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May 6, 2008

Ralph Budwig
Center for Ecohydraulics Research
322 East Front Street
Boise, Idaho 83702

Dear Dr. Budwig:

Enclosed is the final sediment trap design report from Mainstream. This report documents all of the initial designs as well as the detailed descriptions of the final designs. Also included in the report are the drawings and calculations and other appendices documenting all of the work done throughout the year.

Sincerely,

Linsey Abo
Nathan Barrett
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Final Sediment Trap Design: A Report for Dr. Budwig

by:

Mainstream

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May 9, 2008

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Executive Summary

A flume located in the Center for Ecohydraulics is currently being used for water research. In order to conduct research on how sediment reacts in turbulent flow a sediment trap must be designed to trap and continuously weigh the sediment, transport the sediment to the dumpster located in the alley and finally separate the sediment from the water for recirculation. Plates will be used as a stop for the bed load holder where the sediment will accumulate. A funnel, located after the bed load holder attached to the bottom of the funnel, leads to a three pronged drum which will be rotated and attached load cells will be used to take weight recordings. As the sediment falls from the drum it will settle at the bottom of the funnel. The sediment will be mixed with water into slurry and taken up in a controlled manner by an auger attached to a pipe. A slurry pump will be used to pump the slurry through the pipes to the dumpster. In the dumpster the sediment will be allowed to settle once more and the remaining water with only suspended sediment will be pumped and piped back to the beginning of the flume for recirculation. The drum and frame with the attached load cell was designed and built in Moscow. The tank and separation system were designed in Moscow but will be built in Boise. A rough design for the auger in the slurry transport was done in Moscow but will be passed on for further design and building in Boise.
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1.0 Background

The Center for Ecohydraulics Research (CER) is located in the Idaho Water Center (IWC) in downtown Boise. The Center for Ecohydraulics Research Stream Laboratory (CERSL) is a 2500 square foot lab located on the first floor of the IWC. The CERSL features a high gradient sediment flume designed in close collaboration with state and federal agencies and several of the major research laboratories in academia. The facility has been carefully designed to fill a current void in laboratory facilities to study the interaction of sediment and turbulence. Using the flume creates opportunities to test water flows under various conditions allowing for increases in our understanding of water flows. The flume is also widely used as an educational tool for teachers such that these teachers can return to their respective schools and pass on knowledge gained from studying with the flume. Adding a sediment trap creates new educational tools because it creates a way to conduct cheaper, more efficient studies of many different types. All of which can be housed under one roof with the building of a sediment trap.

Many people stand to benefit from the sediment trap’s construction. Researchers will be able to conduct additional experiments and flow conditions using various soils. More natural stream conditions will soon be created allowing environmentalists and other experts to better understand the environment. Teachers and students have a stake in the sediment trap’s construction because of the learning possibilities it creates. New water flow knowledge can also lead to better waterway construction technologies, and, therefore, people that specialize in waterway design will also benefit.

Currently there is no way to trap, weigh, or transport any sediment that is deposited in the flume. Because of this restriction, the flume is constrained to “clearwater” experimentation. The sediment, accumulated by a bed load holder, will need to be weighed continuously then transported to a receptacle outside, then separated for water recirculation. A combination of operational features makes the CERSL facility unique. These include: a steep slope (variable up to 11%), large scale (20m long, 2m wide, and 1.2m deep), and a computer controlled flow, sediment system, and instrumentation system. The maximum water discharge is 1.4 m$^3$/s (or 50 cfs).

A state of the art design for a sediment trap has been developed by the St Anthony Falls Lab at the University of Minnesota that is in use at a few flumes (that are different in size from the CERSL flume) around the U.S. It involves a rotating drum that is suspended by load cells. This exact design will not work for the flume at the IWC due to several reasons. The most important of these reasons is it does not account for the variable 11% slope or the size variances of the flume in Boise. Also, Minnesota has a much easier disposal situation that does not include separation of the water and sediment.

Another concept for sediment removal has been designed which entails catching sediment falling off the end of the flume by using baskets. These baskets would then be transported to the waste facilities outside the building. This concept has not been implemented due to its very high operating costs.

Throughout the construction of the trap a number of experts have been consulted. The IWC, through Dr. Ralph Budwig and Dr. Klaus Jorde, have provided information on the operation of the flume and the sediment trap requirements. The University of Minnesota and their expertise and knowledge of the inner workings of the trap has also been helpful. Jay McCormack and Chris Huck have provided advice and guidance that has kept the project from derailing.

2.0 Problem Definition

The IWC wants to be able to accurately weigh and remove sediment during experiments with the flume. To do this, we will design, fabricate and test a sediment trap system capable of trapping and weighing sediment that is traveling down the bed of the flume.
The sediment trap will be attached to the end of the flume, collecting sediment before the water spills out. A stop or plate will be inserted into the flume to hold and collect the bed load for weighing. The bed load sediment will range in size from less than 1mm to 70 mm. The system must then continuously weigh the sediment with only a brief (less than 10 seconds) interruption while the weighing device is being emptied. The recorded weight measurements will be output in a readable and electronic (voltage) form. After it is measured, the sediment must be removed and disposed of. Throughout this process the flow conditions must remain constant and unchanged. The current sediment system has a computer controlled flow and instrumentation system. Adding a trap will make the flume more versatile and allow for additional uses in the future.

**Needs/Specifications**

The purpose of our needs and specification analysis (see appendix) is to determine a set of specifications that our final design will meet. After talking to the customer, the specifications analysis was needed to decode all the information we obtained.

Our needs and specifications analysis is broken into five subsystems. The subsystems and their needs are as follows: sediment handling which will need to trap sediment, continuously weigh sediment, and hold the bed load in place; flume/sediment trap interface with the need to not alter flow when trap is in use, not alter flow when trap is not in use, fit in space provided, and not break the flume; sediment waste where the water will need to be separated from the sediment; input/output which will need a visual readout, computer feed, and minimal noise output; miscellaneous with needs to finish was is expected of the team, stay under budget, and build a wooden flume model. Within each subsystem, the needs were prioritized (*, **, *** where *** is the highest priority) based on our conversations with the customer, Ralph Budwig. From each need, one to three specifications have been developed. The priority of each spec was examined when we presented the details to Ralph Budwig.

### 3.0 Project Plan

All of the subsystems will be fully designed by Mainstream. The drum and weighing device will be fabricated and built in Moscow. The other subsystems will be translated and handed over to the graduate student who will be in charge of assembling the subsystems together. A wooden prototype was built for the Design Expo for modeling purposes.

### 4.0 Concept Consideration and Selection

#### Functional Model

The purpose of the functional model is to show the various systems of the flume their inputs and outputs. The flume system has been split into four subsystems: the flume, the sediment feeder, the sediment trap and the sump. Three input/output categories are examined: Energy, material and information. Also, the two subsystems of interest, the flume and the sediment trap, have several of the needs added in. This allows us to link each need to the subsystem and ultimately to link the inputs directly to each need. The flume and sediment trap functional model are shown in Appendix D.

#### 4.1 Funnel System

The first system that the sediment encounters is the funnel. The sediment is carried over the bed load holder by the water, and falls to the bottom of the flume. Shortly after the bed load holder, a funnel will direct the sediment to the catchment system. Figure 1 shows a general sketch of the funnel, circled in red. Three ideas were considered for the funnel:

- Parallel walls, both at an angle to the flume (when flume is fully inclined, the funnel is vertical) Figure 2
- One vertical, one negative slope (vertical when flume is fully inclined)- Figure 3
- Hinge system that keeps the funnel vertical at all times
The first idea, with two parallel walls at an angle to the flume, can be seen below in figure 2. The theory for this idea is that when the flume is flat, the sediment will easily fall down to the catchment system. When the flume inclines to a 5% grade, both walls will be slanted slightly.

One benefit of this design is the simplicity. Designing and building the two angled-wall funnel would be easy and not very time consuming. However, the wall that is less vertical when the flume is flat could cause some sediment build up. Also, there is a geometry constraint between the bottom of the flume and the wall under the flume, which may cause a problem with this solution.

The second idea consists of one vertical wall and one inclined wall, as seen in Figure 3. When the flume is inclined, the inclined wall would be vertical, and the vertical wall would be slanted more negative.
Similar to design one, this design would be simple to construct, but wouldn’t have the problem of sediment buildup when the flume is flat. However, the geometry constraint between the flume and the wall still exists for this solution.

The third design would be similar to Figure 3, but would use two vertical walls and the whole sediment trap system would be on a hinge system. When the flume inclined, the hinges would allow the sediment trap (funnel, catchment etc) to remain vertical.

Unlike the previous two designs, this idea is a little more complex. The hinge system would have to be completely sealed and any piping exiting the sediment trap would have to be able to move. One benefit to this design is that the size constraint between the wall and the flume wouldn’t be as big of a factor. However, the added complexity may not add enough value to justify.

A small wooden prototype of the drum and tank was built in order to better understand the geometry of the funnel. After testing our prototype at different angles we decided to pursue the funnel with two walls angled toward each other, as seen in figure 1.

4.2 Catchment system
After the sediment falls through the funnel, it lands in the catchment system. The purpose of the catchment system is to catch the sediment, so that it can be weighed before exiting the flume. The catchment system is a “drum” shaped series of plates that will catch the sediment until one chamber is full or a certain time is reached, and then dumps it. Some sort of rotation system dumps the catchment system. The drum idea was used by the St. Anthony Falls lab and was concluded to be the best option. However, several modifications could be made when applied to our design.

Two different drum geometries were considered for this subsystem, as well as several different methods for rotating the drum. The drum geometries were:
- A three chamber drum
- A four chamber drum

The methods for drum rotation were:
- A “binary” air cylinder – drum only uses two of the three chambers and rotates back and forth
- A motor connected to the shaft through the drum-rotates in $120^\circ$ increments, uses all chambers
- A rack/pinion gear drive – drum uses two of the chambers and rotates back and forth
- Figures 4 and 5 show the three and four chamber drums, respectively.
The three chamber drum is similar to the design used in the St. Anthony Falls lab. Some benefits of this idea are that each catchment can hold a fairly large amount of sediment \((0.0838 \text{ m}^3)\), less material is needed for construction and fewer rotations would be needed per test (less likely to disturb flow and less down time). One issue with the three chamber drum is that it would take longer to rotate (has to move \(120^\circ\)).

The four chamber drum would have the four fins placed \(90^\circ\) to each other. Some benefits to this design are that the load cells wouldn’t have to hold as much weight (greater accuracy) and the construction would be easier than the three chamber drum. One issue with the four chamber drum is that it would have to be rotated \(33\%\) more often than the three chamber drum.

### 4.3 Drum Rotation System

The drum rotation methods also were considered in detail. The first idea, a binary air cylinder is the system that the St. Anthony Falls lab uses. Some of the benefits of this system are that it is fairly simple, it has been proven successful and it would involve mainly one system. Some issues with it are that it could get complicated when the flume rotates, and it only utilizes two of the three chambers on the catchment system.

Another drum rotation method that was discussed was using a motor connected to the shaft. The motor would turn on when the shaft needed to rotate and would turn the shaft. Some benefits to this design would be simplicity and easily contained (all in one spot). One issue with this design is that it would need a lot of torque to turn the drum when full of sediment.

The third drum rotation method would use a pneumatic rotary actuator to provide motion to the shaft. The actuator is a rack and pinion system that is powered by compressed air. The benefits to this solution are that it is very compact and can generate rather large amounts of torque.
The fin sizes needed for the chamber drum are approximately 0.165x2x0.0125 meters. Also, a stress calculation for the shaft was done, which resulted in a shaft diameter of about 0.0254 m (1 inch), with a safety factor of about two. The shaft length is approximately 2 meters. The fins on the drum are assumed to be aluminum, and the shaft is steel. The estimated cost for the two solutions is shown in Tables 2 and 3.

Table 2: Cost analysis for 3 chamber drum

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Spec</th>
<th>Dimensions (m)</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-Fin</td>
<td>Aluminum</td>
<td>$t = 3/16&quot;$</td>
<td>0.165x2</td>
<td>3</td>
<td>$101</td>
</tr>
<tr>
<td>Shaft</td>
<td>Steel</td>
<td>$d = 1&quot;$</td>
<td>$L = 2$</td>
<td>1</td>
<td>$57.45$</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
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<td></td>
<td></td>
<td><strong>$361.45</strong></td>
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</tbody>
</table>

Table 3: Cost Analysis for 4 chamber drum

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Spec</th>
<th>Dimensions (m)</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-Fin</td>
<td>Aluminum</td>
<td>$t = 3/16&quot;$</td>
<td>0.165x2</td>
<td>4</td>
<td>$101</td>
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<tr>
<td>Shaft</td>
<td>Steel</td>
<td>$d = 1&quot;$</td>
<td>$L = 2$</td>
<td>1</td>
<td>$57.45$</td>
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<tr>
<td><strong>Total Cost</strong></td>
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<td></td>
<td></td>
<td></td>
<td><strong>$462.45</strong></td>
</tr>
</tbody>
</table>

As tables 2 and 3 show, the three chamber design is more cost effective. Based on the cost analysis of the three chamber design and its ability to hold a larger amount of sediment the three chamber design was selected.

The following list portrays the cost comparison between the drum rotation options:
1. Pneumatic Cylinder: Costs estimated at $250
   a. $150 for the cylinder
   b. $100 for additional materials for the assembly
2. Air Powered Motor costs up to $1000
3. Pneumatic Rotary Actuator about $500

The pneumatic rotary actuator is not the best choice for this design. It costs more than the pneumatic cylinder system, and while the pneumatic rotary actuator has the added benefit of being purchased, not built, suspending the rotary actuator in the water/sediment mixture will end up being hazardous. The best choice for this situation is the pneumatic cylinder solution. It has already been designed by the St. Anthony Fall’s Lab, so there will be fewer unforeseen design problems that could arise.

4.4 Tank

The initial design for the tank is shown in Figure 6. The initial concept for the tank that is used to hold the drum, sediment, and auger system was going to be a simple tank that was attached to the bottom of the flume. This design included cutting a hole in the flume to allow for the sediment to fall through. The geometry of the tank was chosen such that a horizontal auger would be able to pull all of the fallen sediment to one side of the tank, and out into the slurry pump’s water flow.

Shortly after this design was started, we discussed the concept with Dr. Budwig, and found out that the best way to do the tank design was to include a section of the flume attached to the tank, and simply bolt the piece onto the end of the flume. This method is better because it does not require a cut in the flume, which could weaken its structure. It also has the benefit of allowing the tank to be a separate system from the flume. This way, if anything goes wrong with the tank, the flume will be unaltered.

![Figure 6: Fall tank design](image-url)
The second design for the tank, shown in Figure 7, shows the tank and flume section all as one piece. This design still uses a horizontal auger for sediment removal. The horizontal auger idea worked well in St. Anthony Fall’s Laboratory due to the fact that their flume does not tilt, but was not adaptable to the tilting flume in Boise. For that reason, the idea of the horizontal auger has been replaced by an angled auger that will pull the sediment up and out of the tank, not just out the side.

4.5 Weighing the Sediment
While the sediment is accumulating in the catchment system, the weight must be recorded. After communications with Ralph Budwig, reviewing the St. Anthony Falls sediment trap design and individual research, the team decided to use load cells to measure the sediment weight. Several design ideas were considered. The first idea, which is similar to the St. Anthony Falls load cell system, is seen in Figure 8.

For this idea, a load cell is located above the flume and connected to the ceiling. Two cables are used to hold up a shaft that runs through the drum underneath the flume. As the sediment falls on the drum, the cables increase in tension and the load cell records the weight. The load cell used in this idea would be a hydraulic load cell or a single point load cell. One plus to this design is the simplicity. It would be relatively easy to attach a load cell to the ceiling, as well as two cables. Also, since the St. Anthony Falls lab uses this design, it is proven successful. However, one concern was the safety hazard associated with the cables. If a cable were to
break, it could cause catastrophic damage to the flume and personnel working with the flume. In addition, a shaft running through the sides of the drum creates sealing issues.

The second idea also used a drum with a shaft running through it. However, instead of a load cell above the flume, this concept had a load cell on each side of the shaft, as seen in Figure 9.

![Figure 9: Bending Beam load cells on shaft](image)

The load cells used for this idea would be bending beam load cells. These load cells record the moment that is placed on them and output the weight. The two load cells would be used in series, and the outputs would be added together to get the total weight. One benefit of this design is self-containment; everything involved with weighing is contained underneath the flume, or inside of the flume in a neat fashion. One concern is that when the flume inclines, (between 0-11% grade) the weight measurement could be skewed. If the shaft ran through the tank walls, it would present sealing issues. If the load cells were inside of the sediment trap (below the drum), the load cells would be exposed to the elements (water, sand, rocks), which would create a cleanliness problem with the load cells. The third design concept is similar to the second, because it is self-contained. This idea would simply be one load cell located underneath the drum, as seen in Figure 10.

![Figure 10: Load cell underneath sediment trap](image)

This concept seemed to be fairly simple, because it is self-contained and only involves one load cell. However, this design was not chosen because the load cell would have to be under the tank, thus weighing the sediment, tank, water, and hanger. This would not be the best scenario because a load cell with a capacity well over 5000...
lbs would be needed and the accuracy would be greatly reduced. In addition, the tilting of the flume would change the loading on the load cell, causing the load cell to read the load at an angle when most load cells are calibrated for axial loads.

After reviewing the pros and cons of the designs, both as a team and with the stakeholders in Boise, the load cell configuration was narrowed to two options; the shaft-moment idea, or the load cell above the flume. In order to move forward with this decision, a geometry mock-up of the drum and funnel were made, and advice from the St. Anthony Falls lab was considered. Originally, the team liked the idea of load cells contained within the sediment trap, submerged in the water. However, after visiting St. Anthony Falls, it was very clear that maintaining cleanliness for the load cells is impossible (if submerged) and the load cells cannot function if they don’t remain clean. In addition, the setup with two submersible load cells was significantly more money (approximately $3000) then the other options. Appendix CC shows a diagram of the submersible setup.

After visiting St. Anthony falls, the team considered an option similar to the overhead design that they had implemented. The first conceptualization, shown in figure 8 was the basis of this design, except several parts were changed. First, the load cell could not be connected to the ceiling, because the Boise lab has an overhead crane that restricts the height above the flume to approximately 3 feet. Also, to avoid any issues with mounting a shaft through the drum, the connection between the drum and load cell had to exist within the constraints of the flume. To solve these problems, a frame was designed that will mount to the top of the flume, and extend about 2.75 feet above the flume. The frame supports the load cell, and a hanger is connected to the load cell via mounting plates and chains. The shaft of the drum is then connected to the hanger, so the load cell records the weight of the drum, shaft, hanger and chains.

In order to size the load cell, the worst-case scenario needed to be investigated. The max weight that the load cell would see would happen if no water was in the flume (drum wasn’t submerged) and the drum was full of sediment. Although this should never happen, it is possible, thus the load cells need to be able to handle enough weight. In order to calculate this maximum weight, several assumptions were made:

- The drum material is aluminum ($\rho = 2702 \text{ kg/m}^3$)
- The sediment has the density of sand ($\rho = 1515 \text{ kg/m}^3$)
- The shaft is steel ($\rho = 8054 \text{ kg/m}^3$), L=2 m, d = 0.051 m (2 in)
- The load cell can withstand 150% max without permanent damage

Calculations were made in EES, and a maximum weight of $W_{\text{max}} = 590 \text{ lbs}$ was found. The calculations can be found in Appendix B. The weight of the hanger, chains, drum and shaft were approximated to be 100 lbs.

Another important parameter that was needed was the maximum weight when the fully loaded drum is submerged in water. Archimedes principle was applied to the drum as a function of water depth. When the drum (full of sediment) was fully submerged, the apparent weight of the drum and sediment was 214 kg, or about 53 kg less then out of water. This buoyancy calculation was done assuming an average density (aluminum, steel and sediment). The calculations can be found in Appendix C.

After finding the maximum weight of the drum and sediment system, as well as the submerged weight, a load cell capacity could be selected and a cost analysis could be performed. From the maximum weight, a load cell capacity of 1000 lbs was selected. This means that the maximum load the load cell can withstand without permanent damage is 1500 lbs (150% maximum weight). Also, the uncertainty of this load cell will be within 0.5 N if the measurement is within the range of the load cell (0.02% FSO). Table 4 shows the cost analysis for the load cell system above the frame.
Table 4: One-Load Cell Setup Cost Analysis

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
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<tr>
<td>Visual Indicator</td>
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<tr>
<td>Cable</td>
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<tr>
<td>Software</td>
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<td>$325</td>
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<tr>
<td>Calibration</td>
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</tr>
<tr>
<td><strong>Total Cost</strong></td>
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<td><strong>$1375</strong></td>
</tr>
</tbody>
</table>

4.6 Slurry Removal

Once the sediment is trapped and weighed it will continue to pile up in the tank. Therefore the trap needs to be equipped with a removal system that is capable of transporting sediment at the same rate as the inflow. The transport system will have to take sediment from the tank and move it to a waste bin to be placed in the alley behind the laboratory. Other needs include being lightweight, easy to use, low maintenance and cost effective.

