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

16 → System is easily transported with little effort.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

17 → Size and weight of the system.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

18 → How much are you as a buyer willing to pay for a residential soft wash system?

Select an option below.

A $200-$400

B $500-$700

C $800-$1000

D $1000+

Add choice

Customer Features

Ease of Solution Mixing

Ease of Operation

User Safety

Cost

Efficiency

Ease of Access for Supplies

Transportability

Size/Weight

Engineering Characteristics

Frame Material Selection

Plumbing Material Selection

Type of Pump

Drivetrain Motor

Solution Holding Tanks

Material Joining

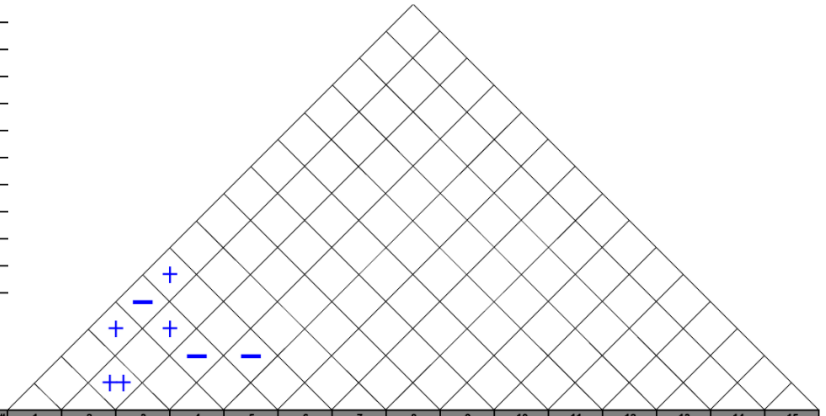
House of Quality

Title: Innovative Softwash System

Author: Daniel Hagen & Nick Juhas

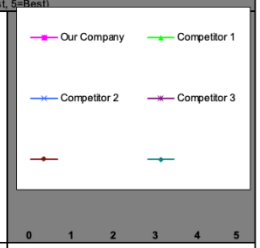
Date: 9/19/22

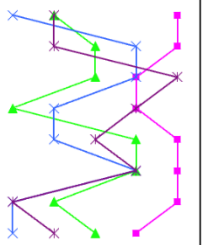
Notes: The results for this House of Quality were obtained from an online survey.



Legend		
⊖	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Column #			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Competitive Analysis (0=Worst, 5=Best)					
Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)			x	x	▲	x	▲	▼																
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Frame Material Selection	Plumbing Material Slection	Type of Pump	Drivetrain Motor	Solution Holding Tnaks	Material Joining										Our Company	Competitor 1	Competitor 2	Competitor 3		
1	9	22.2	8.0	Ease of Solution Mixing		⊖	O		▲											5	2	1	2		
2	3	19.4	7.0	Ease of Operation	O	O	▲	O	▲											5	3	4	2		
3	9	16.7	6.0	User Safety	O	⊖		▲	O	⊖										4	3	4	5		
4	9	13.9	5.0	Cost	⊖	O	▲	⊖	▲	▲										4	1	2	4		
5	3	11.1	4.0	Efficiency		▲	▲	O												5	4	2	3		
6	9	8.3	3.0	Ease of Access for Supplies			▲		⊖											5	4	4	4		
7	9	5.6	2.0	Transportability	▲			⊖	▲											5	2	1	1		
8	3	2.8	1.0	Size/Weight	O	▲	▲	▲	O	▲										4	3	1	2		
9																									
10																									
Target or Limit Value					$500	$150	$250	1:1 Gear Ratio	Holding >= 5 Gallons																
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)					5	5	5	8	9																
Max Relationship Value in Column					9	9	3	9	9	9															
Weight / Importance					247.2	463.9	122.2	286.1	194.4	166.7															
Relative Weight					16.7	31.3	8.3	19.3	13.1	11.3															





Product Objectives

Ease of Solution Mixing (22.2%)

We will use basic plumping for the manifold that will allow the user to control the solution that they are mixing.

Ease of Operation (19.4%)

We will ensure that new users will be able to operate easily and use basic switches for controls and ball valves for flow control.

User Safety (16.7%)

All welds will be grinded to ensure no sharp edges exist. All fittings will be sealed properly to ensure that no chemicals leak onto the user. All tanks will also be sealed with a safety lock.

Cost (13.9%)

We will attempt to use scrap steel to construct the frame. We will minimize the use of PVC angles and T's and use as many straight pipes as we can. We will repurpose plastic tanks.

Efficiency (11.1%)

We will ensure that the user has a manifold that will control the flow of solution that they are creating.

