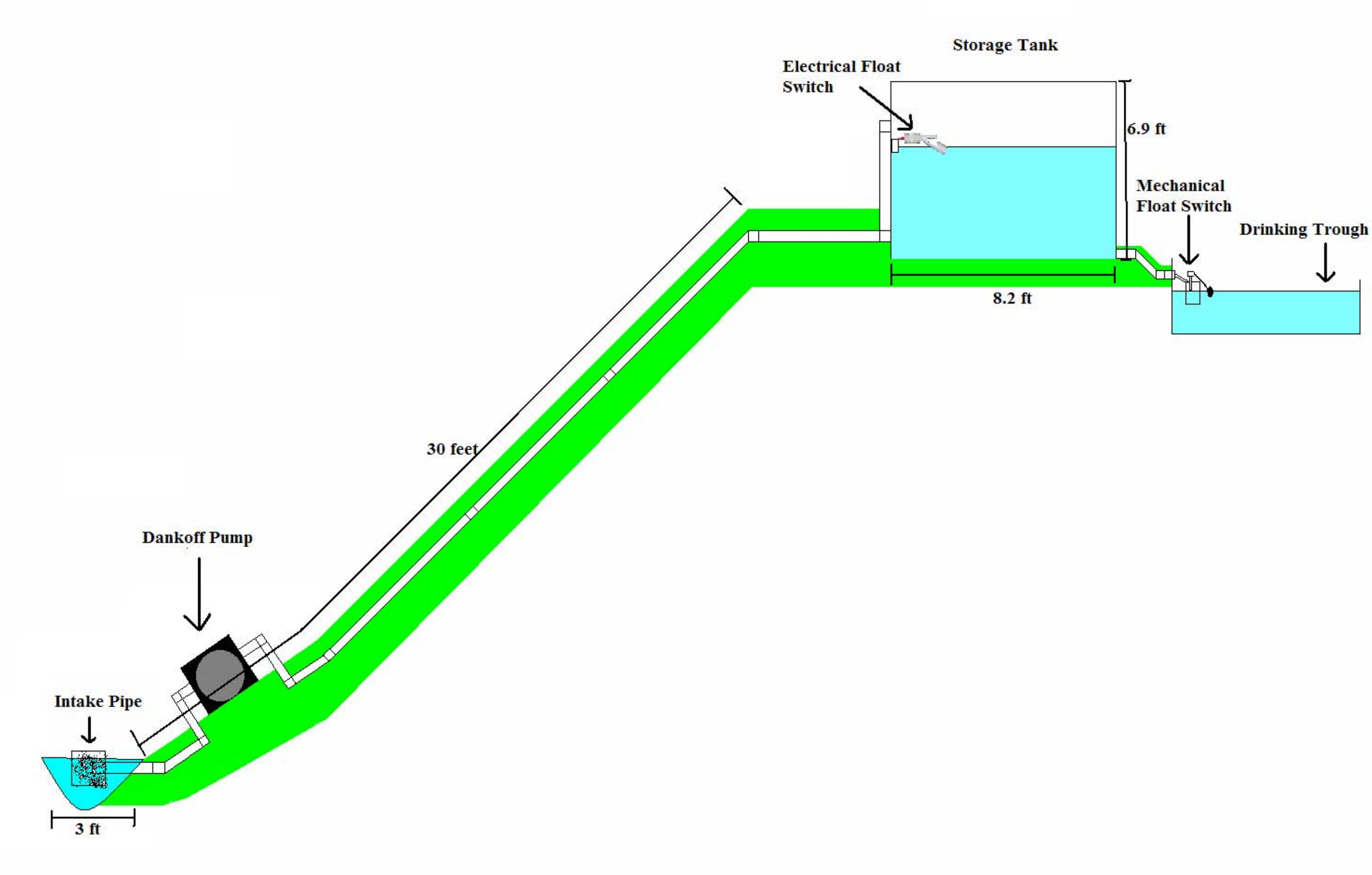
The Bovine Bubbler:

A Sustainable Drinking Water Delivery System for Cattle



Prepared for:

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Santo Domingo, Panama
June 7th, 2006

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Executive Summary

In late March 2006, Team 15-1 was asked to design a sustainable drinking water delivery system for cattle living in Santo Domingo, Panama. Santo Domingo is a remote community of 100 people that lacks electricity, telecommunications, and dependable roads. The village has approximately forty cattle grazing in the area and drinking from the local stream. When the cattle walk down to the stream to drink from the water, they erode the earth. This causes sediment to enter the stream which pollutes the river upstream of the community. The people of Santo Domingo depend on the stream for water, and so do the cattle.

After working on the project for ten weeks, our team developed the Bovine Bubbler based on careful research, meetings with our client and the IDEA team, and limited testing. A solar powered pump will push water from the stream up twenty-five vertical feet to a storage tank, which will release the water into a drinking trough once the drinking trough drops below a level set by the user. Key components of the design are described below.

Initial filter: The purpose of the filter is to stop twigs, leaves, and pebbles from entering the pipe and clogging the filter. This filter will be in the stream and will enclose the opening of the pipe.

Piping: The piping will be made of UV protected PVC. These materials are readily available in Panama and will not have to be shipped in.

Pump: The Dankoff Solar Slowpump 2507 meets all of the requirements for the project. The specifications consisted of maximum head, flow rate, and sediment toleration with a minimum power supply.

Storage tank: The tank stores the pump's energy as potential energy of the water. If it is a cloudy day, cattle can still drink water even though the pump will not be working. The storage tank will be made of ferrocement and will have a top to keep debris and living things out of the water supply.

Pump switch: Inside the tank, there will be an electric float switch that shuts off power to the pump once the tank has reached its maximum level. The float switch will ensure that the pump will not waste energy when there is enough water, the storage tank will not overflow, and the pump will last longer.

Float switch: This float switch is inside the drinking trough and controls the water level. When the water in the trough drops below a certain level, the float switch will let water from the storage tank enter the trough until the trough is full.

Trough: The trough will be completely in the ground to imitate the level of the river that cattle are used to drinking to. Since a minimum of five cattle must drink from the trough at a time, the trough will have dimensions of XX by XX and be XX deep (dependent on local materials available).

The Bovine Bubbler will deliver enough water to meet the drinking requirements of the cattle. Cattle will no longer be eroding land, so the people of Santo Domingo will have cleaner drinking water. A team of engineers are going on a scouting trip to Santo Domingo this summer to determine more data so that parts or all of the Bovine Bubbler can be implemented.