The first step in the removal process is to remove it from the tank itself. Sediment can fall into the tank at rates up to two kilograms per second. Because experiments can last hours or even days it is not practical to just build a large tank and just let it fill with sediment until the experiment is over and the matter of removing the sediment from the tank afterwards would still need to be addressed. To accomplish this task two methods were first developed and are shown below in Figure 11.

![Figure 11: Removal design concepts](image)

The first was an auger based method that would remove slurry from the tank and push it into a pipe stream. The University of Minnesota currently has a working auger system in place. Sediment falls into a tank with a horizontal auger. The sediment is pulled out and dispersed into a flowing pipe stream. An auger setup at Berkley based on the Minnesota concept has augers at angles rather than horizontal. These operate similarly to Minnesota, with sediment being pulled upwards and into a removal pipe.

The second idea removes the auger altogether and just uses gravity and steep tank slopes to funnel sediment into a piping system attached to a slurry pump. Using gravity instead of an auger is a much simpler design. Side slopes in the tank would need to be steep enough to allow sediment to fall into a funnel. At the end of the funnel would be an outlet pipe leading to the waste bin. Somewhere along the pipe a slurry pump would have to be placed in order to keep sediment moving along. This method removes a potentially non-essential component in the auger, creating a lighter, simpler and less expensive solution.
The difference between the two designs boiled down to whether or not the auger was a necessary component. In order to make this decision it became necessary to understand the augers actual purpose and what benefits it provides. A closer look at the actual specifications for the subsystem was also important. The slurry removal system has to be able to remove sediment, but it also cannot interfere with the normal operation of the flume and other design components.

In the Minnesota design an auger was used because it provided a steady stream of sediment into the outtake pipe. If too many large particles hit the pipe at once it can clog up the system and cause sediment to pile up into the tank and the flume. In order to fix the problem the experiment would have to be shut down, piping cleared and then powered up again. Using an auger the amount of sediment hitting the flume at once is controlled by the auger blade. This spreads the sediment removal out and greatly decreases the chance of clogging in the pipes.

A closer look at the gravity system also revealed that it would create problems with the flow conditions in the flume. To pull sediment through the piping at the bottom of the tank it would need to pull a fair amount flow from the tank. Removing water from the tank could drastically alter the flow conditions in the flume itself, which violates one of the most important specifications we were given. Therefore whatever flow rate the pump was running at would need to be replaced without changing flume conditions, thus potentially requiring an additional pump and piping. This is added expense and extra design work, making this solution more difficult and much less attractive.

**Auger Orientation**

The actual orientation of the auger within the trap is another issue. Our design calls for the use of a horizontal auger over an angled one for several reasons. The primary reason was that there was some fear about space being a problem. Right next to where the tank would hang from the flume there is a series of platforms for the various pumps used to pump water out of the holding tank and into the flume. Having an angled auger sticking out of that side of the tank creates spacing problems that would be difficult at best to overcome. Having the auger stick out the other side of the tank was also considered, but on that side it could get in the way of the wheel used to control the tailgate as well as creating a need for extra piping or the addition of a pump platform on that side of the flume. Since most of the auger would be contained within the tank, the horizontal arrangement would only require the auger to stick out the side of the tank far enough to attach to a flexible piece of piping.

The tank itself will need to be designed in order to accommodate the auger. The bottom of the tank will need to be sloped inwards and come to a point at the bottom where the auger will sit. Instead of a point however, a curved surface should be used so that it fits snugly with the diameter of the auger. A set of mounting brackets would also have to be built into the bottom of the tank to hold the auger in place. This prevents small pieces of sediment from settling into the space where the auger cannot reach it. The opening in the side of the tank will also have to be made large enough to allow for sediment to move through without getting stuck and potentially clogging the system up. However this opening cannot be too large because it needs to prohibit water flow as much as possible. The final addition to the tank is a large window. The purpose of the window is so that researchers can see what is going on inside the tank and spot potential problems with the weighing and auger systems before they get out of hand.

Due to the overall tank height needed to house the funnel and weighing drum the bottom of the tank will dip into the sump when it is full. The tank itself has been designed at 56 inches tall and there are 73.8 inches between the maximum holding tank level and the flume bottom. However, with the flume at its maximum 11% slope it drops the tail end by three feet, resulting in the bottom of the tank dipping into the water. Because the auger is horizontal this means that a motor attached right to the end of the bit will end up being submerged. This creates the need for an alternate motor configuration to be designed. A motor mounting plate will have to
be installed upon the side of the tank just above the top of the auger bit. A right angle gear drive can then be used to attach the vertically mounted motor to the horizontally mounted auger.

Based on the calculations shown in Appendix FF an auger with a diameter of 4 inches can be used. An interval between auger blades of 4 inches was also used. Assuming that sediment is entering the trap at two kilograms per minute and that it has the density of wet sand at 1922 kilograms per cubic meter the motor will have to be able to turn the blade fast enough that it can move as much as .25 kilograms with each turn. The auger bit will cost around $500. The auger will also need a motor. Since the flume is indoors, the motor must not create emission problems and therefore an electric one will be used. Depending on the size of motor needed, motors will probably range between $150 and $300. Additional costs will include materials needed to mount the auger onto the trap and then hold it in place. As a whole the auger and motor (not including brackets) will most likely cost in the neighborhood of $1000.

While sediment does tumble into the trap at a rate of up to two kilograms per second it will not meet the auger at that rate because the drum catches it all and drops it down onto the auger all at once. It does not necessarily need to be able to move all the sediment at once, but it must be able to avoid clogging as well as not putting too much into the piping all at once. This is determined by sizing the auger diameter and limiting number of times the auger turns (rotations per minute or rpm) to an amount low enough so that an output higher, but close to two kilograms per second, is achieved. The rpm for a motor can be controlled by adding a gear box to the design. The gear box would be used in line with the motor to reduce the number of rotations actually being made by the auger.

Stopping water flow at the flume-tank interface as well as the tank-piping interface has been a major concern and sticking point for the project. Any flow in between these components could change the flow conditions in the flume. In order to prevent water from moving through the tank a higher pressure level would need to be created in the tank so that water would not flow into it from either the pipe or the flume. Minnesota suggested doing this by having a small source of water, on the order of 5 gpm, pumped into the flume. This small inflow source would force there to be a small amount of flow out of the tank and thus be able to prevent any water from moving through the tank and messing up flume conditions.

The Center for Ecohydraulics has also been working on a solution to the auger system. They came up with an approach that uses an angled auger system instead of the horizontal one. This system would work around the spacing issues caused by the obstructions near the flume. Details on this design are still being worked out and a final decision will not be made until all angles of it have been explored. This new development came late enough in the design process that it was decided that the CER would continue to develop this idea and that any work being done by our team should be halted and any work pertaining to the auger be passed on to Jeff Schoenfelder, a graduate student working for Dr. Budwig. He has been charged with finishing the interface of the auger with the rest of the trap system that has been designed.

4.7 Slurry Transport
Many factors must be considered for slurry transport. These factors include the size and concentration of the solid particles, abrasivity of the slurry, pumping pressures, pipe diameter, reactivity between solids and liquid and surfaces, viscosity of the liquid and the critical velocity. The critical velocity is the velocity the slurry needs to be to prevent settling of solids in the pipe, which could lead to clogging. The factors affecting the settling velocity include the particle size, volumetric concentration of solids, pipe diameter, viscosity of fluid, fluid density, solid settling velocity, and solid density. The pipe wall thickness can be calculated using the maximum design pressure in the pipe, the maximum allowable design stress and allowance for corrosion/erosion.

The specs for our design project include the slurry in the pipes must not go over 3% solids. The pipes must be able to handle a solid particle size of less than 1mm to 70mm. The max discharge of water in the flume is 1.4
m^3/sec with a max flow rate of 30 tons/hr of sediment. The pipes and pump together must be able to handle the transport of the slurry to keep up with the max water and sediment flows.

There are many different types of pipes made for slurry transport. Some of the different types are non ferrous pipes made of polybutylene or polyurethane; there are patents for piping abrasive slurry transport of systems where in the internal surface is uniformly plated with a deposit of chromium which resists abrasion, NK-SL80 abrasion resistant pipe, and others. For our project, typical standard PVC pipe is the cheapest and most applicable. PVC schedule 40 pipe will not corrode and should be used for ambient temperature and low pressure. 3” PVC pipe costs around $5.04/ft and is sold in 10 ft lengths. 4” PVC pipe costs around $5.43/ft.

The Berkley design deals with a flow of 300 gal/min. They use a 3-inch PVC pipe, with a settling velocity of 12 ft/sec. Our design deals with very similar specs. Chris, our University of Minnesota contact, suggested using a broad sweep elbow instead of a 90-degree bend elbow to decrease the amount of energy loss in pipes. There is a 0.5 ft loss in every tight elbow; the broad sweep elbow is only half of that loss. A pump will be needed to help with the transport of the sediment out to the waste bin. Because the final design of the auger system is still undecided, it is uncertain if a slurry pump or regular pump will be needed. Regular pumps are cheaper than a slurry one and it is likely that a larger pump than necessary will need to be purchased due in order to adequately pass 70 millimeter particles.

**4.8 Separator Subsystem**
The purpose of the separator system is to remove any sediment particles from the slurry greater than .0625mm (.00246”) in diameter and to re-circulate the clean water back into the sump at a flow rate of 300gpm. The sediment is to be transported outside the building and deposited into a waste receptacle. There were many ideas and concepts that were brainstormed in order to meet these requirements.

The first plan to separate the sediment from the water was to use centrifugal separators are devices that rely on the velocity of a vortex to exert enough force upon particles suspended in a fluid to move those particles to the outside of the vortex to areas of lower velocity where they can fall out of the fluid. Usually the particles are kept in a small container at the bottom of the separator called the purge tank. This container proceeds to discharge the particles on a timed interval basis leaving the water supply clean and free of sediment.

Centrifugal Separators are typically coupled with other centrifugal separators to ensure the particle separation is efficient. This can be costly when purchasing multiple separators along with the hardware to install them. Typically these devices are used for removing particles in the order of magnitude of microns. The largest separator available for purchase separates particles maxing out at .375 inches.

Though these are very effective at separating particles such as silt and ash, they are not capable of removing the particle sizes required by the Idaho Water Research Center. There would be a high risk of clogging and this could create a potential water hazard.

Another plan is to separate the sediment at the dumpster site located on the wall outside of the research center. In this scenario the slurry will be pumped from the drum directly to the dumpster where the sediment particles will settle out to the bottom of the dumpster, and the water will be pumped from the surface. To do this a floating hose will be placed in the dumpster which will travel back into the research center where it will be connected to a self-priming centrifugal pump. A limit switch will be placed on the end of the floating hose in dumpster that will be used to indicate water levels. When the water level drops, the switch will depress from hitting the sediment on the bottom of the dumpster and will relay a signal to the pump to shut off. A rubber liner must be used in the dumpster to help prevent leaking. This setup is shown in Figure 12 and 13.
Since all of the separation occurs at the dumpster site on the outside of the building this system does not pose any serious water hazard threats if it fails. The components are fairly cheap and reliable as well. The self-priming centrifugal pump is the main expense with a cost ranging from $400 to $1000 depending on the make and model. Self-priming pump is needed because they create and maintain a sufficient vacuum level to draw fluid without external assistance. This would be important so the system can be left to operate without supervision. Self-priming pumps are also capable of pumping when subjected to mixture of water and air. Since the conditions in the dumpster will be unpredictable it is essential that the intake of air does not affect the performance of the pump. There is a possibility of the pump clogging from the intake of a large sediment particle but this can be minimized with the proper pump selection.

The rubber liners are mainly used in pond and waterfall applications and range from roughly $0.59 to $0.70 per sq ft in cost. An average sized dumpster is about 4x8x4 ft which gives an inside surface area of about 128 sq. ft. and costs anywhere from $75 to $100 to completely cover. The liners are made tough with tear and
puncture resistant qualities that will allow the liner to be used repeatedly. However they can be torn or punctured but repair is easy and cheap by applying a patch.

A mechanical limit switch is a device that can be used to determine the physical position of an object. Many limit switches utilize a push button for activation. When an object comes into contact with the button it depresses to either turn on or off the circuit through it.

Another one of the concepts was a piston apparatus that required sucking up the slurry and compressing it. This would strain out the dirt and waste while forcing the clean water though a small outlet in the side. The piston was impractical because it could easily clog with sediment build up and it would require a large amount of maintenance to ensure cleanliness.

![Piston Design](image)

**Figure 14: Piston Design**

Another concept was to use a pipe that was perforated on the bottom with small holes which would allow water to fall out as the slurry traveled down the pipe. This design was not feasible due to the suction effects on the pipe.

![Perforated Pipe Design](image)

**Figure 15: Perforated Pipe Design**
There were a series of designs which supported the concept of separating the slurry at the dumpster site. One of these designs was to place a large grate in the dumpster that would act as a strainer. The slurry would be deposited onto the grate and the water would flow through to the bottom while the sediment would remain trapped on top.

![Diagram of Grate in Dumpster Separation]

*NOT DRAWN TO SCALE

Figure 16: Grate in Dumpster Separation

This design required drilling a hole in the bottom of the dumpster for water to be drained back into the building. Since modifications to the dumpsters are prohibited, this design was also discarded. It was clear that the water had to be removed out of the top of the dumpster so no modifications had to be made.

This led to the next design that incorporated a floating pump in the dumpster. While the dumpster acts as a settling tank for the sediment, the floating pump would remain on top of the water to keep it out of the dirt and debris. The pump would turn on and off by using a limit switch to detect the sediment level. When the water level was low, the pump would float to the bottom of the tank and the limit switch would detect the sediment and turn off the pump. After the water level had risen, the switch would be lifted from the sediment and it would then turn the pump back on. This was a risky design because the pump would be placed outside of the building and it could easily be stolen. It was then decided to put the pump on the inside wall of the building and run a flexible hose through the wall into the dumpster. The flexible hose would allow the limit switch and a flotation device to move freely with the water level. The limit switch would be attached to the end of the hose instead of the pump. This design was also discarded due to the unreliable nature of the limit switches in a turbulent water environment.
Another design that had many positive qualities was the use of a gutter attached to the end of the dumpster. This design has been implemented in other separation applications and has proven to be very efficient and cost effective. The dumpster would be propped up at one end using a wooden block which would force the water to accumulate at one end. After the dumpster had filled high enough with water, it would then begin to spill out over the edge of the dumpster into a large gutter which would lead back into the IWC.

4.9 Sediment Sampling
For research purposes, it was requested there be a way to sample the sediment falling into the drum. This way the profile of the sediment throughout the width of the flume would be able to be recorded and incorporated into the study. The sediment sampling was considered a low priority and is now being designed by the researchers themselves.

5.0 Product description
5.1 Load Cell and Frame
As seen from the concept development section, the load cell above the flume system was selected. However, several changes were made from the conceptual design, due to specifications for the Boise lab. Since the flume in Boise can tilt and the lab uses an overhead crane, the design needed to account for this. Several modifications were made to account for the tilting flume. First, the load cell was connected to a linear bearing, which runs on a linear slide. The load cell system can be manually moved on the linear slide via a cable and winch setup, seen in figure 14. Also, the load cell is connected to the linear bearing with an eyebolt, which allows the load cell to swivel. As the flume tilts up to 11% grade, the eyebolt will allow the load cell to remain vertical, and the load cell will read a 100% axial load. To avoid the overhead crane, the frame was designed to
extend about 2.75 feet above the flume, and will be bolted to the inside of the flume via two 3/16” bolts. By connecting a frame to the top of the tank with a load cell on a linear slide, we were able to buy a cheaper load cell and eliminate the waterproofing issues that would have occurred with other designs.

The system consists of two main parts, the frame and the load cell. The frame consists of several pieces of 1018 HR steel (Sy = 40 ksi) welded together to support up to 1000 lbs. The maximum weight was selected as 1000 lbs as a worst case scenario. The drum, rod and rotation system weighs 100lbs, and a full drum of sediment weighs up to approximately 590 lbs, putting the maximum weight around 700 lbs. This allows a large factory of safety, in case the drum does not rotate and the sediment continues to pile up. A detailed drawing package with all the welding can be seen in appendix F. Several calculations were done in order to determine the size of the frame. For the worse case load scenario of 1000 lbs, stress calculations (both bending and normal), and buckling calculations were done for the members of the frame, as well as the fasteners. These calculations determined the size of stock 1018 HR steel needed to handle the max loading, and include a factor of safety. In addition the considerations established from the calculations, gussets and extra supports were added to the frame to insure stability and to triangulate the loads. The calculations that aided in the design of the frame can be seen in appendix BB.

The load cell that was selected is a LSB350, from Futek. It has a 1000 lb limit, with 150% safe overload. The load cell outputs weight onto an IPM500 digital display, and also to a computer with a software program. The specifications sheets for the load cell, display and software can be seen in appendix G. The load cell display will be connected to the air cylinder actuator, through a circuit. The circuit will read the output of the display, and when a certain value is reached, the circuit will send a signal to the binary air cylinder actuator, which will turn the drum. The circuit will be programmable, allowing for a variety of dumping weights.

In order to account for the 11% change in the flume, the load cell is connected to a linear bearing/rail system via several mounting plates and bolts. Figure 14 shows the linear slide and the load cell setup.

Figure 14 shows the load cell assembly which can be found in appendix DD, along with the load cell assembly directions. This rotation will insure the load cell is reading only an axial load. The detailed drawing package of the load cell system can be seen in appendix H.

5.2 Tank

Figure 18 shows the spring design for the tank and flume section. This design was fairly straightforward. The requirements for the tank were updated to include the fact that it must hang from the current flume, and that the bottom of the tank must be slanted in order for the falling sediment to pile up in the corner. This makes it easier to remove from the tank.
This design is not the actual final design that will be implemented in Boise. The final design will come to a point in the middle of the tank, not at the left side, like what is shown in Figure 18. The reason it has not been designed this semester is that the design change came too late in the semester. Some preliminary models and drawings have been created to start this final change, but the product will be designed and finished by Jeff Shoenfelder. The tank and flume section will be made out of varying thicknesses of stainless steel. The drawing package for the design shown in Figure 18 is shown in Appendix N, and has the details for the sizes and thicknesses of the stainless steel.

5.3 Drum
The differences between the initial design and the final design of the drum are small. Conceptually, we changed from the drum rotating in only one direction to the drum rotation in two directions. The first concept called for a very simple, easy to control motor that would drive the drum 120 degrees every time a chamber filled up to about 80% full. This proved to be a little more complicated than was needed. After discussing this with Chris Ellis and Jim Mullin, of the St. Anthony Falls Lab and the University of Minnesota, we decided to go with a linear pneumatic actuator to drive the drum back and forth 120 degrees at a time. There is no actual physical or geometrical difference between the two drum designs.

For the final design, when the drum fills to 80%, the pneumatic will extend, dumping one chamber of the drum into the tank, while positioning the next chamber to fill with sediment. When that chamber is 80% full, the pneumatic will retract, repeating the process again.
The drum is made out of aluminum. This greatly reduces the weight of the apparatus, which was very important, since the drum is hanging on the hanger, which hangs from the load cell setup. Appendix N shows the dimensions of the drum with a drawing package.

### 5.4 Hanger

The hanger, shown to the right is attached to the frame from above. It holds and provides a pivot for the drum. Attached to the top cross plate will be the pneumatic actuator linkage. The hanger is made out of aluminum, like the drum, in order to decrease the total weight hanging from the load cell set up. The drawing package for manufacturing the hanger is shown in Appendix Q.

### 5.5 Pneumatics

Figure 22 shows a picture of the connecting hinge used to drive the drum’s rotation. Below that, Figure 23 describes what each of the parts is, and how to assemble the hinge. Not shown in the picture that is included in the assembly diagram is the pivot arm. This arm is a necessary part of this assembly, but is not yet manufactured. The drawing for the pivot arm can be found in Appendix Z. The final design for the pneumatic system was entirely designed by Chris Ellis and Jim Mullin.
5.6 Slurry Transport
The final design for the slurry removal system requires an auger to be built and placed into the bottom of the tank. It will need to pull sediment out the side of the tank and into an intersecting pipeline with a fast moving stream of water. Sediment will be pushed into the water stream at a fairly even rate of speed, dispersing the sediment in such a way to minimize pipe clogs. As previously stated, much of this system is still being designed in Boise and many aspects may be changed in the future. The actual list of components is pretty well set with an auger, piping system and a pump being needed. It is the configuration and orientation aspects that still need to be hashed out.