Ease of Access for Supplies (8.3%)

The user will have easy access to repair any plumbing that goes bad as well as to replace chemical in their tanks as needed.

Transportability (5.6%)

A 1:1 gear ratio will be used with a high output motor and throttle control system to ensure the user has ease of mobility under self-propelled power. This overall drivetrain will be able to push the system around with the user exerting little effort.

Size/Weight (2.8%)

We will use lightweight steel to ensure that the frame is sturdy but not too heavy.

Concept Drawings

Manifolds

Concept 1

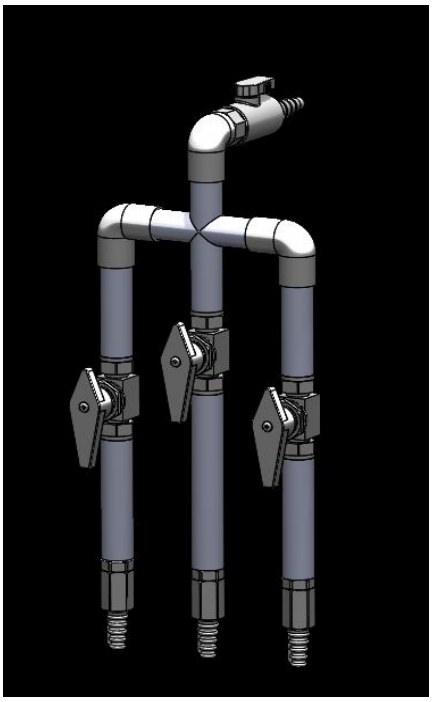


Figure (04)

This concept is made from PVC and would be a cheaper alternative option. This design uses 3 ball valves that allows the user to adjust the amount of chemical that they are pulling. This design will most likely also provide the best suction from the pump to allow for even pulling of each chemical and water.

Concept 2

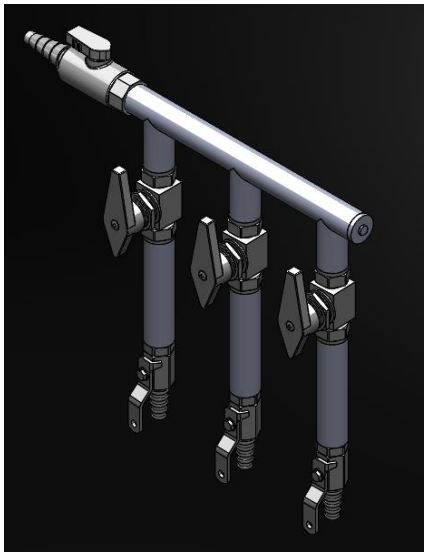


Figure (05)

This concept, also made from PVC would most likely end up being a more expensive method as we would most likely have to have the top pipe specially manufactured. In our case that is not a great option as we will only be making one but could be a good option if you planned to manufacture many. This design will allow for user to adjust each chemical to their liking, to maintain control of their mixture. The only issue is that the flow rate from the farthest to the right will most likely be less than that to the far left.

Concept 3

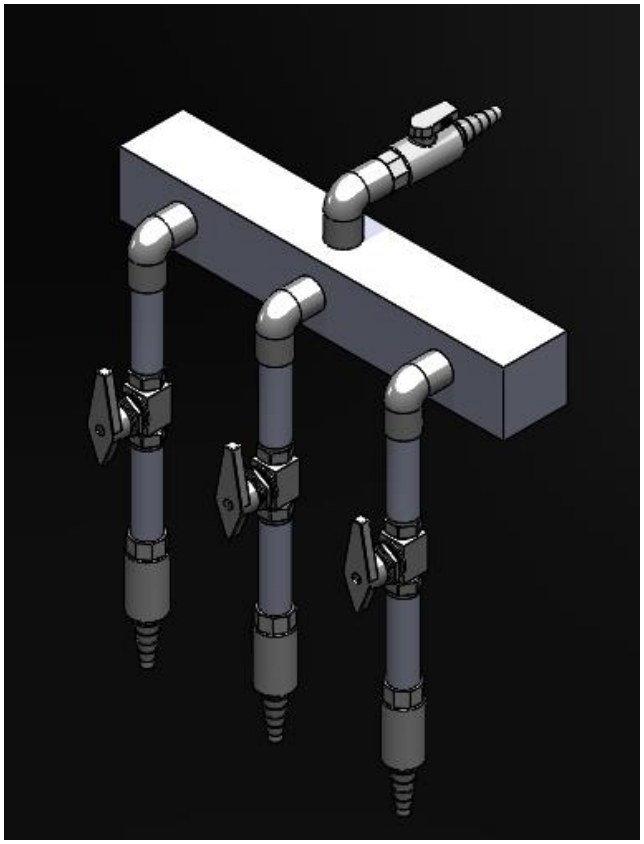


Figure (06)

This final concept will be made from a mixture of PVC for the fittings, but the main manifold would be some sort of machined metal alloy block. This is going to add a great deal of price to the product but would be the most structural design holding up to the outside elements the best. It will use similar methods to pull chemical and adjust how much that the user wants, with the use of ball valves.