Introduction

Aaron Greco of the Engineers for a Sustainable World proposed a design project to the Northwestern University Engineering Design and Communications Section 15, Team 1 (Emily Gates, Paul Han, Edward Scott, and Andrew Wien) in the spring quarter of 2006. Lasting ten weeks, the project goal was to design a drinking system for cattle in a remote part of central Panama and create an instruction manual for the device.

The purpose of our project was to develop a sustainable system that would allow cattle in Santo Domingo, Panama to drink from a small stream without eroding the stream's banks and polluting the water. Santo Domingo is a small cattle-farming community of about 100 people, who get all of their water from a small stream that runs near the village. However, the cattle also drink from this stream and their pastures are upstream from the village. Since the stream has steep 60° banks, when the cattle walk down to the stream they erode the banks and the resulting sediment in the water has become a problem for the townspeople. Our task was to determine the best components for the system and how to make them all work together as efficiently as possible.

A key priority of our design was making the system as sustainable as possible. In other words, the system should require minimal maintenance and be very durable. The system also had to be easy to construct and use for someone with minimal technical knowledge. The community is not very wealthy, so the design had to be cost-effective, and it must be constructed from locally available materials. Additionally, the system must provide the cows with up to 700 gallons of water per day, and operate off solar panels.

The report that follows documents this team's steps through the process of obtaining a solution to the aforementioned problem. It records the evolution of our design, documenting the preliminary research that was done in preparation for this project, and the developments of the design through brainstorming and meetings with the client.

Users and Requirements

Our water delivery system must provide cattle with enough water to drink while preventing pollution of the village's drinking water. The most important users and stakeholders are the cattle, Andres and David Frías (the farmers who own the cattle), the 100 members of the village, and the Center for Panamanian Social Action and Studies (CEASPA). The delivery system must meet the following major requirements:

- It must provide enough water for the cattle to drink on a daily basis.
- It must be extremely low-maintenance so that farmers will not have to devote much of their time per week to operating the system.
- It must be sustainable for a long period of time so that the benefits outweigh the costs.
- It must cost as little as possible.
- It must use local supplies whenever possible since international shipping of parts is extremely costly and therefore not feasible.
- It cannot use more than 120 watts of power
- It must be able to be built by the local resources of Santo Domingo and any equipment that can be brought in

Additional requirements and specifications can be found in the Project Definition (Appendix A).

Research Methods

Team 15-1 used four main sources for our research—our client, EDC 398 team, CEASPA team in Panama, the internet, library books, and past reports—to search for information in the following areas: cattle, climate, region, pipe, pump, trough, filter, storage tank, float switch and support materials. The trough requirements are listed in Appendix B, the climate information is listed in Appendix C, the summary of information gathered from the CEASPA team is in Appendix F, pipe size and friction loss information is in Appendix J, sediment removal and filter information is listed in Appendix K. Information about other areas are from the internet and the book sources listed in the Reference section.

From the results of this research, we were able to develop an initial design for the drinking water system. The final design was based on the design review and test results.

Bovine Bubbler Design

Overview

To solve the problem of erosion caused by cattle polluting the small stream in Santo Domingo, Panama, Team 15-1 developed a sustainable drinking water system for the cattle which allows them to drink without walking down the embankment of the stream and causing erosion. This system accomplished several major goals: it provides plenty of water for the cattle, with a reserve supply that will be available in cloudy weather (the system runs on solar power). It is reasonably inexpensive and highly durable, so it should last for many years with minimal maintenance. Team 15-1 created an instruction manual for how to build the water system to facilitate its construction in Panama.

How it Works

The design uses a pump to get the water from the stream up a steep embankment and to a small plateau approximately 30 feet up the bank of the stream. The water is stored in an approximately 2,000 gallon storage tank, and then distributed to a small drinking trough as the cattle need it. A float switch controls the flow of water from the storage tank to the drinking trough, and another float switch shuts off the pump when the storage tank is full.

