INTRODUCTION

The Problem

The Problem with the existing Sandbagger was that there was no means of returning the sand to the starting point without someone manually doing it.
The task presented was that we had to redesign the Sandbagger so that it could be fully automated. That included a “non-spill” system. A non-spill system means no sand particles would spill on the floor at any time, meaning a fully self-contained unit.

The Sandbagger could be broken up into seven main sections:

- Recycling System
- Layout of Sandbagger
- Bottom Hopper
- Middle hopper
- Weighing System
- Sensors
- Visual Aids

Each section comprising of sub tasks. The report is also broken up into a similar format.

PRELIMINARY RESEARCH

Michael Ong’s Report discusses the alterations done to try and upgrade the sandbagger. This is a summary of what he did: he changed the existing actuators with new ones and provided better means of mounting the actuators. New brackets for the inductive sensors were designed and made. As well as a bracket for the new optical sensor for the middle hopper. Cushioning, paint work and a new tabletop to place the PLC were some of the ideas that he implemented in the upgrade of the Sandbagger in 1992.

The other research performed was on how the PLC functions and how the sensors interact with the PLC. This was done with the use of the Mitsubishi manuals. The last bit of research done was on the all the pneumatics used on the sandbagger. The research included how the actuators worked and how they were activated. As well as research into how the solenoids work and are activated. The people at Festo were very helpful in answering any questions we had on their products.

In the Initial stages the sensors, actuator and PLC was tested for any faults. We tested them both manually and electronically. There were no faults with any of the equipment except for a switch, which is being fixed.

RECYCLING SYSTEM

Sand Moving Mechanism

Initial Ideas for sand conveying

Designing of the recycling system was started after all the testing of the existing mechanisms was complete. The two basic ideas for the recycling system were that the sand would either be pushed up or sucked up. The obvious ideas was a vacuum and a bucket system.

The main ideas that we came up with are as follows:

1. Vacuum
2. Fork lift
3. Bucket Lift
4. Bucket on railing system
5. Archimedes screw

All these ideas had different ways of disposing the sand back into the top hopper. Some ideas used magnets on the side of the bucket and other ideas used different types of levers to try and tip the sand back in the top hopper.

The next process undertook was looking for what products are already available on the market for sand conveying. The main areas I looked in were pneumatic conveying, bucket conveying, dredging and Vacuums. A list of helpful companies is shown in table 1 contact of the appendix. They are only a small amount of companies contacted.

The cheapest price for a mechanism that could move the sand to the top hopper costs 2000 Australian dollars which was too expensive for this project.

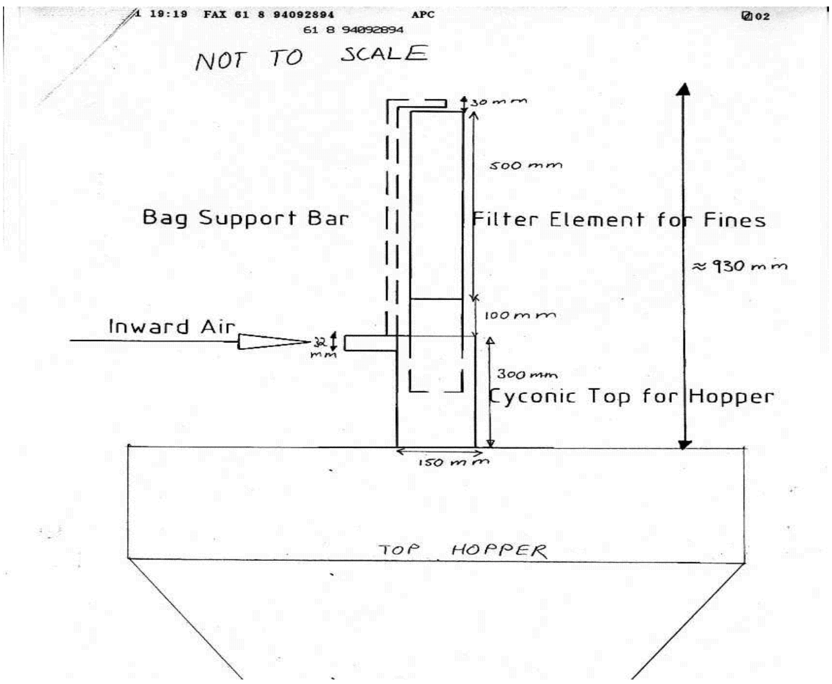
Final Design and Construction for Sand Conveying

We at that stage decided that a pneumatic conveying system would be the cheapest and easiest way of moving the sand. Venturi, Eductors and air mover were researched further (pictures can be found in the appendix). The main reason for deciding on a pneumatic conveying system was that the Sandbagger already has facilities for compressed air. If we were to use a lifting system we would need to buy new equipment to support the motors. The cheapest Pneumatic conveying system was approx. two thousand dollars. I came up with an idea of a crude Eductor made out of a PVC t-junction pipe. I drew up the design and handed it to the workshop to make it. A picture of the final product is shown below:

We then conducted several tests on the eductor at different pressures and with one or two air inlets. The Best result achieved was it took ten seconds for 500 grams to be moved to the top hopper.