Frames

Concept 1:

This concept is a larger design that has a frame built as a trailer foundation. It has two axles with the back axle being fixed and the front axle being attached to a swingable tongue that rotates about a bearing. The tires are pneumatic rubber tires that measure 10 inches in diameter. These tires are meant to hold a heavier load and be pulled over a rougher terrain. This trailer is heavier and more durable but requires more of a force to pull when it comes to the mobility. The trailer has a larger base though which allows for more space for solution holding tanks and soft wash motor design.

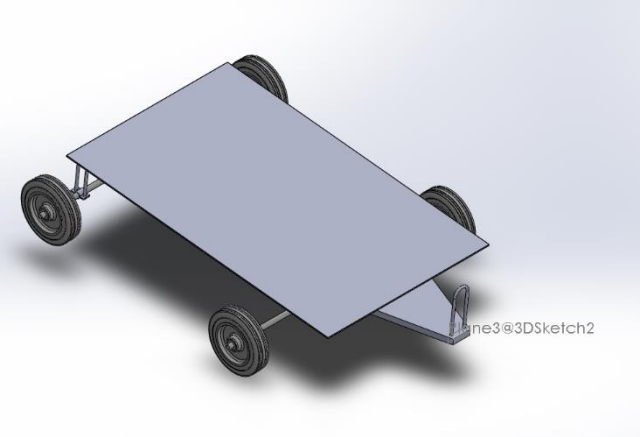


Figure (07)

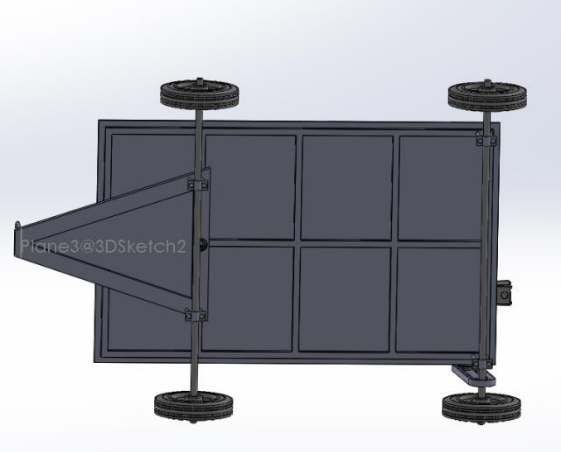


Figure (08)

Concept 2:

This concept design is built as a smaller compact material cart that allows for better mobility, but cuts down on the space available for solution holding tanks and the manifold/soft wash system to occupy. This system uses 8-inch hard rubber wheels in the rear and hard plastic 3-inch wheels in the front that are both supported by swivel mounts and break locks to unsure the cart does not move or roll when it is at rest. The cart also has a handle at ergo height for the average user that allows for a push able function that slowly moves under its own power. The only down fall is that the cart can be difficult to make sharp or quick turns with the two-wheel base in the front.

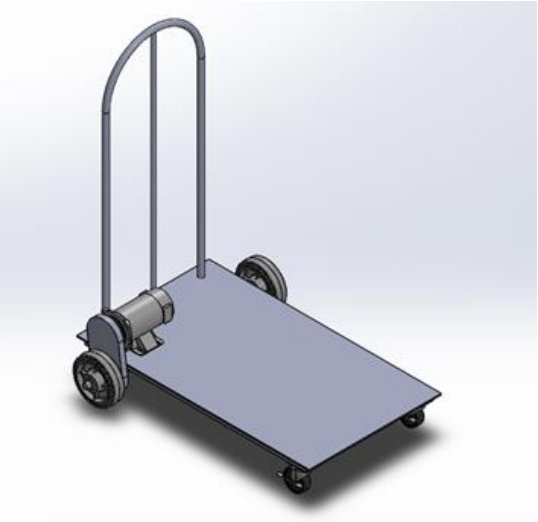


Figure (09)

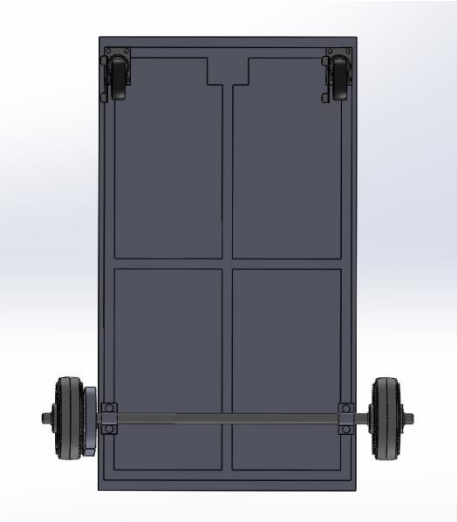


Figure (10)