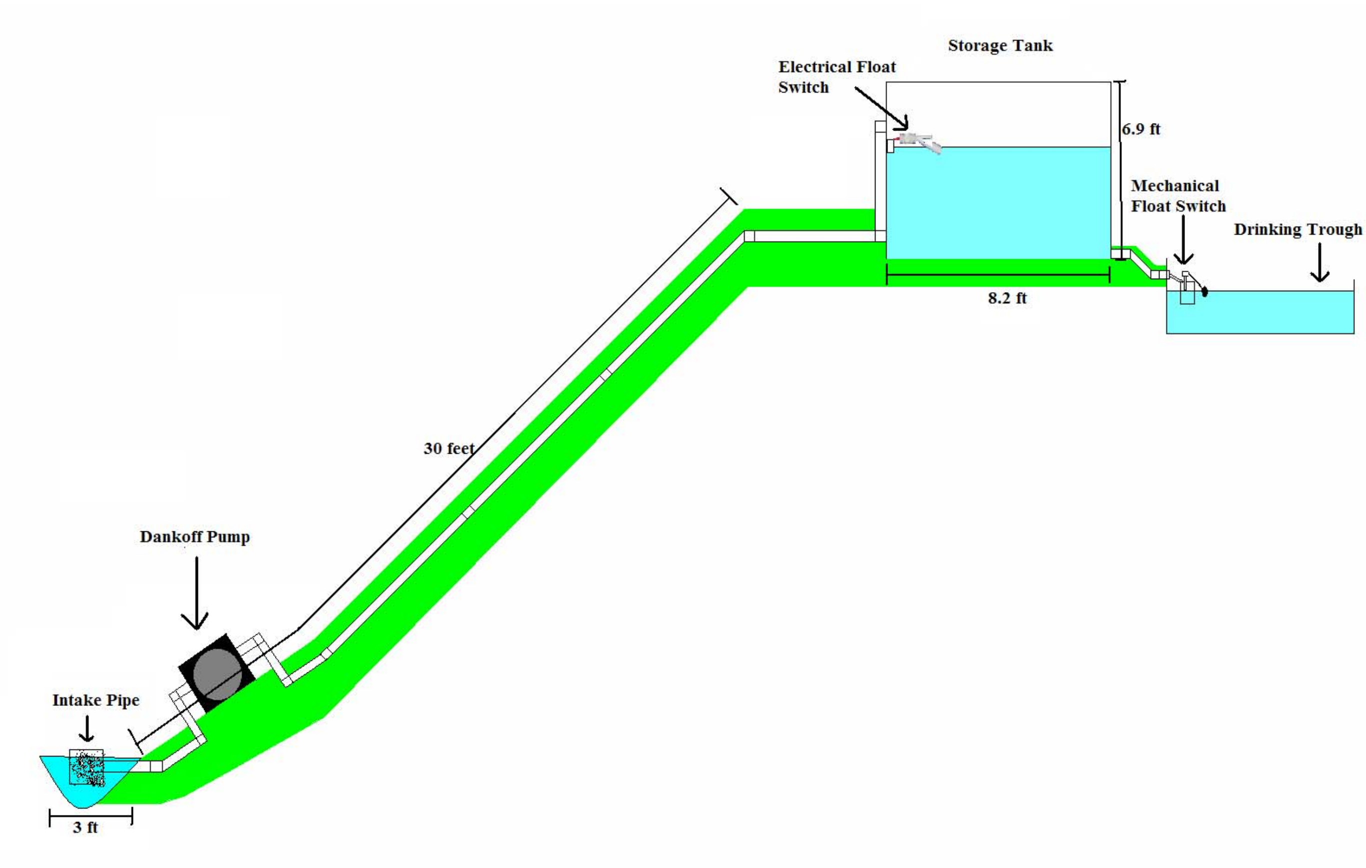

Figure 1: Bovine Bubbler Drinking Water System

Components

Pump

The pump we have chosen to use is the Dankoff Slowpump 2507. This pump is highly efficient but still powerful enough to pump as much water as the cattle need (it can pump up to 4 gallons per minute with the power we have available). The pump is situated inside of a plastic enclosure resting on the bank of the stream to protect it from the elements. Both the pump's intake and its output valve are ¾" male fittings. Specifications for the pump are outlined below:

- Pump
    - Dankoff Slowpump 2507
    - Up to 4 gal./min.

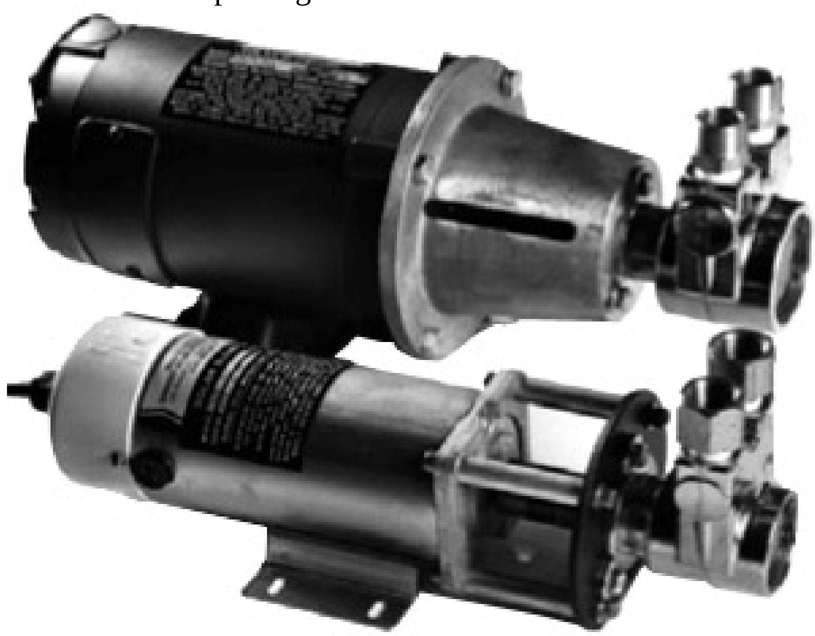

Figure 2: Dankoff Slowpump 2507 (Courtesy of Dankoff)

Filter

One consequence of the efficiency of this pump is that it can tolerate almost no dirt at all. Therefore, a filter is necessary to clean the water from the stream before it enters the pump. Dankoff makes an inline filter (it is installed inline with the pipe) designed for the Slowpump series, which filters debris as small as 10 microns. The filter cartridges are easy to replace and only cost $4 each, making this method of filtering simple and cost-effective. For coarse debris a metal cage will be constructed around the end of the pipe immersed in the stream to prevent large pieces of debris, such as leaves, from entering the pipe and clogging the smaller filter.

Pipe

The PVC pipe leading from the pump to the large storage tank is approximately 30' long and ¾" in diameter. After the pipe is put in place it will be buried to help prevent any damage from occurring to the pipe. All other piping in the project will also be ¾" PVC, as it is inexpensive and readily available. An approximately 6' length is required to run from the stream to the pump's intake, and an approximately 10' length is required to run from the storage tank to the drinking trough. Specifications for the piping are outlined below:

- Filter/Intake Pipe
    - Approx. 6 ft.
    - ¾" PVC
- Pipe from Pump to Storage Tank
    - Approx. 30 ft.
    - ¾" PVC
- Pipe from Storage Tank to Trough
    - Approx. 10 ft.
    - ¾" PVC

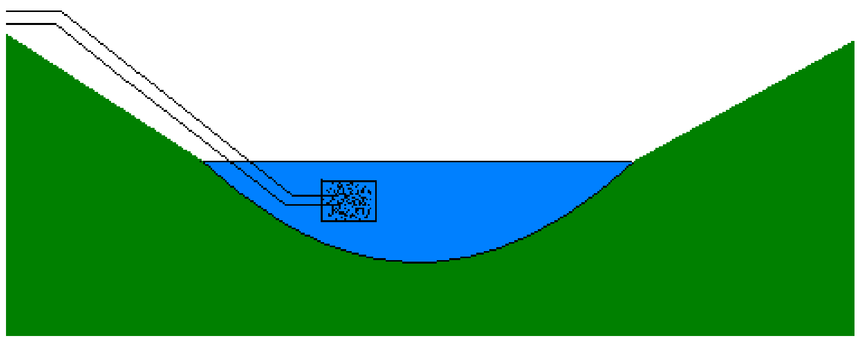

Figure 3: Intake Pipe Diagram

Storage Tank

The volume of water that the storage tank can hold is 2,000 gallons, which is approximately 8 cubic meters. This is enough water to last the cattle for 3-4 days if there is a lack of sunlight to run the pump. The tank is constructed from ferrous cement, and sits on the ground so that the output pipe running to the drinking trough can be placed as close to the bottom of the tank as possible. Water is propelled from the storage tank to the drinking trough by the pressure generated by the weight of the water in the storage tank. The tank is covered to help prevent growth of algae and other organisms in the tank and to keep debris from getting in the water and clogging the pipe running from the storage tank to the drinking trough. Specifications for the storage tank are outlined below:

- Storage Tank
    - Re-enforced Ferrous Cement with dome-shaped cover
    - 2,000 gal. / 8 m^3

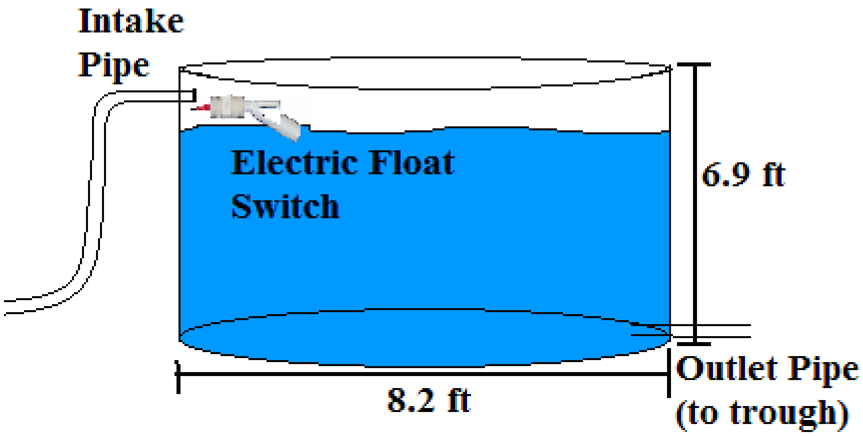

Figure 4: Storage Tank Design

Drinking Trough

The drinking trough itself may be constructed from any number of different materials. One option is plastic containers that can hold approximately 55 gallons. The local people have these readily available, and could construct a trough by cutting two of the containers in half and connecting the four halves together in a line. The trough should be at least partially underground to improve stability and durability. The trough should also be able to serve 5 – 6 cattle simultaneously.

- Trough
  - Potentially made from 55 gal. containers cut in half
  - Could also be made from concrete, plastic pools,etc.

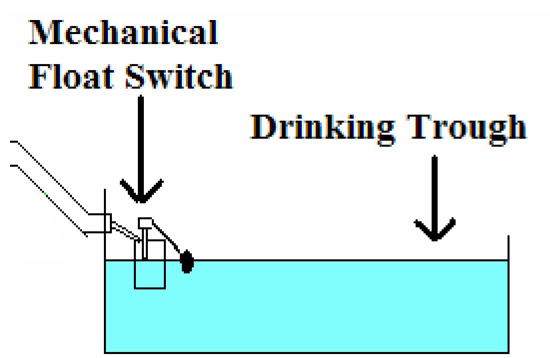

Figure 5: Drinking Trough with Mechanical Float Switch

Mechanical Float Switch

The drinking trough incorporates a float switch to regulate the flow of water from the tank into the trough. This float switch is the same mechanism as is found in toilets. There is a plastic float connected to a stopper. When the water level drops, the stopper unplugs the pipe coming from the storage tank and allows water to flow into the drinking trough. When the water level rises again, the float also rises and plugs the pipe. With this mechanism the cattle's water supply is replenished automatically. The design features a homemade float switch made from easy-to-obtain materials to illustrate the steps that should be taken when building the Bubbler in Panama. Designed specifically for the drinking trough, this float switch should remain unclogged for the lifetime of the entire system because of its isolation from the area where the cattle drink.

Figure 6: Mechanical Float Switch Design

Electrical Float Switch

There is also an electrical float switch incorporated into the storage tank. Wire from the solar panels powering the system runs from the panels to the float switch and then to the pump. When the water level in the storage tank rises, a float also rises. When the tank is full the float pulls apart the contacts in the switch and power to pump is cut. This is done to increase life expectancy of the pump and to avoid needlessly wasting water.

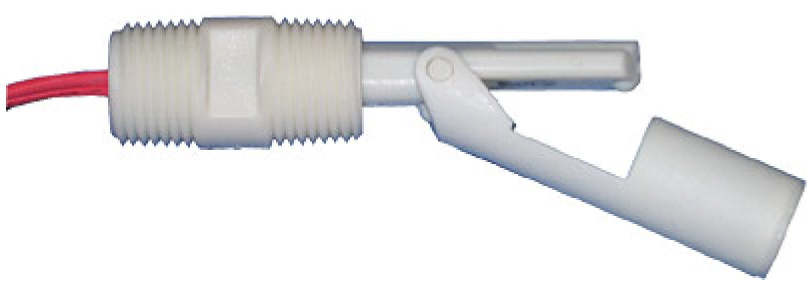

Figure 7: Electrical Float Switch (Omega Engineering, Inc., 13)

Benefits of Bovine Bubbler

The Bovine Bubbler is simple to build and easy to maintain. It is cost-effective and uses materials that are durable and easy to acquire. The system is built to last without constant monitoring and features a storage tank which allows for cattle to have water even when the pump is not running. The major benefits of the Bovine Bubbler are outlined below:

- The system requires minimal maintenance so it gives the local people as little extra work as possible
  - Filters are easy to change: simply snap out the old one and snap in the new one
  - Pump lasts 5-10 years with no need for any parts replacement, so the local people do not have to constantly buy new parts at an extra expense over the initial cost of the project
- Cattle's water supply replenished automatically
  - Storage tank makes sure there's always water in reserve, so even when there a few cloudy days, the cattle have plenty of water and the local people do not have to go to extra trouble to get the cattle water
  - Float switch refills trough when water level gets low, so the local people do not even have to keep track of the water in the trough. The system practically runs itself.

