

# INL GRINDER WATER FILTRATION SYSTEM

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# Executive Summary

For this project, we were tasked by Idaho National Laboratories (INL) to redesign a grinder/polisher water filtration system. The main function of this system is to rinse off a grinder and polisher within a hot-cell, filter the particulate and water solution, and recirculate the clean water back on the grinder and polisher.

The current system in use by INL needs to be redesigned because it needs cleaning often, the filter is expensive and inefficient, and the pump gets exposed to particulates from the grinder and polisher. As these are our three biggest challenges, we set out to design a system that focuses on particulate centralization and filter efficiency. Solving these issues will result in a system that can work for long durations and can be easily replaceable when needed.

Given a budget of approximately \$5,450 we successfully designed a system that is fully functional and cost efficient. Our filters and pump, which are the key components of the system, are approximately one fourth of our total budget. This is what makes our design so effective. The rest of our budget goes towards features that are more permanent in nature. Making our pump and filter easily removable allows for our design to be much cheaper and more functional in the long run.

While we believe that our design is quite advanced from what is in the hot-cell right now, there are still a few modifications to be made. Fortunately, all the modifications are quite small and are inexpensive. As we approach the end of the semester, we will complete all of the modifications that we possibly can and the remainder of the changes will be handed over to INL for completion.

# Background

As mentioned in the executive summary, INL has an existing grinder/polisher water filtration system in place. However, it is not as effective as it could be. INL decided to contact us to redesign the system because the current system not only clogs easily, but is difficult to determine the location of the blockage when it is clogged.

INL needs a system that can provide clean water at a consistent flow rate, filters the water coming off of the grinder/polisher, and can be operated with manipulators. This project has the opportunity to be something that INL can put directly into the hot-cell. When asked by INL to complete this project, the intent was that we would make this prototype completely functional. This means that all of our metals would be stainless steel to be able to hold up in the hot cell and all components would work for the given space and function.

In completing this project, we provide INL with a long term solution that is affordable and dependable. In addition, the system is designed to allow crucial components such as the pump and filters to be replaced without removing the rest of the system. Overall, this project was a huge success and is something that INL can use right away.

# Problem Definition

The goal of our project was to provide INL with a new grinder filtration system that corrects many of the issues with the current grinder filtration system. Initially, we were told that INL only wanted a prototype of the final design. Through some discussion with our mentor we decided that the final deliverable to INL would be a completely working system that could be place into the hot cell at INL.

Due to this deliverable, it was imperative that we had all the proper parts to deliver to INL. This included the filters, the pump, the tubing, the fittings and valves, and the system base. In addition to the entire system and its part, we also needed to include a manufacturing plan and all the specification sheets for our pump, filter, and fittings.

The goals of the group was to create a simplistic system that allowed for easy manufacturing and use. This required us to go through multiple designs to insure that the best system possible could be created within our time and budget constraints.

# Project Plan

## Team Roles

To begin this project we had to break up roles for the administrative side of the project as well as the technical side. The following roles are what we determined for administrative work:

- Archivist- Thomas Moore
  - Team lead of documentation
  - Team wiki master
- Facilitator- Drew Fagan
  - Records and circulates meeting minutes and meeting agendas
  - In charge of schedule and enforcing action items
- Financier- Jerry Kahn
  - Tracks the team budget
  - Lead for travel accommodations
- Liaison- Troy Sanders
  - Is the lead contact for the project
  - Orders components

For the technical side of the project, we wanted to break the system up into components that each team member would be responsible for. The following are the roles of the team members:

- Filter- Thomas Moore
  - Designed a two part filter for the total system
  - Designed a way to make the filters removable
- Integration- Troy Sanders
  - Determined how the tubing would be applied to the system
  - Found how to incorporate each subsystem together
- Pump- Drew Fagan
  - Selected a pump for the designed application
  - Designed a mount for the pump
- Tank- Jerry Kahn
  - Designed a tank that promotes centralization of particles
  - Incorporated the tank to work well with the pump

## Scheduling

The current Gantt chart in the Appendix does not reflect our initial schedule well, as our plans for manufacturing changed significantly. Originally, we wanted to have a full drawing package completed before winter break. With the drawing package done going into the spring semester, we were going to send out the drawings to a fabrication shop as soon as we all returned to

Moscow. With this planned for late January or early February, we would receive a completed shell of a system before Spring Break. This would have allowed us to execute testing on filter efficiency and make any adjustments as we felt necessary. However, after returning from winter break, we thought we could learn a lot more about the project if we manufactured the system ourselves. While manufacturing the system on our own, this pushed our completion date back significantly. After increasing our manufacturing time, we hoped to finish by April 13th. This would leave us a week to try and test the filter and flow rate. In the end, we had to work up until April 22nd, where we took a trip down to INL to show the system. This worked to our advantage as we learned a few things from INL before we made certain components permanent to the system. Overall, we fell behind in our schedule but we learned much more as a result.

## Concepts Considered

### Filter

The initial intent behind our designing of the filter was to make it much more affordable, and able to collect the particles to make the system easy to clean. The initial design was simple and effective, we decided to make the water enter the system through the filter so that the particles were collected right away. In the old apparatus the particles were able to clog different parts of the system; which made detecting the source of the problem rather difficult. Putting the filter at the beginning was the logical choice because the rest of the system would not be subjected to the particles. These initial requirements of the filter are what lead the team towards our initial design concepts for the filters

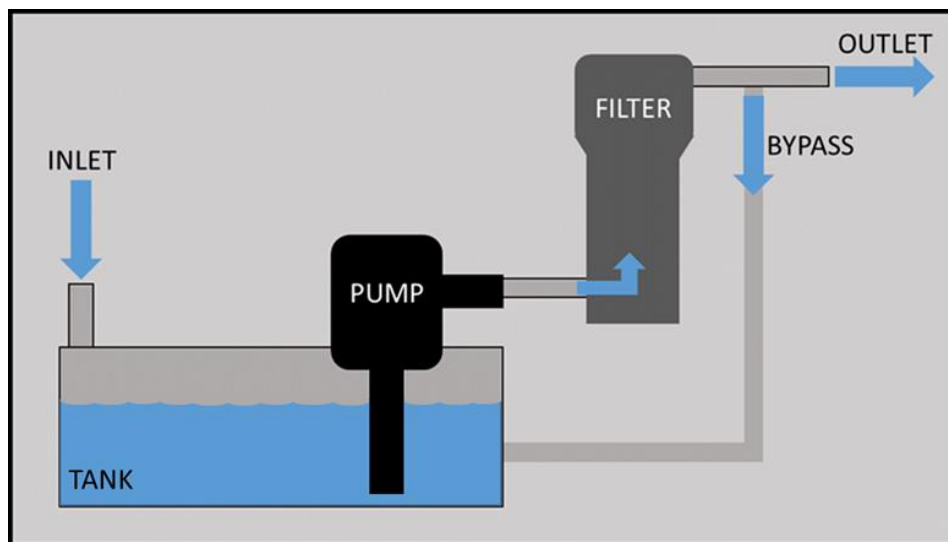


Figure 1: Current INL grinder water filtration system flow diagram

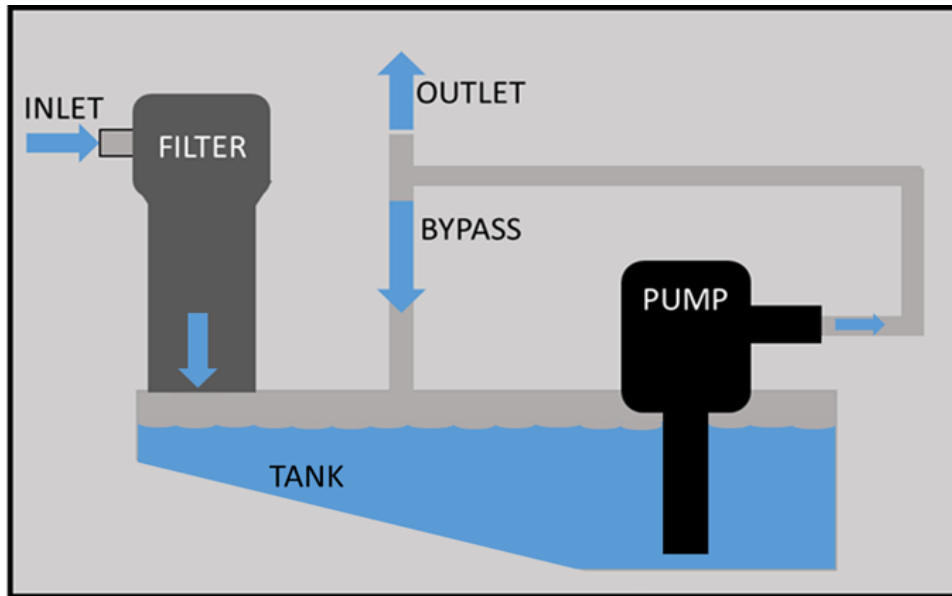


Figure 2: Preferred design flow diagram

The pictures above display simple flow diagrams for the prior system that was being used, and the ideas that we initially brainstormed for solving the problems that were presented to us by INL. As you can see in INL's initial system, water would enter the system and it would be directly stored in the tank. From here the water was then pumped out of the tank into the filter, but the particles weren't collected here, they were just simply filtered. After leaving the filter, the water would exit the nozzle or go through the bypass back into the tank.

The initial concept for the filter was very simple; we just wanted to collect the particles within the filter and do so as affordably as possible. The design is seen below on the left; this design is very simple and consists of only a few different components. In the flow diagram you can see that all the internal components, and fixtures are attached to the lid. This was a design concept that we carried throughout the rest of our designs, and we decided to use in our final product. This concept allows the operator of the system to easily remove the filter and either clean it or replace it. On the initial flow diagram you can also see 2 different sources of water coming in through the top of the system, this was an Idea that we had to send not only the water that is coming off the grinding disc through the filter, but we also initial decided that we would like to send the bypass back through the filter so that we could push the water through the filter. Though this is not a design that we used in the final design we did do a variation of it which you can see in the filter section of concept selection.