As specified, the current tank design calls for an angled auger to be used instead of a horizontal one. The auger, the accompanying motor and the gear box will need to be mounted and supported to ensure proper operation. The auger will need to move sediment loads up to two kilograms per second and deposit them in an attached
pipe. An auger diameter of 4 inches should be sufficient to do this. The area around the auger bit should be encased so that sediment does not just fall off the blade, but instead can be lifted into the pipe.

The piping system has been laid out according to our design but some changes may need to be made depending on the final design of the auger motor system and positions of the pump when purchased. The piping will be purchased and assembled in Boise. A pipe will need to attach near the auger to collect sediment. This will have to connect to flexible pipe in order to allow for the 11% tilt of the flume. The flexible portion will have to reconnect to rigid piping, connect to the pump and then to the dumpster. Another pipe will be needed to go from the dumpster to the sump. A rough sketch of the piping layout is shown in the Appendix AA.

### 5.7 Separator System

Slurry will be dumped into a large roll off dumpster on the outside wall of the IWC. The dumpster will act as a settling tank for the sediment and the suspended water on top will be pumped out, and returned into the building where it will be re-circulated. The pump will be placed inside the building and will be controlled by a float switch which sits inside the waste bin. The water will pass through two strainers before entering the sump. One will be a simple suction strainer that is attached to the end of the suction pipe immersed in the water at the dumpster site. The other will be a double basket strainer which will be placed on the inside of the building before the pump. A schematic of this design is given below in Figure 23. The pump will be controlled by a float switch which will also be immersed in the waste receptacle. A parts list of these items is included in Appendix M.

Figure 24: Final Design Schematic
The dumpster that will be used is provided by BFI and is a construction dumpster that is used to discard heavy construction materials, such as concrete, gravel and asphalt. It has dimensions of 20’L×8’W×4’H which gives it a total capacity of 20 yards. Due to weight constrictions, the dumpster is only allowed to be filled to a maximum capacity of 10 yards with dry sediment. This means that the dumpster can be filled to an even height of two feet with dry sediment. Since these dumpsters are not water tight, a liner will need to be installed to ensure there are no leaks. The liners will be discarded along with the sediment, so it is recommended to use an inexpensive plastic liner as opposed to a rubber liner which costs around $152. Visqueen plastic liner is a construction grade plastic that can be purchased at any hardware store for around $30. It generally comes with a set width of 20 feet and various different lengths can be selected. The liner is to be cut at a length of roughly 24 feet. This allows a sufficient overhang of two feet around the perimeter of the dumpster.

A rigid 4” suction hose will be used to remove the water from the waste bin. It will be removable with the use of cam and groove hose couplings which are shown in Appendix T. These couplings will allow the apparatus to be attached and reattached when the dumpster needs to be emptied.

The bridge strainer aids in blocking large sediment particles from entering the suction line. It is vertically installed at the end of the suction hose with the bottom of the strainer 20 inches from the top of the dumpster. A schematic of this scenario is given below in Figure 24. Additional installation instructions along with strainer specifications are provided in Appendix V.

![Bridge Strainer Schematic](image)

*NOT DRAWN TO SCALE

Figure 25: Bridge Strainer Elevation Schematic

Since the dumpster is to be filled up to 24 inches with sediment, this will allow the Bridge Strainer to sit about four inches above the settled debris to allow proper water intake. As shown below in figure 25, the strainer comes with a solid top and bottom, and a standard 1/4” mesh inlet located around the 2” outer circumference.
Since this strainer’s inlet is around the perimeter instead of facing down, it will ensure as much of the settled sediment is left behind as possible. The coupling is designed to glue to a 6” Schedule 40 or Schedule 80 PVC pipe. A reducing coupling will be used to connect the strainer to the 4” suction line. Other coupling information is given in Appendix W.

After the water has passed through the Bridge Strainer at the suction port, it will then flow inside the building and will pass through a basket strainer. The basket strainer removes the remaining debris from the suction hose before the water enters the sump. The 4” 53TX Duplex Basket Strainer from EATON Filtration shown below in Figure 26, is used in applications where space is limited and where lines must run continuously.

A lever is simply used to divert the flow from one basket to another when one fills with sediment. Additional operating information and mounting specs can be found on the EATON website and in Appendix Y. Pressure taps will be installed up and downstream of the strainer that will indicate when the flow needs to be diverted and the corresponding basket removed and cleaned. Various mesh sizes are available for the baskets so virtually any particle size can be removed from the system.

Pump operation will be controlled using the 2” FM20 Multi-Level Float Switch with a Double pole Double Throw relay (Pump Down), as shown below in Figure 27 and in Appendix U. This switch has a total length of 10” and is configurable for 1 to 5 levels of depth.
It comes with internal mounting on the top that will be screwed into a (1/2") diameter threaded PVC pipe to protect the circuit wires. It will then be hung vertically into a 2.5” diameter perforated PVC pipe which can easily be made by drilling 1/8” holes into 2.5” PVC pipe 12” long.

The 12” perforated pipe should also be wrapped with a layer of aluminum or fiberglass window screening. Generally, window screening is a size no. 60 mesh, which will block any particles larger than 0.011” in diameter from getting into the float switch. The pipe provides a protective shell around the float switch while still allowing it to function properly. The switch, pipe and screen will then be attached with zip ties to the 4”
PVC suction pipe with the bottom of the float switch 4” above the top of the bridge strainer. This gives the bridge strainer sufficient water level depth above its inlet port for suction.

When the water level reaches the top float on the switch the circuit will close turning the pump on. As the pump sucks the water level back down to the first float, the circuit will re-open and turn the pump off. The 10” height between the bottom float and top float provides a sufficient amount of water depth to accumulate before turning the pump on. It takes the pump 3.3min to pump the water level in the dumpster down 10” at 300gpm. Because the dumpster is constantly filling, this is the minimum time the pump will remain on, ensuring the pump will not burn out from being repeatedly switched off and on.

After the location of the pump is established inside the IWC, a piping schematic can be determined. With this information along with the pump elevation relative to the suction port in the dumpster, the proper pump for the system can be selected. Attached in Appendix X is an equation sheet showing the solution path for the required pump head and the NPSHA for the system. Since the pump location has not been established, the pipe length, pump elevation and elbow count have been left out of the head loss and the NPSHA equations. When these parameters are known, they can be incorporated into the equation solver to get the pump requirements. The pipe length can simply be entered at the top of the equation sheet after the total pipe length variable “L”, measured in feet. The number of 90 degree elbows used in the system can be inserted in front of the “l_f_elbow” variable in the “H_L” equation with a multiplication sign. The corresponding elevations of the pump and suction port can be entered as “z_2” and “z_1”, respectively, in feet at the top of the equation sheet.

A self-priming centrifugal pump is to be used in the system. This type of pump can pump a gas, liquid, or combination of a liquid and gas. A self-priming pump creates a vacuum that can be operated with suction if water is located in the body of the pump. This will keep the pump primed in-between suction intervals so the system can perform automatically, thus allowing the pump to intake water during each suction interval without having to be manually primed each time. The Gormann-Rupp Company designs and sells a variety of quality self-priming centrifugal pumps that can be used to meet the requirements for this system.
6.0 Product Evaluation

6.1 Tank

When looking at the possible failure and the DFMEA for the tank, two possible failure modes were evaluated. First, the tank might break off of the rest of the flume section. This is the worst case scenario of failure for the tank, and must be prevented. In order to make sure this does not happen, the tank has been designed with wall thicknesses and material that is much stronger than necessary. The initial thought was that the tank’s walls would need to be at least 1/4 inches thick. However, this proved to be much thicker than necessary. The calculations have been made with a wall thickness of 1/8 inches, since this is much less expensive and easier to machine. These calculations are shown in Appendix R and give a factor of safety for the tank’s walls of 140.

The second failure evaluated was the possibility that the tank had severe leaks. These could be caused by improper design of the tank’s walls so that they do not form a good seal with each other. The effects of this failure could lead to sediment falling straight from the tank into the sump. Since the main purpose of the tank is to stop sediment from entering the sump, the design to stop this must be done very carefully. The main design choice to prevent this failure was welding the sides of the drum together, rather than bolting them together and relying on gaskets to keep the seals. The welds do not need to be replaced, like gaskets would eventually need to be, and there is no installation with welds, like there is with bolts and gaskets.

6.2 Drum/Pneumatics

The evaluation for the possible failure of the drum was very basic. Essentially, the only way the drum will fail is if it stops rotating. If this happens, the drum’s chamber will continue to fill, and eventually overflow with sediment. If this happens, the operator of the flume will have to stop the current experiment, and find out exactly what went wrong. In order to help prevent this, the pneumatic linkage mechanism has been designed to have physical stops built into it to stop it from extending or retracting further than necessary.

6.3 Slurry Transport

Design failure analysis produces only a few potential problems. For the auger and pump the only problems that could occur are either that they stop running or they clog up. If either of these occurs the problems could be a difficult fix. Any clogging will have to be cleared and that may require the entire system to be shut down and piping or the tank to be opened up. A stoppage is most likely indicative of a motor stopping. To fix this again things will have to be shut down and the problem determined. For the piping leaks, breaks and clogging are all potential issues. Once again the entire flume will have to be shut down to fix these issues should they occur. In Table 5 each of the potential problems are listed along with the actions taken to reduce these problems. A more complete look at this is included in Appendix O be as part of the DFMEA chart.

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<th>Component</th>
<th>Potential Failure</th>
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<td>Auger</td>
<td>Clogging/Motor Stoppage</td>
<td>Tank fills with sediment</td>
<td>Tank window so error can be found early.</td>
</tr>
<tr>
<td>Pump</td>
<td>Clogging/Motor Stoppage</td>
<td>Sediment clogs piping and backfills into tank</td>
<td>Check to see if anything is dumping into waste bin.</td>
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<td>Leaks</td>
<td>Minor Flooding</td>
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<tr>
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<td>Clogs</td>
<td>Sediment clogs piping and backfills into tank</td>
<td>Check to see if anything is dumping into waste bin.</td>
</tr>
</tbody>
</table>
7.0 Cost Analysis
Since the sediment trap was such a high profile project staying within a certain budget was not a major concern. Our client said he would prefer our project stay under $100,000. This included trips to Boise and Minnesota, materials, manufacturing, transportation of project to Boise, and the cost of installation. So far a little over $6,000 has been spent by the team, the majority being parts of the load cell frame drum system. The table below shows all the purchases made by the team throughout the project.

The majority of Mainstream’s project will be purchased and assembled in Boise so the team put together a parts list to be purchased in Boise. The estimated costs of parts to be purchased in Boise totaled around $25,000. The total estimated cost of the project not including transportation cost, installation cost, and manufacturing on parts to be ordered in Boise was $38,525. A more detailed budget log can be viewed in the Appendix L.

Mainstream Budget Log

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<tr>
<td>11/12/2007</td>
<td>Nathan presentation trip to Boise (transportation, food)</td>
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<td>Aaron’s supplies for drum prototype (Home Depot)</td>
<td>$22.45</td>
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<tr>
<td>1/25/2008</td>
<td>Nathan trip to Minnesota</td>
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</tr>
<tr>
<td></td>
<td>&gt;Flight</td>
<td>$386.50</td>
</tr>
<tr>
<td></td>
<td>&gt;Hotel</td>
<td>$158.40</td>
</tr>
<tr>
<td></td>
<td>&gt;Food</td>
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</tr>
<tr>
<td></td>
<td>&gt;Mileage</td>
<td>$30.15</td>
</tr>
<tr>
<td>2/27/2008</td>
<td><strong>Load Cell Sub-System</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;Load Cell/Output</td>
<td>$1,375.00</td>
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<tr>
<td></td>
<td>&gt;Shipping</td>
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<tr>
<td></td>
<td>&gt;Insurance</td>
<td>$12.25</td>
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<tr>
<td></td>
<td>&gt;A-Frame Parts</td>
<td>$598.05</td>
</tr>
<tr>
<td></td>
<td>&gt;Shipping</td>
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</tr>
<tr>
<td>3/5/2008</td>
<td><strong>Drum System</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;Drum Materials</td>
<td>$352.56</td>
</tr>
<tr>
<td></td>
<td>&gt;Frame Connection</td>
<td>$687.62</td>
</tr>
<tr>
<td></td>
<td>&gt;A-Frame Metal</td>
<td>$1,080.00</td>
</tr>
<tr>
<td>3/22/2008</td>
<td>Materials for load cell prototype</td>
<td>$11.65</td>
</tr>
<tr>
<td>3/28/2008</td>
<td>Additional load cell A-Frame parts</td>
<td>$25.03</td>
</tr>
<tr>
<td>4/11/2008</td>
<td>Overhead frame + Pneumatics</td>
<td>$148.69</td>
</tr>
<tr>
<td>4/16/2008</td>
<td>Machining of drum</td>
<td>$350.00</td>
</tr>
<tr>
<td>4/17/2008</td>
<td>Wood flume prototype</td>
<td>$149.59</td>
</tr>
<tr>
<td>4/18/2008</td>
<td>Frame parts and machining</td>
<td>$642.00</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>$6,124.18</td>
</tr>
</tbody>
</table>

8.0 Recommendations
8.1 Tank
Since the tank has yet to be manufactured, it is advised that the drawing package for the tank/flume section is reviewed and double checked for accuracy. It would be a terrible waste if the bolt pattern on the flume section being built does not match up with the bolt pattern on the flume. Extra precautions have already been taken to ensure that the bolt patterns do line up, but it never hurts to check one more time.
8.2 Drum/Pneumatics
With regards to the drum and pneumatic actuator, construction of the pneumatic and its linkage is not as reliant on the accuracy of the assembly. The system has been designed to be adjustable. This means that if the bolts, rod ends, and actuator arm don’t initially line up perfectly, they can be adjusted after assembly so that the entire mechanism works right.

8.3 Basket Strainer
The 4” 53TX Duplex Basket Strainer has a significantly large pressure drop of 3.5psi for the flow rate required. This is above the recommended pressure drop of 1-1.5psi from EATON filtration. The 3.5psi pressure drop was calculated at a flow rate of 300gpm with a basket mesh size of no. 40, which will filter out particles as small as 0.0165” in diameter. If debris as small as silt were needed to be removed from the system, a mesh size of no. 240 should be implemented, which would remove particles as small as .00246” in diameter. However, because a no. 240 mesh is a smaller mesh it will create an even larger pressure drop in the system, requiring the baskets to be cleaned more frequently due to the wider range of sediment particles captured. If the water is dense with particles, the baskets may need to be cleaned as often as every 10 minutes or less. The finer the mesh used, the more of a pressure drop associated with it, in addition to more frequent cleaning required. Tests should be performed on the settling rate of the sediment particles in the waste bin to determine the quantity and size of the debris that will be sucked into the pipeline. This will help give a better understanding of the type of strainer and or filtering apparatuses required to optimize the system.

Since the slurry will be pumped into the dumpster at a flow rate of 300gpm, it can be assumed that the water level will rise about 10” every 3.3 minutes. This is the amount of time the pump will remain turned off while the water level rises back up to the top of the float switch. Assuming this is the shortest amount of settling time possible, the majority of unwanted debris must settle out within 3.3min to avoid being pumped into the suction hose. If after performing these experiments it is found that the unwanted particles settle out within this time frame, it may be effective and affordable to use the 4” 53TX Duplex Basket Strainer. If most of the unwanted sediment particles remain suspended in the water, the following options may need to be considered.

A series of strainers and bag filters may be used to catch the sediment debris before they reach the sump. This system could be automatically controlled using pressure taps that would signal the various valves to open and close depending on the amount of sediment they contained. Though it would cost significantly more than the Duplex Basket Strainer, it would insure that there is a sufficient amount of equipment that would be required for removing all of the unwanted particles.

EATON also provides the Model 2596 Self-Cleaning Automatic Strainer that only has a 1psi pressure drop all the way down to a no. 100 mesh basket at 300gpm. Because there is no cleaning associated with this strainer, a discharge port is required for the accumulated sediment. This would entail implementing an additional transport system in order to dispose of this sediment waste. As with the other strainers, it can be purchased in Cast Iron, Bronze, Carbon Steel or Stainless Steel, with Cast Iron being the cheapest at about $10,000.

8.4 Dumpster
Multiple layers of visqueen plastic may be required to ensure the dumpster is properly relieved of any leaks. If this still does not create a leak free environment, a rubber liner can be used at a more expensive cost.

Because the slurry pipe is in a fixed position, a large sediment pile may result at one end of the waste bin. In this case, the sediment will need to be manually and evenly dispersed along the bottom of the dumpster to allow it to fill to the maximum capacity of 10 yards. It may help to disperse the sediment and water if the dumpster were raised at the slurry input end by an object such as a wooden block. The water would then flow to the opposite end making it more convenient for the rigid suction hose to remove it.
8.5 Camlock Fittings
During self-priming, the pump is required to remove all the air out of the suction side of the pipeline before pumping water. If the Camlock Fittings are not air tight when installed, it may cause the pump motor to continue attempting to remove the air, and could result in motor failure.

8.6 Load Cell System
There are several recommendations for the load cell system’s design. One area is with the winch and cable system. The winch needs to be calibrated so that the load cell and hanger can be moved with fewer rotations. Currently, it takes many rotations (30+) to move the load cell on the linear slide. If the winch were better calibrated, it would be quicker to move the load cell and hanger.