Recommended Next Steps

The client's original design request, that the system be modular and easily recreated in different places, is met by our design. Later in the design process, however, it became clear that the system should be as variable as possible and we have had to adjust certain aspects of our design to attempt to make the system adjustable. There is much more than can be done with this preliminary sketch of the design. We would recommend that the client take a second scoping trip to Panama to gather specific information about the site where the system is to be located. With the new information gathered, the client could consider performing the following tasks to improve the design:

- **Look** into wind as a source of power for the system. It may change the pump used as well as potentially the capacity of the storage tank. It may also affect the size of the piping from the pump to the tank.
- **Consider** a centralized trough system so that multiple pastures can make use of a single system to save on cost and replacement parts.
- **Consider** more cost-effective solutions and change our estimations of costs into exact figures based on the availability of materials in Panama and further research into alternatives.
- **Find** more local resources from Panama to use for the system on the scoping trip to save on costs and shipping hassles.
- **Consider** alternative methods of putting the system together which would save time and money and have more clear directions for the construction of the design.
- **Perform** Safety testing and consider reducing the number of potential problems with the design using Failure Mode Analysis. The Failure Mode Analysis currently notes the possibility that pieces of design may fall apart, rough measurements of the concrete storage tank including thickness, construction and design, and an overall lack of specifications for building because of the lack of specific information about the location of the system placement.
- **Test** the sustainability of each section of the design. Because we are unable to test the system, we cannot be sure of its durability over time and do not want the system to be installed only to find that it will break down shortly thereafter.
- **Translate** the Instruction Manual into Spanish for the locals to read.

Conclusion

To summarize, our design meets all of the requirements set forth for the system. The Dankoff pump is capable of providing plenty of water for the cattle and the filter system keeps the pump running smoothly. The storage tank can hold a three-day reserve supply of water for the cattle, so even in cloudy conditions the cattle do not run out of water. Our mechanical float switch keeps the drinking trough full of water so it is never difficult for the cows to get to the water, and our electrical float switch prevents the system from overflowing.

The Bovine Bubbler is simple to build, even for people with no experience in construction. It should take no more than a few days to build and cost no more than $1500. The Bubbler is durable and nearly maintenance free, requiring only filter replacement every few weeks. Our system is a simple, effective substitute for direct cattle access to the stream and fulfills both the hydration needs of the cattle and the sustainability needs of the residents, while providing the townspeople with the cleaner water that they desire.

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Expert Contacts:

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Brainstorming Meeting:

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Appendix A: Project Definition

Our team's project definition defines who the clients are, the mission of the project, the users and stakeholders and the constraints, requirements and specifications of the solution.

Project Name:	Sustainable Drinking Water Delivery System for Cattle
Client:	Aaron Greco
Team members:	Andrew Wien, Emily Gates, Edward Scott, Paul Han Team 1, Section 15
Date:	May 28th, 2006
Version:	Three

Mission Statement:

- To develop general guidelines for a sustainable system that enables cattle to drink water from a stream without polluting the stream or eroding the surrounding land.

Constraints:

- Must use power
- Cannot use more than 24 volts
- Cost needs to be minimized
- Built with local supplies
- Built by hand or with small machinery

Users and Stakeholders

Primary Users:
- Cattle of Santo Domingo
- People who raise the cattle

Other Stakeholders
- Our client, Aaron Greco
- The people of Santo Domingo
- The builders of our design

Requirements	**Specifications**
• Water requirements o Meets water needs of cattle	• Must supply 2667 liters per day • Pump delivers water at the minimum rate of 10.5 liters per minute
• Pump requirements	• Can pump up 25 vertical feet • Water must be filtered to 10 microns before entering the pump
• Piping	• Must withstand/be protected from ultraviolet radiation from the sun • Should be between ½ and ¾ inches in diameter to allow for the minimum flow rate
• Storage Tank o Provides enough water for cattle to drink in case of cloudy days	• Needs to hold at least 8 cubed meters of water (8000 liters) • Must be easily emptied for cleaning

• Drinking trough perimeter	• Minimum perimeter for 5 cattle to drink
	  o 5 feet for a circular trough
	  o 7.5 feet for a rectangular trough

• Power	• System cannot use more than 120 watts of power • Float switch cannot use any power
• Minimal maintenance	• Parts do not need to be replaced in the short run • Replacements or changes do not need to be made in less than one week intervals • Replacing parts (such as filters) require very little instruction
• Construction	• Cannot require any machinery • Requires minimal people and time to build

Table A.1: Requirements and Specifications for Design

Appendix B: Trough Requirements

This appendix outlines the trough requirements in terms of cattle drinking space, storage capacity, and available space. All of the information is summarized at the bottom of the page in the section marked “Summary”. The information outlined below was obtained through research into Water Requirements for Beef Cattle (10) and The Panama Solar Recharge Project (15). Calculations were performed by Andrew Wien and Edward Scott.

Cattle Drinking Space

The trough must have a large enough perimeter to allow for at least 5% of the cattle to drink at once. Each animal drinking space should be at least 20 inches in perimeter if the trough is circular and 30 inches if the edges are straight lines. We have a fifteen foot radius of available space to dig a trough, so room is not an issue.

Storage Capacity

The trough must have some reserve storage capacity. If not, we would have to provide two gal/min flow rate per available drinking space to ensure that water would always be available for cattle to drink. If we allow for as low as two drinking spaces, we would need to supply four gal/min, or 15 L/min, which is over the maximum flow rate for the selected pumps. So the trough must have some reserve capacity.

Each cow will drink no more than 7.5 liters per hour, so at least 340 liters of water must be replenished in an hour. Since our pumps can supply up to 780 liters per hour, we will only need 340 liters of reserve capacity.

Available Space

There is a small area of flat land located thirty feet from the stream where we can dig a trough. The circular area has a fifteen foot radius and is 25 vertical feet above the stream. See the diagram below

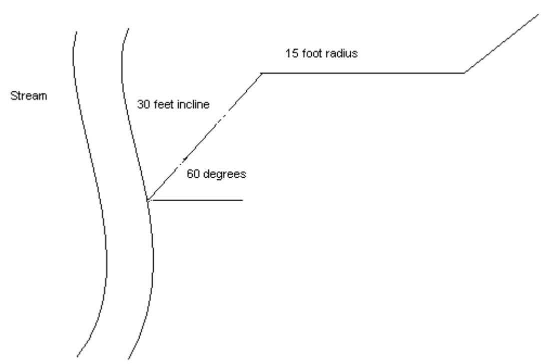


Figure A.1: Available Trough Area- Drawn by: Andrew Wien

Summary

- Minimum perimeter: At least 5 feet for a circular trough and 7.5 feet for a rectangular trough

- Minimum reserve capacity: 340 liters, or 0.34 meters cubed.
- Available space: A circle with radius of 15 feet and circumference of 95 feet

Appendix C: Climate Charts

This appendix contains information pertaining to the temperature and climate of the area and of Panama in general. These charts were used to determine which types of materials to use and the potential height of the stream during rainy/dry season. See Reference 1.