Dust Extraction

The second part of the recycling system was extracting the sand from the compressed air, so that the sand could be put into the top hopper. I investigated the possibility of a cyclone. I later found out that a cyclone for our flow rate of 600 litres per minute would not extract all the dust. The very fine particles would escape thus around 96% - 98% of dust would be extracted. I researched further for other products for dust extraction. Refer to figure 4 & 5 in the appendix. The most efficient and cost effective product found was made by Advanced Pollution Control (a rough sketch is shown below).



The dust extraction unit has a cyclonic top for the hopper this allows the compressed air to expand and majority of the heavy particles will fall down into the hopper. The bag support it to hold the filter bag up so that maximum amount of area is exposed so that more dust is collected. The filter bag is made for very fine particles that we might be dealing with.

Piping

There were a few options we were going to use for piping. We initially were going to use metal piping seeing as it would be the most durable against the abrasiveness of sand. The workshop was unable to bend the metal pipe in the radius we needed. Thus we decided to use plastic PVC tubing. There were two different types, there was beverage tubing, which is basically clear plastic tubing and there was a product called heli-steel. Helisteel is a clear plastic tubing except it has a spiral of metal supporting the tube. We decided on the helisteel as it would support itself and it would be less likely to collapse. The reason for purchasing clear tubing is to allow us to see where the sand is flowing and if there is a blockage we will be able to find out exactly where it has occurred.

Mounting the piping

Allowances had to be made if in the future the pipe manages to become blocked. There has to be a way of opening either end so that we are able to unblock the tubing. To give the Eductor more support we decided to use an aluminum pipe from the Eductor through the actuate support. This was done to stop the eductor from moving when sand flows through it. The Eductor should not move because if it does the flow rate will be altered, thus it could cause the Eductor to become congested.

The heli-steel tubing would start from the aluminum pipe up to the dust extraction system.

LAYOUT

Layout of Hoppers

Initial ideas

There needed to be a means of putting the sand from the middle hopper into the Eductor, so that the sand can be recycled to the top. I came up with three different types of layouts.

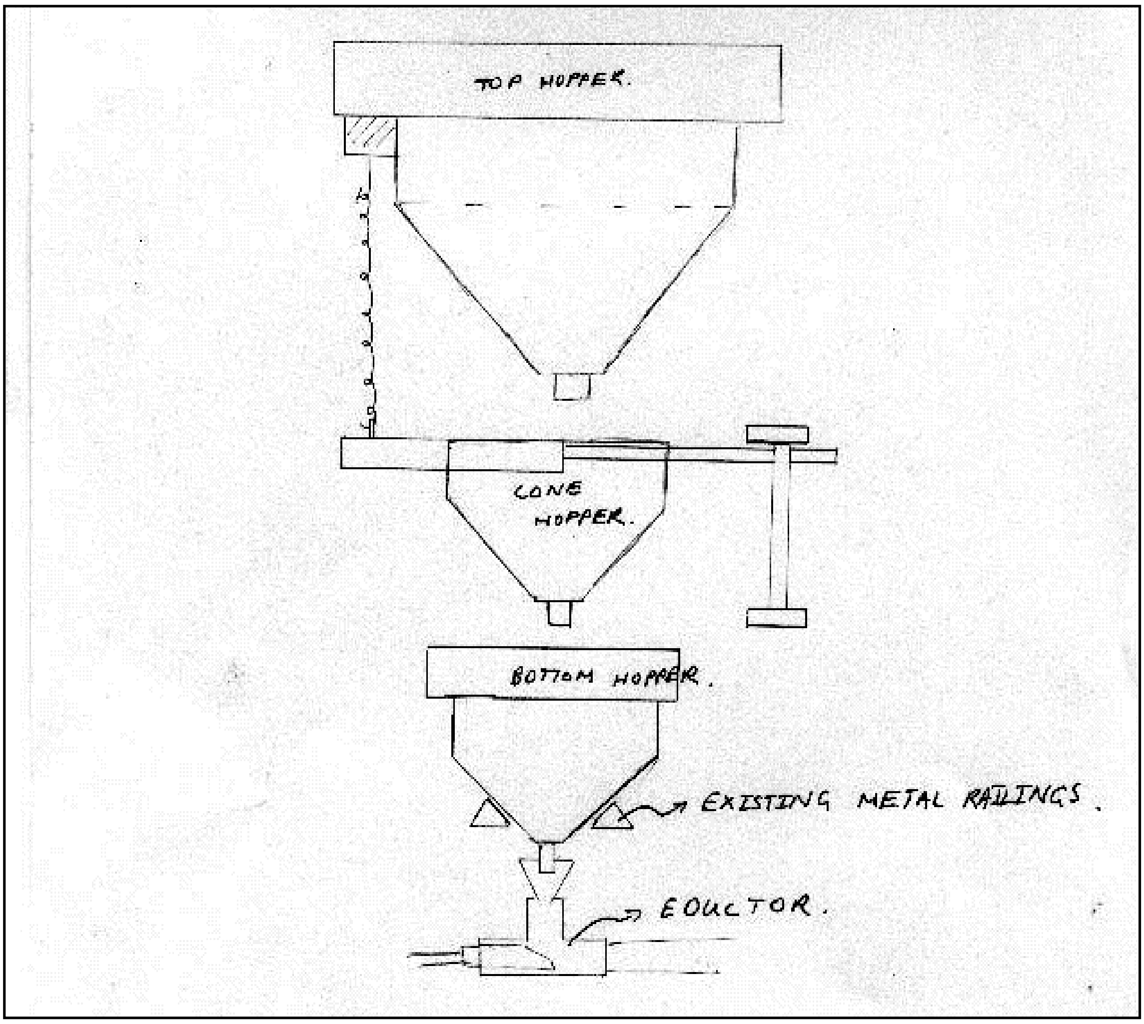
The first incorporated a four-hopper system. As shown by the picture Layout one in the appendix. The top hopper and middle hopper would be kept in the same position. I was going to add another two hoppers underneath the existing ones. The hopper under the middle hopper would have the load cell attached to allow for weighing and the bottom hopper would funnel the sand used into the Eductor. The reason behind the design was to find a means of weighing the sand with a load cell. At that stage the load cell needed to be separated from the spring. The reason behind it was to show the error in the mechanical spring in comparison with the load cell.