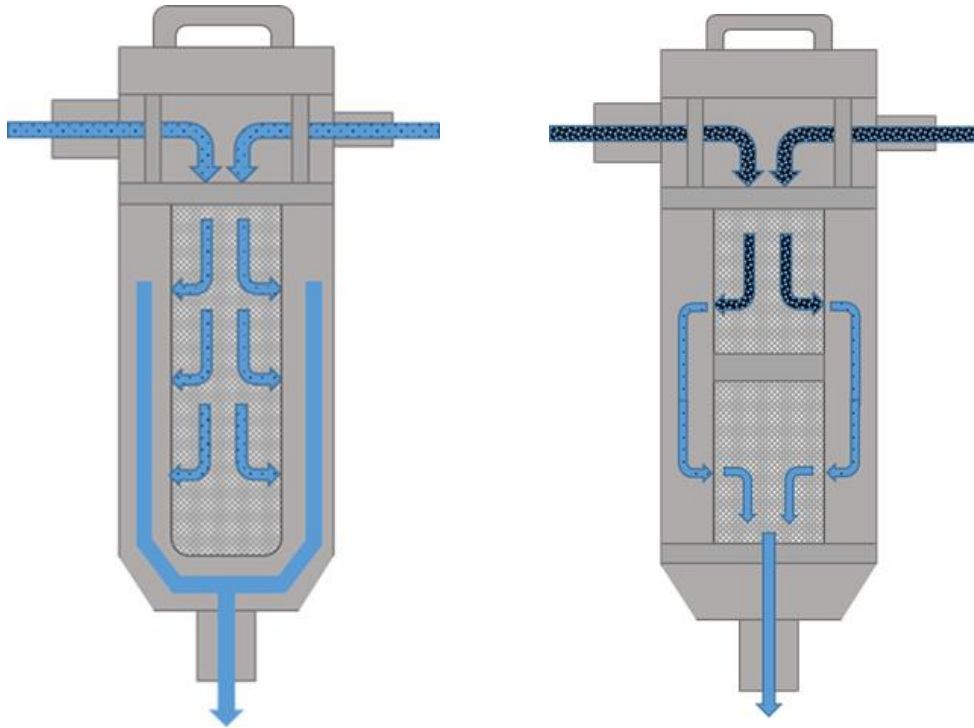


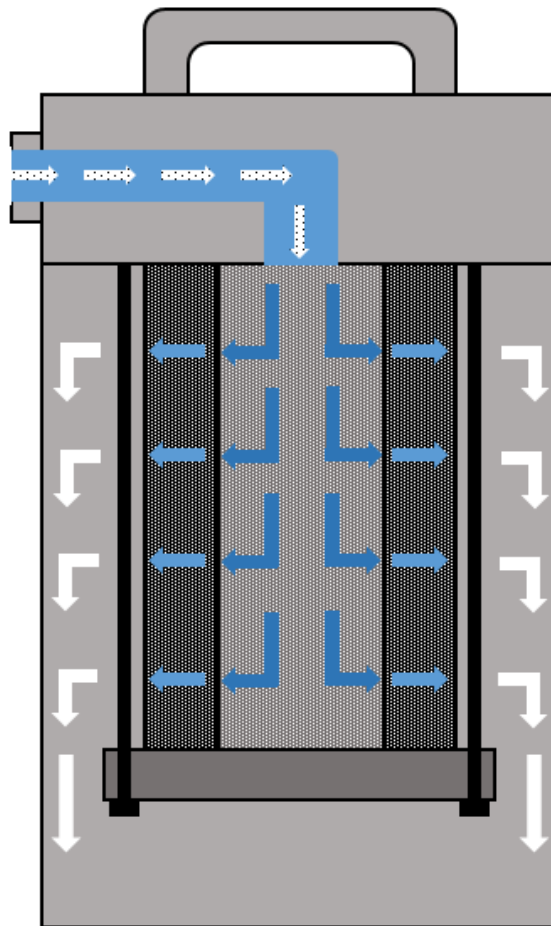
Figure 3: Two initial filter concepts

The second filter that you can see above on the right was a concept that we started to steer towards when INL told us that they might want to incorporate a rough and a fine filter into the system. This idea was used in the final design because we found it important to make a filtration system that would collect the larger particles first, and then step down in the fine filter to collect the rest of the particles to achieve the micron rating that we were shooting for. This secondary design that you can see above is straightforward. Water enters through the inlet or the bypass, and from here it begins to go through the first stage of filtering (The Rough Filter). Next, the water exits the rough filter leaving the larger particles behind and starting to enter the next stage in filtering (The Fine Filter). As you can see above the two filters would have been separated by a stainless-steel barrier. Overall, this was a very creative design, but it was a little too complicated and it would have been hard to incorporate into our system. Complexity wasn't the only problem with this design though; in this design as the water would leave the rough filter and enter the fine the particulate was being stored outside of the filter. This is something that we really wanted to stay away from, because we wanted to collect all of the particulate and make the cleanup process much easier.

After deciding that we wanted to collect all the particles inside of the filters we began to brainstorm the concept that you can see below. Overall, this flow diagram is like the final design that we incorporated in the system. There are some key features to this design that I would like to point out. First, this system was designed when we had decided against running the bypass through the filter. Through a series of discussions, we decided that if we added the bypass into the top of the system it would end up pushing the water back through the inlet and pool up near the grinder. We were leaning towards just the inlet going through the filter. The other major design characteristic was that we found a way to collect the particles inside both the rough and



the fine filters. Making it so that the 2 stage filters were inside one another was critical to our design, and this is something that we did incorporate into our final solution. As water would enter this system it would initially enter the rough filter, where most of the particles were collected. From here the water would continue to the fine filter where the rest of the particulate was collected. The two mesh screens that would have been used in this system were held in place by a cap on the bottom and two long bolts that secured them to the top. In this design we were having to make the mesh cylinders ourselves, and when designing this we wanted to provide INL a solution that they could buy whenever they were looking to replace the filters; not giving them something they would have to continuously make.



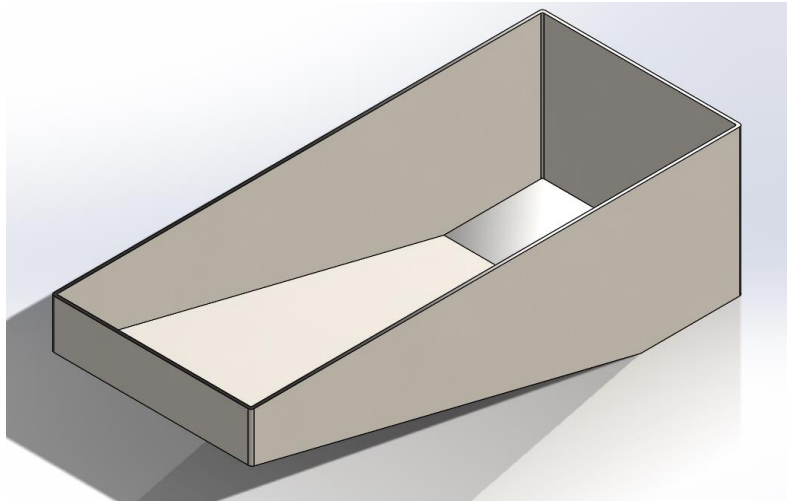
*Figure 4: Final filter design*

This filter design was one of the designs that we were planning to use for our system, and it wasn't until we started to look for the mesh screens that found the inspiration to design the filters that were used in our final system. In final design we worked with a group of people at Utah Biodiesel Supply, to make filters that perfectly suited our needs, and that were able to be re-made if INL needed to replace them.

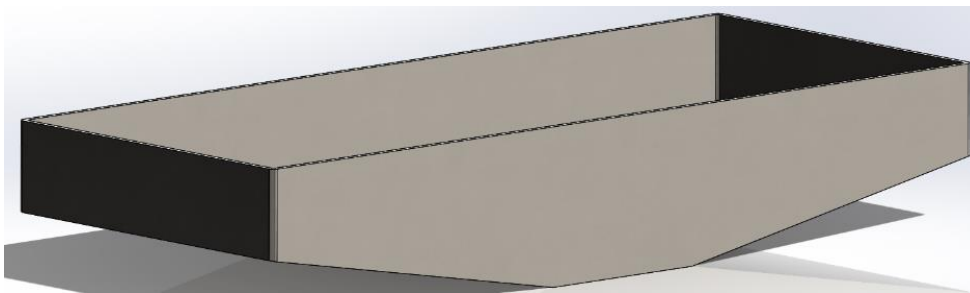
## Tank

INL made it known that a large issue with their current design was that it was very difficult to clean when particulate accumulated. In order to counteract this the team decided that it would be best to make a tank that would cause any particulate that made its way into the tank to accumulate in a set location. It was also discussed to make the span more of the length of the system in order to help have a more centralized center of gravity. It also was a goal to have an initial volume similar to that of the previous tank as to determine dimensions for the concepts the team had. Which lead to our initial concepts for the tank design.

The first of our initial concepts was a simpler design that focused on locating any particulate in one location that would be easy for INL to access using their manipulators. The design was simply a slanted bottom that came to a flat area that skewed to one side as can be seen below. The second concept was brought about with a similar focus as the first design. However, instead of being slanted toward a flat area that was skewed to one side it had two slanted sides that came to a flat section in the center of the tank as seen below. This design would be more difficult to clean but would help to give a more centralized center of gravity.

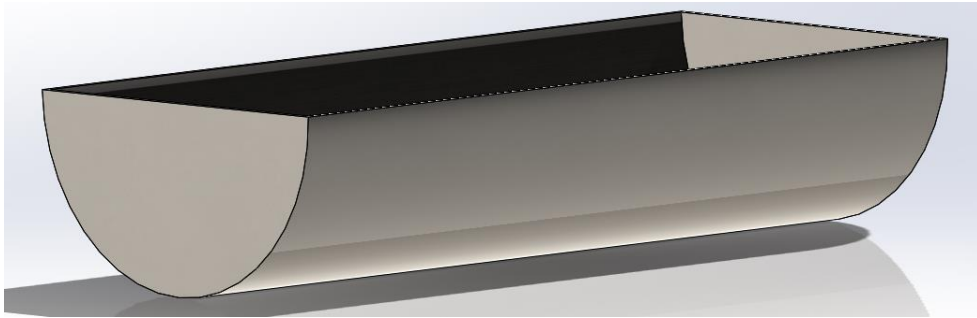


*Figure 5: First tank concept*

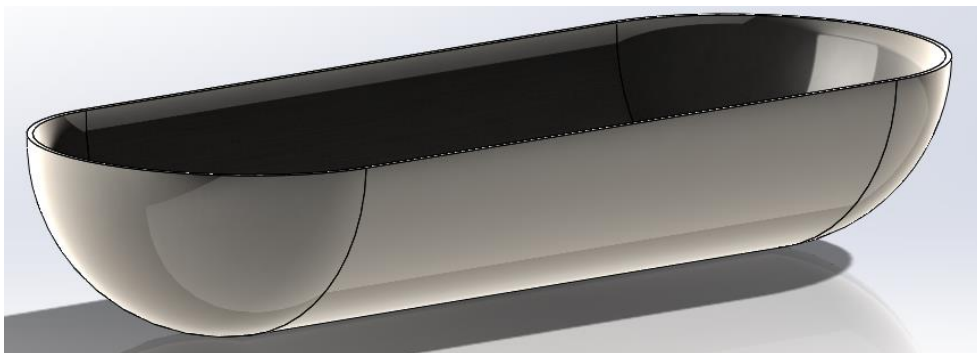


*Figure 6: Second tank concept*

Our last two initial concepts came about after the first snapshot where we received recommendation for a spherical tank. The first of these two designs to be considered was a half cylinder that resembled a trough as seen below. Initially the idea was that having a curved bottom would allow for accumulation of any particulate in the low point. We also believed that it would be easier to clean out if need be since there would fewer corners for particulate to get stuck in. This led to a design that was like a pill cut in half lengthwise, which would add hemispherical sections to each end as seen in Figure 8. This design would completely eliminate corners for particulate to be stuck in. However, we believe that it is more difficult to manufacture the hemispherical pieces.