Concept 3:

This concept once again utilizes the function ability of a smaller material cart. Unliked concept 2 this cart has a once 3-inch swivel wheel in the front supported by a base with the break functionality. This swivel base then interacts with a bearing that is attached to the handle to allow for easy and quick turning. The back wheels are 8-inch hard rubber wheels and are fixed to a rotating axle that will be used to drive the system. This system although has a smaller area for design functions the movability is maximized and has a lightweight frame that still can support the needed materials and motors for our system.

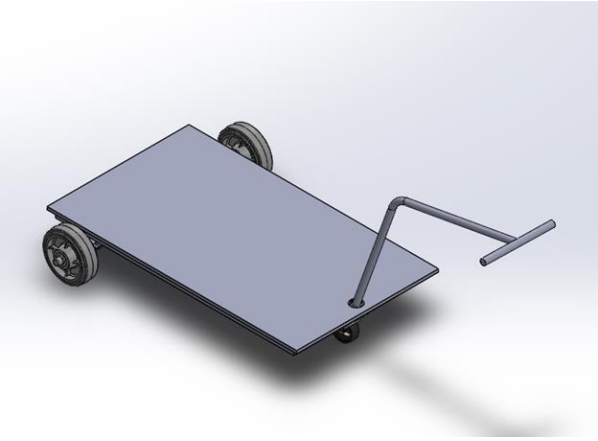


Figure (11)

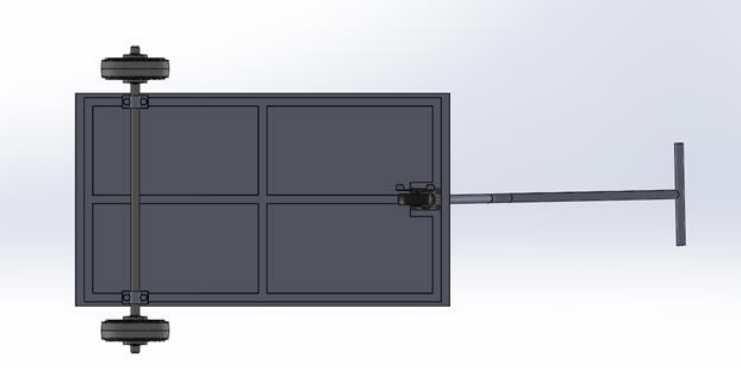


Figure (12)

Project Budget

The below project budget is subjected to change slightly as the prices of steel and materials varying day to day in today's market. Overall, this is a rough estimate of what our budget will breakdown to when the full design and assembly of the product will be created.