The second layout used a three-hopper system. The bottom hopper would catch the sand, funnel the sand into the Eductor as well as weighing the sand used with the load cell. The reasoning behind the layout is to minimizes the amount of hoppers used in the first layout. The reason for minimizing the amount of hoppers means a decrease in costs and alterations to the existing hoppers. See Layout two in the appendix.

The reason behind the third idea was to try and keep the existing sandbagger layout including the bottom bucket. So that in future we would be able to have a train rail system. The idea encompasses a bottom hopper underneath the existing bottom bucket. There would need modification to the bottom bucket so that it would be able to tip the sand into the bottom hopper. Trap doors or a slide would be the best approach to tip the sand in the bottom hopper. See Layout three in appendix.

Final Design

After some discussion we decided that we could hang the existing spring off the load cell. Thus it would mean that we would be able to use the second layout and modifying it. The modification of the second layout would mean that we would not need to hinge the hopper on a pivot all we would need to do is mount it on the existing frame work. The load cell then would provide the means of measuring the middle hopper. This also makes the other two layouts obsolete because we did not need another hopper to weigh the sand with a load cell. The final design is as follows: (Rough Sketch of final Layout design)



Amount of Sand Needed

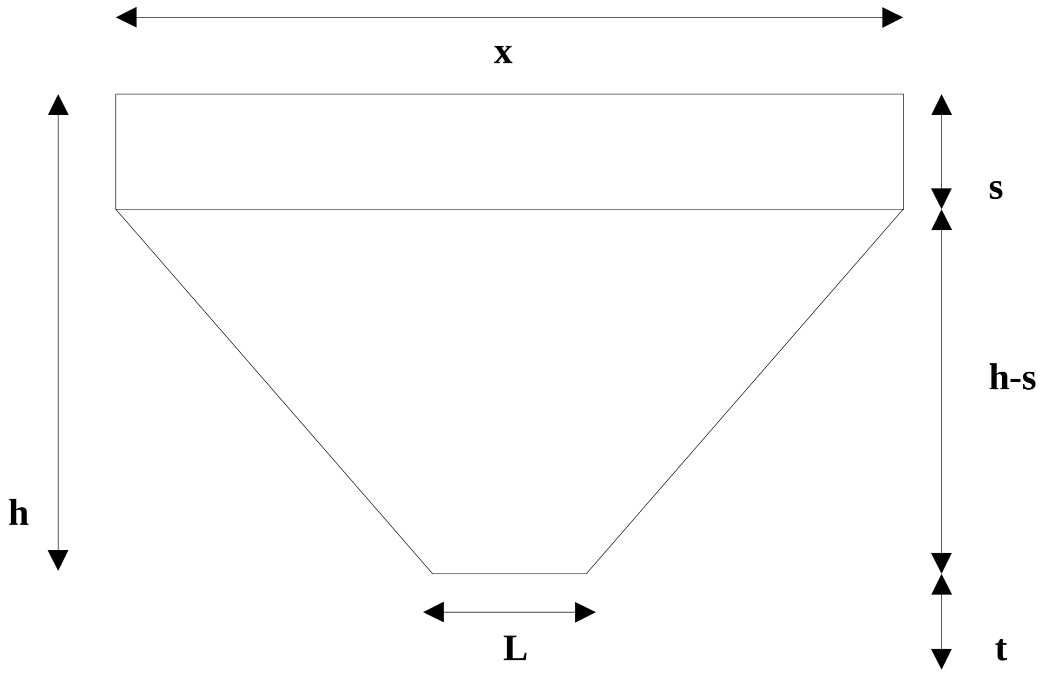
It was decided that we would not use the full capacity of the top hopper, which I worked out to be 163kg. It would mean that we would need to have a hopper on the bottom the same size as the hopper on the top. Seeing as we will only weigh a maximum of 5 kg

BOTTOM HOPPER

The Bottom Hopper was being designed in the same shape as the top hopper. The reasons was to try and maximize the amount of sand held, as well as providing a funnel for the sand to go into the Eductor. The other reason why we chose a square pyramid was one of aesthetics. The sandbagger would have to look good visually because of the camera we were going to place on it. Thus three different shaped hoppers would look unappealing