*Figure 7: Third tank concept*



*Figure 8: Fourth tank concept*

We decided to move forward with the first of our initial concepts. It was then translated into a sheet metal part with a flat pattern. The sheet metal pattern was created in a way to minimize the amount of welding that would need to be done.

This would lower the chance of leaks and allow them to be found easily if need be. Once the pump had arrived, we found that we had to make alteration to the tank due to the pump shaft being longer than expected. In order to accommodate the extra length we increased the depth of our tank by an inch.

We believed this was the final design until discovering that it would difficult and expensive to have bent. It was decided that the sides should be sheared off and then be welded on so that it would be viable for the team. This design counteracted previous decisions that had been made, but helped the budget and timeline stay intact.

## Pump

The pump is one of the most essential elements of the system as it supplies the water to the grinder and polisher. Referencing the specifications, the pump needs to be easily removed, provide the correct volumetric flow rate, and be able to withstand the hot-cell environment.

The very first thing our team did was look at the previous system's pump. The original pump was manufactured by Graymills and operates at 115 volts. The pump is compact in design and is a vertically mounted centrifugal pump. The elongated shaft separates the impeller from the motor body making the pump excellent for a tank coupled design. Given that our new system would not have to use the pump to push water through the filter, this pump would have been a great attribute to our new system. However, the pump has been discontinued by Graymills.

Knowing that we had to find other options, we took to Engineering Equation Solver (EES) to try and size a pump that would best work for our system. Taking a look in the appendix one can see the calculations. Based off the old system, we approximated the diameter of the tubing to be  $\frac{1}{4}$  inch. The tubing had an estimated height and length of two feet. Using Bernoulli's equation, it was determined that the minimum head needed by the pump was 6 feet for a flow rate of  $\frac{1}{5}$  gallon per minute. Sizing a pump for these parameters was a challenge as these requirements are significantly low.

Knowing the parameters for sizing the pump, we looked back to Graymills to see if there were any other pumps that would work for the desired flow rate and head. Two pumps served as possible solutions to our new system; the Agitor and LV series pumps. Both of these pumps provide around 15 feet of head for  $\frac{1}{5}$  gpm flow rates and have similar shafts to the original pump. It was slightly concerning that both of these pumps supply over twice the amount of head than needed. However, the bypass that we incorporated into system would make it easy to control the flow.



*Figure 9: LV Series*



*Figure 10: Agitor Series*

For the LV Series, the pump is constructed of stainless steel except for the impeller and volute which is composed of a thermoplastic; Celcon. This was of concern as the hot-cell environment is notoriously harsh on materials other than stainless steel. As a result, we got in contact with the Graymills representative who ensured us that the LV series pump is used in a similar application with submarine fuel cells. In addition, that pump also saw larger uranium slurries than expected in the INL application. Overall, the LV pump will work just fine for the desired application.

Looking at other solutions, the Agitor series pump is a great alternative if the LV pump does not last as long as the representative suggested. The Agitor is made entirely of stainless steel and has an agitator that stirs the tank while pumping. The only downsides to this pump is that it is significantly more expensive and the agitator counteracts the purpose for our slanted tank.

Overall, the LV series pump is the best for this application as it is much cheaper and is compatible with the pump. However, if INL is not satisfied with the long term performance of the LV pump, the system has been designed to be able to mount the Agitor series as well.

## Integration

The integration of the system was of vital importance as it was the combination of all of the parts of the system. Since it could not be done completely until all other parts of the system were final, most of the design choices for the first few iterations of the system were done without taking some important design features in mind. Though changes in design were few and far between, they were still integral in perfecting the final design.

The first iterations of the design were extremely simplistic. The base of the system was the same as the current system that INL had and had the L-bracket legs attached to a gauge 11 stainless steel base. Next, the filter was placed first in the system. It was placed on top of a deck plate that was used as the top of the tank and was connected to the other end of the L-bracket legs. The filter did not go into the tank, but instead its cone shaped bottom was placed on top of small hole cut out of the deck plate. It was to drain into the tank.

The pump wasn't picked out yet, so we used the model in the CAD drawing that was given to us by INL. The mounting system for the pump was also CAD model given to us by INL. This would later end up causing lots of problems, as until we got the correct pump, we could not properly place where the pump needed to be.

In this initial design, the tubing was ½" diameter. At the time, there was no problem with this tubing size, but as the project went on, it became clear that that size of tubing was too big and would cause problems in integrating the rest of the system.



*Figure 11: Initial system design*

The first design was a good starting place for the integration, but overall it was incomplete. The filter came before the pump and the pump came directly at the end of the tank. This design concept was kept the same throughout the rest of the integration design process. However, there were no handles for the EEM, no complete filter or pump (and pump mount) design, and no care was given to the center of gravity of the whole system. This would later cause large concerns when it came to the final integration design.

The second iteration of the design was much closer to the final design. This design included the proper pump and the finalized filter design. This made it much easier to design the system within the specifications given by INL.

Firstly, the tubing was changed to fit in between all the various parts of the system while allowing Swagelok connectors to be manipulated with the mechanical manipulator hands. It became clear once the proper pump and filter were placed in the system that the initial designed  $\frac{1}{2}$ " tubing was too big to fit between our various parts. The  $\frac{1}{2}$ " Swagelok connections and valves were also very large making it impossible to integrate them in our system. We decided to go to the next size of tubing down, which was  $\frac{1}{4}$ ". This size of tubing and Swagelok connections fit well in our system and was determined to be the best tubing size for our final design.

Next, the filter housing was lowered, so that the filter would go directly into the tank. This was done to make the system easier to weld and eliminated the need for a filter mounting unit. Supports for the nozzle plate were added. A handle for the EMM was put in between these supports. This handle was our target center of gravity for the entire system and the final design would be integrated to place the system center of gravity on this point.

The shape of the hole in the top deck plate needed to change with the addition of the pump and pump mount. Instead of the basic circular shape, a teardrop shape needed to be created. This allowed for the pump with its impeller to be taken in and out of the tank seamlessly.

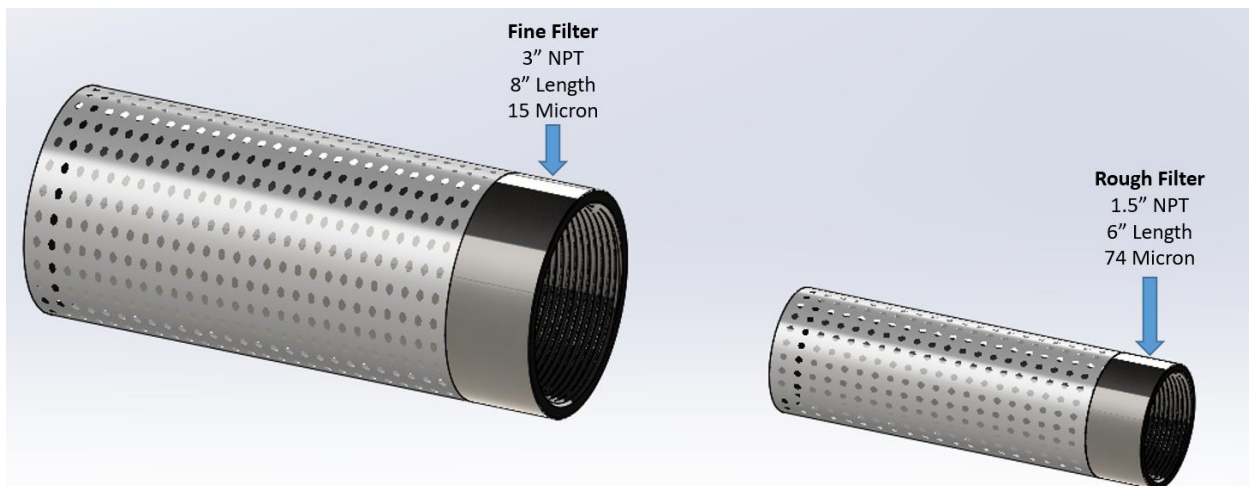
Lastly, the top nozzle plate was made to fit out Swagelok valves. This change allowed the tubing to fit into the needle valves for our outlet and bypass simplistically. The system legs were changed to rectangular bar stock instead of L-brackets. This allowed the support section of the system to be welded easier in relation to the tank and the legs.

This second design was very close to our final design for the system and was only changed slightly before the final design.

## Concept Selection

### Filter

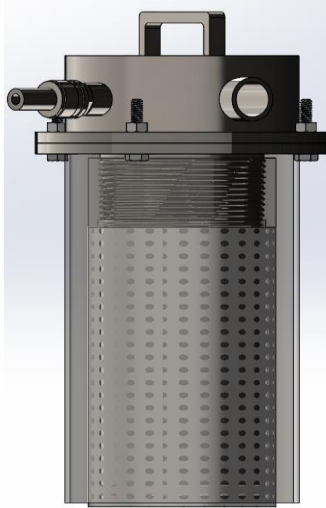
After deciding that we wanted the filters to be inside one another we needed a way to make this system replaceable and affordable. We were looking for filter screens then we stumbled across a company known as Utah Biodiesel Supply who specialized in creating different types of filters for all different types of applications. After extensively looking through their options, we decided to make a filter that combined two different filters that they had previously made. Our initial design for the filter cartridges can be seen below. Overall, this design is relatively simple, and you can see most of the details of each cartridge by their labels on the following picture. In this design we see that the tops of the filters are pipe couplings that were welded to the filter mesh. To have the support that we needed we decided to use a quarter inch perforated tube as our support cylinder, but inside of that perforated tube there is a sheet of the mesh that has the correct Micron rating. Overall, this is a really good design and we think that this was the best solution for the double stage filtering.