Month	Average Sunlight (hours)	Temperature				Discomfort from heat and humidity	Relative humidity		Average Precipitation (mm)	Wet Days (+0.25 mm)
		Average		Record						
		Min	Max	Min	Max		am	pm		
Jan	10	22	31	17	34	Extreme	88	84	25	4
Feb	9	22	32	18	35	Extreme	85	81	10	2
March	8	22	32	18	36	Extreme	81	78	18	1
April	7	23	31	18	36	Extreme	81	81	74	6
May	5	23	30	21	36	High	87	88	203	15
June	4	23	31	21	35	Extreme	90	90	213	16
July	5	23	31	19	35	Extreme	90	91	180	15
Aug	5	23	30	20	34	Extreme	90	91	201	15
Sept	5	23	29	20	34	High	91	91	208	16
Oct	5	23	29	20	35	High	90	92	257	18
Nov	5	23	29	19	34	High	91	92	259	18
Dec	7	23	31	19	34	Extreme	90	89	122	12

Table C.1: Temperature Chart for Balboa Heights Panama

The following bar chart shows the years average weather condition readings covering rain, average maximum daily temperature and average minimum temperature.

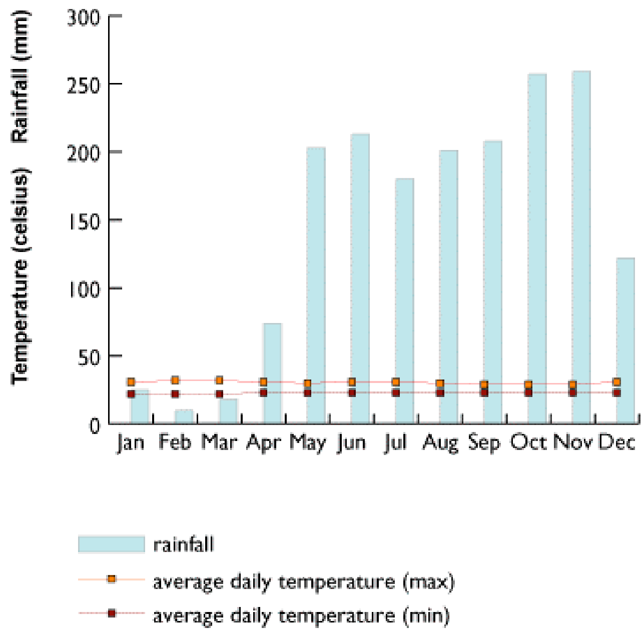


Figure C.1: Graph of Average Rain and Temperature in Panama

Appendix D: Brainstorming Ideas

Appendix D is the original list of ideas garnered from the brainstorming session held on April 11th 2006. The first page is the list of un-clustered ideas while the second page is the same list separated into groups based on the type of solution it is.

1. Pump Upstream
2. Trough Turbine
3. Settling Pond
4. Pre-Trough Water Storage
5. Support For Pipe
6. Multiple Troughs
7. Filter
8. Log Ride Trough
9. Self-Circulating Trough
10. Dual Pipes
11. V Filter
12. Underground Pipe
13. Bamboo Pipe
14. Suction Effect from Drain Pipe
15. Easy-Empty Trough
16. Elongated Trough
17. Rectangular Pipe
18. Sedimentation Trough
19. Water Circulation
20. Underground Drain
21. Float Switch

22. Separate Storage
23. Simple Pump ‘n’ Drink
24. Overfill Pipe
25. Mini-Stream

Water Circulation

2. Trough Turbine
8. Log Ride Trough
9. Self-Circulating Trough
10. Dual Pipes
19. Water Circulation
24. Overfill Pipe

Filtering System

3. Settling Pond
7. Filter
11. V Filter
18. Sedimentation Trough
19. Rectangular Pipes

Pumping System

1. Pump Upstream
12. Underground Pump
14. Suction Effect from Drain Pipe
20. Underground Drain

Pipes

5. Support for Pipe
13. Bamboo Pipe

Trough System

4. Pre-Trough

6. Multiple Troughs
15. Easy Empty Trough
16. Elongated Trough
21. Float Switch
22. Separate Storage
23. Simple Pump ‘n’ Drink
25. Mini-Stream

Appendix E: Alternatives Matrix

Appendix E is the alternatives matrix our team put together April 26th 2006 to outline our design options and to determine which areas needed more research to make an informed design decision.

Alternatives	**Pumps/Water Source**	**Sediment Removal**	**Piping Materials**	**Drains**	**Support Materials**
1	kyocera pump	settling pond	HDPE	Float Switch	mud
2	dankoff pump	homade cloth filter	CPVC	Safety Drain	concrete
3	rain water drainage	metal wiring	PVC		underground pipe
4		reusable filter	ABS		bamboo

Table E.1: Design Alternatives Matrix

Appendix F: Summary of Diego Rivera Interview (CEASPA Team)

Appendix F is a summary of the information received via teleconference between Diego Rivera and the IDEA 398 Team working on solar energy. The IDEA 398 Team is powering our system and the electric fences in the surrounding area. They interviewed Diego on May 1st 2006 and sent our team the information garnered.

Cattle/Drinking

- Cattle Rotation Method: the time spent at each subsection of the pasture varies from 7-20 days.
- There are approximately 45 cows in total.
- They drink 2-3 times a day, for about 3-4 minutes (each cow drinks about 10 L each time they go to the river)

Trough

- As of now, the cows drink water from the river in different locations, depending on what subsection of the pasture they're grazing at. Yet, according to Diego, a trough could be installed in a central location.
- The **plastic containers** that could be used as troughs hold 55 gallons. (16" – 16" – 22"). They are generally cut in half length-wise.

Regional Information

Flat Areas

- Most areas of the pasture are not flat. However, Diego says there are a couple of flat sections (~200m^2) about 80-100m from the river where the trough could be installed. He will send us pictures of these areas by next Monday.
- He first suggested installing the trough at the "corral", a flat region where the cows are vaccinated and washed.
- Water to wash the cows is brought up from the river with buckets.
- There is no problem with the corral getting dirtier from converting it into a the drinking station. Diego also suggestions we could fence off a separate small portion of the corral to install the trough.