Calculations

The next step is working out a general formula to obtain the mass the hopper could hold. Below is the diagram of all the symbols used in calculating the equation and the formulas:



$$\frac{(h - s + t)}{\frac{x}{2}} = \frac{t}{\frac{L}{2}} \qquad 1$$

$$Volume = (x^2 s + \frac{1}{3}(h - s + t)x^2 - \frac{1}{3}L^2 t) \qquad 2$$

Solve 1 and 2

$$Mass = volume \times density$$

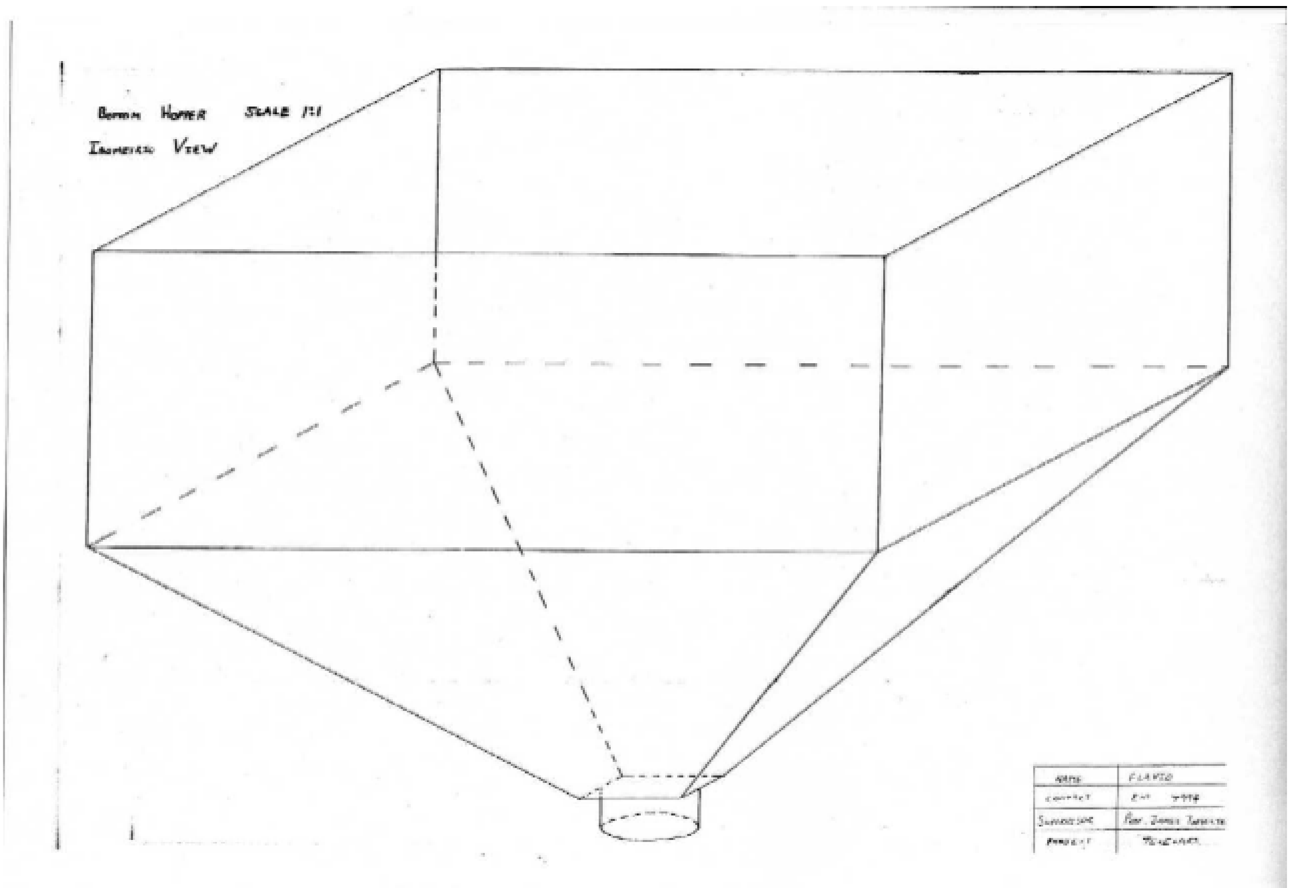
$$M = \frac{1}{3}\rho(-s[L^2 + Lx - 2x^2] + h\{L^2 + Lx + x^2\})$$

The equations were worked out with Mathematica 4 a print out of the coding used is shown in the appendix.

It also led to another derivation of the existing formula to work out the height of the hopper with the known specifications. It is shown below:

$$h = \frac{1}{2}\cot[a](-L + x + 2s\tan[a])$$ a= angle of the side of the hopper

This equation then was used to find the height needed.



The Best dimensions found were L= 35 mm, x= 280 mm, s= 110mm, h= 233mm

Bottom Hopper Layout

The next problem faced was on how was the Eductor going to fit on the bottom hopper as well as a control mechanism to control the flow rate of sand. The reason for controlling the flow rate was, if the sand filled the Eductor at once then the eductor would clog up and start to become extremely inefficient.