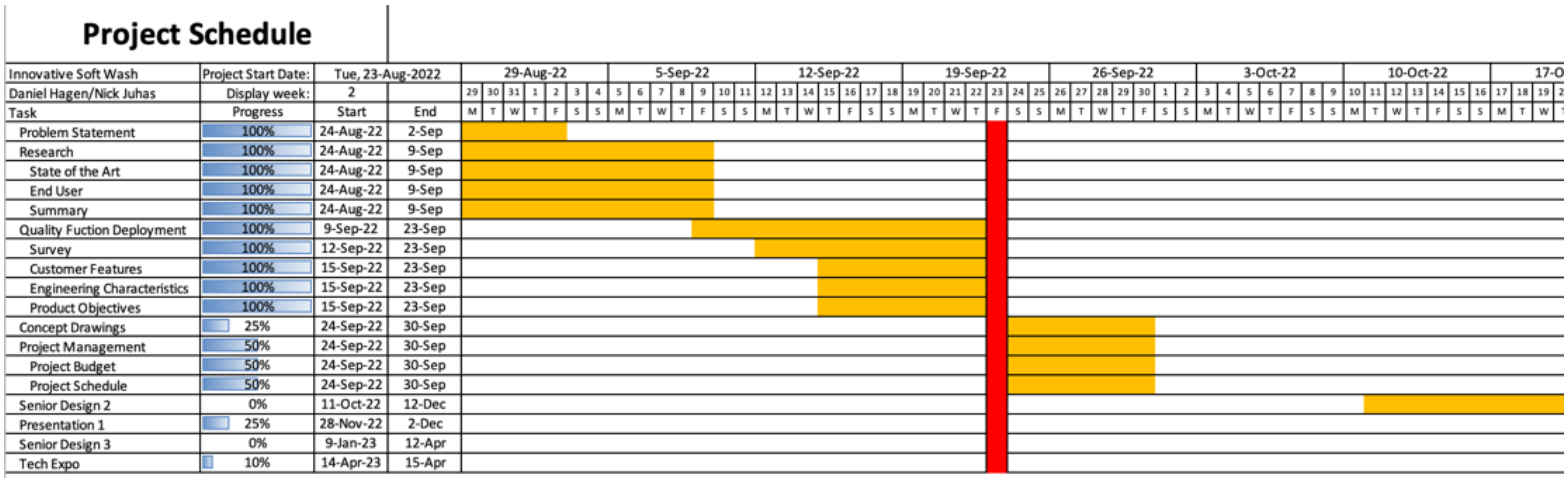
Manufactured Items	**Purchased Items**		
Frame	24V Motor	$ 100.00	
Manifold	24"x44"x1/8" Steel Plate	$ 700.00	Varies depending on market
Drive Train	1" PVC Tubing	$ 10.00	Varies depending on market
Tank Bracket	5-gallon tanks	$ 20.00	
	Gears	$ 100.00	
	10 gallon tank	$ 50.00	
	Drive Belt	$ 25.00	
	Wheels	$ 80.00	
	Axles	$ 70.00	
	12V Deep Cycle Battery	$ 110.00	
	12V regular battery	$ 100.00	
	Ball Valves	$ 225.00	
	12V Pump	$ 200.00	
	Steering Bearing	$ 60.00	
	PVC Tees	$ 10.00	Varies depending on market
	PVC 90-degree elbows	$ 10.00	Varies depending on market
	Controls	$ 50.00	
	Rachet Straps	$ 30.00	
	Total	$1,950.00	

Project Schedule

The schedule below is based on given dates that are subjected to change. These dates are preset and could have fluctuation depending on the future of senior design 2 and 3 along with the presentation and tech expo dates. Overall, this is the highlighted areas on what we have accomplished and what is to be accomplished the rest of the year.

Project Schedule

Innovative Soft Wash	Project Start Date:	Tue, 23-Aug-2022
Daniel Hagen/Nick Juhas	Display week:	2
Task	Progress	Start	End
Problem Statement	100%	24-Aug-22	2-Sep
Research	100%	24-Aug-22	9-Sep
State of the Art	100%	24-Aug-22	9-Sep
End User	100%	24-Aug-22	9-Sep
Summary	100%	24-Aug-22	9-Sep
Quality Fuction Deployment	100%	9-Sep-22	23-Sep
Survey	100%	12-Sep-22	23-Sep
Customer Features	100%	15-Sep-22	23-Sep
Engineering Characteristics	100%	15-Sep-22	23-Sep
Product Objectives	100%	15-Sep-22	23-Sep
Concept Drawings	25%	24-Sep-22	30-Sep
Project Management	50%	24-Sep-22	30-Sep
Project Budget	50%	24-Sep-22	30-Sep
Project Schedule	50%	24-Sep-22	30-Sep
Senior Design 2	0%	11-Oct-22	12-Dec
Presentation 1	25%	28-Nov-22	2-Dec
Senior Design 3	0%	9-Jan-23	12-Apr
Tech Expo	10%	14-Apr-23	15-Apr



Product Design Changes

During this process of designing and building our project from the ground up there were a lot of things that had to be taken into consideration. One of the biggest concerns was always keeping the price of the entire design to a minimum. The price played a huge role in almost all of our design changes to keep the product in a price range that was affordable to the average consumer. The design changes will be discussed in further detail below.

Frame Design Change:

The biggest price point was the design and fabrication of our cart that would essentially hold and contain the entire system. With the constant rising and fluctuation of steel prices we decided to go with a prefabricated cart that we then could make modifications to fit our overall needs. This change would consist of eliminating the purchasing of a large steel plate and other elements such as individual axles, wheel assemblies, and handle fabrication. By using a prefabricated product, we were able to cut or frame/cart cost from $800 to $200 which is a huge savings when it comes to the final design of the system. Instead of the frame being complete solid steel the cart now utilized steel cross wiring as the base with support beams in the shape of a 2ft by 4ft rectangle. To ensure that the contents of the cart would have a solid base to rest upon a solid chemical resistant polypropylene plastic 2ft by 4ft plate was placed

on top of the steel wiring and bolted down to allow for a solid base for the holding tanks, pump, batteries, and motor to be attached to. This not only cut down on the overall cost, but it also cut down on the overall weight, which allowed for the drivetrain to propel the system with a lot more ease. This frame also came with complete axle, wheel, and wall assemblies that we were able to modify to benefit our design. The only downfall was that we had to change the front design from being a single swivel wheel to a two-wheel axle due to the swivel wheel being extremely high in cost and then custom bearing had to be made to support the one-wheel drive system in the front which would almost cost the entire budget of the project to just create a custom swivel wheel. By going to a two-wheel axle though in the front it also gave the cart more stability even though the turning radius would not be as sharp with a two-wheel turning system.