*Figure 12: Two stage filter design*

Utah biodiesel was prepared to get our filters made and shipped to us in the timeline that we needed, so we pulled the trigger. To mount the newly-designed filter cartridges to the top of the filter we simply welded to concentric pipe nipples to the filter lid. Water enters through the inlet that is coming directly off the grinding disc, and from there it goes through our rough filter. The

rough filter uses 1/4-inch NPT pipe coupling on the top and has an overall length of 6 inches. The inner mesh of the rough filter is a solid 74 Micron rating; which can collect the larger particles that will be introduced to our system. From here water would flow out of the rough filter and into the fine filter. The fine filter uses a 3-inch NPT pipe coupling on the top, and is overall 8 inches long. The Micron rating of the mesh in this filter is 15 microns, but it is a Dutch weave so even though it can filter up to 5 micron the Utah Biodiesel Supply company has to claim that its rating is 15 microns.



*Figure 13: Complete filter design*

The picture above is the current design of our filter that we use in our system. Overall, we are very pleased with the design of our filter and we think that it did a good job of meeting all our specifications. One thing to note is that we did go back to having the bypass come back into the top of the filter. Although in this design it does not actually go through the filter cartridges it just runs along the side of them so that it can help direct the flow. The top of the filter is made from a solid stainless-steel block which overall made it heavy. The filter housing is made from a 5-inch diameter schedule 40 pipe, and we were pleased with how it worked in our system. To mount the top of the filter to our filter housing and we had to come up with a unique idea. We created a flange system that was welded to both the top and to the filter housing. We made two identical



*Figure 14: Manufactured final filter design*



flanges and welded them into place so that the top of the filter would be able to mount to the filter housing in four different locations. Overall, this is a well-done design and it did a good job of achieving what we hoped when we were initially designing.

## Tank

There were two main criteria that we wanted to meet with the tank. First, we wanted the tank to be easy to clean. Second, we wanted something that would be easy to manufacture. We believed that our first initial concept fit those criteria the best.

The design was then altered when we learned that the pump had a longer shaft than what we were expecting. Later we had determined that we wanted to reduce the amount of welding on the tank to minimize places for leaks to occur. This led to the creation of a flat pattern for our first initial concept. However, later we discovered that our design would require tooling to be made in order for it to be bent. Which is what led to the final design having the side sheared off, inset an eighth of an inch and then welded back on.

## Pump

Considering the two pump options outlined in the concepts considered section, either the LV or Agitor series will work in the system. Both of these pumps are vertically-mounted centrifugal pumps that are designed to be mounted with the motor body sitting above the tank surface. This is an effective design because tubing will be permanently attached to the discharge port. This design is for ease of removal.

Comparing the two pump options, the LV series pump works best for the system. The LV series pump is best for the new system because it is significantly cheaper and works well with the slanted tank design. In addition, the weight of the LV pump is much less than that of the Agitor series and is a good solution for keeping the center of gravity in the middle of the system. Looking deeper at the LV series there are many options to choose from. The pump that correlates best for the required head and system architecture is the LVM21A pump. This pump runs at 1/8 hp, has a shaft length of 8 5/8 inch, and requires 115 volts. In addition, the discharge port of this pump is 3/4 inch National Pipe Thread. Provided that our tubing is only a quarter inch, a ninety degree elbow with a reducer threads directly into the pump discharge port to be compatible with our tubing.



*Figure 15: Removal of pump and pump mount*

One of the bigger challenges of this pump is the ability to mount it. The final pump mount design is a two part mount that bolts to the bottom of the motor body with  $\frac{1}{4}$ -20 bolts. The two part design is essential as the diameter of the impeller is the same as the motor body making it impossible for a mount to simply slip on over the impeller. As one can see from the above picture, the two part mount comes together around the shaft and is then bolted. Due to the length of the shaft, the mount is designed so that the bottom of the motor body is elevated 1.75 inches off of the deck plate. This allows the inlet of the pump to have clearance off the bottom of the tank. This clearance is essential to avoid cavitation.

## Integration

The final design selection was dictated by two main specifications: the filter coming before the pump and the center of gravity being on the center of the system. Since having the pump before the filter was the main issue of the current system at INL it was imperative to put the filter before the pump. There was never a point in our design process where the pump can be before the filter. We decided as a team to make sure this first specification was always addressed no matter what challenges it may have provided. In the final design, the water from the grinding disk goes directly into the filter, then the tank, and then the pump. This allowed the particulate to be collected inside the filters before the tank, which made for easier maintenance of the filters.

Getting the center of gravity into the center of the system was a difficult challenge for us to conquer. The pump and the mounting system weighed more than we initially had calculated in Solidworks. Due to this, the system was going to be heavier towards the pump side unless we could place more weight towards the filter side. Fortunately, the tank was slanted and had more of its weight on the filter side. This helped move the center of gravity, but it was still skewed towards the pump side of the system with this. To counteract this, the support system for the nozzle plate was made out of  $\frac{1}{4}$ " thick stainless steel instead of gauge 11 stainless steel. The

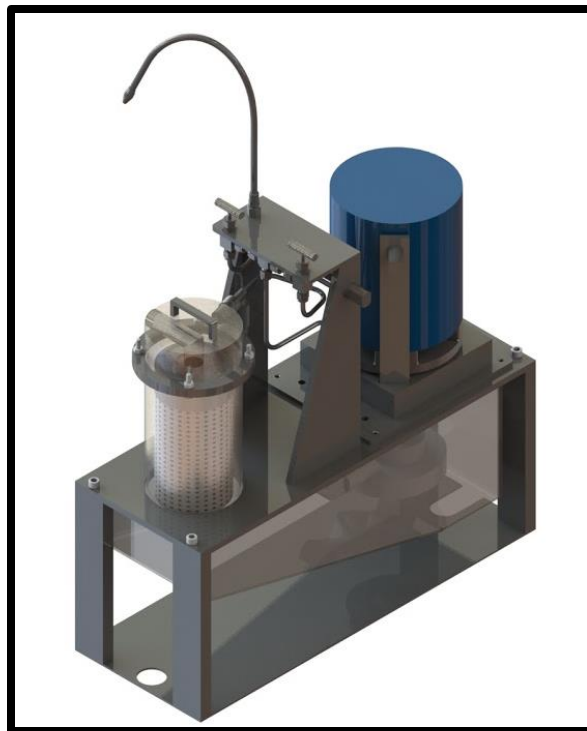
nozzle plate was also made out of  $\frac{3}{8}$ " thick stainless steel to move the center of gravity towards the center.

In the end, the center of gravity is still slightly towards the pump side, but close enough to the center, that the EEM could still lift the system without it being tilted in one direction when the EEM was secured. Once these two specifications were met, the system integration design could be considered final and complete.

## System Architecture

The aim for the final design was to meet the specifications given to us by INL while also remaining simplistic and easy to manufacture. The final design is justified as it meets the goals of the project completely.

The final filter design was made to filter out particulate up to 15 micron in a two stage filtration system, collect particulate on the inside of the filters, and be lifted with the mechanical slaves. The two stage filtration system is a valuable part to our system. This system allows our filters to be able to hand large and small particulate in two separate stages, which creates a failsafe in our water purification. Because of the two stage filtration, it is unlikely that any particulate up to 15 micron will go through the system. If this was a one stage filtration system, it would get clogged easily due to the fact that all the particulate would be contained in one filter. This two stage system allows for big and small particulate to be contained separately which allows for longer use and for separate cleaning or replacing of the filter.



*Figure 16: Final system integration*

In the current system at INL, flow enters the filter on the outside which allow particulate to sluff off into the filter housing and tank. This makes it difficult to determine where the system is clogged in addition to making cleaning harder. With our filter design, the particulate is collected on the inside of the filter as the water flows through them. This allows for the filters to be removed without fear of the particulate falling into any unwanted areas.

The filter needed to be removed easily, so an addition of a handle was added to the top of the filter cap which made it possible for both filters to be removed from the system at the same time for easy replacement and cleaning as well.

The design of the tank was made in a fail safe way to allow any stray particulate to be moved to one side of the tank for easy removal. One of the major specifications for the final system was to make it easy to clean and remove particulate. The tank was given a slanted design, which was a major improvement over the current tank design at INL. The slanted tank moves any stay particulate to right under the pump. The pump is easily removable and the hole that the pump goes into is large enough that the manipulators could use a vacuum to suck out the particulate that is left inside the tank. The slanted tank adds a large amount of value, as cleaning a rectangular tank would be difficult as the particulate could settle anywhere at the bottom of the tank.

A water level sensor was added to the tank to measure the level of water. This was not an original specification that was given to us by INL, but was talked about as a valuable addition if we were able to do so. We decided to implement a level sensor so that if the flow in the filter was clogged we could have an indication that they needed to be cleaned or replaced. This water sensor only goes halfway into the tank. Due to this, any person operating the system can tell when the water is no longer entering the tank fast enough. If the tank water level gets too low the pump will no longer work and will break, thus this water level sensor allows the user to know the water level is getting low before it hits a critical condition.

The entire pump section of the design added value to our system. The pump that was chosen was able to be mounted vertically, which allowed for it to be easily pulled out of the tank with the EMM. The pump was also lighter than any of the other pump alternatives. Due to this, the pump did not skew the center of gravity too much to the pump side of the system.

The pump mount was made in such a way that it closed up the teardrop shape needed to fit the pump into the tank properly. This allowed the tank to be completely closed, which stopped any water to escape the system due to splashing.

The use of Swageloks in the integration was valuable to us in designing and out client. Swagelok creates a watertight seal that insures that no water will leave the tubing at the fitting connections. This helps further keep our system completely closed. It was suggested by INL to use Swagelok Quick Disconnects for connections that would need to be taken off to move other parts of the system. These were used for the tubing coming out of the tank and through the pump mount and for the bypass into the filter cap.

The bypass was always part of the design as it was a specification given by INL. However, the bypass was initially designed to go right into the tank. This was changed in the final design to go into the filter cap and have the bypass flow along the inside of the filter housing. This allowed a constant flow of water to pass along the filters and help push water coming in from the grinder through the filters.