Another possible area for improvement is the bolts connecting the linear bearing to the load cell plates. The current bolts are grade 5 SAE bolts, and Grade 8 may be beneficial for extra support. In addition, all the nuts on the load cell system should be retightened with Loctite, or a similar thread locking substance, when the design is finalized.
# APPENDIX A

## SPECIFICATIONS

### Sediment Handling

<table>
<thead>
<tr>
<th>Spec Number</th>
<th>Priority</th>
<th>User Need</th>
<th>Source</th>
<th>Specs</th>
<th>Target value</th>
<th>Unit</th>
<th>Related specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>***</td>
<td>Trap Sediment</td>
<td>Dr. Budwig</td>
<td>Handle up to a certain mass flow rate (of just sediment, or sediment + water)</td>
<td>2</td>
<td>kg/s</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>***</td>
<td></td>
<td></td>
<td>Handle up to a certain size of sediment</td>
<td>1 to 70</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>***</td>
<td>Continuously Weigh Sediment</td>
<td>Dr. Budwig</td>
<td>Must weigh sediment with a certain accuracy</td>
<td>0.1</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>**</td>
<td></td>
<td></td>
<td>Maximum time in between measurements</td>
<td>5</td>
<td>seconds</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>*</td>
<td></td>
<td></td>
<td>Minimum duty cycle</td>
<td>24</td>
<td>hours</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>***</td>
<td>Hold the bed load in place</td>
<td>Dr. Budwig</td>
<td>Create a minimum and maximum bed load height in the flume</td>
<td>0 to 4.5</td>
<td>inches</td>
<td></td>
</tr>
</tbody>
</table>

### Flume/Sediment Trap Interface

<table>
<thead>
<tr>
<th>Spec Number</th>
<th>Priority</th>
<th>User Need</th>
<th>Source</th>
<th>Specs</th>
<th>Target value</th>
<th>Unit</th>
<th>Related specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>***</td>
<td>Do not alter the flow when the trap is in use</td>
<td>Dr. Budwig</td>
<td>Flume water velocity must not change by a certain amount</td>
<td>?</td>
<td>ft/s</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>***</td>
<td></td>
<td>Dr. Budwig</td>
<td>Flume water depth must not change by a certain amount</td>
<td>1</td>
<td>inch</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>***</td>
<td>Do not alter the flow when the trap is not in use</td>
<td>Dr. Budwig</td>
<td>Flume water velocity must not change by a certain amount</td>
<td>?</td>
<td>ft/s</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>***</td>
<td></td>
<td>Dr. Budwig</td>
<td>Flume water depth must not change by a certain amount</td>
<td>1</td>
<td>inch</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>***</td>
<td>Fit in the space provided</td>
<td>Dr. Budwig</td>
<td>Stay within the flume dimensions provided by Butch Fullerton to a certain accuracy</td>
<td>0.1?</td>
<td>inch</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>***</td>
<td>Do not break the flume</td>
<td>Dr. Budwig</td>
<td>Keep the added load on the flume below a certain weight</td>
<td>XX</td>
<td>lbs</td>
<td></td>
</tr>
</tbody>
</table>
## Sediment Waste

<table>
<thead>
<tr>
<th>Spec Number</th>
<th>Priority</th>
<th>User Need</th>
<th>Source</th>
<th>Specs</th>
<th>Target value</th>
<th>Unit</th>
<th>Related specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>* * *</td>
<td>Separate the water from the sediment</td>
<td>Dr. Budwig</td>
<td>Allow only silt sized sediment to remain in the water</td>
<td>&lt;silt (?)</td>
<td>inches</td>
<td></td>
</tr>
</tbody>
</table>

## Input/Output

<table>
<thead>
<tr>
<th>Spec Number</th>
<th>Priority</th>
<th>User Need</th>
<th>Source</th>
<th>Specs</th>
<th>Target value</th>
<th>Unit</th>
<th>Related specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>**</td>
<td>Visual readout</td>
<td></td>
<td>Size</td>
<td>2 x 4</td>
<td>inches</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>**</td>
<td>Able to be seen from distance</td>
<td></td>
<td></td>
<td>10</td>
<td>ft</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>* * *</td>
<td>Location</td>
<td></td>
<td>On the panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>* * *</td>
<td>Computer feed</td>
<td></td>
<td>Voltage only?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>*</td>
<td>Minimize Noise Output</td>
<td></td>
<td>Keep the noise level of all parts of the trap below a certain number</td>
<td>?</td>
<td>decibels</td>
<td></td>
</tr>
</tbody>
</table>

## Miscellaneous

<table>
<thead>
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<th>Spec Number</th>
<th>Priority</th>
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<th>Source</th>
<th>Specs</th>
<th>Target value</th>
<th>Unit</th>
<th>Related specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>* * *</td>
<td>Finish the sediment trap</td>
<td>Dr. Budwig</td>
<td>Complete the project within a certain amount of time</td>
<td>8</td>
<td>months</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>* * *</td>
<td>Stay under budget</td>
<td>Dr. Budwig</td>
<td>Do not exceed a certain cost while allowing some of the budget to go to transportation and installation</td>
<td>75,000</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>* * *</td>
<td>Build a wooden flume model</td>
<td>Dr. Budwig</td>
<td>Finish the model by a certain time</td>
<td>March 1st</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>* *</td>
<td>Keep the geometry accurate to the original within a certain accuracy</td>
<td></td>
<td></td>
<td>1</td>
<td>Inch</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX B

DRUM WEIGHT CALCULATIONS

EQUATIONS:

\[ \dot{m} = 2 \text{ [kg/s]} \]

Volume:

\[ \text{Vol} = \frac{1}{2} \cdot L \cdot \text{base} \cdot \text{height} \]
\[ L = 2 \text{ [m]} \]
\[ \text{base} = 0.508 \text{ [m]} \]
\[ \text{height} = 0.165 \text{ [m]} \]
\[ \text{thick} = \frac{0.025}{2} \cdot 1 \text{ [m]} \]

To find time:

\[ \rho = \text{rho} \left( \text{'Sand'}, 25 \right) \]

\[ \text{Vol} = \frac{\dot{m}}{\rho} \cdot \text{time} \]

To find weight:

\[ \text{Weight}_{\text{sediment}} = \text{Vol} \cdot \rho \]
\[ \text{Weight}_{\text{drum}} = 3 \cdot \text{base} \cdot \text{thick} \cdot L \cdot \rho_{\text{drum}} \]
\[ \text{Weight}_{\text{shaft}} = \pi \cdot \frac{0.051}{4} \cdot 2.25 \text{ [m]} \cdot \rho_{\text{shaft}} \]

\[ \rho_{\text{shaft}} = \text{rho} \left( \text{'Stainless AISI302'}, 25 \text{ [C]} \right) \]
\[ \rho_{\text{drum}} = \text{rho} \left( \text{'Aluminum'}, 25 \text{ [C]} \right) \]

SOLUTIONS:

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

\[ \text{base} = 0.508 \text{ [m]} \]
\[ \text{height} = 0.165 \text{ [m]} \]
\[ \text{hour} = 0.01764 \text{ [hr]} \]
\[ L = 2 \text{ [m]} \]
\[ \text{min} = 1.058 \text{ [min]} \]
\[ \dot{m} = 2 \text{ [kg/s]} \]
\[ \rho = 1515 \text{ [kg/m}^3\text{]} \]
\[ \rho_{\text{drum}} = 2702 \text{ [kg/m}^3\text{]} \]
\[ \rho_{\text{shaft}} = 8054 \text{ [kg/m}^3\text{]} \]
\[ \text{thick} = 0.0125 \text{ [m]} \]
\[ \text{time} = 63.43 \text{ [s]} \]
\[ \text{Vol} = 0.00332 \text{ [m}^3\text{]} \]
\[ \text{Weight}_{\text{drum}} = 103 \text{ [kg]} \]
\[ \text{Weight}_{\text{sediment}} = 127 \text{ [kg]} \]
\[ \text{Weight}_{\text{shaft}} = 37.02 \text{ [kg]} \]
\[ \text{Weight}_{\text{total}} = 267 \text{ [kg]} \]

No unit problems were detected.
**APPENDIX C**

**LOAD CELL CALCULATIONS**

**Load Cell Calcs: Weight as a function of water depth**

**Problem:** To size the Load cell (LC), the maximum weight of the Drum, Shaft and sediment is needed. The max weight will be seen IF the drum is fully out of water. Although this should never happen, it must be assumed that it may

From Nathan Barrett's Calculations, it was found that the weight of the Drum and the Sediment will be approximately $W = 230 \text{ kg}$, assuming the sediment density is that of sand (1515 kg/m$^3$) and the drum is made out of aluminum.

According to our estimations, the height of the apparatus (drum with shaft) is approximately 0.307 meters. The following data shows the weight a LC will read depending on the depth of water. The water depth is taken from the bottom of the bottom fin.

<table>
<thead>
<tr>
<th>Length (m)</th>
<th>0.508</th>
<th>meters</th>
<th>Width (m)</th>
<th>0.025</th>
<th>meters</th>
<th>Height (m)</th>
<th>0.165</th>
<th>meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>gamma h$_{20}$</td>
<td>9810 N/m$^3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Weight</td>
<td>267.02 kg</td>
<td></td>
<td>Shaft diam</td>
<td>0.051 m (=2 inch)</td>
<td></td>
<td>Shaft weight</td>
<td>37.020 kg</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>Displaced Volume (m$^3$)</th>
<th>Force of Buoyancy (N)</th>
<th>Total Weight (kg)</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>267.02</td>
<td>1515</td>
</tr>
<tr>
<td>0.03</td>
<td>0.000381</td>
<td>1.18</td>
<td>265.84</td>
<td>8054</td>
</tr>
<tr>
<td>0.06</td>
<td>0.000762</td>
<td>2.35</td>
<td>264.67</td>
<td>2702</td>
</tr>
<tr>
<td>0.09</td>
<td>0.001143</td>
<td>3.53</td>
<td>263.49</td>
<td>4090.33</td>
</tr>
<tr>
<td>0.12</td>
<td>0.001524</td>
<td>4.71</td>
<td>262.31</td>
<td>avg</td>
</tr>
<tr>
<td>0.15</td>
<td>0.001905</td>
<td>5.89</td>
<td>261.13</td>
<td></td>
</tr>
<tr>
<td>0.18</td>
<td>0.006882</td>
<td>21.27</td>
<td>245.75</td>
<td></td>
</tr>
<tr>
<td>0.21</td>
<td>0.012597</td>
<td>38.93</td>
<td>228.09</td>
<td></td>
</tr>
<tr>
<td>0.24</td>
<td>0.013740</td>
<td>42.46</td>
<td>224.56</td>
<td></td>
</tr>
<tr>
<td>0.27</td>
<td>0.014883</td>
<td>45.99</td>
<td>221.03</td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td>0.016026</td>
<td>49.53</td>
<td>217.49</td>
<td></td>
</tr>
<tr>
<td>0.33</td>
<td>0.017169</td>
<td>53.06</td>
<td>213.96</td>
<td></td>
</tr>
</tbody>
</table>

*at z = 0.165 m, water hits shaft*

Assumed shaft length = 2.25m

After the water reaches 0.31 meters, the drum and shaft assembly will be fully submerged.
**Sys Sketch** - the height, Z, is the water Height. The dimensions of the fins are not to scale.

**Load Cell Selection:**

Load cells are basically a strain-gauge encased in metal, used to measure weight. The weight causes the strain-gauges to elongate, and when a known voltage is passed through the gauges, the elongation changes the voltage out.

Based on our maximum weight, the Load cell that will be used is the **YB Single Point** Load Cell, manufactured by **Sentran LLC**. Two setups are in mind:

**Two load cells in series - one on each side of the shaft**

The load cell capacity needed is 200 kg (to make sure damage won’t occur if loaded without water). For this option, the following components would be needed:

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kg LC</td>
<td>2</td>
<td>$210</td>
</tr>
<tr>
<td>Summing Box</td>
<td>1</td>
<td>$225</td>
</tr>
<tr>
<td>Visual Indicator</td>
<td>1</td>
<td>$425</td>
</tr>
<tr>
<td>Cable</td>
<td>20 ft?</td>
<td>$20</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td><strong>$1,090</strong></td>
</tr>
</tbody>
</table>

**One Load Cell:**

For this design, one load cell would be used to collect the data. The geometry is currently unknown.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 kg LC</td>
<td>1</td>
<td>$210</td>
</tr>
<tr>
<td>Visual Indicator</td>
<td>1</td>
<td>$425</td>
</tr>
<tr>
<td>Cable</td>
<td>20 ft?</td>
<td>$20</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td><strong>$655</strong></td>
</tr>
</tbody>
</table>

The Accuracy will be greater than 0.5 N if the load is less than 254 kg.
APPENDIX D

FUNCTIONAL MODEL OF THE FLUME
Sediment Trap

Sub-system Function Embodiment

Sampling

Possible Failure Result of failure

Sediment piles up
System Pipe... Sediment not caught Piles up – into flume? Sediment not caught Sump
Mess outside Mess in/outside
APPENDIX E

FUTEK LOAD CELL ORDER FORM

S-BEAM LOAD CELL IN TENSION AND COMPRESSION
(PREVIOUSLY L2350/L2351)

#28 AWG, 6 Conductor PU Cable (5ft) Option

SPECIFICATIONS:
RATED OUTPUT: 2 mV/Vv nom.
SAFE OVERLOAD: 150% of R.O.
ZERO BALANCE: ±1% of R.O.
EXCITATION (VDC OR VAC): 25 MAX
BRIDGE RESISTANCE: 1000 Ω nom.
NONLINEARITY: ±0.05% of R.O.
HYSTERESIS: ±0.05% of R.O.
NONREPEatability: ±0.05% of R.O.
Creep: ±0.002% of LOAD
TEMP. SHIFT ZERO: ±0.001% of R.O./°F (±0.0014% of R.O./°C)
TEMP. SHIFT SPAN: ±0.008% of LOAD  (±0.014% of LOAD/°C)
COMPENSATED TEMP.: 60 to 180°F (16 to 72°C)
OPERATING TEMP.: -40 to 200°F (-40 to 93°C)
WEIGHT: 7.5 lb (3.4 kg) (3000 lb - 12 lb or 519 kg)
MATERIAL: ANODIZED ALUMINUM (3000 lb - 17-4PH SS)
DEFOCATION: 0.003 to 0.010 (0.08 to 0.25) mm
CONNECTOR: 4 Pin LEMO Receptacle (EGG.08B34.CL)
ACCESSORIES AND RELATED INSTRUMENTS:
CALIBRATION: 3 psig TENSION; 150k Ω SHUNT CAL. VALUE
CALIBRATION (AVAILABLE): COMPRESSION
CALIBRATION TEST EXCITATION: 10 VDC

FUTEK
ADVANCED SENSOR TECHNOLOGIES INC.

This drawing is submitted solely for the information and
exclusion of the original address, the user to be checked
and/or the original or part of any part or of the drawing
without the permission from FUTEK.

10 THOMAS
IRVINE, CA 92618 USA
1-800-235-FUTEK (38835)
INTERNET: http://www.futek.com

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APPENDIX F

FRAME WELDING PACKAGE

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>PRICE</th>
<th>QTY.</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vertical Support 4 x 2&quot; x 1&quot; x .25</td>
<td>4</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cross Brace 2 x 2&quot; x 1.5&quot; x .75&quot;</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Stability Bar 4 x 1&quot; x 1.75&quot; x 14&quot;</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Gusset 2 Sq. Ft 3/8&quot; PLATE</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Support 2 x 3/8&quot; Sq. BAR x 22&quot;</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MAINSTREAM

A-FRAME SUBSYSTEM

SIZE: A

DWG. NO.: 1

REV: 1

SCALE: 1:20

SHEET 1 OF 9
APPENDIX G
SOFTWARE SPECIFICATIONS

IPM500/IBT500 SOFTWARE (OPTIONAL)

CONFIGURATION

IMPORTANT NOTE:
Before starting IPM500/IBT500 software, you have to configure the IPM500/IBT500 display first. Please see instructions in this CONFIGURATION section.

1. Hit MENU button to scroll through options until you see SEC 1 appears on the screen.
2. Hit PEAK button once to show value. Then hit PEAK button again to switch between the digits and RESET button to change the number until the value is set to 0001.
3. Hit MENU button once to show value. Then hit PEAK button once again to switch between the digits and RESET button to change the number until the value is set.
4. SEC 3 will appear automatically after Start is pressed on the screen.

INSTALLATION

1. Step 1
Start installation of the software and run setup.exe.
2. Step 2
Enter name and organization information.
3. Step 3
Welcome screen. Click Next.
4. Step 4
License agreement. Click Yes.
5. Step 5
Select location to install software and click Next.
6. Step 6
Click Next to start installation.
7. Step 7
Automatic installation started.
8. Step 8
Software installation is completed and you can drag the shortcut to your desktop.

www.futek.com Tel: 1-800-23-FUTEK or 949-465-0800 futek@futek.com

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DOC M#24 4/15/09 REV 10/1/09

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## APPENDIX H

**LOAD CELL/FRAME DRAWING PACKAGE**

![Diagram of load cell/ frame drawing package]

**SCALE: 1:40**

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>PRICE</th>
<th>QTY.</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vertical Support</td>
<td>$31.96</td>
<td>4</td>
<td>$</td>
</tr>
<tr>
<td>2</td>
<td>Cross Rail</td>
<td>$213.07</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>U-Bolt 3060711</td>
<td>$7.88</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rod End 4749215</td>
<td>$17.39</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Plate under rail</td>
<td>–</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>Top Mount Rail 6/95135</td>
<td>$142.60</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Linear Block</td>
<td>$101.82</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Pulley 3959134</td>
<td>$6.95</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Pulley Block</td>
<td>–</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>10</td>
<td>Plate under load cell</td>
<td>–</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>11</td>
<td>U-Bolt 20535T12</td>
<td>$7.59</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Pulser LS8350LC</td>
<td>$225.00</td>
<td>1</td>
<td></td>
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<tr>
<td>13</td>
<td>Plate above LC</td>
<td>–</td>
<td>3</td>
<td>–</td>
</tr>
<tr>
<td>14</td>
<td>Stabilizer Bar</td>
<td>–</td>
<td>4</td>
<td>–</td>
</tr>
<tr>
<td>15</td>
<td>Gusset</td>
<td>–</td>
<td>4</td>
<td>–</td>
</tr>
<tr>
<td>16</td>
<td>Support</td>
<td>–</td>
<td>3</td>
<td>–</td>
</tr>
<tr>
<td>17</td>
<td>Screw Cover</td>
<td>–</td>
<td>4</td>
<td>–</td>
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</table>

### MAINSTREAM

**SUBSYSTEM**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>DWG. NO.</th>
<th>REV</th>
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<tbody>
<tr>
<td>A</td>
<td>1</td>
<td></td>
</tr>
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</table>

**SCALE: 1:20**

**SHEET 1 OF 13**
NOTE: CROSS BRACE CENTERED ON STABILITY BAR (1/16") FROM EACH SIDE
**NOTE:** 1" X 2" BAR STOCK  
BREAK ALL SHARP CORNERS

---

**MAINSTREAM**

**VERTICAL SUPPORT**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>DWG. NO.</th>
<th>REV</th>
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<tbody>
<tr>
<td>A</td>
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<td>1</td>
</tr>
</tbody>
</table>

**SCALE:** 1:15  
**WEIGHT:**

---

**UNLESS OTHERWISE SPECIFIED:**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>A36 HR STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINISH</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>DRAWN</th>
<th>M.E.</th>
<th>DATE</th>
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<tr>
<td></td>
<td></td>
<td>2/26/08</td>
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</tbody>
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<table>
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<tr>
<th>CHECKED</th>
<th>ENGR APR.</th>
<th>MFG APR.</th>
<th>Q.A.</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td></td>
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<td></td>
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</tbody>
</table>

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**DIMENSIONS ARE IN INCHES**

<table>
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<tr>
<th>TOLERANCES</th>
<th>.005</th>
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<tr>
<td>PRINCIPAL</td>
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<table>
<thead>
<tr>
<th>ANGULAR MATCH</th>
<th>1 BEND</th>
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</thead>
<tbody>
<tr>
<td>TWO PLACE DECIMAL</td>
<td></td>
</tr>
<tr>
<td>6 DECIMAL</td>
<td></td>
</tr>
</tbody>
</table>

| INTERPRET GEOMETRIC TOLERANCING PER: | |
|-------------------------------------| |

<table>
<thead>
<tr>
<th>DO NOT SCALE DRAWING</th>
</tr>
</thead>
</table>

NOTE: 2" X 1.5" BAR STOCK
BREAK ALL SHARP EDGES

SCALE: 2:5

SCALE: 1:15

DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.003

INTERPRET GEOMETRIC
TOLERANCES, PER:

MATERIAL: A36 HR STEEL
FINISH:

UNLESS OTHERWISE SPECIFIED:

NAME
DATE
DRAWN
2/18/08

Q.A.

CHECKED

ENG. APPR.

MFG. APPR.

COMMENTS:

MAINSTREAM

CROSS BRACE

SIZE
A

DWG. NO.

REV
1

SCALE: 1:5
WEIGHT:

SHEET 5 OF 13
PLATE UNDER RAIL

1" x 0.75" BAR STOCK
BREAK ALL SHARP EDGES

Scale: 1:4

Material: A36 HR STEEL
Finish: 

Do not scale drawing

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES: ±.030
PLANE CURVE
ANGULAR: Mach: ± 1 Bend: ± .050
TWO PLACE DECIMAL: ±.030
THREE PLACE DECIMAL: ±.010

INTERPRET GEOMETRIC TOLERANCING PER:

MAINSTREAM

SIZE A | DWG. NO. 1 | REV 1

Scale: 1:5 | Weight: 

Sheet 6 of 13
NOTE: 1" x 1/2" BAR STOCK
BREAK ALL SHARP CORNERS

MAINSTREAM

STABILITY BAR

UNLESS OTHERWISE SPECIFIED:

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINISH</td>
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</tr>
</tbody>
</table>

DO NOT SCALE DRAWING

SCALE: 1:3

WEIGHT:

SHEET 10 OF 13
NOTE: 3/8" PLATE
NOTE: 3/8 SQUARE STOCK
BREAK ALL SHARP CORNERS

SCALE: 1:8

MAINSTREAM

SUPPORT

UNLESS OTHERWISE SPECIFIED:

NAME

DATE

DRAKEN

MUE

3/24/08

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL ± 0.006
ANGULAR: MACHINE ± 1°
BEND ± 3°
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.001

INTERPRET GEOMETRIC TOLERANCING PER:

Q.A.

MATERIAL:

STEEL

FINISH:


DO NOT SCALE DRAWING

SIZE

DWG. NO.