Manifold Design Change:

The manifold design was very similar to the original design plan based on concept design number three. There were some small changes that took place that increased the original cost of material but would enhance the overall design from a functionality standpoint. Instead of using straight pieces of PVC, I was able to find NPT Male and Female pieces of Polyethylene piping that would screw together nicely and could be tightened done with a wrench to ensure the fitment was tight. On top of this, to prevent any leakage from occurring I included the use of nylon tape in the threads to help prevent any leakage as it was super important that there were no weak places present in the manifold itself. We also included check valves inside of the manifold which increased the price of material a little bit too. The purpose of the check valves is to make sure that once the chemical leaves its corresponding tank there is no chance for it to return to the wrong tank or to any tank for that matter. The check valve prevents all back fed pressure at the manifold, so once you have a liquid that is combined it is not able to make its way back through the system. The last thing that I would change would be to increase the tank size of the water, we do have the extra room for it, as well as the ability to increase the weight without risking the integrity of the frame, this would allow for longer wash times to occur between fill ups.

Product Testing

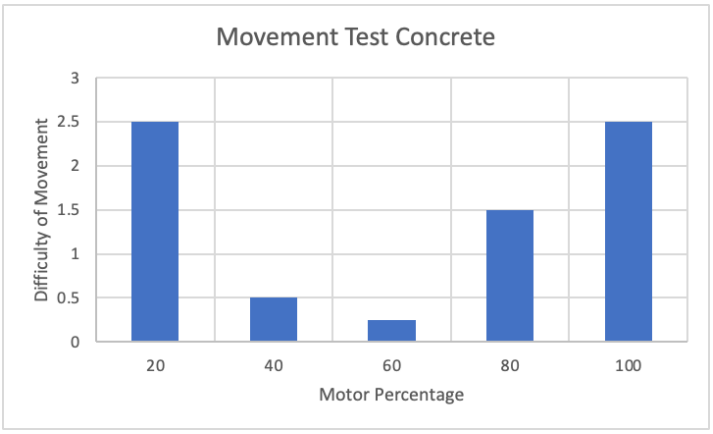
When it came to testing our design and seeing how well it performed after it had been fully assembled there were two key concepts that we needed to focus the testing around. The two concepts that the testing was focused on was how well the soft wash part of the system would clean a dirty surface that had been out in the weather and elements for years, along with how well the drivetrain portion of the design would move the system forward or backwards.

Drivetrain Testing:

To test the drivetrain section of our project we focused the testing on how much the operator would have to pull the cart to make the cart move to the desired location. When testing this the 24V DC motor was able to be incremented in increments of 10% up to 100% power. When testing this we placed the cart on concrete, grass, gravel, and uneven surfaces. When testing the cart on the varying surfaces we then were able to rate the difficulty on moving the entire cart on a scale of 1 to 5 with 1 being an easy movement and 5 being a difficult movement. When running the test, we were able to come to the results that operating the motor between 40% and 60% power which can be seen below in the figures below provided the best overall results. These results were the best overall due to the system being propelled slowly at a typical walking pace of an operator. If the motor power was less than 40% the cart would not propel itself forward and would require the operator to pull with excessive force to move the cart in the direction that it needed to go. If the speed of the motor was above the 60% threshold, then the cart would either be propelled too fast, subjected to spinning the tires and losing traction, or the potential of the chain drive coming off due to the sprockets rotating at too high of a speed. With all of this being taken into consideration the overall best results were between the 40% and 60% range for the motor speed due to the operator would have to apply little to know pulling force to move the cart to the desired location, the motor speed would not cause traction slipping or loss due to the axle spinning at a slower rate, and finally the chain/sprocket connection was not subjected to high speeds so that the chain did not slip or have any concerns in that area.