The final design decisions added exponential value to our product and allowed us to learn valuable information that we could use in our future endeavors in the industry. After meeting our client, we were given a short list of changes that could be made in our system that could add even more value to our system. These changes are further discussed in the Future Works section of this report.

## Design Evaluation

A design plan was made to ensure that the system would be able to function completely. An initial set of tests were designed for the pump.

The first test requires the system to be set up with all components except the filters. The procedure is to recirculate  $\frac{1}{2}$  of the water flow through the outlet nozzle and the remaining half through the bypass. Over time, the outlet water flow would be decreased while the bypass water flow was increased. This will ensure that the tubing could handle the pressure of the flow. This was tested at INL and it was proven that the system could handle the flow at any level for flow for the outlet and bypass.

The second test required us to be able to smoothly pick up the pump mount with the EMM. At INL, we were able to remove and replace the pump mount without a problem. It was determined that this test was successful.

A total system test was planned to run the whole system with filters to see if the flow rate of water into the tank could be maintained at a level that was safe. This test was to be ran at 15 minutes. We were not able to run this test, but it is recommended that INL run this test as soon as possible to determine if the system can run smoothly with the filters in place.

A second total system test was to be conducted to test the ability of the filters to collect particulate. Sand or a stainless steel slurry was to be weighed. The filters were then to be weighed separately and then placed back into the system. The system was to be ran with small amounts of particulate added. After 5 minutes the test would be concluded and the filters would be weighed again to determine how much particulate was remaining in the filters. This test would determine if the filters could still provide enough flow to the tank with buildup of particulate and if the filters allowed too much particulate to go into the tank. We were not able to run this test, but it is recommended that INL perform this test shortly after obtaining the system to confirm that the system collects the amount of particulate they expect and if the system will work as designed with filter and particulate hindering flow.

## Future Work

Although the design met all client specifications, there were some improvements that need to be made to our design before it could be used at INL. These changes were suggested to us by INL and are as follows: incorporation of flexible tubing, moving the bypass to enter the filter housing, changing of the type of Swagelok quick disconnects, varying the heights of the guide pins, and T-bar handles on screws.

The flexible tubing was suggested to us during our last visit with INL. In the final concept, the tubing cannot be removed easily with the mechanical manipulators, which makes it almost impossible to remove sections of our system in the hot cell. Flexible mesh tubing is available on the market and can be purchased for around the same price of the current tubing, which is about \$200. Using this tubing throughout the whole system is recommended, as the manipulators can move the flexible tubing out of the way if it becomes a hindrance to the working environment.

Our team originally considered having the bypass enter through the filter housing. However, it was believed that the bypass flow would create a pressure difference to promote flow through the filters if entering through the lid. Through talking with our client, they were able to suggest that it would be easier for them to remove the filters with the bypass connected to the housing. This eliminates the need for a Swagelok quick disconnect attached to the filter cap, saving time and money for INL. The flow from the new suggested bypass will help move the water through the filters without any issue.

The Swagelok quick disconnects that are currently on our final design are a certain type that does not work well with the mechanical manipulators. This requires too much straight pipe length to take off and currently cannot be removed with the manipulators. It is suggested that SS-QC4-B-400 and SS-QC4-D-400 be used as the new quick disconnects for the system. It is assumed that they will cost the same as the current quick disconnects, but it is uncertain as a price cannot be given to us at this time.

Our current system doesn't have any guide pins, which was a requirement given to us by INL. We were going to place  $\frac{3}{8}$ " diameter 1 inch long guide pins. It was suggested to us that it would be better if the system instead had varying length long guide pins. Two guide pins were to be used: one long guide pin and one short guide pin. This was to be used on any part of the system that required removal and replacement. The filter cap and the pump mount are the only two parts of our system that require removal, so guide pins should be added to make sure that the manipulators can place parts in the correct locations relative to other parts of the system (i.e. tubing and screw holes).

It was recommended early in the project that T-bar handles were to be added to all the screws, but after taking out system to INL it was determined that the screws could be removed with and

extended handle Allen wrench. T-bar handles are still recommended to be added to all screws via welding.

The estimated cost for all these changes is \$300 dollars. This is assuming that the cost of tubing and the Swageloks are the same and that welding can be done at INL. The bar stock and dowel pins needed for the T-bars and the guide pins will be the remaining costs. The estimated time to implement these changes is 1-2 weeks depending on how long it takes for materials to arrive and the welding. The recommended changes are can be done quickly and without much hassle and it is suggested that the changes be made before the system is dropped into the hot cell.

# Appendix

		Fall Semester																
		September			October			November			December							
		9/4	9/11	9/18	9/25	10/2	10/9	10/16	10/23	10/30	11/6	11/13	11/20	11/27	12/4	12/11	12/18	
Event	Week.	Comments																
Instructor Meeting	Jerry, Drew, Tommy, Troy																	Completed 9/8/2017
Client Phone Call	Jerry, Drew, Tommy, Troy																	Completed 9/18/2017
Client Interview- Visit to Idaho Falls	Jerry, Drew, Tommy, Troy																	Planned for 9/24-9/25
Transcript of client interview sent to client	Drew																	Completed 9/28
List of target specs sent to client	Troy																	Completed 9/28
Logbook check 1	Jerry, Drew, Tommy, Troy																	Completed 10/3
Subsystem assignments	Drew																	Assignments for Tank, Pump, Filter, and Integration
Snapshot Day #1	Drew, Tommy, Troy, Jerry																	Have presentation ready in pairs of twos
General design ideas submitted to group	Drew, Tommy, Troy, Jerry																	Submit on the Thursday 10/12
Have personal components selected	Drew, Tommy, Troy, Jerry																	Completed 10/27
Integrate design ideas together	Drew, Tommy, Troy, Jerry																	Completed and modeled in solidworks
Draft Wikipage	Tommy																	Wikipage is up and drafted
Draft Prototype Complete	Jerry, Tommy																	Prototype has been modeled in solidworks
Notify INL of Design Review Date and Time	Troy																	Completed 11/6/2017
Get Design Review slides to Dr. Swenson	Troy																	Due Friday 11/10/17
Budget projection meeting	Drew, Tommy, Troy, Jerry																	With subsystem selections, create budget allocations
Logbook check 2	Drew, Tommy, Troy, Jerry																	Submit to Dr. Swenson by Tuesday 11/7/17
Idaho Pitch Competition	Drew, Tommy, Troy, Jerry																	Our project has classified material- no competition
Design Review	Drew, Tommy, Troy, Jerry																	Design review is set for November 14th at 2pm
Team Member Citizenship	Drew, Tommy, Troy, Jerry																	Online submission is due to the lead instructor
Snapshot Day #2	Drew, Tommy, Troy, Jerry																	Friday at 6:30
Sort details for ordering a pump	Drew, Fagan																	Call Graymills and consider the options
Documentation of project learning for portfolio	Tommy																	Due Sunday 12/3 to Tommy
Sort details for tank fabrication	Jerry																	Tank welds and other fab details should be compiled
Have a fabrication shop selected for tubing	Troy																	Fab is outsourced to ensure we dont kink tubing
Project Portfolio	Troy																	End of semester deliverable
Wikipage	Tommy																	End of semester deliverable
Logbook Review	Drew, Tommy, Troy, Jerry																	End of semester deliverable
Progress Report Due to INL	Troy																	End of semester deliverable
Have a pump ordered for the system	Drew, Fagan																	Each subsystem should have parts ordered



		Spring Semester												May							
		January			February			March			April			May							
Week:	Responsible	1/8	1/15	1/22	1/29	2/1	2/5	2/12	2/19	2/26	3/5	3/12	3/19	3/22	4/2	4/9	4/16	4/23	4/27	5/7	
Event	Responsible		x																		
Flat details for tank fabrication	Jerry																				
Figure out how we will fabricate our system	Troy																				
Fittings and tubing layout final	Troy				x																
Filter design confirmed	Tommy																				
Finalize Pump Mounting system	Drew																				
Meeting with Bill to go over fab details	Drew, Jerry, Tommy, Troy																				
Detailed Design Review	Drew, Jerry, Tommy, Troy																				
Logbook Check	Drew, Jerry, Tommy, Troy																				
Order Sheet metal	Troy																				
Order swagelok fittings	Jerry																				
Order filter and components	Tommy																				
Contact Graymills about Pump details	Drew																				
Generate code for the CNC	Drew, Jerry, Tommy, Troy																				
Have the beginning cuts complete	Drew, Jerry, Tommy, Troy																				
Send out the remaining pieces to CDA Metals	Tommy																				
Team Member Citizenship Review	Drew, Jerry, Tommy, Troy																				
Team Portfolio Due	Drew, Jerry, Tommy, Troy																				
Wiki Page Update	Tommy																				
Drill all the holes	Drew, Jerry, Tommy, Troy																				
Have shell of the system ready for welds	Jerry, Troy																				
Have the pump mount/handle ready for welds	Drew																				
Have filter completely fabricated	Tommy																				
Have welds done	Drew, Jerry, Tommy, Troy																				
Obtain bolts for fastening	Troy																				
Incorporate fittings and tubing to system	Troy																				
Run the system for the first time	Drew, Jerry, Tommy, Troy																				
Make adjustments to the system	Drew, Jerry, Tommy, Troy																				
Secondary Testing	Drew, Jerry, Tommy, Troy																				
Booth Display/Poster	Drew, Jerry, Tommy, Troy																				
Technical Presentation at Expo	Drew, Jerry, Tommy, Troy																				
Design report/Portfolio due	Troy																				
Final Hardware and software	Troy																				
Wikipage approval	Tommy																				
Project poster	Drew, Jerry, Tommy, Troy																				
Work Area checkout	Drew, Jerry, Tommy, Troy																				
Electronic archive/File management	Drew, Jerry, Tommy, Troy																				

"Drew Fagan"  
"Pump Calculations"

"Given"

D = 0.020833 [ft] "0.5 inch outside diameter tubing"  
L = 2 [ft] "Length"  
x = 0 "Quality of the water"  
T = 80 [F] "Temperature inside the cell"  
rho=density(Water,T=T,x=x) "Density of the water"  
mu=viscosity(Water,T=T,x=x) "Viscosity of the water"  
g = 32.174\*convert(ft/s^2,ft/hr^2) "Gravity"  
g\_c = 32.174\*convert(ft-lbm/s^2-lbf,ft-lbm/hr^2-lbf) "G sub c value"  
epsilon = 0.0000015 "Stainless steel tubing"  
DELTA\_Z = 2 [ft] "Change in height"