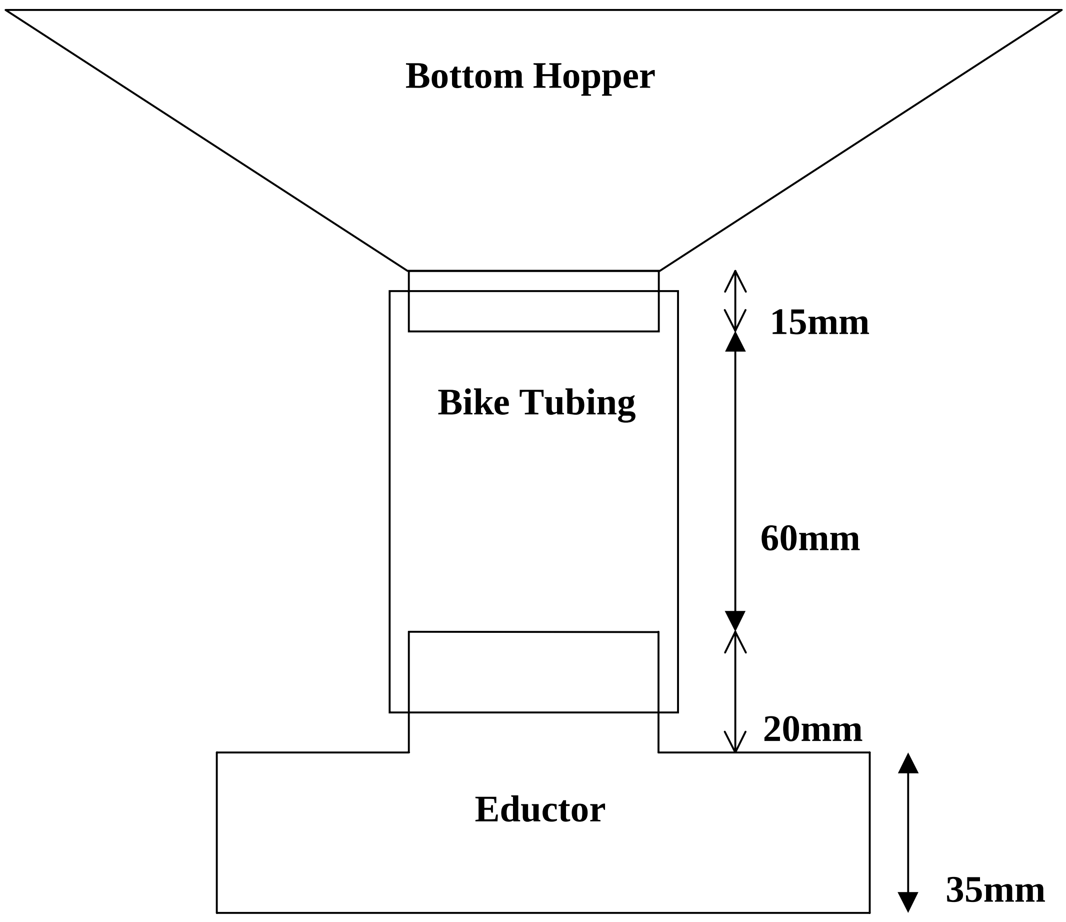
The final layout idea incorporated the existing railing where the bottom inductive sensor was positioned. A replica of the same system used for the middle hopper was implored. The only difference being that the bike tube would have to extend to the Eductor. The actuate support would have to modified to allow for the piping for the recycling system. An actuate and two solenoid manifold was purchased for the layout. We also managed to find a spare solenoid, we used this to control the airflow for the new actuate seeing as the existing solenoid manifold could not fit another solenoid. The new manifold was used for the eductor, so that the air can be switched on and off electronically.

See appendix for Bottom hopper layout.

Lifting of the Sandbagger

The layout of the Sandbagger that was chosen meant that we would have to lift the sandbagger a certain height to allow the eductor, clamp and actuate support to fit underneath the bottom hopper. The calculations done meant that the height the sandbagger needed to be lifted would be 130 mm.

The diagram of the calculations is as follows:



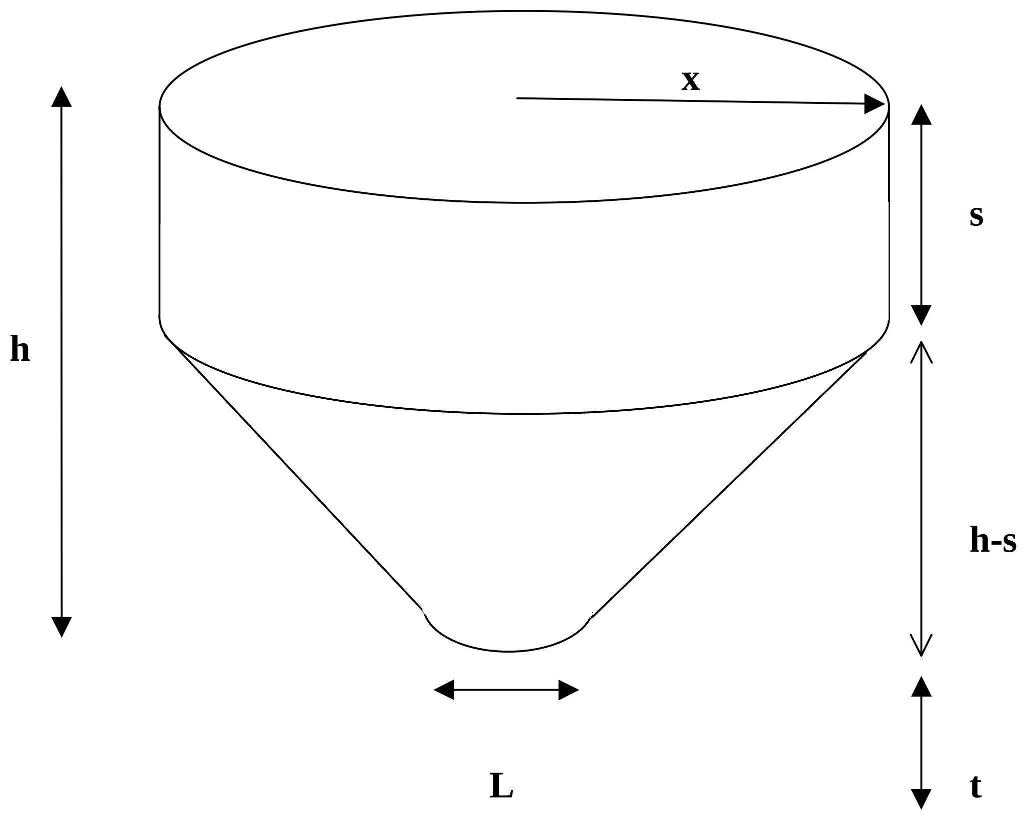
MIDDLE HOPPER

Problems

There were a couple of problems with the existing middle hopper. It was in the shape of a square pyramid. The shape of the square pyramid caused two major problems. The first being that it did not allow the sand to fully drain from the hopper. The second problem was when the sand overflowed a substantial amount was left behind. This would then pose errors in the weighing of the sand. Thus we needed to change the shape of the middle hopper to into a cone or cylinder shape to over come the problems.

Calculations

Again Mathematica 4 was used to work out the following formulas for the cone hopper. The same reasoning used for the bottom hopper was used except for a couple of minor differences. Below is the diagram of all the symbols used in calculating the equation and the formulas:



$$\frac{(h - s + t)}{\frac{x}{2}} = \frac{t}{\frac{L}{2}} \qquad 1$$

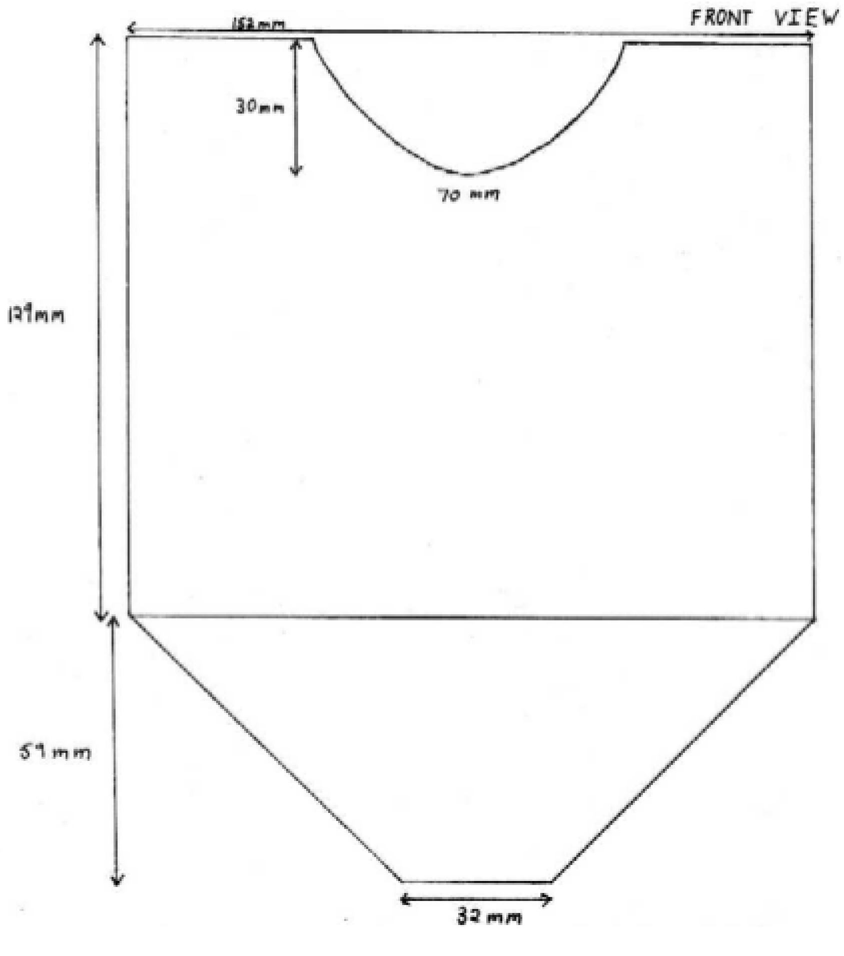
$$Volume = \pi x^2 s + \frac{1}{3}(h - s + t)x^2\pi - \frac{1}{3}L^2\pi t) \qquad 2$$

Solve 1 and 2

$$Mass = volume \times density$$

$$M = \frac{1}{3}\rho\pi \left(-s[L - x]\{L + 2x\} + h[L^2 + Lx + x^2]\right)$$

The Best dimensions were L= 35 mm, x= 76 mm, s= 129mm, h= 188mm. Below is a diagram of the cone hopper:



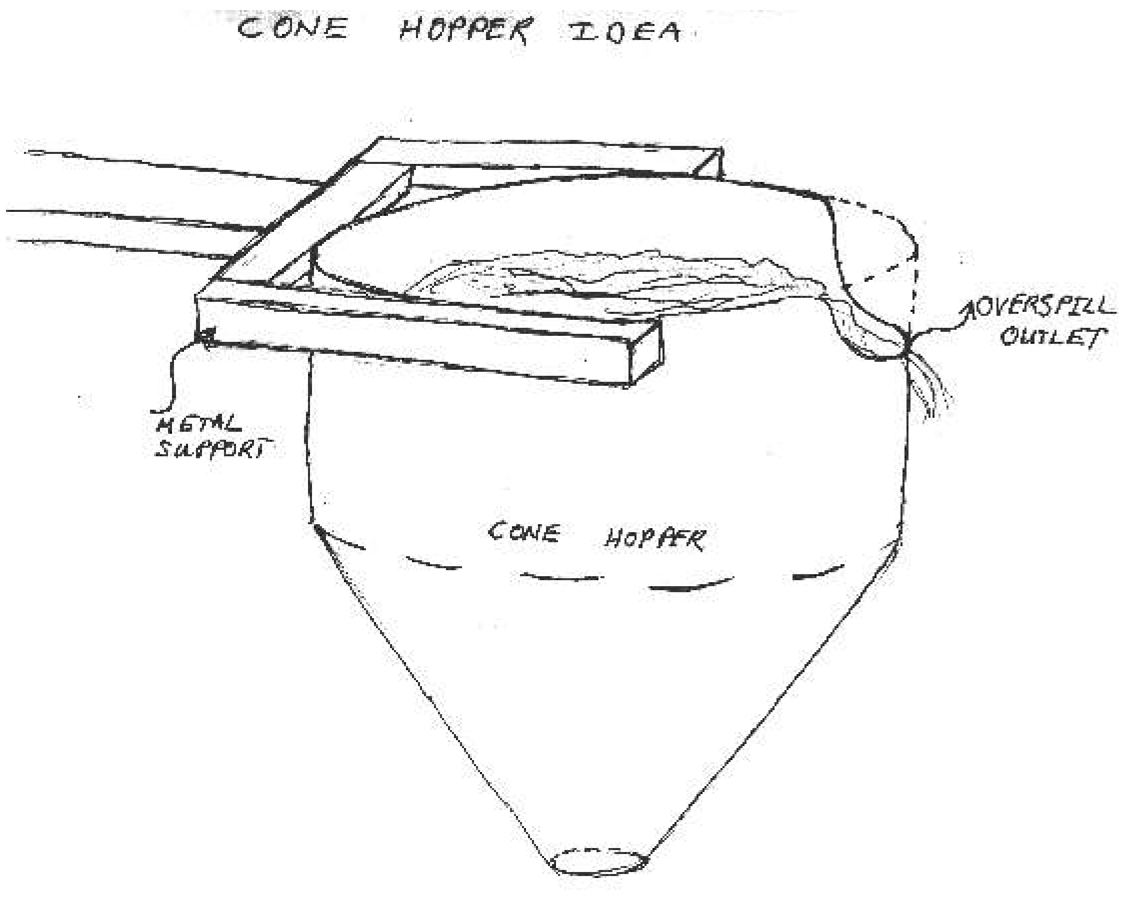
The middle hopper could hold 5kg as well as overcoming the problem with the existing hopper. The other issue involved was it had to fit in the old hopper support and it could not be any higher than 190 mm, otherwise if it was too tall it would not allow enough room for the bottom hopper.

Middle Hopper Layout

The middle hopper layout caused some problems because the new hopper was higher than the existing hopper. Thus a new clamp had to be redesigned and a hopper ring idea was implored to make the alterations as easy as possible. The hopper ring was designed because we had no means of attaching the clamp to the hopper. With the hopper ring we could then use the existing sensor holder and clamp support. See appendix figure middle hopper layout.

Sand over flow

We needed a means of controlling the overflow of sand from the middle hopper to the bottom hopper. There were two ideas explored in controlling the overflow of sand. The first was to cut out a section of the middle hopper so that the sand would escape through the cut out section. The second idea was to cut out a section out of the existing middle hopper support. The section that we cut out is shown below:



WEIGHING SYSTEM

Load Cell

The selecting of the load cell was based on the design of the hopper layout. We decided to choose a load cell with a capacity of 10kg the reason being that the middle hopper could hold 5kg and the weight of the hopper support weighs 4.5 kg. Thus we needed to make sure that if the hopper overflows it would be within the safe over load zone which is 150%.

Choosing a load cell

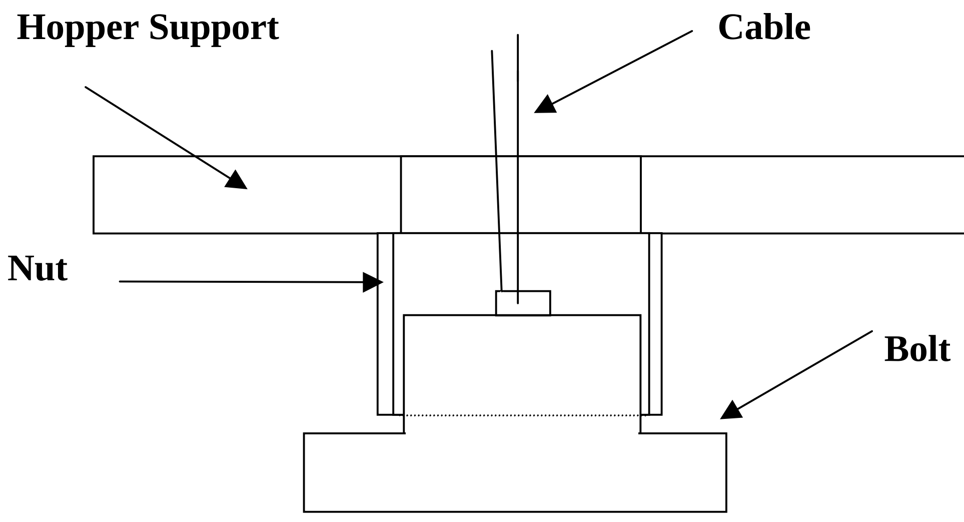
The Pricing for the load cell varied from 2000 Australian dollars to 500 Australian dollars. We decided to use Precision Transducers load cell the PT2000 because of how cheap it was as well its performance. The reason we decided for a beam load cell was due to the configuration we could use. It was easier to mount in comparison with the s-shape and c-shaped load cells. The last reason why we decided on a load beam were due to the fact that the load beam works well under tensile loads.