Movement Test Concrete					
Motor %	20	40	60	80	100
Difficulty of Movement	2.5	0.5	0.25	1.5	2.5
1 Easy - 5 Hard					

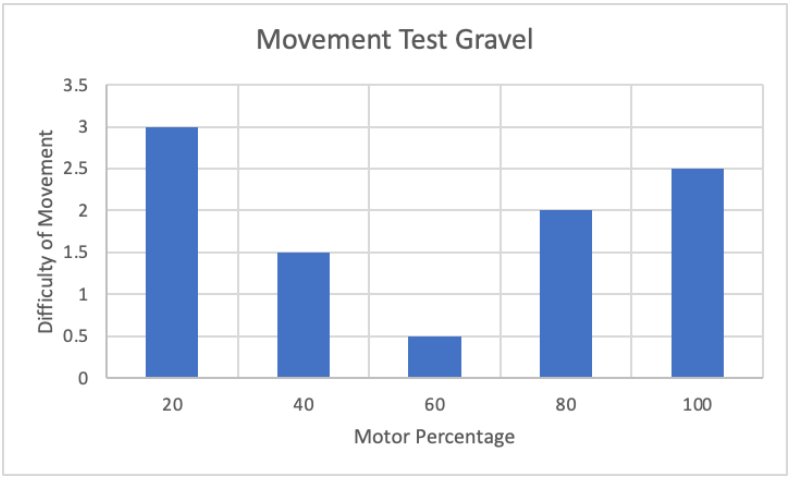
(Figure 13)



(Figure 14)

Movement Test Gravel					
Motor %	20	40	60	80	100
Difficulty of Movement	3	1.5	0.5	1.5	2.5
1 Easy - 5 Hard					

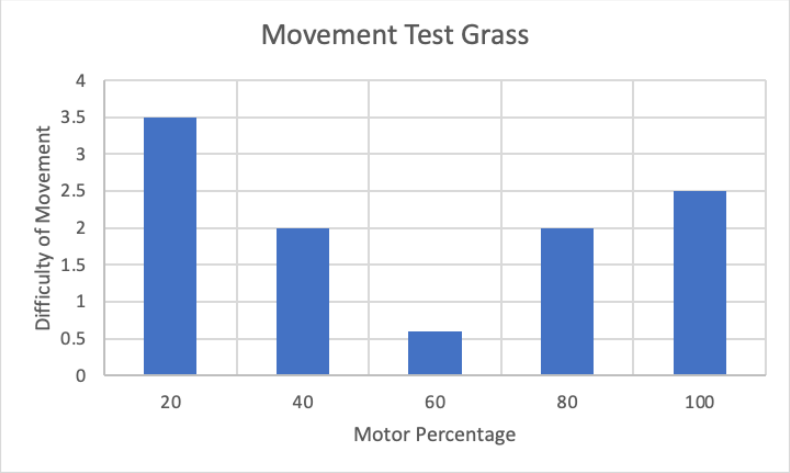
(Figure 15)



(Figure 16)

Movement Test Grass					
Motor %	20	40	60	80	100
Difficulty of Movement	3.5	2	0.6	2	2.5
1 Easy - 5 Hard					

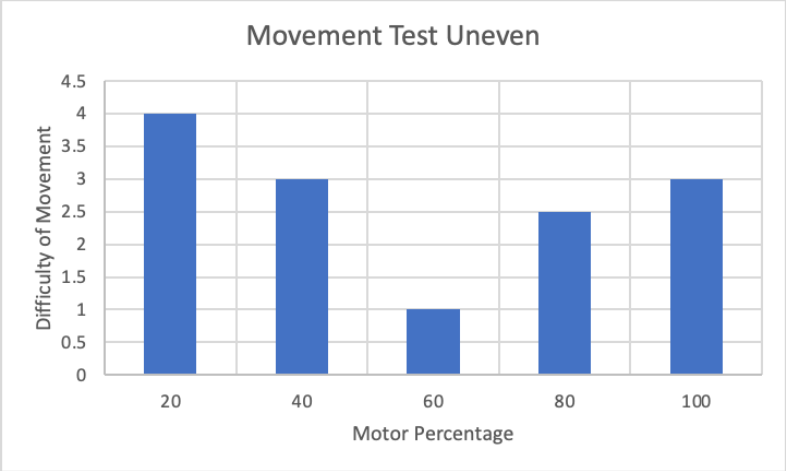
(Figure 17)



(Figure 18)

Movement Test Uneven					
Motor %	20	40	60	80	100
Difficulty of Movement	4	3	1	2.5	3
1 Easy - 5 Hard					