\$IFNOT Parametric Study

V\_dot = 0.2\*convert(gpm,ft^3/hr) "Desired Flow Rate"  
\$ENDIF

$$H_p = \text{DELTA\_Z} + (f \cdot (L/D) + \text{sumK}) \cdot V^2 / (2 \cdot g)$$

$$f = 0.25 \cdot \log_{10}((\epsilon/D)/3.7 + 5.74/Re^{0.9})^{-2}$$

$$f_t = 0.25 \cdot (\log_{10}(\epsilon/D)/3.7)^{-2}$$

$$\text{sumK} = 0.78 + 0.5 + 8 \cdot (30 \cdot f_t) + (8 \cdot f_t)$$

$$Re = (\rho \cdot V \cdot D) / \mu$$

$$V_{\text{dot}} = A \cdot V$$

$$A = \pi \cdot D^2 / 4$$

SOLUTION

Unit Settings: Eng F psia mass deg

$$A = 0.0003409 \text{ [ft}^2\text{]}$$

$$\Delta z = 2 \text{ [ft]}$$

$$f = 0.04486$$

$$g = 4.170\text{E}+08 \text{ [ft/hr}^2\text{]}$$

$$H_p = 2.223 \text{ [ft]}$$

$$\mu = 2.075 \text{ [lbm/ft-hr]}$$

$$\rho = 62.21 \text{ [lbm/ft}^3\text{]}$$

$$T = 80 \text{ [F]}$$

$$\dot{V} = 1.604 \text{ [ft}^3\text{/hr]} \{0.2 \text{ [gpm]}\}$$

$$D = 0.02083 \text{ [ft]}$$

$$\epsilon = 0.0000015 \text{ [ft]}$$

$$f_t = 0.01127$$

$$g_c = 4.170\text{E}+08 \text{ [ft-lbm/hr}^2\text{-lbf]}$$

$$L = 2 \text{ [ft]}$$

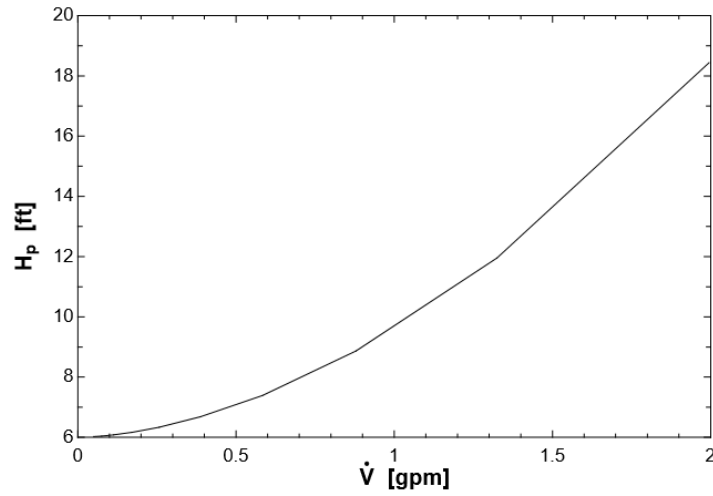
$$Re = 2940$$

$$\text{sumK} = 4.074$$

$$V = 4706 \text{ [ft/hr]}$$

$$x = 0$$

No unit problems were detected.



Date 2/17/2018

Side Profile  
Bending

Base Weld ( $1/8"$  fillet)

$$A = 1.414hd$$

$$A = 1.414(1/8)(1.5)$$

$$A = 0.265125 \text{ in}^2$$

$$I_a = \frac{d^3}{6} = \frac{1.5^3}{6}$$

$$= 0.5625 \text{ in}^4$$

Second M:  $I_a \times .767 = 0.0497109$

$$M = (0.625)(18.5 \text{ lb})$$

$$M = 11.5625 \text{ lb-in}$$

$$F = 18.5 \text{ lb}$$

Stress Analysis

$$\tau' = \frac{18.5 \text{ lb}}{0.265125 \text{ in}^2} = 69.778 \text{ psi}$$

$$\tau'' = \frac{(11.5625 \text{ lb-in})(0.125 \text{ in})}{0.0497109 \text{ in}^4} = 28.917 \text{ psi}$$

$$\tau_{\text{tot}} = \sqrt{28.9^2 + 69.778^2}$$

$$\tau_{\text{tot}} = 75.526 \text{ psi}$$

$$\sigma = \sqrt{(28.9^2 + 3(69.77)^2)} = 124.25 \text{ psi} = \sigma'$$

Drew F. M.

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## Integral Bonnet Needle Valves



## Part No.

SS-1RS4-A-SH

## Part Description

Stainless Steel Integral Bonnet Angle-Pattern Needle Valve, 1/4 in. Swagelok Tube Fitting, Regulating Stem, 316 SS Bar Handle

## Specifications

General	
Body Material	316 Stainless Steel
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Connection 1 Size	1/4 in.
Connection 1 Type	Swagelok® Tube Fitting
Connection 2 Size	1/4 in.
eClass (4.1)	37010201
eClass (6.0)	37010203
Flow Pattern	2-Way, Shutoff, Angle
UNSPSC (11.0501)	40141602
UNSPSC (4.03)	40141602
UNSPSC (PGE)	401416AL
UNSPSC (SWG01)	40141602

! The complete catalog contents must be reviewed to ensure that the system designer and user make a safe product selection. When selecting products, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

⚠ Caution: Do not mix or interchange valve components with those of other manufacturers.

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## 90° Elbows



## Part No.

SS-400-2-12

## Part Description

Stainless Steel Swagelok Tube Fitting, Male Elbow, 1/4 in. Tube OD x 3/4 in. Male NPT

## Specifications

General	
Body Material	316 Stainless Steel
Bulkhead	No Bulkhead
Connection 1 Size	1/4 in.
Connection 1 Type	Swagelok® Tube Fitting
Connection 2 Size	3/4 in.
Connection 2 Type	Male NPT
eClass (4.1)	37020715
eClass (5.1.4)	37020501
eClass (6.0)	37020501
eClass (6.1)	37020501
UNSPSC (10.0)	40142604
UNSPSC (11.0501)	40142604
UNSPSC (13.0601)	40183101
UNSPSC (15.1)	40183101
UNSPSC (4.03)	40141718
UNSPSC (PGE)	401753AN
UNSPSC (SWG01)	40141718

! The complete catalog contents must be reviewed to ensure that the system designer and user make a safe product selection. When selecting products, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

⚠ Caution: Do not mix or interchange valve components with those of other manufacturers.

## Tees



**Part No.**  
SS-400-3  
**Part Description**  
Stainless Steel Swagelok Tube Fitting, Union Tee, 1/4 in. Tube OD

## Specifications

General	
Body Material	316 Stainless Steel
Body Type	Tee
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Connection 1 Size	1/4 in.
Connection 1 Type	Swagelok® Tube Fitting
Connection 2 Size	1/4 in.
Connection 2 Type	Swagelok® Tube Fitting
Connection 3 Size	1/4 in.
Connection 3 Type	Swagelok® Tube Fitting
eClass (4.1)	37020716
eClass (5.1.4)	37020506
eClass (6.0)	37020506
eClass (6.1)	37020506
Series	Swagelok Tube and Adapter Fittings
UNSPSC (10.0)	40142605
UNSPSC (11.0501)	40142605
UNSPSC (13.0601)	40183102
UNSPSC (15.1)	40183102
UNSPSC (17.1001)	40141700
UNSPSC (4.03)	40141729
UNSPSC (PGE)	401753AN
UNSPSC (SWG01)	40141729

## Straights



**Part No.**  
SS-400-71-2  
**Part Description**  
Stainless Steel Swagelok Tube Fitting, Bulkhead Female Connector, 1/4 in. Tube OD x 1/8 in. Female NPT

## Specifications

General	
Body Material	316 Stainless Steel
Body Type	Female Bulkhead Connector
Bulkhead	Bulkhead
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Connection 1 Size	1/4 in.
Connection 1 Type	Swagelok® Tube Fitting
Connection 2 Size	1/8 in.
Connection 2 Type	Female NPT
eClass (4.1)	37020719
eClass (5.1.4)	37020590
eClass (6.0)	37020590
eClass (6.1)	37020590
Series	Swagelok Tube and Adapter Fittings
UNSPSC (10.0)	40142613
UNSPSC (11.0501)	40142613
UNSPSC (13.0601)	40183110
UNSPSC (15.1)	40183110
UNSPSC (17.1001)	40141700
UNSPSC (4.03)	40141720
UNSPSC (PGE)	401753AN
UNSPSC (SWG01)	40141720

## Straights



## Part No.

SS-400-1-4

## Part Description

Stainless Steel Swagelok Tube Fitting, Male Connector, 1/4 in. Tube OD x 1/4 in. Male NPT

## Specifications

General	
Body Material	316 Stainless Steel
Body Type	Male Connector
Bulkhead	No Bulkhead
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Connection 1 Size	1/4 in.
Connection 1 Type	Swagelok® Tube Fitting
Connection 2 Size	1/4 in.
Connection 2 Type	Male NPT
eClass (4.1)	37030703
eClass (5.1.4)	37020590
eClass (6.0)	37020590
eClass (6.1)	37020590
Series	Swagelok Tube and Adapter Fittings
UNSPSC (10.0)	40142613
UNSPSC (11.0501)	40142613
UNSPSC (13.0601)	40183110
UNSPSC (15.1)	40183110
UNSPSC (17.1001)	40141700
UNSPSC (4.03)	40141720
UNSPSC (PGE)	401753AN
UNSPSC (SWG01)	40141720
UNSPSC (SWG02)	41

## Full Flow Quick-Connect Bodies



## Part No.

SS-QF4-B-4PM

## Part Description

Stainless Steel Full Flow Quick Connect Body, 1.7 Cv, 1/4 in. Male NPT

## Specifications

General	
Body Material	316 Stainless Steel
Bulkhead	No Bulkhead
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Configuration	Body
Connection 1 Size	1/4 in.
Connection 1 Type	Male NPT
eClass (4.1)	37110302
eClass (5.1.4)	37110302
eClass (6.0)	37020500
eClass (6.1)	37020500
Flow Coefficient	1.7 - Coupled with a stem
Lubricant	Dow Corning 111
O-Ring	Fluorocarbon FKM
Pressure Rating Coupled at Max Temp	400 PSIG @ 400 °F /27.5 BAR @ 204 °C
Pressure Rating Coupled at Room Temp	6000 PSIG @ 70 °F /413 BAR @ 21 °C
Series	Full-Flow Quick-Connect
Size	1/4 in.
UNSPSC (10.0)	27121701
UNSPSC (11.0501)	27121701
UNSPSC (13.0601)	27121701
UNSPSC (15.1)	27121701
UNSPSC (17.1001)	31160000
UNSPSC (4.03)	31163101
UNSPSC (PGE)	401753AN
UNSPSC (SWG01)	31163101