REV

A


SCALE: 1:2

SHEET 12 OF 13
## APPENDIX I

**FUTEK DIGITAL DISPLAY ORDER FORM**

**FUTEK MODEL IPM500 (D500)**

*DRAWING NUMBER: F11037-B*

**FEATURES:**
- 60 Conversions per second (90 Hz NMR)
- 50 Conversions per second (50 Hz NMR)
- Scalable to 5 digits: ±99,999
- Isolated selectable excitation to power sensors
  - 5 VDC @ 50 mA, 10 VDC @ 120 mA
- Peak and valley hold and remote auto tare
- Plug-in screw terminal
- Weight: 9 Oz (0.25 Kg)

**ENVIRONMENT:**
- Operating Temperature: 32°F to 130°F (0°C to 56°C)
- Storage Temperature: -100°F to 180°F (-73°C to 82°C)
- Relative Humidity: 95% at 100°F (38°C)

**OPTIONS:**
- Isolated linearized analog outputs:
  - 0 to 10 Vdc or 4 to 20 mA
- Dual setpoint controller (Alarm)
  - w/2 Form Contact relays: 10 Amp Max
- TEDS IEEE1451.4, USB 2.0, RS232 (Combined)
  - TEDS supports templates 30, 31, 33 & Dallas DS2433.
  - RS485 not supported in TEDS version.
- RS485 (No TEDS support)
- Worldwide input power: 85 to 284 VAC & 50 to 370 VDC
- Worldwide input power: 8 to 57 VDC and 8 to 28 VAC, 500mA minimum

**ACCESSORIES:**
- FSH02450- IAC160 TEDS Female DB9 Adapter
- GOD0667- USB Cable A-B Male, 6ft (2 M)
- FSH02048- Software (Data Display & Recording, TEDS read & write)
- FSH02825- RS232 Cable for TEDS option
- GOD00360 Cable & GOD00362 RJ11/DB9 Connector For RS485 Option

### Analog Output

<table>
<thead>
<tr>
<th>Stock #</th>
<th>Analog Output</th>
<th>Alarm Output</th>
<th>TEDS/USB</th>
<th>RS232</th>
<th>Power</th>
<th>Old Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSH00010</td>
<td>AC Dc, Dc</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>AC</td>
<td>D001</td>
</tr>
<tr>
<td>FSH00011</td>
<td>DC Dc</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>DC</td>
<td>D002</td>
</tr>
<tr>
<td>FSH00087</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>AC</td>
<td>D003</td>
</tr>
<tr>
<td>FSH00090</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>DC</td>
<td>D004</td>
</tr>
<tr>
<td>FSH00091</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>DC</td>
<td>D005</td>
</tr>
<tr>
<td>FSH00092</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>AC</td>
<td>D006</td>
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<td>FSH00093</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>DC</td>
<td>D007</td>
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<td>FSH00094</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>AC</td>
<td>D008</td>
</tr>
<tr>
<td>FSH00095</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>DC</td>
<td>D009</td>
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<td>FSH00096</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>AC</td>
<td>D010</td>
</tr>
</tbody>
</table>

**J1- Power and Digital Controls**

- AC Hi (VDC 5)
- DC Lo (DC PRT)
- D011

**J2- Dual Setpoint Controller Relay Outputs (Alarm)**

- Alarm 1-4 M/C Contact
- Alarm 1-4 Common
- Alarm 1-4 Common
- Alarm 1-4 Contact
- Alarm 1-4 Common

**J3- Digital Interface**

- TEDS DATA
- TEDS GROUND
- ISOLATED GROUND
- SENS
- TX

**J4- Analog Output**

- 0 to 20 MA Output
- 0 to 10 VDC Output
- ISOLATED GROUND

**J5- Signal Input**

- Excitation
- Sense
- Signal
- Excitation
- Sense

**Default Settings**

- Input: STR
- Setup: 1200
- Filter: 11000
- Lo Gain: 00000
- Hi Gain: 20000
- DECIMAL PNT: 3

---

**FUTEK ADVANCED SENSOR TECHNOLOGY INC.**

**10 THOMAS**

**IRVINE, CA 92618 USA**

**1-800-23-FUTEK (38835)**

**INTERNET:**

http://www.futek.com

---

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APPENDIX J

FUTEK LOAD CELL QUOTATION

Table: QUOTATION

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Extension</th>
</tr>
</thead>
</table>
| 1    | STOCK NO. FSH00971  
Model: LSB350 - 1000 lb (L2531)  
Tension & Compression Load Cell  
Ver. 1 - Standard  
Material - 2024-T4 1/2-20 Thread  
4 Pin Lemo Receptacle, EGG.0B.304.CL2 | 1 | $275.00 | $275.00 |
| 2    | STOCK NO. FSH01787  
Model: ZCC940 - 20 ft (L)  
4 Pin Lemo FGG.0B.304.CL2 to Cable Assembly  
Ver. 1 - CC4 Connection  
Material - PVC 28 AWG 4 Conductors Braided Shielded | 1 | $105.00 | $105.00 |
| 3    | STOCK NO. FSH02541  
Model: IPM500 - 0.1 (D506)  
Signal Conditioned Digital Display (Load Cell Version)  
Ver. 1 - Peak/Valley and Output Symmetry Scaling TEDS (IEEE1451.4) Recognition TEDS, USB, and RS232 | 1 | $495.00 | $495.00 |
| 4    | STOCK NO. SLT00007  
NIST Traceable System Calibration w/ Load Cell & Display w/ Certificate, 5 points | 1 | $150.00 | $150.00 |
| 5    | STOCK NO. FSH02048  
IPM490/IPM800/IB1490/IB1500 RS232 Software (CD)  
Peak, Tare, Data Logging. -Requires RS232/USB Option on Display and Windows 2000, XP or Vista | 1 | $350.00 | $350.00 |

Delivery Time: In Stock

Thank you for the opportunity to Quote!

Total (est.): $1,375.00
# Appendix K

## Load Cell Cost Analysis

### A-Frame Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Quan.</th>
<th>Cost</th>
<th>Manuf/Part #</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top-Mount Rail</td>
<td>1</td>
<td>$142.60</td>
<td>McMaster-Carr/6709K33</td>
<td>$142.60</td>
</tr>
<tr>
<td>Square U-Bolt</td>
<td>1</td>
<td>$7.88</td>
<td>McMaster-Carr/3060T71</td>
<td>$7.88</td>
</tr>
<tr>
<td>Guide Block</td>
<td>1</td>
<td>$101.82</td>
<td>McMaster-Carr/6709K11</td>
<td>$101.82</td>
</tr>
<tr>
<td>Chain</td>
<td>25</td>
<td>$5.90</td>
<td>McMaster-Carr/3410T62</td>
<td>$147.50</td>
</tr>
<tr>
<td>Steel Connectors</td>
<td>2</td>
<td>$18.25</td>
<td>McMaster-Carr/3812T11</td>
<td>$36.50</td>
</tr>
<tr>
<td>Rod End</td>
<td>1</td>
<td>$17.39</td>
<td>McMaster-Carr/60685K131</td>
<td>$17.39</td>
</tr>
<tr>
<td>Mounted Pulley</td>
<td>6</td>
<td>$6.39</td>
<td>McMaster-Carr/3099T34</td>
<td>$38.34</td>
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<tr>
<td>Hand Winch</td>
<td>1</td>
<td>$66.10</td>
<td>McMaster-Carr/3205T16</td>
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<td>Wire Rope</td>
<td>1</td>
<td>$16.00</td>
<td>McMaster-Carr/3440T15</td>
<td>$16.00</td>
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<tr>
<td>U Bolts to go under LC</td>
<td>2</td>
<td>$7.59</td>
<td>McMaster-Carr/29535T12</td>
<td>$15.18</td>
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<td>Eye Bolt</td>
<td>1</td>
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<td>McMaster-Carr/3014T118</td>
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<tr>
<td>Threaded Rod</td>
<td>1</td>
<td>$2.88</td>
<td>McMaster-Carr/95412A752</td>
<td>$2.88</td>
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<tr>
<td>M4 80 mm Mach Screw</td>
<td>1</td>
<td>$5.87</td>
<td>McMaster-Carr/91290A192</td>
<td>$5.87</td>
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<td>#10-24 2.5&quot; Mach Screw</td>
<td>1</td>
<td>$4.38</td>
<td>McMaster-Carr/91253A257</td>
<td>$4.38</td>
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<tr>
<td>#10-24 3&quot; Mach Screw</td>
<td>1</td>
<td>$7.92</td>
<td>McMaster-Carr/91251A084</td>
<td>$7.92</td>
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**Total Cost of Parts**: $617.33

### Materials

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<tr>
<th>Part</th>
<th>Quantity</th>
<th>Cost</th>
<th>Dimensions/Mat'l</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Support</td>
<td>4</td>
<td>$201.00</td>
<td>1&quot; x 2&quot; x 60&quot; - 1018 HR Steel</td>
<td>$804.00</td>
</tr>
<tr>
<td>Horizontal supports</td>
<td>2</td>
<td>$419.23</td>
<td>2&quot; x 1.5&quot; x 79.25&quot; - 1018 HR Steel</td>
<td>$838.46</td>
</tr>
<tr>
<td>Mounting Plate</td>
<td>1</td>
<td>$35.28</td>
<td>1&quot; x 4&quot; x 3&quot; - 1018 HR Steel</td>
<td>Donated</td>
</tr>
<tr>
<td>Pulley Mount Blocks</td>
<td>2</td>
<td>$22.80</td>
<td>1&quot; x 4&quot; x 3&quot; - 6061-T6 AL</td>
<td>Donated</td>
</tr>
<tr>
<td>Plate under top rail</td>
<td>1</td>
<td>$31.00</td>
<td>1&quot; x 0.75&quot; x 24&quot; 1018 HR steel</td>
<td>Donated</td>
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</tbody>
</table>

**Total Cost of Materials**: $1,642.46

### Labor on A-frame

<table>
<thead>
<tr>
<th>Shop</th>
<th>Hours</th>
<th>Rate (per Hr)</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities</td>
<td></td>
<td></td>
<td>$600.00</td>
</tr>
</tbody>
</table>
### Load Cell/Output

<table>
<thead>
<tr>
<th>Part</th>
<th>Quan.</th>
<th>Cost</th>
<th>Manuf/Part #</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Cell</td>
<td>1</td>
<td>$275.00</td>
<td>Futek/LSB350</td>
<td>$275.00</td>
</tr>
<tr>
<td>Digital Display</td>
<td>1</td>
<td>$495.00</td>
<td>Futek/IPM500</td>
<td>$495.00</td>
</tr>
<tr>
<td>NIST Calibration</td>
<td>1</td>
<td>$150.00</td>
<td>Futek</td>
<td>$150.00</td>
</tr>
<tr>
<td>Software Package</td>
<td>1</td>
<td>$350.00</td>
<td>Futek/IPM500 Software</td>
<td>$350.00</td>
</tr>
<tr>
<td>Cable</td>
<td>1</td>
<td>$105.00</td>
<td>Futek/ZCC940 (20 ft)</td>
<td>$105.00</td>
</tr>
</tbody>
</table>

Total Cost of Materials $1,375.00

### TOTAL COST OF SYSTEM $4,234.79

### Pier/Plate Materials

<table>
<thead>
<tr>
<th>Part</th>
<th>Quantity</th>
<th>Cost</th>
<th>Dimensions/Matl</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier template</td>
<td>2</td>
<td>$253.50</td>
<td>0.125&quot; x 26&quot; x 75&quot;</td>
<td>$507.00</td>
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<tr>
<td>Top Plate</td>
<td>1</td>
<td>$298.16</td>
<td>0.25&quot; x 79&quot; x 18&quot;</td>
<td>$298.16</td>
</tr>
<tr>
<td>Convex rubber stopper</td>
<td>8</td>
<td>$2.99</td>
<td>McMaster-Carr/ 1273A45</td>
<td>$23.92</td>
</tr>
<tr>
<td>Bar to drum</td>
<td>2</td>
<td>$272.55</td>
<td>0.5&quot; x 5&quot; x 79&quot;</td>
<td>$545.10</td>
</tr>
</tbody>
</table>

Total Cost of Materials $1,374.18
## APPENDIX L

**PROJECT COST ANALYSIS**

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/21/2007</td>
<td>Team trip to Boise (transportation, hotel, food)</td>
<td>$421.12</td>
</tr>
<tr>
<td>11/12/2007</td>
<td>Nathan presentation trip to Boise (transportation, food)</td>
<td>$291.00</td>
</tr>
<tr>
<td>1/4/2008</td>
<td>Aaron's supplies for drum prototype (Home Depot)</td>
<td>$22.45</td>
</tr>
<tr>
<td>1/25/2008</td>
<td>Nathan trip to Minnesota</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;Flight</td>
<td>$386.50</td>
</tr>
<tr>
<td></td>
<td>&gt;Hotel</td>
<td>$158.40</td>
</tr>
<tr>
<td></td>
<td>&gt;Food</td>
<td>$60.45</td>
</tr>
<tr>
<td></td>
<td>&gt;Mileage</td>
<td>$30.15</td>
</tr>
<tr>
<td>2/27/2008</td>
<td><strong>Load Cell Sub-System</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;Load Cell/Output</td>
<td>$1,375.00</td>
</tr>
<tr>
<td></td>
<td>&gt;Shipping</td>
<td>$16.29</td>
</tr>
<tr>
<td></td>
<td>&gt;Insurance</td>
<td>$12.25</td>
</tr>
<tr>
<td></td>
<td>&gt;A-Frame Parts</td>
<td>$598.05</td>
</tr>
<tr>
<td></td>
<td>&gt;Shipping</td>
<td>$17.50</td>
</tr>
<tr>
<td>3/5/2008</td>
<td><strong>Drum System</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;Drum Materials</td>
<td>$352.56</td>
</tr>
<tr>
<td></td>
<td>&gt;Frame Connection</td>
<td>$687.62</td>
</tr>
<tr>
<td></td>
<td>&gt;A-Frame Metal</td>
<td>$1,080.00</td>
</tr>
<tr>
<td>3/22/2008</td>
<td>Materials for load cell prototype</td>
<td>$11.65</td>
</tr>
<tr>
<td>3/28/2008</td>
<td>Additional load cell A-Frame parts</td>
<td>$25.03</td>
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<tr>
<td>4/11/2008</td>
<td>Overhead frame + Pneumatics</td>
<td>$148.69</td>
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<tr>
<td>4/16/2008</td>
<td>Machining of drum</td>
<td>$350.00</td>
</tr>
<tr>
<td>4/17/2008</td>
<td>Wood flume prototype</td>
<td>$149.59</td>
</tr>
<tr>
<td>4/18/2008</td>
<td>Frame parts and machining</td>
<td>$642.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$6,124.18</strong></td>
</tr>
</tbody>
</table>
Estimated Future Cost

To be purchased in Boise from Consolidated Supply Co

PVC Schedule 40, 3" pipe per 20 ft (40ft), $1.27/ft $50.80
PVC Schedule 40, 6" pipe per 20 ft (40ft), $3.37/ft $134.80
90 degree 3" bend fittings 4 at $8.37 $33.48
90 degree 6" bend fittings 2 at $58.13 $116.26
6" to 3" coupling $23.29
6" to 4" brushing $34.16
4" to 3" brushing $6.59
T pipe 6" $93.81
Flex PVC 3" for 4' section $23.95
Flex PVC 6" for 4' section $67.95
Shipping for PVC Flex $39.15

Total pipe cost $624.24

Estimated Costs
Slurry Pump $5,000.00
Separator System
Liners $65.25
Wood block $10.00
Multi-level switch $225.00
Relay switch $35.00
2 Strainer duplex 4" $3,300.00
Pump $4,000.00

Misc.
Aluminum/lb $3.95
Steel/lb $1.35
Tank $10,511.00
Auger and Motor $1,164.00

Installation cost
manufacturing cost

Total Cost of Project $38,524.51
**APPENDIX M**  
**BOISE PARTS LIST**

**Piping**  
**Consolidated Supply Co. (located in Boise)**  
(208)322-5511

PVC-DWV (drain waste and vent)

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC Schedule 40, 3&quot; pipe per 20 ft (40ft), $1.27/ft</td>
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<td>$50.80</td>
</tr>
<tr>
<td>PVC Schedule 40, 6&quot; pipe per 20 ft (40ft), $3.37/ft</td>
<td></td>
<td>$134.80</td>
</tr>
<tr>
<td>90 degree 3&quot; bend fittings 4 at $8.37</td>
<td></td>
<td>$33.48</td>
</tr>
<tr>
<td>90 degree 6&quot; bend fittings 2 at $58.13</td>
<td></td>
<td>$116.26</td>
</tr>
<tr>
<td>6&quot; to 3&quot; coupling</td>
<td></td>
<td>$23.29</td>
</tr>
<tr>
<td>6&quot; to 4&quot; brushing</td>
<td></td>
<td>$34.16</td>
</tr>
<tr>
<td>4&quot; to 3&quot; brushing</td>
<td></td>
<td>$6.59</td>
</tr>
<tr>
<td>T pipe 6&quot;</td>
<td></td>
<td>$93.81</td>
</tr>
</tbody>
</table>

[www.flexpvc.com](http://www.flexpvc.com)  
1(800)-PVC-FLEX

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex PVC 3&quot;, 8' section</td>
<td>$44.95</td>
</tr>
<tr>
<td>Flex PVC 6&quot;, 8' section</td>
<td>$129.95</td>
</tr>
<tr>
<td>Shipping for both</td>
<td>$56.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex PVC 6&quot;, 50' section</td>
<td>$659.00</td>
</tr>
<tr>
<td>Flex PVC 3&quot;, 50' section</td>
<td>$183.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex PVC 3&quot;, 4' section</td>
<td>$23.95</td>
</tr>
<tr>
<td>Flex PVC 6&quot;, 4' section</td>
<td>$67.95</td>
</tr>
<tr>
<td>Shipping for both</td>
<td>$39.15</td>
</tr>
<tr>
<td>Part</td>
<td>Company</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------------</td>
</tr>
</tbody>
</table>
| Dumpster                    | BFI                      | 20 yard construction (8’×4’×20’)                            | $44.29 initial delivery  
|                             |                          | $3.54/day for rent                                         | $338.28 to be emptied      |
| Intake Strainer: Bridge     | ETT Fire                 | Part# 9183-100                                              | $150                       |
| FM-Series Multi-Level Float Switch | SMD Fluid Controls, Inc. | FM20 2” Diameter 316SS Float Switch “Pump Down” internal mounting | $225                       |
| Relay Switch                | SMD Fluid Controls, Inc. | Model dependant on pump requirements                        | $35                        |
| Basket Strainer             | EATON Filtration         | Model 53TX Duplex Basket Strainer 4” (cast iron)            | $3300                      |
| Visqueen Plastic Liner      | Any Hardware Store       | 20’×100’                                                    | $35                        |
| Fiberglass window Screening | Any Hardware Store       | 12” ×8” square piece                                        | $4                         |
| Camlock Fitting             | Hardware Store or mcmaster.com | 4” Threaded male and female                              | $30-50 each                |
| Reducing Coupling           | Hardware Store or mcmaster.com | 6” reduced to 4”                                        | $10                        |
| Zip Ties                    | Hardware Store           | Heavy Duty length ≥ 10”                                     | $20                        |
| Self Priming Centrifugal Pump | To Be Determined         | Required pump dependant on installation location inside IWC | $500-$1500                 |
| PVC Piping and Connections  | Consolidated Supply Co.  | 4” PVC, amount and parts depends on pump location inside IWC | ---                       |
# APPENDIX N

## DRUM DRAWING PACKAGE

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>SHEET NO.</th>
<th>PART NAME</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>DRUM WALL</td>
<td>0.25&quot; 6061-T6</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>STEEL SHAFT</td>
<td>1&quot; STOCK, 72&quot; LONG</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>BEARING</td>
<td>McMaster: 7815K56</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>AL SHAFT</td>
<td>1&quot; ID X 1.5&quot; OD X 72&quot; LG</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>DRUM CAP</td>
<td>0.125&quot; 6061-T6</td>
<td>2</td>
</tr>
</tbody>
</table>

---

**DRUM ASSEMBLY**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>DWG. NO.</th>
<th>REV</th>
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<tbody>
<tr>
<td></td>
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<td></td>
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</table>

**SCALE:** 1:15

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**FINISH**

**DO NOT SCALE DRAWING**

---

**UNLESS OTHERWISE SPECIFIED:**

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<tr>
<th>DRAWN</th>
<th>NAME</th>
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<td>02-25-08</td>
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**DIMENSIONS ARE IN INCHES**

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<th>TOLERANCES</th>
<th>TOLERANCES</th>
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<tr>
<td>MAX</td>
<td>MIN</td>
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**TOLERANCES:**

<table>
<thead>
<tr>
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<th>TOLERANCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX</td>
<td>MIN</td>
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</tbody>
</table>

**ENGAPR:**

**MFGAPR:**

**Q.A.:**

**COMMENTS:**

---

**TITLE:**

DRUM ASSEMBLY
<table>
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<th>UNLESS OTHERWISE SPECIFIED:</th>
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<th>DATE</th>
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</thead>
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<td>DIMENSIONS ARE IN INCHES</td>
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<td>TOLERANCES:</td>
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<tr>
<td>RATIONAL:</td>
<td>ENG APPR.</td>
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<tr>
<td>ANGULAR:</td>
<td>MFG APPR.</td>
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<tr>
<td>BEND:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWO PLACE DECIMAL:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>THREE PLACE DECIMAL:</td>
<td></td>
<td></td>
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<tr>
<td>INTERPRET GEOMETRIC</td>
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<tr>
<td>TOLERANCES PER:</td>
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<tr>
<td>MATERIAL:</td>
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<tr>
<td>Q.A.</td>
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<tr>
<td>COMMENTS:</td>
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<td>NEXT ASSY:</td>
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<tr>
<td>USED ON:</td>
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<tr>
<td>DO NOT SCALE DRAWING:</td>
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</tr>
</tbody>
</table>