River

- The fence charger is about 160-200m from the river.
- River water level changes from 1ft to 3ft during rainy season.
- River in mud is too sandy to be used as construction material.

Weather

- There is some strong wind (although not strong enough to blow down a tree)
- During rainy season, it rains ~ 4hrs per day, sometimes in the morning, other times in the afternoon.

Materials:

- Most houses in Santo Domingo are built of concrete. The small shack that houses the fence charger is built of wood (found in the area) and Metal sheets.
- There are small solar panels on top of a chapel that charge a battery which in turn is used to power some small light bulbs at night. Diego will find out the model and serial number this week.
- The angle of the roof of the shack that houses the fence charger is ~ 35degrees and faces west.
- Electrical wiring/supplies can generally be obtained in Panama city.
- Ranchers can easily clean/replace filter pumps when necessary (once a week)
- No detailed maps with elevations are available (that he knows of). There is an ongoing project to make one.

Appendix G: Pump Alternatives

Appendix G outlines the pump alternatives and the pumping specifications for each alternative. The information provided below was obtained from the pump brand's respective websites (References 2, 7).

A diaphragm pump will function better than other pumps. They require little maintenance, can handle limited dry pumping, and use a small amount of energy (Budhraja, 53). We are currently deciding between two diaphragm pumps (see table 2 below), both of which meet the following standards.

- Flow rate is at least 10.5 L/min in order to constantly supply the trough with enough water for cattle to drink
- The pump cannot require more than 24 volts to operate. The 398 team is designing a power source with that voltage, so we cannot exceed that limit.

	Kyocera SD 12-30	**Dankoff Slowpump 2507**
Price	700	$450
Flow Rate	13 L/min	14 L/min
Wattage Required	100 W	100 W
Voltage	12 to 30 volts	12 or 24 volts
Submersible?	yes	No, works on the surface of the water but was designed to work in streams
Debris toleration	Unknown at this point, but likely much more tolerable of dirt and debris	Not tolerant of dirt or debris over 10 microns

Table G.1:Kyocera compared to Dankoff
Information taken from Kyocera and Dankoff Websites (see Reference Section)

Appendix H: Cattle Information

Appendix H outlines the most pertinent information about cattle for our project. Information about the number of cattle and rotation methods was obtained from Diego Rivera (see Appendix F) and our client, Aaron Greco. The information about the drinking frequency and number of gallons needed is from Water Requirements for Beef Cattle (Reference 10).

	Liters a Day (L/day)	Liters per minute (L/min)
Avg. Water Requirement	1677	6.50
Max. Water Requirement	2669	10.35

Table H.1: Average and Maximum Daily Water Intake for Herd of Cattle (Buhara, 54 - Water requirements for Beef Cattle)

- Cattle Rotation Method: the time spent at each subsection of the pasture varies from 7-20 days.

- There are approximately 45 cows in total.

- They drink 2-3 times a day, for about 3-4 minutes (each cow drinks about 10 L each time they go to the river)

Appendix I: Pipe Alternatives

This appendix outlines general pipe information and the different alternatives available for piping in the Bubbler. For more information, see References 3, 4 and 6.

Materials used for drainage pipes include cast iron (CI), glass-fiber reinforced plastics (GRP), high density polyethylene (HDPE), concrete, asbestos, pitch fiber, PVC (polyvinyl chloride), CPVC (chlorinated polyvinyl chloride) and ABS (acrylonitrile butadiene styrene). Among these, plastic pipes (HDPE, PVC, CPVC, ABS) are the most popular types of pipes since they are much lighter and therefore easier to handle. The following are the basic information of each type of pipe:

- PVC is a white plastic pump that is typically used only for vents and drains

- ABS is a black plastic pump that is also typically used only for vents and drains

- CPVC is another rigid plastic used for hot and cold water supply lines because it can handle normal water pressure loads. Compared to copper lines, CPVC is lightweight, easy to work with, doesn't corrode and may be priced about 3/4ths less compared to other plastic pipes.

- HDPE is a type of plastic pipe that is light and strong against physical and chemical changes. It does not corrode, and its service life is from 50 to 100 years. Compared to PVC pipes, it is less prone to crack in cold weathers.

More specific information about plastic pipes can be obtained from Drainage Installations, Fitting Plastic Pipe, Introduction (See Reference Page)
Also, specific numbers for friction loss in pipes is obtained from the past report, Panama Solar Recharge Project, page 56. Friction loss data according to different pipe sizes and fitting sizes are in Appendix J.

Appendix J: Friction Loss from Pipe Size and Fitting Size

Appendix J is made up of two tables from the Panama Solar Recharge Project (see Reference 20). These tables outline the friction loss due to the flow through PVC piping.

FLOW IN LITERS PER MINUTE	NOMINAL PIPE SIZE LOSS IN METERS OF HEAD PER ONE METER OF PIPE					
	15.8 mm 1/2"	20.9 mm 3/4"	26.6 mm 1"	35.1 mm 1 1/4"	40.9 mm 1 1/2"	52.5 mm 2"
5	0.0058					
10	0.021	0.0053				
15	0.044	0.011				
20	0.076	0.019	0.0057			
25	0.11	0.029	0.0086			
30	0.16	0.041	0.012			
35	0.21	0.054	0.016			
40		0.069	0.021	0.0055		
45		0.086	0.026	0.0069		
50		0.1	0.031	0.0084		
60		0.14	0.043	0.012		
70		0.19	0.058	0.016	0.0073	
80			0.074	0.020	0.0093	
90			0.092	0.025	0.012	
100			0.11	0.030	0.014	0.0047
125			0.17	0.046	0.021	0.0071
150				0.064	0.030	0.010
175				0.085	0.040	0.013
200				0.11	0.051	0.017
225				0.14	0.064	0.021
250				0.17	0.077	0.026

Table J.1: Metric Friction Loss for SCH 40 PVC pipe in Equivalent Meters

TYPE OF FITTING AND APPLICATION	NOMINAL SIZE OF PIPE FITTING (NPT)					
	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"
	EQUIVALENT LENGTH OF PIPE (IN METERS)					
INSERT COUPLING	0.9	0.9	0.9	0.9	0.9	0.9
THREADED ADAPTER (PLASTIC TO THREAD)	0.9	0.9	0.9	0.9	0.9	0.9
90° STANDARD ELBOW	0.6	0.6	0.9	1.2	1.2	1.5
STANDARD TEE (STRAIGHT FLOW)	0.3	0.6	0.6	0.9	0.9	1.2
STANDARD TEE (90° FLOW)	1.2	1.5	1.8	2.1	2.4	3.3
GATE VALVE	0.3	0.3	0.3	0.3	0.6	0.6
SWING CHECK VALVE	1.5	2.1	2.7	3.7	4.0	5.2

Table J.2: Metric Friction Loss for Fittings in Equivalent Meters of Pipe

(Tables from Panama Solar Recharge Project, page 56)

Appendix K: Sediment Removal Research and Direction

This appendix shows the research on sediment removal and filters for the Dankoff 2507 pump. We eventually decided to go with the filters offered by the Dankoff Company because of compatibility and ease of use. For more information see References 2, 5 and 7.