Load cell Mounting

There were two ways we could mount the load cell. The first meant that we could hang the load cell off the existing frame. The second idea meant we had to build a support from the middle of the sandbagger up to the load cell. An example of the second idea would be a shelf bracket. The best option was the first option, due to the reason less materials would be needed to construct the bracket. There would need to be three brackets. One bracket to hold the load cell to the frame. We decided to make it out of 4mm steel as to stop the load cell bending in anyway. The bracket had to hold 15kg min. The second would be used as a stopper, so that it would stop the load cell bending any further. If the load cell bends too much the elements in the load cell would fail. Thus we made this as strong as possible because any more than a 0.5 mm deviation in the metal would mean the load cell would fail. The last load cell was used to attach the spring to the load cell. This was made out of 3mm aluminum. It was placed on the end of the load cell for best results. Diagrams of the load cells can be found in the appendix see load cell Bracket.

Spring

There were some modifications done to the spring placing and also the supports of the spring. What we initially decided on to cut out a section out of the chip board top. A section of 60mm by 20mm was cut out. The reason being the spring was not clearing the chipboard and was interfering with it. To have a repeating experiment we needed to get rid of all the anomalies such as the spring rubbing against the chip board top. The other modification we did was to use a cable instead of a threaded metal pipe for the connection of the spring to the middle hopper support. Initial ideas included an accelerator cable arrangement. It was not used because if we needed to modify it frequently the cable would start to fray. Thus we decided on a simple “nut and bolt” solution which is shown below:



The reason for using a cable instead of the existing connection was due to spring being on an angle. This would not allow the load cell to give an accurate reading because the force supplied by the spring would only be a component of the actual load.

SENSORS

Choosing a sensor

There needed to be some sort of feedback for us to know when to switch on the Eductor and when to switch it off. There were two options, one option was that an ultrasonic sensor would be used. The second option would be a capacitor sensor. We were not going to use any optical sensors because of the environment they would be in. Over a period of time the surface of the sensor would be scratched and thus retarding the signal, also dust would cause a problem because it could start forming on the optical sensor.

Sensor choice

We chose an ultrasonic sensor because we could adjust it to any level. With the capacitor sensor we would have to drill into the bottom hopper, thus not allowing a range of options to put the sensor. Even though the sensor was a lot cheaper than the ultrasonic it did not allow any error or adjustment. The sensor would have to be mounted to the frame so that it could “look” into the bottom hopper. The sensor would trigger the Eductor to turn on when the sand reaches an upper level. Then when the sand reaches a lower level the sensor would toggle the Educator to turn off and stop the recycling process.

The sensor we bought was the Banner U-GAGE T30 series ultrasonic sensor. The reason why this sensor was purchased was because of the range the sensor. The bottom hopper is only 233mm high, thus we needed a sensor with a small dead band and a very small range. The other reason we decided with the sensor was that it could be used with sand.

Sensor Mounting

The major problem with the sand in the bottom hopper is that it does not form a flat surface, it forms a cone shape mound. With any ultrasonic sensor the best performance is achieved when the ultrasonic sensor is mounted normal to the surface of the object being measured. Thus we needed to do some experiments to see exactly what angle the sand forms and also were would be a good location to place the sensor.

The manufacturers gave some suggestions on brackets would be suitable to use with the sensor. The bracket that was chosen was an angle mount bracket, it allows the bracket to swivel. It is shown in the back of the appendix. There is going to be a slight modification to the bracket. The idea is to put a pivot on the bracket so that the angle the sensor could be changed. Refer to sensor mounting in the appendix.

Visual

For the student there has to be a means of showing what is happening and the process the sand is going through. We are planning to have a camera on a bracket set up so that the students can see the sandbagger through the Internet. There has to be some sort of visual feedback to highlight certain sections of the sandbagger. For example students would need to be able to see the actuator opening and closing.

Camera

For student to see what the sandbagger we decided to attach a camera to the sandbagger. The camera chosen is the Intel computer camera. The reason being is that the camera already transmits the signals digitally thus there would be no need to convert any of the signals. The camera would be situated on a bracket and mounted to the sandbagger frame.

Ideas

The initial ideas are as follows:

- Flag indicator so that when the actuator or part of machine moves a flag is sprung up
- Fluorescent paint
- Retro-reflective material
- LED's

The best idea is the retro-reflective material; it was previously used for the sheep-shearing robot. The only draw back for the retro-reflective material is that it needs a light source shining normal to its surface. Thus we need to research further into light sources, we have found a ceiling mounted light that would be able to be used.

The Sandbagger would need to be painted after all the new modifications have been done for better visual appeal.

Appendix