## Full Flow Quick-Connect Bodies



**Part No.**  
SS-QF4-B-400

**Part Description**  
Stainless Steel Full Flow Quick Connect Body, 2.2 Cv, 1/4 in. Swagelok Tube Fitting

## Specifications

General	
Body Material	316 Stainless Steel
Bulkhead	No Bulkhead
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Configuration	Body
Connection 1 Size	1/4 in.
Connection 1 Type	Swagelok® Tube Fitting
eClass (4.1)	37110302
eClass (5.1.4)	37110302
eClass (6.0)	37020500
eClass (6.1)	37020500
Flow Coefficient	2.2 - Coupled with a stem
Lubricant	Dow Corning 111
O-Ring	Fluorocarbon FKM
Pressure Rating Coupled at Max Temp	100 PSIG @ 400 °F /6.8 BAR @ 204 °C
Pressure Rating Coupled at Room Temp	6000 PSIG @ 70 °F /413 BAR @ 21 °C
Series	Full-Flow Quick-Connect
Size	1/4 in.
UNSPSC (10.0)	27121701
UNSPSC (11.0501)	27121701
UNSPSC (13.0601)	27121701
UNSPSC (15.1)	27121701
UNSPSC (17.1001)	31160000
UNSPSC (4.03)	31163101
UNSPSC (PGE)	401753AN
UNSPSC (SWG01)	31163101

## Full Flow Quick-Connect Stems



**Part No.**  
SS-QF4-S-400

**Part Description**  
Stainless Steel Full Flow Quick Connect Stem without Valve, 2.2 Cv, 1/4 in. Swagelok Tube Fitting

## Specifications

General	
Body Material	316 Stainless Steel
Bulkhead	No Bulkhead
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Configuration	Stem
Connection 1 Size	1/4 in.
Connection 1 Type	Swagelok® Tube Fitting
eClass (4.1)	37110302
eClass (5.1.4)	37110302
eClass (6.0)	37020500
eClass (6.1)	37020500
Flow Coefficient	2.2 - Coupled with a body
Lubricant	Without lube on any components
Pressure Rating Coupled at Max Temp	100 PSIG @ 400 °F /6.8 BAR @ 204 °C
Pressure Rating Coupled at Room Temp	6000 PSIG @ 70 °F /413 BAR @ 21 °C
Series	Full-Flow Quick-Connect
Size	1/4 in.
UNSPSC (10.0)	27121701
UNSPSC (11.0501)	27121701
UNSPSC (13.0601)	27121701
UNSPSC (15.1)	27121701
UNSPSC (17.1001)	31160000
UNSPSC (4.03)	31163101
UNSPSC (PGE)	401753AN
UNSPSC (SWG01)	31163101

## INSTRUCTIONS for OPERATION and MAINTENANCE

# Graymills LV SERIES PUMPS

### I DESCRIPTION AND OPERATING CHARACTERISTICS

- a) LV series pumps are of centrifugal type designed for liquids of light viscosity. Standard pumps are made to operate at viscosities no higher than 400 SSU. Special models may operate at a higher viscosity.
- b) Liquid is drawn in through the bottom intake and discharged at relatively low pressure. Because of the low pressure, restrictions such as small I.D. tubing and heavy viscosity will reduce flow drastically.
- c) Do not run dry, the bushing may be damaged.

### II MAXIMUM VISCOSITY RANGE FOR "SAFE" OPERATION

- a) Standard LV Series pumps can operate with liquids having a maximum viscosity of 400 SSU without overloading the motor. For heavier viscosities a motor of the next larger horsepower is generally used. Check this specification as it may or may not have been considered in ordering.
- b) Rotary air motors cannot be overloaded or injured by heavy viscosity or binding. They will merely stop turning.
- c) The pump will deliver less flow as the viscosity increases. Temperature may affect viscosity. The viscosity of a 100 SSU oil, for example, may increase substantially as it gets colder. If the liquids are too heavy, the motor will slow down and stall. Overload protection is recommended.

### III ABRASIVE RESISTANCE OF MATERIALS

- a) LV pumps in shorter lengths have a labyrinth and there is no metal to metal or bearing contact. Such models can be used with abrasive slurries and pigments. Longer models have a carbon throttle-bushing above the impeller to give support to the shaft. The bushing and shaft sleeve may wear considerably without materially affecting the pump performance even though some liquid will leak through the bushing area.

### IV CHEMICAL RESISTANCE OF PLASTICS USED IN CONSTRUCTION

- a) The pump bodies, impeller and impeller nut are made in GM2GY, and GM2GG which are a thermoplastic combining high mechanical strength, stiffness and stability through a broad range of temperatures. It has excellent chemical resistance, but not complete chemical resistance. It can be used for water, many solvents such as benzine and toluene, chlorinated hydrocarbons, ketones, water and detergent solutions, brine and many inorganic chemicals used in cleaning or processing.
- b) The pump column is made of No. 316 or No. 302 stainless steel. Chemical resistance should be determined by the customer in consultation with Graymills.
- c) Consult the factory on specific applications of the LV pump with chemicals which may have an effect on materials of construction. Our chemical resistance information is based upon data supplied by the basic plastic manufacturers and/or Graymills tests. The user should conduct his own test where there is any question about the suitability of plastics or metals, strength, etc.



## V EFFECT OF TEMPERATURE ON CHEMICAL RESISTANCE

- Pumps should not be used continuously with temperatures exceeding 155°F without consultation with the factory. (Actual maximum temperature for GMZGY is substantially higher, however, pumping some liquids at elevated temperatures for long periods may cause gradual deterioration of the plastic, brittleness or crazing or loss of strength in wall thickness.) GMZGY may be used with water up to 170°F.
- Example: A pump made of GMZGY plastic was operated for 1400 hours in oil at a temperature of 194°F. No malfunction or leaks were evident but the plastic parts had decreased in thickness. The same type of pump operated in 150°F. oil showed absolutely no loss. Obviously, if a user were to operate occasionally at the higher temperature and then remove the pump or permit the oil to cool, many years of service could be expected before the breakdown point was reached.

## VI EFFECT OF TEMPERATURE ON VISCOSITY

- The viscosity of some liquids like oil will change with the temperature. This will affect the flow. The thicker the liquid, the less the flow. The effect is much more noticeable when small piping or tubing is used. If delivery is critical, make sure that the tests are conducted with liquids at the temperatures at which they will normally be operating or within the range in which they may operate.

## VII ELECTRICAL CONNECTIONS

- Check your electric current with the voltage, cycle and phase of the motor. LV pumps should rotate in a clockwise direction when looking at the intake end of a pump (with motor away from you). 3-Phase motors can be wired to run in either direction. Make sure the motor is running in the right direction. When running backwards the pump will deliver at reduced flow but no harm will be done. Grounding the motor is recommended. Overload protection is recommended.

## VIII MOUNTING

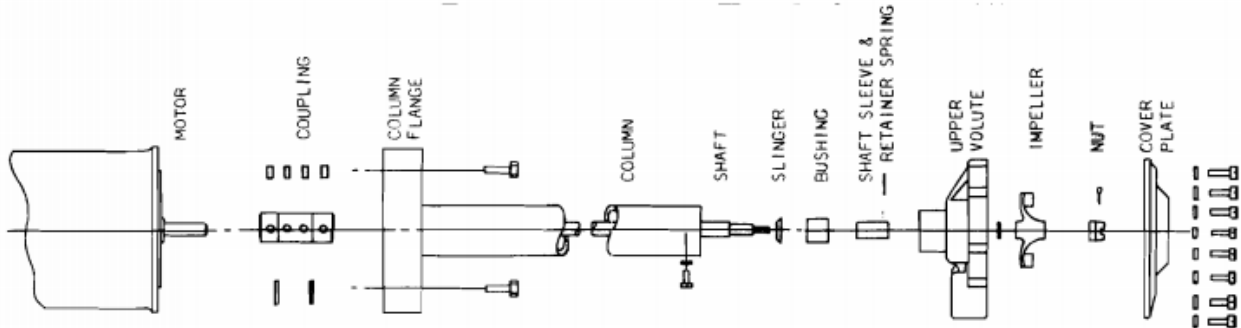
- Use care in making connections. LV Series pumps are of strong construction. The wall thickness of the plastic is such that there is excellent shock and impact resistance, however, care should be used in handling. The discharge is 3/4" standard pipe thread.
- Tapered pipe threads should be carefully tightened to avoid fracturing plastic. Pipe sealing compounds are not generally required because of the excellent sealing of the metal pipe thread to the plastic.
- Pump should be mounted vertically with the impeller covered by liquid. Do not block the intake by resting the pump too close to the bottom.
- To get the greatest possible flow, use the maximum size pipe, hose or tubing. Use Gate valves and not Globe valves. Avoid fittings which tend to offer restrictions, even though they may appear to be of adequate size externally.

## IX WHAT TO CHECK IF FLOW IS REDUCED BELOW RATED OUTPUT

- Is pump running in the right direction? (3 phase only)
- Are there any unusual restrictions in the piping such as crimped hose, excess fittings, small tubing, etc.?
- Is the motor running on the correct voltage, cycle, and phase?
- Is the liquid too heavy or did temperature decrease make it so? Some liquids will also get thicker when pumped. Some will be thicker when quiet and will thin out when pumped.
- Is the pump intake starved or is the pump above liquid level and not priming?
- If a long pump is used in a deep tank the lift is determined by the distance from the top of the liquid to point of delivery. As liquid is pumped down the lift will be greater and less flow will result.
- Check for binding within the body of the pumps caused by rags, strings or chips.
- Make sure pump intake is not in the sludge, slurry, or is not directly on the bottom of the container which will restrict the intake.