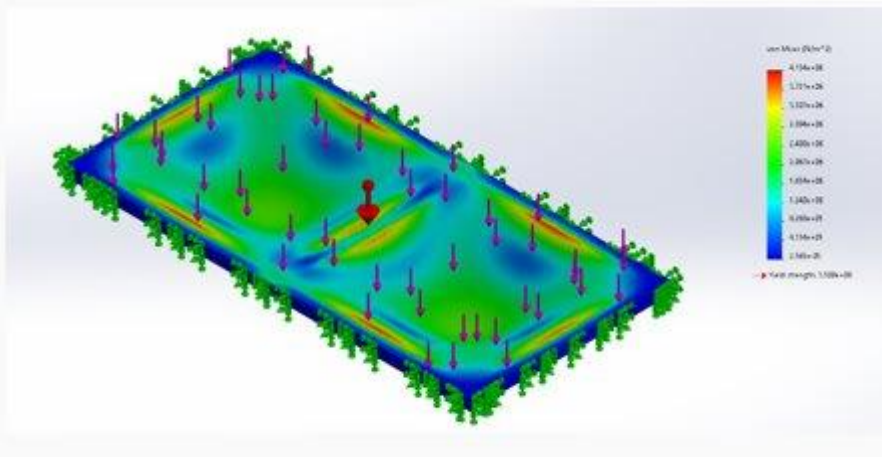
(Figure 19)



(Figure 20)

Frame Testing:

During this process the only frame test that was performed was a FEA analysis on the overall frame. This was based off when the cart is fully loaded the weight from the liquids and batteries would be around 250 lbs. The cart showed that it would hold well over that weight meaning that our components would be safe to rest on top of and be carried using the cart design. Once we assembled everything and fully loaded the cart, we put a 500 lb load in it for 8 hours and the cart showed no signs of deformation and failure in any of its components (axles, wheels, bearings, base plate, etc.). This proves our FEA analysis to be correct and that the user does not have to worry regarding any frame failures due to weight of the components placed on top of the system.



(Figure 21)

Overall Recommendations/Changes

Throughout any engineering process or design after the first overall prototype is fully built and assembled there are always changes or improvements that can be made to the system. No design process is ever perfect the initial time that it is created. During this design process of creating our innovative soft wash system there were a lot of things that went right and worked out to benefit the system as a whole and there were many things that also could have been approved for future design revisions. The sections to follow will cover the main recommendations and changes that we would pursue in the future if we were to revise our design from a manufacturing standpoint.

Frame Recommendations:

During the design process of the frame/cart some design changes were made to allow for cost savings. The design of the cart in the end worked out great for our system to carry and enclose all of the components. A few changes that would potentially be considered in the future would be the overall size of the cart and the axle types of the cart. The overall size for potential manufacturing of our product we would like to cut down on the length by a foot and go from a 2ft by 4ft frame to a 2ft by 3ft frame. This would allow for easier shipping of the product and be able to contain a lot of components in a smaller space which also allows for potential savings again using less material for a smaller and more compact design. This could be done due to the point that we have extra room for more storage that is available on the cart which that extra room could be minimized and make the system easier to store and transport. Next, we would change the rear axle design by adding bearings into the axle versus a sleeve that allows the drive axle to rotate. By adding bearings, it would allow for a more smooth and free spinning axle to drive the system and not produce any friction. The sleeves that are currently in place can cause a buildup of friction, putting extra resistance on the motor that is not needed if the sleeves are not thoroughly greased. Also, by adding bearings it would eliminate not only the friction but also having to apply a lubricant or grease to the axle to ensure that it is constantly free spinning.

Manifold Recommendations:

Overall, the manifold worked very well with the design that we had. Like I mentioned before the use of check valves in the manifold is very crucial to the safety and health of your other chemicals, because after you mix them, you don’t want that mixture to leak back into your different holding tanks in the cart. The portion of this that I would change would be more so on the plumbing side of things. Starting off with the

water tank only be 10 gallons, I think it is crucial to up the water holding tank to a 20-gallon tank in order to have better output for a longer period of time. This was a crucial part that goes along with the next part which would be hard to change. Although the 4GPM pump is excellent for washing roofs from a ground level as you are to get that spray height of 24” that you are looking for so that a ladder is not needed for cleaning. I would investigate finding a way to be able to lower the GPM of the pump, but still being able to get that height that is needed to reach the peaks of roofs without the use of a ladder.

Conclusion

Throughout the last 16 months of planning, designing, and executing this project it has been the best learning experience that I could have asked for. By taking the skills from the classroom, the knowledge from Co-Op experience and combining that all together to create a product was very cool to see. Having the knowledge to not only investigate what it would take to build a product like this and calculate everything that needed to be calculated, run analysis on the framing that I learned in both school as well as on the job was a cool feeling to see it all come together finally. Then from a project management side of things, taking the skills that I have built over the last 2 years between Co-Op and working almost full time showed me everything that I have learned by going to UC. Overall, our project and design turned out the way we projected it to and even though there were some unexpected issues and design changes we were able to create a fully developed product that met all our requirements and expectations. As a group we were also able to sit down and analyze what areas we would have done differently and what areas we believed we succeeded in. This project allowed us to grow as seniors and greatly benefitted us as we moved from the college atmosphere into the vast world of engineering!

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