DRUM WELD

SIZE | DWG. NO. | REV
A    |         |   

SCALE: 1:15
WEIGHT:

SHEET 7 OF 7
# Appendix O

## DFMEA

**Design Failure Mode and Effect Analysis (DFMEA)**

**Project:** Mainstream  
**Year:** 2007-2008  
**Revision Date:** March 4, 2008  
**Revision Number:** 1  
**Team Members:** Nathan Barrett, Michael Elger, Aaron Gauthier, Linsey Abo, and Cody Newbill

<table>
<thead>
<tr>
<th>ITEM AND FUNCTION</th>
<th>POTENTIAL FAILURE MODE(S)</th>
<th>POTENTIAL EFFECT(S) OF FAILURE</th>
<th>SEV</th>
<th>POTENTIAL CAUSE(S) OF FAILURE</th>
<th>OCCUR</th>
<th>CURRENT DESIGN CONTROLS</th>
<th>DETECT</th>
<th>RPN</th>
<th>RECOMMENDED ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Frame</td>
<td>Weld Failure</td>
<td>Frame falls</td>
<td>8</td>
<td>Overloading, bad welding, excessive dynamic loads</td>
<td>1</td>
<td>Welding and Bolts</td>
<td>5</td>
<td>40</td>
<td>Calculate Stresses at fillet welds at worst case</td>
</tr>
<tr>
<td></td>
<td></td>
<td>System falls</td>
<td>8</td>
<td>Overloading, excessive dynamics, fatigue</td>
<td>1</td>
<td>Safety factors</td>
<td>1</td>
<td>8</td>
<td>Make sure the system isn't overloaded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No control of linear slide</td>
<td>5</td>
<td>Overload, wear on cable</td>
<td>1</td>
<td>strong cable, good winch</td>
<td>1</td>
<td>5</td>
<td>Prototype</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load cell falls in water</td>
<td>8</td>
<td>Overload, too much torque on bolt</td>
<td>1</td>
<td>Design for worst case</td>
<td>1</td>
<td>8</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load cell fails in water</td>
<td>8</td>
<td>3/16” bolts fail, too much torsion</td>
<td>1</td>
<td>4 bolts, supports</td>
<td>1</td>
<td>8</td>
<td>Bolt failure analysis</td>
</tr>
<tr>
<td>Load Cell</td>
<td>Inaccurate readings</td>
<td>Mis-readings, inaccurate data</td>
<td>5</td>
<td>Dirty environment, overload</td>
<td>1</td>
<td>1000 lb load cell with much less actual load</td>
<td>9</td>
<td>45</td>
<td>Talk to installation and users</td>
</tr>
<tr>
<td></td>
<td>Mechanical failure</td>
<td>LC breaks, mis-readings</td>
<td>8</td>
<td>Torsion, mis-handling</td>
<td>1</td>
<td>All load is axial</td>
<td>8</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Pipes/Transport</td>
<td>Pipe Leak</td>
<td>Minor Flooding</td>
<td>5</td>
<td>Poor pipe connections</td>
<td>2</td>
<td>Proven materials and parts.</td>
<td>3</td>
<td>30</td>
<td>Solid Connections and pressure calculations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Major Flooding</td>
<td>9</td>
<td></td>
<td>1</td>
<td></td>
<td>2</td>
<td>18</td>
<td>Consulted with pipe specialist.</td>
</tr>
<tr>
<td>Funnel</td>
<td>Doesn't deliver sediment to drum</td>
<td>Weight data inaccurate</td>
<td>6</td>
<td>Drum not installed properly</td>
<td>4</td>
<td>Tank window</td>
<td>6</td>
<td>144</td>
<td>Proper training for person that installs/removes funnel</td>
</tr>
<tr>
<td>Flume Section</td>
<td>Falls off</td>
<td>Gate, tank and flume section fall into sump</td>
<td>10</td>
<td>Bolts shear, inadequate attachment</td>
<td>2</td>
<td>Accurate bolt/weld calculations</td>
<td>4</td>
<td>80</td>
<td>Inspect flume periodically</td>
</tr>
<tr>
<td></td>
<td>Severe Leaks</td>
<td>Flow profile altered</td>
<td>7</td>
<td>Improperly sealed</td>
<td>4</td>
<td>Accurate bolt/weld calculations</td>
<td>4</td>
<td>112</td>
<td>Inspect flume periodically</td>
</tr>
<tr>
<td></td>
<td>Falls off</td>
<td>Tank, auger, piping break/fall into sump</td>
<td>Sediment leaks into sump, flow profile altered</td>
<td>10</td>
<td>Bad welding/manufacturing</td>
<td>1</td>
<td>Accurate bolt/weld calculations</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------</td>
<td>------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>----</td>
<td>---------------------------</td>
<td>---</td>
<td>-------------------------------</td>
<td>---</td>
<td>----</td>
</tr>
<tr>
<td>Severe Leaks</td>
<td>7</td>
<td>Poorly designed/manufactured</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drum</td>
<td>8</td>
<td>Sediment piles back into flume and sump</td>
<td></td>
<td></td>
<td>Agitator fails Drum Jams</td>
<td>5</td>
<td>Visual through tank window</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>Drum stops</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>turning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auger</td>
<td>7</td>
<td>Tank fills with sediment</td>
<td></td>
<td></td>
<td>Large sediment particles</td>
<td>2</td>
<td>Large diameter piping</td>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td>Clogs</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td>Motor fails</td>
<td>3</td>
<td>Tank window</td>
<td>3</td>
<td>63</td>
</tr>
<tr>
<td>Auger</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stops</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slurry Pump</td>
<td>4</td>
<td>Sediment backfills into tank/flume</td>
<td></td>
<td></td>
<td>Sediment chokes pipe</td>
<td>4</td>
<td>Separator no longer filling</td>
<td>8</td>
<td>128</td>
</tr>
<tr>
<td>Clogs</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td>Motor fails</td>
<td>3</td>
<td>Separator no longer filling</td>
<td>8</td>
<td>168</td>
</tr>
<tr>
<td>Slurry Pump</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX P

TANK DRAWING PACKAGE

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART</th>
<th>QTY</th>
<th>SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BEAM</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>TUNNEL</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>FLUME SECTION WALL</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>WALL SUPPORT</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>BEAM CONNECTION PLATE</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>SIDE WALL SMALL</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>FRONT/BACK WALL LARGE</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>
NOTE: W 24 X 94 I BEAM
APPENDIX Q

HANGER WELDING DRAWING PACKAGE

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>QTY.</th>
<th>SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TOP PLATE</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>DRUM SUPPORT PLATE</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

DIMENSIONS ARE IN INCHES

THIRD ANGLE PROJECTION

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Project Name: UNIVERSITY OF IDAHO ME DEPARTMENT

PART #: QTY:

Score: 1:20 SHEET 1 OF 6
2X Ø3/8"-16 UNC-2A X 1.5"

NOTE: THREADED BOTH ENDS

3/8" ALUMINUM BAR STOCK

UNLESS OTHERWISE SPECIFIED: NAME DATE

| DIMENSIONS ARE IN INCHES TO LARGEST DECIMAL | DRAWN |
| TOLERANCES: | CHECKED |
| FINISH: | Q.A. |
| MATERIAL: | COMMENTS |

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APPLICATION DO NOT SCALE DRAWING

SCALE: 1:2 WEIGHT: SHEET 6 OF 6

ACTUATOR ARM

NEXT ASSEMBLY USED ON FINISH

SIZE A DWG. NO. REV
APPENDIX R
TANK FAILURE CALCULATIONS

Geometry

\[
\begin{align*}
L_{\text{long}} &= 60 \, \text{[in]} \cdot 0.0254 \, \text{[m/in]} \\
L_{\text{short}} &= 30 \, \text{[in]} \cdot 0.0254 \, \text{[m/in]} \\
t &= 0.125 \, \text{[in]} \cdot 0.0254 \, \text{[m/in]}
\end{align*}
\]

\[
\begin{align*}
\text{Vol}_{\text{wet,sediment}} &= 60 \cdot 30 \cdot 50 \cdot 1 \, \text{[in]}^3 \cdot 0.0254^3 \cdot 1 \, \text{[m}^3\text{/in}^3]\ \\
\text{Vol}_{\text{steel}} &= L_{\text{long}} \cdot 50 \, \text{[m]} \cdot 2 \cdot t + L_{\text{short}} \cdot 30 \, \text{[m]} \cdot t \cdot 2
\end{align*}
\]

Material Constants

\[
\begin{align*}
\rho_{\text{wet,sediment}} &= 2000 \, \text{[kg/m}^3]\ \\
\rho_{\text{steel}} &= 8 \, \text{[g/cm}^3]\cdot 0.001 \, \text{[kg/g]} \cdot 100^3 \cdot 1 \, \text{[cm}^3\text{/m}^3]\ \\
\text{Sy}_{1045,Q,T,600F} &= 1.52 \times 10^9 \, \text{[Pa]} \\
\text{Sy}_{1050,Q,T,205C} &= 1.12 \times 10^9 \, \text{[Pa]} \\
\text{Sy}_{1050,\text{normalized}} &= 7.48 \times 10^8 \, \text{[Pa]}
\end{align*}
\]

Masses

\[
\begin{align*}
\text{mass}_{\text{wet,sediment}} &= \text{Vol}_{\text{wet,sediment}} \cdot \rho_{\text{wet,sediment}} \\
\text{mass}_{\text{steel}} &= \text{Vol}_{\text{steel}} \cdot \rho_{\text{steel}}
\end{align*}
\]

Force and Stress

\[
\begin{align*}
P &= \text{mass}_{\text{wet,sediment}} \cdot 9.81 \, \text{[m/s}^2] + \text{Vol}_{\text{steel}} \cdot 76500 \, \text{[N/m}^3]\ \\
A &= 2 \cdot L_{\text{long}} \cdot t + 2 \cdot L_{\text{short}} \cdot t \\
\sigma &= \frac{P}{A}
\end{align*}
\]
\[ \text{Sy}_{1045,Q,T,600F} = n_{1045} \cdot \frac{P}{A} \]
\[ \text{Sy}_{1050,Q,T,205C} = n_{1050,Q,T} \cdot \frac{P}{A} \]
\[ \text{Sy}_{1050,\text{normalized}} = n_{1050,\text{norm}} \cdot \frac{P}{A} \]

**Solutions**

\[
\begin{align*}
L_{\text{short}} &= 0.762 \ [\text{m}] \\
n_{1050,\text{norm}} &= 140.9 \\
p_{\text{wet,sediment}} &= 2000 \ [\text{kg/m}^3] \\
\text{Sy}_{1050,Q,T,205C} &= 1.120 \times 10^9 \ [\text{Pa}] \\
\text{mass}_{\text{steel}} &= 5032 \ [\text{kg}] \\
n_{1050,Q,T} &= 211 \\
s &= 5.308 \times 10^6 \ [\text{Pa}] \\
t &= 0.003175 \ [\text{m}] \\
\end{align*}
\]

**Unit Settings:** \([\text{kJ}]/[\text{C}]/[\text{kPa}]/[\text{kg}]/[\text{degrees}]\)

\[
\begin{align*}
A &= 0.01452 \ [\text{m}^2] \\
\text{mass}_{\text{wet,sediment}} &= 2950 \ [\text{kg}] \\
P &= 77057 \ [\text{N}] \\
\text{Sy}_{1045,Q,T,600F} &= 1.520 \times 10^9 \ [\text{Pa}] \\
\text{Vol}_{\text{steel}} &= 0.629 \ [\text{m}^3] \\
L_{\text{long}} &= 1.524 \ [\text{m}] \\
n_{1045} &= 286.3 \\
p_{\text{steel}} &= 8000 \ [\text{kg/m}^3] \\
\text{Sy}_{1050,\text{normalized}} &= 7.480 \times 10^8 \ [\text{Pa}] \\
\text{Vol}_{\text{wet,sediment}} &= 1.475 \ [\text{m}^3]
\end{align*}
\]

No unit problems were detected.
**APPENDIX S**

**TORQUE ON DRUM CALCULATIONS**

**Torque on the Drum**

**Moment of inertia:**

\[
I_z = m \cdot \left( r \cdot 0.0254 \text{ [m/in]} \right)^2
\]

\[
m = \rho_{\text{sed}} \cdot \text{Vol}
\]

\[
\text{Vol} = \pi \cdot \left( r \cdot 0.0254 \text{ [m/in]} \right)^2 \cdot L \cdot 0.0254 \text{ [m/in]}
\]

\[
r = 9 \text{ [in]}
\]

\[
L = 48 \text{ [in]}
\]

\[
\rho_{\text{sed}} = 1800 \text{ [kg/m}^3]\]

**Torque provided by 1.5” bore cylinder:**

\[
\text{Lin}_{\text{radius}} = 6 \text{ [in]}
\]

\[
\theta = 10 \text{ [deg]}
\]

\[
\sin (\theta) = \frac{\text{moment}_{\text{arm}}}{\text{Lin}_{\text{radius}}}
\]

\[
F = 162 \text{ [lbf]}
\]

\[
T_{\text{available}} = F \cdot \text{moment}_{\text{arm}}
\]

**Angular acceleration of drum at full force:**

\[
\alpha = \frac{T_{\text{available}} \cdot 0.0254 \text{ [m/in]} \cdot 4.44 \text{ [N/lbf]}}{I_z}
\]
Solutions:

Unit Settings: [F]/[psia]/[lbf]/[lbrm]/[degrees]

\( \alpha = 2.022 \text{ [rad/s}^2] \)
\( F = 162 \text{ [lbf]} \)
\( l_2 = 9.414 \text{ [kg-m}^2] \)
\( L = 48 \text{ [in]} \)
\( \text{Link radius} = 6 \text{ [in]} \)
\( m = 360.3 \text{ [kg]} \)
\( \text{moment arm} = 1.042 \text{ [in]} \)
\( r = 9 \text{ [in]} \)
\( \rho_{\text{sed}} = 1800 \text{ [kg/m}^3] \)
\( \theta = 10 \text{ [deg]} \)
\( T_{\text{available}} = 168.8 \text{ [in-lbf]} \)
\( \text{Vol} = 0.2002 \text{ [m}^3] \)

No unit problems were detected.

Calculation time = .0 sec

Drum Hanger Failure

\( g = 9.81 \text{ [m/s}^2] \)

Drum Dimensions/Properties

\( r = 9 \text{ [in]} \)
\( L = 48 \text{ [in]} \)
\( \rho_{\text{sed}} = 1800 \text{ [kg/m}^3] \)
\( t = 0.25 \text{ [in]} \)
\( w = 3 \text{ [in]} \)
\( \text{hole}_d = 0.75 \text{ [in]} \)

Drum Weight

\( \text{Vol} = \pi \cdot (r \cdot 0.0254 \text{ [m/in]} )^2 \cdot L \cdot 0.0254 \text{ [m/in]} \)
\( m = \rho_{\text{sed}} \cdot \text{Vol} \)
\( \text{Drum weight,full} = m \cdot g \)
\( \text{Drum weight,empty} = 100 \text{ [lbf]} \cdot 4.448 \text{ [N/lbf]} \)

Stresses

\( A_{\text{hole}} = t \cdot (w - \text{hole}_d) \)
\[ \sigma_{\text{max}} = \frac{\text{Drum weight, full}}{A_{\text{hole}} \cdot 0.0254^2 \cdot 1} \text{ [m}^2/\text{in}^2\text{]} \]

\[ \sigma_{\text{min}} = \frac{\text{Drum weight, empty}}{A_{\text{hole}} \cdot 0.0254^2 \cdot 1} \text{ [m}^2/\text{in}^2\text{]} \]

\[ \text{Sy} = 150 \text{ [MPa]} \]
\[ \text{Su} = 324 \text{ [MPa]} \]

\[ n_{\text{yield}} \cdot \sigma_{\text{max}} = \text{Sy} \cdot 1000000 \text{ [Pa/MPa]} \]
\[ n_{\text{fracture}} \cdot \sigma_{\text{max}} = \text{Su} \cdot 1000000 \text{ [Pa/MPa]} \]

**Solution**

**Unit Settings:** [kJ]/[C]/[kPa]/[kg]/[degrees]

\[ A_{\text{hole}} = 0.5525 \text{ [in}^2\text{]} \]
\[ g = 9.81 \text{ [m/s}^2\text{]} \]
\[ m = 360.3 \text{ [kg]} \]
\[ r = 9 \text{ [in]} \]
\[ \sigma_{\text{min}} = 1.226 \times 10^6 \text{ [Pa]} \]
\[ t = 0.25 \text{ [in]} \]
\[ \text{Drum weight, empty} = 444.8 \text{ [N]} \]
\[ \text{Drum weight, full} = 3534 \text{ [N]} \]
\[ \text{hole_d} = 0.75 \text{ [in]} \]
\[ \text{r\_fracture} = 33.27 \]
\[ \text{L} = 48 \text{ [in]} \]
\[ \rho_{\text{sed}} = 1800 \text{ [kg/m}^3\text{]} \]
\[ \text{Su} = 324 \text{ [MPa]} \]
\[ \text{Vol} = 0.2002 \text{ [m}^3\text{]} \]
\[ n_{\text{yield}} = 15.4 \]
\[ \sigma_{\text{max}} = 9.739 \times 10^6 \text{ [Pa]} \]
\[ \text{Sy} = 150 \text{ [MPa]} \]
\[ w = 3 \text{ [in]} \]

No unit problems were detected.

Calculation time = .0 sec
APPENDIX T

CAMLOCK

Plastic Cam-and-Groove Hose Couplings

For information about pipe size, see pages 2-3.

How to Order Cam-and-Groove Hose Couplings

1. Determine the coupling size. Coupling size is an industry designation, not the actual measured size. For sockets and cap x sockets, the coupling size is determined by measuring the open end (X) of the socket. For plugs and plug x caps, the coupling size is determined by measuring the plug end that fits into the socket (Y). Both the coupling size and actual socket and plug sizes are listed in each presentation.

2. Determine if you want the plug and socket to have a threaded end or a barbed end. A threaded end can be male or female to match your hose end fitting or tool. A barbed end inserts directly into a hose.

3. For a threaded end, determine the pipe size. Pipe size is also an industry designation, not the actual measured size. To determine pipe size, first use a ruler to measure the inside diameter (ID) or outside diameter (OD), as shown above. Then, round up the measurement to the closest ID or OD listed in the chart and select the corresponding pipe size. For example, if the ID (female) or OD (male) measures 1\(\frac{1}{8}\)", the next highest ID or OD in the chart is 1\(\frac{1}{4}\)", and the corresponding pipe size is 1\(\frac{1}{2}\)".

<table>
<thead>
<tr>
<th>Threaded ID (for female) or OD (for male)</th>
<th>1/8&quot;</th>
<th>1/4&quot;</th>
<th>1/2&quot;</th>
<th>5/8&quot;</th>
<th>3/4&quot;</th>
<th>1&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Size (NPT)</td>
<td>1/4&quot;</td>
<td>3/8&quot;</td>
<td>1/2&quot;</td>
<td>5/8&quot;</td>
<td>3/4&quot;</td>
<td>1&quot;</td>
</tr>
</tbody>
</table>

Plastic Cam-and-Groove Hose Couplings

- Maximum Pressure: See table below
- Temperature Range: See table below
- For use, see table below. Not recommended for compressed air or gas.

Plastic cam-and-groove couplings are lighter in weight and resistant to more chemicals than the metal versions. They're ideal when you want to quickly connect and disconnect medium- to large-diameter hose lines.

Cam-and-groove couplings consist of two pieces: a socket (also called a coupler) and a plug (also called an adapter). To be used together, the socket and plug must have the same coupling size. To connect, insert the plug into the socket and press the levers down. The levers fit snugly into the groove on the plug's body and force the plug down against the gasket to form a tight seal. To disconnect, lift both of the levers up and pull out the plug.

All couplings are made to MIL-C-27487 specifications. All sockets have Type 304 stainless steel levers and zinc-plated steel pull rings unless noted, except the nonlocking polypropylene sockets, which have Type 304 stainless steel pull rings. The polypropylene plugs have an eyelet for attaching a chain. For replacement gaskets, see page 250.