## X DISASSEMBLY, or TO REPLACE BUSHING OR SHAFT SLEEVE

- Remove the screws holding the volute cover plate to the body and remove cover plate with gasket.
- Remove the cotter pin and then the impeller retaining nut.
- Withdraw the impeller.
- The shaft sleeve is now accessible and may be inspected or removed by releasing the spring which holds it to the shaft.
- The bushing can now be inspected. To remove the bushing:
  - Take out the screws holding the upper volute to the pump column, then pull the volute from the column.
  - Push the bushing from the volute.
- The pump column can be removed from motor as one unit by removing motor bolts and dropping the column. (This will not be necessary for bushing or sleeve replacement.)
- If it is necessary to remove the shaft from the motor, take out the set screws and carefully support the coupling then drive out the pin. **DO NOT DISTURB THE ALIGNMENT OF THE SHAFT.**

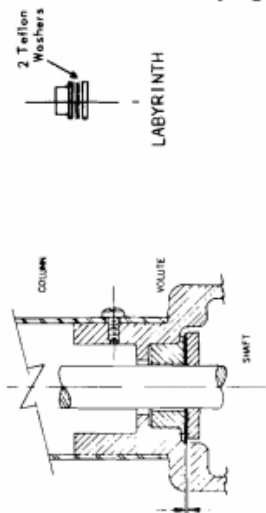


## XI REASSEMBLY

- Reverse the procedure in X. Make sure the shaft is running true.

## XII LABYRINTH

- Labyrinth used in place of bushing and sleeve on certain models.
- The 1/4" thick slinger is pressed on shaft with two teflon washers sandwiched between slinger and upper half of labyrinth.



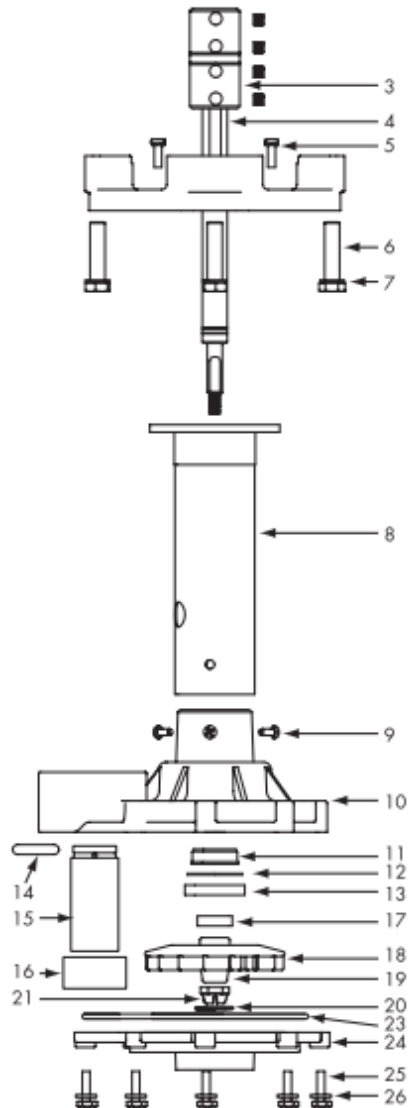
**LV SERIES**

**ELECTRIC MOTORS IN (B) LENGTHS AS SHOWN BELOW**

ITEM	DESCRIPTION	8-5/8"	10-7/8"	12-1/2"
1	Motor (see next page)			
2	Slinger	573-19212	744-11817	744-11817
3	Coupling (316 SS)	573-12029-88	573-12029-88	573-12029-88
4	Shaft (316 SS)	555-20861-88	555-20686-88	555-20690-88
5	Vapor Diffuser/Motor Adaptor with screws	532-20906-31	532-20906-31	532-20906-31
6	3 Screws - pump to column (316 SS)	752-02473-88	752-02473-81	752-02473-81
7	Lockwashers	754-00564-88	754-00564-81	754-00564-81
8	Pump Column	438-20863-88	438-20687-88	438-20691-88
9	4 Screws	751-04435-81	751-04435-81	751-04435-81
10	Pump Housing	507-21230-71	507-21230-71	507-21230-71
11	Nylon Insert 3/4"ID	573-19213	573-19213	573-19213
12	TEFLON® Washer	660-22498	660-22498	660-22498
13	Slinger	573-19212	573-19212	573-19212
17	Upper Impeller Ring	582-19182-81	582-19182-81	582-19182-81
18	Impeller, 1/6hp, 1725RPM	525-15868-74	525-15868-74	525-15868-74
18	Impeller, 1/3hp, 3450RPM	525-15898-74	525-15898-74	525-15898-74
18	Impeller, 1/2hp, 3450RPM	525-15899-74	525-15899-74	525-15899-74
18	Impeller, 3/4hp, 3450RPM	525-15866-74	525-15866-74	525-15866-74
18	Impeller, 1hp, 3450RPM	525-15868-74	525-15868-74	525-15868-74
19	Lower Impeller Ring	582-19182-81	582-19182-81	582-19182-81
20	Spacer Washers (as required)	754-03966-88	754-03966-88	754-03966-88
21	Castle Nut	543-16580-74	543-16580-74	543-16580-74
22	Cotter Pin (not shown)	756-00893-81	756-00893-81	756-00893-81
23	'O' Ring (Gasket)	745-04340	745-04340	745-04340
24	Volute Cover	526-16733-71	526-16733-71	526-16733-71
25	8 Volute Cover Screws	751-07279-88	751-07279-88	751-07279-88
26	8 Flat Washers	754-04289-88	754-04289-88	754-04289-88

ITEM	DESCRIPTION	18-1/2"	24"	36"
1	Motor (see page 2)			
2	Slinger	744-11817	543-18389-74	744-11817
3	Coupling (316 Stainless Steel)	573-12029-88	573-12029-88	573-12029-88
4	Shaft (316 Stainless Steel)	555-20915-88	555-20693-88	555-20699-88
5	Vapor Diffuser/Motor Adaptor with screws	532-20906-31	532-20906-31	532-20906-31
6	3 Screws - pump to column (302 S.S.)	752-02473-81	752-02473-81	752-02473-81
7	Lock Washers	754-00564-81	754-00564-81	754-00564-81
8	Pump Column	438-20917-88	438-20694-88	438-20700-88
9	4 Screws	751-04435-81	751-04435-81	751-04435-81
10	Pump Housing	507-21230-71	507-21230-71	507-21230-71
14	Shaft Sleeve	571-16982-88	571-16982-88	571-16982-88
15	Sleeve Retainer Ring	765-16983-88	765-16983-88	765-16983-88
16	Bushing	760-04372	760-04372	760-04372
17	Upper Impeller Ring	582-19182-81	582-19182-81	582-19182-81
18	Impeller, 1/6hp, 1725RPM	525-15868-74	525-15868-74	525-15868-74
18	Impeller, 1/3hp, 3450RPM	525-15898-74	525-15898-74	525-15898-74
18	Impeller, 1/2hp, 3450RPM	525-15899-74	525-15899-74	525-15899-74
18	Impeller, 3/4hp, 3450RPM	525-15866-74	525-15866-74	525-15866-74
18	Impeller, 1hp, 3450RPM	525-15868-74	525-15868-74	525-15868-74
19	Lower Impeller Ring	582-19182-81	582-19182-81	582-19182-81
20	Spacer Washers (as required)	754-03966-88	754-03966-88	754-03966-88
21	Castle Nut	543-16580-74	543-16580-74	543-16580-74
22	Cotter Pin	756-00893-81	756-00893-81	756-00893-81
23	'O' Ring (Gasket)	745-04340	745-04340	745-04340
24	Volute Cover	526-16733-71	526-16733-71	526-16733-71
25	8 Volute Cover Screws	751-07278-88	751-07278-88	751-07278-88

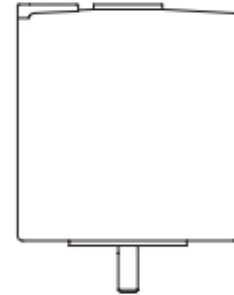
See next page for Motor information



Note: Plastic parts, impellers, castle nut and volute parts are made of GM2GY (Celcon). Also available in Polypropylene on special order. Use same number with suffix "76" instead of "71."

**LV SERIES**
**ELECTRIC MOTORS**

NUMBER	HP	RPM	TYPE	SHAFT LENGTH	SHAFT DIA	VOLTAGE	HZ	PHASE	SUFFIX
323-04076	1/6	1725	TENV (w/ tol)	2-1/8	5/8	115	60/50	1	A
323-05572	1/6	1725	TENV (w/ tol)	2-1/8	5/8	230	60/50	1	B
323-05687	1/6	1725	TENV	2-1/8	5/8	230/460	60/50	3	F
335-04075	1/3	3450	TENV	2-1/8	5/8	230/460	60/50	3	F
336-05640	1/2	3450	TEFC (w/ tol)	2-1/8	5/8	115/230	60/50	1	E
336-05416	1/2	3450	Explosion Proof	2-1/8	5/8	230/460	60/50	3	KF
336-04055	1/2	3450	TEFC (w/ fit)	2-1/8	5/8	230/460	60/50	3	F
336-05640	1/2	3450	TEFC	2-1/8	5/8	115/230	60/50	1	E
327-03565	3/4	1725	Explosion Proof	2-1/8	5/8	115/230	60/50	1	KE
337-04059	3/4	3450	TEFC	2-1/8	5/8	230/460	60/50	3	F
338-04063	1	3450	TEFC	2-1/8	5/8	230/460	60/50	3	F



It was paypal invoice # 2018-1087

Pricing may be slightly different depending on when they're ordered too (metal prices fluctuate somewhat).

Here's the specs for the filters as well:

**Filter #1 (fine filter)**

- 3" NPT Female Fitting at top
- 8" long (including fitting)
- 1/4" perf side & bottom
- with 15 micron mesh INSIDE
- liquid flows into center and out the sides

**Filter #2 (rough filter)**

- 1.5" NPT Female Fitting at top
- 6" long (including fitting)
- 1/4" Perf side & bottom
- with 74 micron mesh INSIDE
- liquid flows into center and out the sides

so they'd just need to reference [PayPal Invoice # 2018-1087](#) when they request it so I know which system to look in, but it'd be pretty easy to look up.

## Useful Contacts

Purpose	Company	Name	Phone	Email
Pump Specifications	Graymills	Tom	312-961-1484	N/A
Pump Ordering	Graymills	Dennis	773-477-4100	N/A
Filter Specs/ordering	Utah Biodiesel Supply	Graydon	N/A	graydon@utahbiodieselsupply.com
Welding	University of Idaho	Bill Magnie	N/A	bmagnie@uidaho.edu
Sheet metal and cutting	CDA Metals	John Logan	208-292-0300	johnl@cdametals.com