Minimum Sediment Removal:

The Dankoff Slowpump 2507 cannot handle sediment larger than ten micrometers, so any filter must filter out particles over that amount.

Sedimentary Pool:

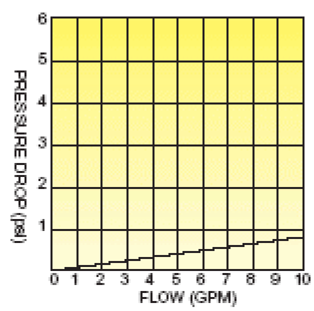
Our team decided that a settling pool will not work in Santo Domingo. There is not sufficient room to dig out a pool that will collect water by means of gravity. All settling pools would require a pump to get the water to them, defeating the purpose of the pool.

Information taken from meeting with Aaron Greco on Tuesday, April 25th

Filters:

Flowmax Filter Cartridges

- Are relatively cheap: price ranges from $8-$45 depending on the size of the pipe
- Removes sediment up to five micrometers
- Can be washed off and reused
- Flow rates range from 7-25 gpm



Flow-Max® cartridge (5 µ)

Figure K.1: Chart comparing Flow Rates and Pressure Drops for 5 µm filters

Filter Bags

- Made of a polypropylene fabric
- Designed to remove sediment from water
- This specially designed fabric will only filter .180 mm, which does not meet requirements
- We cannot use local fabrics as filters for the same reason. They will not remove enough sediment from the water.

Appendix L: Electric Float Switch Information

Appendix L outlines the information gathered about two of the electric float switch options. The specific brand of the float switch does not matter, as long as the basic function of turning off power to the pump exists in the product. The following are merely recommendations based on preliminary research into inexpensive electric float switches. For further information, see References 13 and 14.

LVH-200 Model from Omega Engineering, Inc.

“The OMEGA® LVH-200 single station horizontal level switch is cost effective for level control applications in small tanks where it is more convenient to install a level switch through the sidewall of the tank. When the float arm is raised to the switch housing, the switch is activated. As the float drops away from the housing, it is deactivated. The movement of the float brings the imbedded magnet into close proximity to the encapsulated reed switch, causing it to actuate. The contact function may be selected as either normally open or normally closed. When triggering inductive or capacitive loads, use the LVH-200 with external solid state relays.” (Omega, 13)

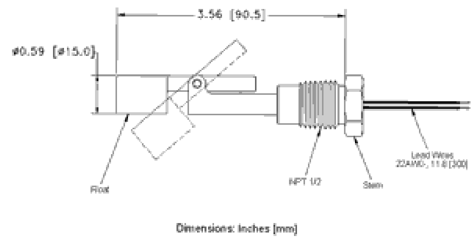
“**SPECIFICATIONS**

Accuracy: ±5 mm in water
Repeatability: ±2 mm in water
Reed Type: dry contact, SPST
Thread NPT: 1/2"
Length, Overall: 114 mm (4.5")
Float Diameter: 18 mm (0.70")
Max. Temperature: -40 to 107 Degrees C (-40 to 225 Degrees F)
Cable: 60 cm (2'), 2 wire 22 gauge
Max. Pressure Rating: 100 psi
Min. Sp. Gravity Liquid: 0.55
Max. Switching Current: 20 VA @ 120 Vac (CE: 30 Vrms and 42.2 Vpeak or 60 Vdc)
Signal Output: Dry switch closure, selectable NO or NC states
Orientation: Horizontal” (Omega, 13)

"These industrially recognized plastics are an economic choice for general use. Ideal for replacement parts or configured for OEM applications. Easily installed for both Normally Open (NO) or Normally Closed (NC) operation."

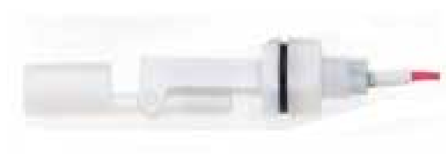
"FH07-0000

Polypropylene Side Mounted Switch
With ½" NPT pipe threads



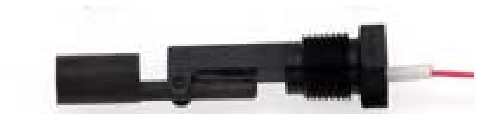
FH07-0001

Polypropylene Side Mounted Switch
with PF1/4 threads for Bulkhead
mounting in ½" through-hole



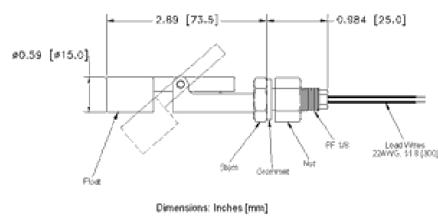
FH08-0000

Nylon-6 Side Mounted Switch
With ½" NPT pipe threads



FH08-0001

Nylon-6 Side Mounted Switch
with PF1/4 threads for
Bulkhead
mounting in ½" through-hole"



Part Number	Switch Type	Maximum Switching Current	Maximum Switching Voltage	Maximum Temperature	Maximum Pressure	Specific Gravity
FH07-0000	50 watt	.5 Amps	250 VDC	90 C	25 psig	.70
FH07-0001	50 watt	.5 Amps	250 VDC	90 C	25 psig	.70
FH08-0000	50 watt	.5 Amps	250 VDC	120 C	25 psig	.70
FH08-0001	50 watt	.5 Amps	250 VDC	120 C	25 psig	.70

Figure L.1: Table of Current/Voltage/Temperature/Pressure Information for Switch Types

"Notes:

- All reed switches are UL rated for resistive loads, consult application notes for reed switch load considerations" (Strain Management Devices, 14)