WARNING: Neither the socket nor the plug has a valve, so it is important to relieve all pressure on the lines before disconnecting the couplings. Locking- lever sockets lock the coupling together when the levers are closed to prevent accidental disconnection. Cap x sockets (also known as dust caps) and plug x caps (also known as dust plugs) block the open end of a coupling to keep contamination out and prevent damage to the internal parts of the coupling.

Also Available: Items marked with a ▲ are also available with BSPT (British Standard Pipe Tapered) threads. Please ask for 553011 and specify size and type of socket or plug.

<table>
<thead>
<tr>
<th>Material</th>
<th>Features/Applications</th>
<th>Color</th>
<th>Gasket Mat'l</th>
<th>Max. Pressure @ 72° F</th>
<th>Temp. Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypropylene</td>
<td>An economical choice. Glass-fiber reinforced for strength. Very good abrasion and corrosion resistance. Use with water and coolants.</td>
<td>Black</td>
<td>EPDM</td>
<td>1/2&quot; - 2&quot;, 125 psi</td>
<td>-30° to +150° F</td>
</tr>
<tr>
<td>FDA/NSF Polypropylene</td>
<td>FDA (food and beverage), NSF-51 (food), and NSF-61 (drinking water) compliant. Fair abrasion and corrosion resistance. Very good corrosion resistance. Good chemical resistance.</td>
<td>Opaque White</td>
<td>FDA-Compliant Neoprene</td>
<td>1/2&quot; - 1&quot;, 125 psi; 1 1/2&quot;, 100 psi; 3&quot;, 50 psi</td>
<td>10° to 160° F</td>
</tr>
<tr>
<td>Nylon</td>
<td>Glass-fiber reinforced for strength. Very good abrasion, corrosion, and chemical resistance. Use with water, coolants, gasoline, and varnish.</td>
<td>Yellow</td>
<td>EPDM</td>
<td>1/2&quot; - 1&quot;, 175 psi; 1 1/2&quot;, 150 psi; 3&quot;, 100 psi; 4&quot;, 50 psi</td>
<td>-30° to +158° F</td>
</tr>
<tr>
<td>PVDF (Kynar)</td>
<td>FDA (food and beverage), NSF-51 (food), and NSF-61 (drinking water) compliant. Excellent abrasion, corrosion, and chemical resistance. Use with gasoline, hydraulic oil, sodium, linseed oil, and lactic acid.</td>
<td>Translucent White</td>
<td>EPDM</td>
<td>1/2&quot; - 1&quot;, 125 psi; 1 1/2&quot;, 100 psi; 3&quot;, 75 psi</td>
<td>-20° to +158° F</td>
</tr>
</tbody>
</table>

Male Pipe x Socket with Type 304 Stainless Steel Levers (B Coupler)
APPENDIX U

FLOAT SWITCHES

FM - Series Multi-Level Float Switches
Dependable and rugged 316 Stainless Steel float level switches for replacement or custom applications.

**FM20-xxxx 2” Diameter 316SS Float Switch**
These larger, more buoyant floats are perfect for years of corrosive resistant service.
Configurable for 1 to 5 levels, these switches may be used to control pumps, alarms or indicate general fluid levels.

**FM22-xxxx 1 ½” Diameter Buna Float and SS Stem**
These highly buoyant floats are ideal for heavy equipment, generators and fluid recovery involving lubricating oils, fuels and wastewater. Easily configured for oil water interface detection.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Switch Type</th>
<th>Maximum Switching Current</th>
<th>Maximum Switching Voltage</th>
<th>Maximum Temperature</th>
<th>Maximum Pressure</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM20-xxxx</td>
<td>50 watt</td>
<td>.5 Amps</td>
<td>250 VDC</td>
<td>150 C</td>
<td>250 psig</td>
<td>.60</td>
</tr>
<tr>
<td>FM22-xxxx</td>
<td>50 watt</td>
<td>.5 Amps</td>
<td>250 VDC</td>
<td>120 C</td>
<td>150 psig</td>
<td>.50</td>
</tr>
</tbody>
</table>

**Standard Features:**
- 50 Watt Resistive SPST Switches
- 2.5” min. required between levels
- Up to 5 levels, 10’ long

**Other Available Switches:** (UL rated for resistive loads)
- 100 Watt, Full Size SPST, Switch 3Amps (3 levels)
- 100 Watt, Full Size SPDT, Switch 3Amps (3 levels)

---

**FM10-xxxx 1" Diameter, SS Multi Level Float Switch**
This durable design is ideal for corrosion resistant applications in restrictive spaces

**FM11-xxxx 1" Diameter PP Float with SS Stem**
The Polypropylene float makes this ideal for general use and potable water applications.

**FM12-xxxx 1" Diameter Buna Float with SS Stem**
This miniature multi-level is ideal for petroleum products, hydraulic oils and wastewaters.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Switch Type</th>
<th>Maximum Switching Current</th>
<th>Maximum Switching Voltage</th>
<th>Maximum Temperature</th>
<th>Maximum Pressure</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM10-xxxx</td>
<td>50 watt</td>
<td>.5 Amps</td>
<td>250 VDC</td>
<td>150 C</td>
<td>250 psig</td>
<td>.60</td>
</tr>
<tr>
<td>FM11-xxxx</td>
<td>50 watt</td>
<td>.5 Amps</td>
<td>250 VDC</td>
<td>105 C</td>
<td>100 psig</td>
<td>.70</td>
</tr>
<tr>
<td>FM12-xxxx</td>
<td>50 watt</td>
<td>.5 Amps</td>
<td>250 VDC</td>
<td>120 C</td>
<td>150 psig</td>
<td>.50</td>
</tr>
</tbody>
</table>

**Standard Features:**
- 50 Watt Resistive SPST Switches
- 1.5” min. required between levels
- Up to 4 levels, 6’ long

**Notes:**
- Standard fittings, flanges or custom mounting configurations available. Use an adjustable compression fitting to provide more flexibility.
- Temperature devices can be incorporated with your float switch to reduce tank intrusion and assembly costs. See Combination sensors.
- Other switch types and materials available. Contact our technical sales department or submit a custom application.

Please fill in configuration sheet and application specifications and return for quote or order.

### Select Part

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FM20</td>
<td>2” 316 Stainless Steel</td>
<td>FM22</td>
</tr>
<tr>
<td></td>
<td>(Requires 2.1” hole for external mount)</td>
<td></td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FM10</td>
<td>1” 316 Stainless Steel</td>
<td>FM11</td>
</tr>
<tr>
<td>FM12</td>
<td>1” Buna-N / SS</td>
<td></td>
</tr>
</tbody>
</table>

### Mounting Type

- [ ] External
- [ ] Internal

### Standard Fittings

- Pipe Plugs
  - [ ] 1/4”
  - [ ] ½”
- Bulkhead
  - [ ] ½”-13
  - [ ] ¾”-10
- 150# Flange
  - [ ] 1”
  - [ ] 3”

- Adjustable compression fitting
- [ ] Adjustability + 

**Other:**

### Float Stops

- [ ] 300 Series SS Grip Rings
- [ ] 316SS Collars with Set Screw

**Wire Type**

- [ ] 22 Awg. Teflon (Standard)

**Lead Length**

- [ ] 24” (Standard)

### Wiring Configuration

- [ ] [ ]
- [ ] [ ]

**NOTE:** Switch Points measured from bottom of mounting surface to switch actuation at float center. Please check Normally Closed (NC), Normally Open (NO) or Single Pole Double Through (SPDT). (FM20- 5 levels Max, FM10- 4 Levels Max.)
Pump Level Control

Controlling your fluid level with a pump or valve can easily be achieved by combining your SMD Fluid Controls product with a Double Pole Double Throw (DPDT) relay. By using two single point float level switches or a multi-level float switch, we can help you configure your tank system to automatically pump-up or pump-down to provide a more complete solution. This method allows you to automatically control a pump or valve to fill or drain as needed. Let us assist you by providing you with accessories to complete your application. Contact SMD to configure your application or see these figures below to design your own automatic level control using SMD fluid control products.
Intake Strainers: Bridge

Part # 9183-100 (6” only)

Design Usage:

The original "Bridge Strainer".

- Designed for vertical installation into shallow water from a bridge or pier. Strainer has a solid top and bottom with inlet around the 2” outer circumference. The strainer is diamond shaped to deflect debris and prevent silt buildup which would obstruct intake of water. The strainer has external eyelets on each side providing an anchor point around a post or pier pilling.

- The Bridge Strainer is designed to be placed with the bottom plate 4”-6” above the stream bed if needed. It is preferable for this location to be in a flat area of the stream (Not in a depression). The sharp end of the strainer should be pointed downstream and the entire strainer should be located on the downstream side of the pier pilling, if at all possible, for added protection. See diagram for installation techniques.

Pull Down & Flow Rates:

- 100% pull down to the top plate at lower flows. Flows of 1,250 - 1,500 gpm may require 6” - 8” of water above the top plate. Generally the swifter the stream flow the lower the water can be above the strainer plate and still maintain high flow rates.

Material:

- Sheet Aluminum formed for maximum flow and strength.

- Aluminum Wire mesh provides maximum intake.

- SST Screws and Nuts

- 6" Schedule 80 PVC Male coupling designed to glue to 6" Schedule 40 or Schedule 80 PVC pipe. Adapters to SDR 30 also available upon request.
Dimensions:

- Special design is diamond shaped with anchor eyelets.
- Width at widest point = 12 inches
- Length at longest point = 12 inches
- Thickness at intake = 2 inches

Installation Suggestions:

- If needed consult your local Soil Conservation Department for stream flow data and assistance with figuring drought conditions. In many locations the (RC&D) Resource Conservation and Development group can also be called upon for assistance.
- Before installation severe drought conditions at that specific site should be considered for both location in the stream bed and depth above the bottom. In cases of extreme drought and stream flow, it may be advantageous to build a shallow 1 ft. dam to create a deeper area in which to locate the strainer. In some situations local laws may need to be researched prior to any construction. It is recommended any retainer wall be placed downstream far enough to prevent silt build up around your strainer.
- If possible choose a stream bed location where the bottom is settled. (No Silt)
- If stream flows warrant, attach the strainer on the down side of the pier pilling for added protection from large debris (such as tree trunks and limbs) floating downstream during flooding conditions. The pipe should be attached along its vertical path for security.
- The strainer is designed so the pipe will glue vertically to the top of the strainer. Final assembly will resemble a shoe or foot. As the vertical pipe terminates at the head it may be advantageous to use a 45 degree head assembly. Make sure, if assembled on a bridge, it does not protrude inside of the railing causing a hazard to traffic. A check with DOT regulations may also be necessary before installation.
The completed installation should assure that the center line of the strainer is in line with the flow of the stream.

As a rule of thumb, the bottom plate of the strainer should be above the stream bed by 4 - 6 inches. If you have sufficient stream depth (say 2 ft.) you may wish to increase the clearance slightly.

If the piping terminates on the stream bank, upon completion of the installation reshape and properly re-seed the bank at the point of entrance to prevent soil erosion. If needed consult your local Soil Conservation Department for assistance in this project.

The strainer assembly terminates in what is commonly referred to as a Dry Hydrant head or suction point. There are a variety of ways in which these can be installed. Most common is the above ground head, however a flush mount installation is available for ground installation and works well in many situations. Specific instructions under "Dry Hydrant Installations" can also be found on this web site for your design choice.
APPENDIX W
REDUCING COUPLING

Plastic Pipe Fittings and Pipe
3 products match your selections

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APPENDIX X

SEPARATOR EQUATIONS

V_dot=300[gpm]
D=4[in]
L=0[ft]
z_2=0 [ft]
z_1=0 [ft]
g=32.174[ft/s^2]

V_dot*convert(gpm,ft^3/s)=A*V
A=pi*(D*convert(in,ft))^2/4

required pump head
H_p=(z_2-z_1)+H_L

elevation change head loss from pump to suction port (z_2-z_1)
where z_1=height of suction port and z_2=height of pump

head loss in system (H_L)
H_L=l_f_pipe+l_f_elbow+l_f_entrance+l_f_exit+l_f_bridge_strainer+l_f_basket_strainer+l_fReducer+l_f_cams

Head loss created from system piping (l_f_pipe)

l_f_pipe=pi(L/(D*convert(in,ft)))*(V*2/(2*g))

1/sqrt(f)=2*log10(epsilon*convert(in,ft)/(D*convert(in,ft)))/3.7+2.51/(Re_D*sqrt(f))
epsilon=.000059[in]
Re_D=rho*V*D*convert(in,ft)/mu
rho=Density(2,845 [lb/m^3],x=0)
mu=Viscosity(Water,T=60 [F],x=0)*convert(lbm*ft/s,lbm/ft/s)

Head loss created from system elbows (l_f_elbow)

l_f_elbow=K_elbow*V^2/(2*g)
K_elbow=30*f_t
f_t=.017

Other system head losses @ 300gpm

l_f_bridge_strainer=0.462131[ft]
l_f_basket_strainer=8.08729[ft]
l_f_reducer=K_reducer*V^2/(2*g)
K_reducer=0.881
l_f_cams=l_f_entrance+l_f_exit
l_f_entrance=K_entrance*V^2/(2*g)
K_entrance=.78
\[ I_f \text{ exit} = K_{\text{exit}}V^2/(2g) \]
\[ K_{\text{exit}} = 1 \]

"NPSHA>NPSHR or cavitation occurs"

\[ \text{NPSHA} = P_{s}/\gamma_s + V_s^2/(2g) - P_{\text{sigma}}/\gamma_s \]

"\( P_{\text{sigma}} = \text{vapor pressure} \)"

"\( P_s = \text{suction pressure} \)"

\[ P_{\text{sigma}} = P_{\text{sat}}(\text{Water}, T=60 \text{[F]}) \text{convert(psia,psf)} \]

\[ \gamma_s = \rho_s g/\gamma_c \]
\[ \gamma_c = 32.2 [(\text{lbm} \cdot \text{ft})/(\text{lb} \cdot \text{ft}^2)] \]

\[ V_s = V \]

"Energy Equation"

"the subscript 1 refers to the suction inlet in the waste bin, subscript 2 refers to the suction point just before entering the pump"

\[ P_{\text{1}}/\gamma_s + (z_{\text{1}} - z_{\text{2}}) + H_L = P_{\text{2}}/\gamma_s \]

\[ P_{\text{2}} = P_s \]

\[ P_{\text{1}} = 2116 \text{ [psf]} \]

**system input variables**

\[ \dot{V} = 300 \text{ [gpm]} \]

\[ D = 4 \text{ [in]} \]

\[ L = 0 \text{ [ft]} \]

\[ z_2 = 0 \text{ [ft]} \]

\[ z_1 = 0 \text{ [ft]} \]

\[ g = 32.174 \text{ [ft/s^2]} \]

\[ \dot{V} \cdot 0.002228009 \cdot \frac{\text{ft}^3 \text{psm}}{\text{gpm}} = A \cdot V \]

\[ A = \pi \cdot \left[ \frac{D}{4} \cdot \frac{0.0833333333 \cdot \text{ft}}{\text{in}} \right]^2 \]

**required pump head**

\[ H_p = z_2 - z_1 + H_L \]

**elevation change head loss from pump to suction port (z_2-z_1)**
where \( z_1 \) = height of suction port and \( z_2 \) = height of pump

head loss in system (\( H_p \))

\[
H_p = |l_{pipe} + l_{elbow} + l_{entrance} + l_{taklet} + l_{bridgestrainer} + l_{basketstrainer} + l_{reducer} + l_{cans}|
\]

Head loss created from system piping (\( l_{pipe} \))

\[
l_{pipe} = \frac{L}{D \cdot \frac{0.08333333}{fr} \cdot \frac{V^2}{g}}
\]

\[
\frac{1}{\sqrt{f}} = -2 \cdot \log \left( \frac{s}{D \cdot \frac{0.08333333}{fr}} \cdot \frac{3.7}{Re_p \cdot \sqrt{f}} \right) + \frac{2.51}{Re_p \cdot \sqrt{f}}
\]

\( s = 0.000059 \) [in]

\( Re_p = \rho \cdot V \cdot D \cdot \frac{0.08333333}{fr} \cdot \frac{V^2}{\mu} \)

\( \rho = \rho ["Water", T = 60 \text{ [F]}, x = 0] \)

\( \mu = \mu ["Water", T = 60 \text{ [F]}, x = 0] \cdot 0.000277778 \cdot \frac{\text{lbm/ft-s}}{\text{lbm/ft-h}} \)

Head loss created from system elbows (\( l_{elbow} \))

\[
l_{elbow} = K_{elbow} \cdot \frac{V^2}{2 \cdot g}
\]

\( K_{elbow} = 30 \cdot f_1 \)

\( f_1 = 0.017 \)

Other system head losses @ 300gpm

\[
l_{bridgestrainer} = 0.462131 \text{ [ft]}
\]

\[
l_{basketstrainer} = 8.08729 \text{ [ft]}
\]

\[
l_{reducer} = K_{reducer} \cdot \frac{V^2}{2 \cdot g}
\]

\( K_{reducer} = 0.851 \)

\[
l_{cans} = l_{entrance} + l_{taklet}
\]
\[ I_{\text{entrance}} = K_{\text{entrance}} \cdot \frac{V^2}{2 \cdot g} \]

\[ K_{\text{entrance}} = 0.78 \]

\[ I_{\text{exit}} = K_{\text{exit}} \cdot \frac{V^2}{2 \cdot g} \]

\[ K_{\text{exit}} = 1 \]

NPSHA > NPSHR or cavitation occurs

\[ \text{NPSHA} = \frac{P_e}{\gamma} + \frac{V_s^2}{2 \cdot g} - \frac{P_s}{\gamma} \]

\[ P_{\text{vapor}} = \text{vapor pressure} \]

\[ P_s = \text{suction pressure} \]

\[ P_e = P_{\text{sat}} \cdot \left( \frac{\text{Water}, \ T = 60 \ [\text{F}]}{\gamma} \right) \cdot \left( 144 \cdot \frac{\text{psf}}{\text{psi}} \right) \]

\[ \gamma = \rho \cdot \frac{g}{g_c} \]

\[ g_c = 32.2 \ \left( \frac{\text{lbm} \cdot \text{ft}}{\text{lbm} \cdot \text{s}^2} \right) \]

\[ V_s = V \]

Energy Equation

the subscript 1 refers to the suction inlet in the waste bin, 
subscript 2 refers to the suction point just before entering the pump

\[ \frac{P_1}{\gamma} + z_1 - z_2 - H_L = \frac{P_2}{\gamma} \]

\[ P_2 = P_s \]

\[ P_1 = 2116 \ [\text{psf}] \]

SOLUTION

Unit Settings: [F]/[psia]/[lbm]/[degrees]

\[ A = 0.08727 \ [\text{ft}^2] \]

\[ \varepsilon = 0.000056 \ [\text{in}] \]

\[ f = 0.0117 \]

\[ \nu = \varepsilon \cdot \frac{32}{\text{ft}} \ [\text{ft} \cdot \text{lbm}^{-1} \cdot \text{s}^{-1}] \]

\[ H_L = 13.04 \ [\text{ft}] \]

\[ K_{\text{Lamb}} = 0.51 \]

\[ K_{\text{exit}} = 1 \]
L = 0 [ft]
L_{range, strainer} = 0.4621 [ft]
L_{abow} = 0.466 [ft]
L_{exit} = 0.9117 [ft]
L_{tank} = 0.785 [ft]
NPSHA = 21.23 [ft]
P_2 = 1303 [psf]
P_0 = 36.92 [psf]
ρ = 62.37 [lbm/ft³]
V = 300 [gpm]
z_1 = 0 [ft]

\textit{f}_{\text{baskel, strainer}} = 8.087 [ft]
\textit{f}_{\text{pump}} = 1.623 [ft]
\textit{f}_{\text{friction}} = 0.7111 [ft]
\textit{f}_{\text{pipe}} = 0 [ft]
μ = 0.0007537 [lbm/ft-s]
P_1 = 2116 [psf]
P_2 = 1303 [psf]
Re_0 = 211250
V = 7.659 [ft/s]
V_s = 7.659 [ft/s]
z_2 = 0 [ft]

No unit problems were detected.
APPENDIX Y

BASKET STRAINER

Model 53BTX Duplex Basket Strainer, 3/4" to 4"
Iron, Bronze, Carbon Steel or Stainless Steel · Threaded or Flanged

Overview

The Model 53BTX Duplex Strainer will give years of trouble-free service, protecting expensive pipeline system components from damage by unwanted particles. Because the system flow never has to be shut down for basket cleaning, the Model 53BTX basket strainer is perfect for lines that must run continuously or for batch systems that can't be stopped. A quick, easy turn of the handle operates the diverter cartridge that switches the system flow from one basket chamber to the other, allowing the out of service basket to be cleaned or changed.

No-Hassle Strainer Basket Servicing

The Model 53BTX features a design that makes strainer basket servicing a no-hassle operation. No more "race against the clock" during basket servicing to get the job done before the basket chamber overflows with fluid. The Model 53BTX keeps the chamber dry during service. This gives you time to clean or replace the strainer basket without ever having to worry about leakage and overflow. And...without overflow, there is no need to clean up after servicing the strainer basket. The Model 53BTX is simply a better way to work.

A Better Duplex Strainer Design

A unique flow diverter valve cartridge in the Model 53BTX isolates the two strainer basket chambers and prevents fluid by-pass. An easy-to-turn handle operates the cartridge and diverts the system flow from one chamber to the other, the flow in the pipeline is never shut off, perfect for batch or continuous process applications. When a strainer basket needs to be cleaned, the lever handle is turned to take the basket out of service and to divert the flow through the other chamber. The position of the handle clearly indicates at all times which chamber is in service. No special tools are needed to access the strainer basket for cleaning. The chamber is first drained and then the cover is lifted and swung clear of the chamber opening. The dynamic diverter cartridge seals prevent fluid bypass into the out-of-service chamber, making for easy, hassle-free strainer basket servicing.

A Better Flow Diverter Cartridge

The heart of the Model 53BTX Duplex Strainer is the unique flow diverter cartridge that features a patent pending, highly dynamic sealing system on the diverter balls that ensures exceptionally long life and positive sealing. The design works so well that there is no need for manual internal or external ball support adjustment, and the low operating torque means the strainer can be operated with an easy-turn lever handle, a gear box is not needed. A double sealing system on both the upper and lower stems guards against any possible leakage. Special reinforced polymer seals are used for extended service life. Should cartridge service become necessary, it's easy to accomplish. Just remove four bolts and the cartridge comes right out through the top of the strainer. There is no need to take the strainer completely apart or to remove it from the line.

Better For All Applications

The compact, low profile Model 53BTX Duplex Strainer fits into spaces ordinary strainers might not, yet it still uses full-size strainer baskets with low pressure drop performance. And, there is a strainer basket for every application. The standard basket is made of Type 316 stainless steel; however, if required, Monel, Brass or Hastelloy C materials are available. Baskets with openings from 1/2" down to 45 microns are offered so you can choose the best size for your application with no compromises. For easy basket servicing there are two drain plugs, not just one, on each strainer basket chamber. Additionally, there is an easy-to-access vent valve on top of the strainer body. Finally, standard foot mounting pads insure a rock solid installation no matter where the strainer is installed. Available options for the Model 53BTX Duplex Basket Strainer include differential pressure gauges, with or without switches, and magnetic separators installed in the strainer basket for removing fine ferrous particulates matter.

Offered in pipeline sizes from 3/4" to 4", the Model 53BTX can be supplied with threaded or flanged pipe connections. Stainless steel strainer baskets with a low-pressure drop design are standard — and you can choose perforated/mesh sizes from 1/2" down to 400 microns. Special alloy baskets are available as an option — as are differential pressure gauges and switches, magnetic separators, drain valves, a basket chamber vent and a pressure gaging assembly.

Features

An Elegant Design That Is Simplicity Itself

1. Eyebolts for easy access
2. Flanged or threaded connections
3. Dynamic ball sealing system
4. Double stem seals
5. Easy-to-turn operating handle
6. Unique seat design. No adjustments!
7. Huge selection of strainer baskets
# APPENDIX Z

PNEUMATICS PARTS LIST

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<th>Part Description</th>
<th>Material</th>
<th>Part Number</th>
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**Total Cost:** $276.44
APPENDIX BB
FRAME CALCULATIONS

2/16/88
A-Frame Analysis

For a simply supported center load [cross brace]

\[ \begin{align*}
F & = \frac{L}{2} \\
L & = \text{span}
\end{align*} \]

For 1018 HR steel, \( S_y = 44 \text{ KSi} \)

There will be two cross braces + a maximum load of \( P = 1000 \text{ lbs} \), so each side can be designed with \( F/2 \)

For a maximum bending stress of \( \sigma_b = 20 \text{ KSi} \)

\[ \sigma_b = \frac{M_y}{I} \]

\[ 20 \text{ KSi} = \sigma_b = \frac{(500 \text{ lb} \times \frac{1}{2} \text{ in} \times \frac{1}{2} \text{ in})}{\frac{1}{12} (1.5 \text{ in} \times \text{t})^3} \]

\[ t \approx 1.61 \text{ in} \]

So a cross section of \( 1.5'' \times 2'' \) will be plenty

---

BUCKLING

To determine if the vertical supports will buckle, the static loading for buckling will be determined

\[ F_{cr} = \frac{\pi^2 EI}{(KL)^2} \]

For 1018 HR steel,

\[ E \approx 10^6 \text{ psi} \]

\[ L = 36'' \]

\[ w = 1'' \]

\[ K = \text{Buckling constant} = 0.7 \]

\[ F_{cr} = \frac{\pi^2 (10^6 \times \frac{1}{12}) \times \frac{1}{2} (1'')(36'')}{0.7 (36'')^2} \]

\[ F_{cr} = 42,300 \text{ Kips} \]

There is no chance of buckling.
IF the frame is welded to the tank, what would the welds look like?

\[ F_x = 1000 \sin 30 = 500 \text{ lbs} \]

Vertical support at 11% grade.

\[ 108.8 \text{ lbs} \]

\[ b \]

\[ d \]

\[ A = 0.707 h (2b + d) \quad \text{Area for 3 side weld} \]

\[ h \text{= Throat height} \]

\[ b \text{= Throat length} \]

\[ I_w = \frac{d^4}{12} (6b + d) \]

\[ \sigma_{max} = \frac{(109.8 \text{ lbs})(36 \text{ in})(1 \text{ in})}{\frac{1}{12} (1.2 \text{ in})(15 \text{ in})^3} \]

\[ \sigma_{max} = 14.05 \text{ ksi} \quad \text{Max Bending Stress} \]

\[ \sigma_{max} = \frac{F}{A} = \frac{1000 \text{ lbs}}{(1.5 \text{ in})} = 667 \text{ psi} \quad \text{Max Tensile Stress} \]

Total stress: \[ \sigma_{total} = \sigma_b + \sigma_t = 14.92 \text{ ksi} \]

\[ \sigma_{max} = \frac{V}{A} \]

\[ 14.92 \text{ ksi} = \frac{1000 \text{ lbs}}{A} \]

\[ A = 0.0747 \text{ in}^2 \]

\[ 0.707 h (2b + d) = 0.0747 \]

\[ h = 0.011 \text{ increase} \rightarrow \text{less than } \frac{1}{16} \text{"} \]

The throat height will be 0.12", since less is not practical.
For bolts on linear slides:

- There are four bolts. For the worst case, 1 bolt has all 1000 lbs on it.

Assuming Grade 5 bolts, $G_{\text{max}} = 95$ ksi

$$95 \text{ ksi} = \frac{1 \text{ ksi}}{A}$$

$$A = \frac{1}{95}$$

$$\frac{\pi}{4} d^2 = \frac{1}{95}$$

$$d^2 = \frac{4 \pi}{95}$$

$$d = 0.1157 \text{ in} \rightarrow \text{less than 2/16 in}$$

With 3/16 in bolts, $G_{\text{max}} = \frac{1 \text{ ksi}}{\frac{\pi}{4} \left(\frac{3}{16}\right)^2} = 36.2 \text{ ksi}$

$$\frac{1}{1} = 2.62$$

Pulley Mounts:

$$q = \frac{K}{A}$$

$$95 \text{ ksi} = \frac{500}{A}$$

$$d = 0.0818 \text{ in} \rightarrow 2/16 \text{ in bolt OK}$$
For the bolts on the bottom of the vertical support:

Assume 1000 lbs on top fastener.

For grade 5 SAE bolts, $S_y = 95 \text{ ksi}$.

\[ 95 \text{ ksi} = \frac{1000 \text{ lbs}}{\frac{P}{4} d^2} \]

\[ d = 0.1158 \text{"} \rightarrow \text{less the 2/16"} \]

3/16" will work.

To yield bolts [3/16"], $P = \ldots$

\[ 95 \text{ ksi} = \frac{P}{\frac{P}{4} (\frac{3}{16})^2} \]

\[ P = 2623 \text{ lbs} \]
Appendix CC

Load Cell Graphic

Load cells used to catch/measure sediment in water.

Side view - There will be two load cells + geometry setup.

Front view:

\[ W_1 + W_2 = \text{Sediment Load} + \text{catchment sys} + \text{Shaft} \]

In addition to the 36" of water in picture, another 0-1m of water will be added as well.
In the case that the load cell assembly is disassembled, this manual will help in reassembly. The drawing package in appendix XX shows all the parts needed to assemble to load cell system, as well as the part numbers for the of-the-shelf parts. The cost analysis, in appendix XX also has part numbers.

The linear slide is attached to the mounting plate via four bolts, which are 4 mm in diameter and 80 mm long. The plate and linear slide are separated by the screw covers, which overlap on top of the linear slide. On the mounting plate, a square u-bolt holds the eye bolt that connects to the load cell via ½-20 threads. The eye bolt is held in place (only moves in plane with the tilting flume) by several washers and two stoppers. Below the load cell is another plate, which is connected to the load cell via a ½-20 threaded rod. The plate beneath the load cell has two u-bolts attached to it, which attach to the 9/32” chain that runs to the hanger.
**APPENDIX EE**

**PROJECT TIMELINE**

- Began project
  - Began to set project specifications
- Set final project specifications
  - Began preliminary design work
- Continued preliminary design work
- Finished preliminary design
  - Finished interim report
- Began and finished improved design choices
  - Changed project specs
- Began prototype testing apparatus
- Began Initial product manufacturing
- Finished product manufacturing
  - Finished final report

- Trip to Boise to obtain initial design ideas
- Visited St. Anthony Falls Lab for Sediment trap help
- Trip to Boise to finalize design parameters
APPENDIX FF

AUGER CALCULATIONS

Maximum Sediment flow rate

Auger Diameter

Auger Shaft Diameter

Distance between auger blades

Electric Motor RPM

Gear Box Reduction Ratio

Density of wet sand

Assumed Porosity of Sand

Maximum Mass of Sediment Removed

Auger rotations per minute

\[ D = 4 \text{ in} \]
\[ d = 1.75 \text{ in} \]
\[ L = 4 \text{ in} \]
\[ \text{RPM} = \frac{1750}{\text{min}} \]
\[ r = \frac{1}{2} \]
\[ \rho = 1922 \frac{\text{kg}}{\text{m}^3} \]
\[ \eta = 50\% \]

\[ M = (1 - \eta) \cdot \rho \cdot L \cdot \frac{\pi}{4} (D - d)^2 = 0.25 \text{ kg} \]

\[ R = r \cdot \text{RPM} = 875 \frac{1}{\text{min}} \]

\[ M \cdot R = 3.653 \frac{\text{kg}}{s} \]
Cody Newbill
909 W. A St. Apt D, Moscow, ID 83843
(208) 989-2656
cnewbill@vandals.uidaho.edu

SKILLS/ABILITIES

Research Experience
- Participated in research project sponsored by the National Science Foundation
- Self directed research, design, manufacturing and testing of project
- Prepared numerous technical and professional grade documents
- Helped set project scope and goals
- Worked within confined budget

Customer Relations
- Met with project client for product specifications
- Helped compile periodic product updates

Problem Solving
- Provided ideas and feedback during brainstorming and troubleshooting sessions
- Worked with others to help work toward solutions

Communication
- Presented findings from design project to superiors
- Consulted with experts in areas where information was lacking
- Provided team members with updates and questions for client

WORK HISTORY

NSF REU Intern
Virginia Tech, Blacksburg, VA
May 2007-August 2007

Sediment Trap Design Project
University of Idaho, Moscow, ID
September 2007-May 2008

EDUCATION

Graduate
Vallivue High School, Caldwell, ID
May 2002

Student
University of Idaho, Moscow, ID
Biological and Agricultural Engineering Soil and Water Option
Senior

References
Dr. David Vaughan
Professor
Virginia Tech
308 Seitz Hall
Blacksburg, VA 24060
(540) 231-7608
Dr. Jay McCormack
Assistant Professor
University of Idaho
234H Gauss Johnson Lab
Moscow, ID 83843
(208) 885-7134
Objective: Highly motivated individual seeking entry level position as an application engineer, or conducting engineering analysis. Particularly interested in fluid mechanics, heat transfer and experimental analysis.

Education:
2004-2008 Bachelor of Science, Mechanical Engineering
University of Idaho Moscow, ID
Current Standing: Senior
G.P.A. 3.30

Mechanical Engineering Experience:
Summer 2007 Mechanical Engineering Internship
Hewlett-Packard Company Vancouver, WA
Designed, tested and analyzed experiments, solved undefined fluid dynamics problems, dealt with air flow and ink flow. Research included characterizing micro air pumps, failing ink cartridges and analyzing data generated from pressure transducers and DAQ units. Organized intern events, and created in-depth documentation for HP use.

2004-Present Mechanical Engineering Projects Moscow, ID
Sediment Trap for transport studies 2007-2008 (Senior Design)
Skills Learned:
- High level system Design
- Working in a multi-disciplinary team
- Defining needs and specifications
- Advanced CAD and Drawing
- Developing Customer Deliverables
- Working with Machine Shops
- Experience designing, building and testing
- Breaking down a large scope project

Designed apparatus, found minor losses 2007 (Senior Lab)
Designed an airfoil for model aircraft 2006 (Fluid Dynamics)
Calculated and ran tests for a pump curve 2006 (Fluid Dynamics)
Designed and tested flow in porous media 2006 (Fluid Dynamics)

Sales Experience:
Summer 2005, 2006
Independent contactor, selling educational products to families. Executed all the sales, accounting, delivery and inventory
The Southwestern Company Nashville, TN

First summer:
• Personal retail sales of $20,580
• Prospected and approached over 3000 families from various socio-economic backgrounds
• Relocated to Massachusetts
• Gold Seal Gold Award (80 hours a week all summer)

Second summer:
• Personal retail sales of $28,000
• Assisted with leadership and management of first year sales people
• Relocated to Kansas
• Gold Seal Gold Award
Objective:
I am seeking a career that will allow me to exercise my abilities, challenge me daily and provide a continuous learning environment in the Environmental Engineering industry.

Education:
University of Idaho
B.S. Environmental Engineering
GPA: 3.22
Expected graduation date: May 2008

Course Highlights:
- Organic Chemistry, Microbiology, Biochemistry, Soils

Computer Skills:
- Excel, Word, Power Point, Auto Cad, Math Cad, Visual Basic

Related Work Experience:
05/07 to 08/07 Twenty Mile South Farm Boise, Idaho
Summer Environmental Internship
- Calculated daily Evapotranspiration values using local weather data
- Analyzed and compiled soil data on Nitrogen and Phosphorus levels
- Sampled and dried biosolids to calculate percent total solids
- Installed soil moisture monitors to track soil water levels
- Soil sampled and took GPS perimeters of fields

Other Work Experience:
2005 Bureau of Land Management Burley, Idaho
Wild Land Fire-Fighter
- Serviced trucks and did other projects, fought and contained over 15 fires
- Learned the values of communication, team work, organization and preparedness

Senior Design Project:
Client: Center for Ecohydraulics Boise, Idaho
Project Description:
- Design a sediment trap to catch and continuously weigh collected sediment in an existing water flume used for sediment research in turbulent flow.
- After the sediment is weighed it is transported in slurry form to a dumpster located in a near by alley. The sediment and water are then separated in order to recycle the water back into the flume.

Honors/Activities:
College
- Competed on the University of Idaho Track and Field team
- Member of the Gamma Phi Beta sorority serving as the Assistant Treasurer, Standards Chair and a member on the Executive Board

Community Activities:
- Received Outstanding Junior award and award for perfect class attendance for two semesters
- Annual National Make a Difference Day and Relay for Life
Nathan P. Barrett

240 Baker St #5
Moscow, ID  83843
(360) 440-0186
Email: nathanbarrett@vandals.uidaho.edu

Objective
To obtain an entry-level mechanical engineering position.

Education

| Bachelor of Science in Mechanical Engineering | Cumulative GPA: 3.56/4.0 |
| University of Idaho                          | Graduated May, 2008     |

| Master of Science in Mechanical Engineering | Cumulative GPA: N/A    |
| University of Idaho                         | Graduating in May, 2010|

Mechanical Engineering Experience

Projects

• Sediment Trap  
  (2007-2008)
  Worked with the Center for Ecohydraulics Research at the Idaho Water Center. Collaborated with both mechanical and biological/agricultural engineers to design a system to trap bed load sediment from a 20m flume in the Boise facility to assist in the study of river flow and erosion.

• Finite Element Analysis of a Simple Aluminum Component  
  (Spring, 2008)
  Used COSMOS, a SolidWorks finite element analysis tool, to compute the magnitude of the crack-tip-plastic-zone of a middle-tension specimen with a center through crack. Other parameters involved with the finite model included displacement and overall stress magnitudes around the crack.

• Loudspeaker Design Project  
  (Spring, 2008)
  Designed a sealed and vented cabinet for a Pioneer A11EC80 – 02F full range speaker. Analyzed the frequency response of diaphragm pressure, velocity and displacement amplitude, along with the phase response of the diaphragm and vent displacements and velocities.

• Flame Speed Experiment Design  
  (Fall, 2007)
  Measured the speed of a flame as a function of the amount of water injected into the fuel supply. Flame speed was measured by taking a digital image of the flame and measuring its cone angle.

Internships

• Naval Underwater Warfare Center  
  (Summer, 2007)
  Worked for the Naval Underwater Warfare Center (NUWC) in the Rapid Prototyping and Fabrication Department. Learned and used SolidEdge, a 3D CAD program for creating drawing packages. Projects included helping to design a new method for the repair of helicopter blades used by the Armed Forces.
Courses and Areas of Study:

GD&T
Machine Component Design
Dynamic Analysis of Machine Design
Thermal Energy Systems Design

Computer Aided Design Methods
Intermediate Mechanics of Materials
Experimental Methods for Engineers
Elements of Materials Science

Computer Skills

C++ Programming
CATIA
SolidWorks
SolidEdge
COSMOS
AutoCAD

Matlab
Engineering Equation Solver
TK Solver
Microsoft Word
Microsoft Excel
Rhino

Awards/Activities

• Dean’s List (2004 – 2008)
• UI Scholars Program Scholarship Recipient
• Presidential Scholarship Recipient
• UI Honors Scholarship Recipient
• UI Honors Member (2004–2006)
• Idaho Robert Lee Promise Scholarship Recipient
• Walter C. Hayes Scholarship Recipient
• Henry F. Gauss Scholarship Recipient
• Charles DeVlieg Foundation Scholarship Recipient

Past Work History

• Crew Member, McDonald’s, Winslow, WA

• Summer Laborer, Boise School District, Boise, ID
  Landscaping for Boise schools. (Summer, 2003)

References

Available upon request
Aaron B. Gauthier
PO Box 292 Hope, ID 83836 (208) 651-0260 email: aarong@vandals.uidaho.edu

OBJECTIVE
Seeking position as a full-time engineer.

EDUCATION
University of Idaho
2004- present
College of Engineering

RELEVANT COURSES

COMPUTER SKILLS
TK Solver 5.0
Solid Works 2006
Microsoft Excel
EES (Engineering Equation Solver)

WORK HISTORY
2006 and 2007
Special Additions Landscaping
Private landscape business
- Operated heavy machinery, installed sprinkler systems, constructed driveways, and other related duties.

2005
Hope Builders
Private construction business
- All levels of carpentry ranging from structural framing to detailed finish work.

2004
Glahe and Associates
Private surveying business
- Boundary, Topographic, and Construction Surveying.

PROJECTS
Sediment Trap
Currently engaged in project for the Idaho Water Center which entails design, fabrication, and testing of a sediment trap system capable of trapping and weighing sediment that is traveling down the bed of a large flume.

Heating System
Used heat transfer skills to design a heating system that provided accurate and controllable heat flux to a computer chip.

Hydroponics System
Used knowledge of fluid mechanics to analyze the mechanical and fluid components of a hydroponics system.

Water Rocket
Mechanical Design Analysis; designed, built and tested water rocket. Goal to model flight path, speed, and height at apex.

HONORS
2003-04fall. University of Idaho Dean’s list School of Engineering
2002-2004 Ambrosiani-Pastore Foundation, Inc.
2000-2002 National Honors Society Member

REFERENCES
Available upon request.