Portable Cattle Watering System

Senior Project Report

For:
Professor Vijaya Raghavan
ABEN-495

By:
Alexander Maclaren
110142494

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McGill

Executive Summary

The purpose of this project was to design a portable watering system. This system is to meet the daily water requirements of a 200 cow-calf herd of beef animals. It has to be easily portable from pasture to pasture. This system is to be used on the Ducks Unlimited demonstration site in Lefeive, Ontario where Rodney Maclaren pastures some of his beef herd during the summer months.

The environmental effects of having cattle drinking directly from water sources are very negative. Not only is the aquatic environment of these water sources damaged, but also animal’s health gets affected. Certain studies on these effects are reviewed and discussed in this design project.

There are many types of stationary cattle watering systems on the market. The most popular ones were considered. It was determined that a solar powered battery backup system would be best suited for this situation. In the final design a solar powered pumping system is to be mounted onto a steel wagon that includes a large water reservoir and two water troughs mounted to it. The system will also include an electric fence system to help keep animals out of the water sources.

With the increasing environmental regulation against cattle having direct access to water sources, a system like this one will be a must for some future operations. As for now the estimate of weight gain of the animals using this system considered. The payback period for the estimated cost of $10 736.00 for this system will be 8.5 years with a 200 head cow-calf herd using the proposed system.

Acknowledgements

I would like to thank the many individuals for their help throughout the completion of this project. First I would like to thank my father Rodney Maclaren for giving me the idea for this project. Secondly, I would like to thank Sylvain Lepage for the many ideas and help that lead to the final design. I also would like to thank Dr. E. McKyes for his guidance throughout the initial proposal part of this project and finally Dr. V. Raghavan for his guidance during the final design of this project.

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Introduction

Water is an essential nutrient for livestock production. Clean quality water is not only important for human consumption and use, it is also important to supply grazing animals with it for their needs. Studies by W. Willms et al., 2002, show the direct relationship between water quality and cattle weight gains. The better the quality of the water, the more the animals drink and eat which means the more weight or milk they produce.

In many operations, livestock kept in pastures drink directly out of the water body within it. This water source could be a dugout, pond, creek, lake, river, etc. Studies have shown that allowing animals to directly access water sources can severely change the physical and biological conditions of the water source, (Line, 2003). These altered conditions lead to reduced water qualities that in turn reduce the cattle's performance. Not only is the water quality reduced for cattle consumption, the downstream water quality is also reduced. Today environmentalists are actively trying to reduce water access by cattle. This movement was recently increased when Walkerton, Ontario had an E. Coli outbreak in their town's drinking water. After the investigation into it, the media reported that a possible source of the E. Coli water contamination came from an upstream farm where there was a large amount of cattle manure run off leaching into the water source. Even though this was an unordinary case, the generally public now sees that cattle and water access as a deadly thing.

In order to prevent cattle from directly accessing water sources, non- direct cattle watering systems have to be set up. Many different types of non-direct stationary cattle watering systems are available on the market today. Factors like budgets, locations and the type of water source determine which one of these systems will work for a specific operation.

The problem with a stationary watering system is that it can only be set up in one location. In large cattle grazing operations, like Maclaren Farms in Eastern Ontario, cattle rotate from pasture to pasture over the grazing season. If a watering system is located in one specific spot, the cattle have to go back to this watering area to drink each time. With a herd of 200 cow-calf pairs grazing 50 to 100 acres size fields all in a 1200 acres block of land, having one stationary watering site would be very impractical. To over come this, there would have to be a number of stationary systems set up through out the various pastures. Having numerous stationary systems would be costly and require a lot of maintance. To solve this problem a portable cattle watering system will be designed. It should have provision to be pulled from pasture to pasture, be fast to take down and set up. By having this portable system, cattle performance will hopefully increase and decrease damage to the water sources.

Literature Review

Direct Watering Problems

Cattle are extremely hard on the environment surrounding water sources. They tend to overgraze the forages around the water edges. This leads to a reduced root structure system to hold the soil intact, so the cattle's sharp hooves are then able to easily puncture through the root structure and cause the soil to erode. Figure 1 shows a good example of this along the South Nation River near Plantagenet, Ontario.

Figure 1: Damaging effects of direct cattle watering access

Allowing cattle to directly access the water source leads to increased bacteria and nutrients in the water from their urine and manure. Increased levels of phosphorus, nitrogen from soil erosion and phosphorus from the animal manure promote the growth of algae. This leads to the degrading of the aquatic habitats especially the fish (McCormack, 1998).

Cattle health is at greater risk when they drink directly from the water source. They can be exposed to water-transmitted diseases, bacteria, virus and cyst infections, along with the toxins from blue green algae. There is a greater chance that the animal may obtain foot rot and/or leg injuries. Possible death due to drowning or getting stuck in the mud could occur. These factors all lead to increased stress on the animals, which directly lead to reduced weight gains.

Benefits of Non-Direct Watering Systems

Having a non-direct watering system will keep the cattle out of the water source if it is fenced off or it will greatly reduce the amount of time the animals spend in and around the water source. A study by Sheffield et al. (1997) found that having a water trough installed in the field had a significant reduction in the amount of time the animals spend around the water source edge (stream bank). Although the animals still had complete access to the water source, the study showed that there was an 81% reduction in the time the cattle spent drinking from the stream and a 53% reduction in the amount of time they spent in the area along the stream bank.

By keeping the animals out of the water or reducing the amount of time they spend in it, there will be an improvement in their health and a reduction in stress which will in turn result in greater weight gains and/or milk production. Figure 2 shows a beef cow that has wondered into a water source. Her legs and udder are completely covered in mud. She probably was almost stuck in the mud and had to use a lot of her energy to get out of it. This is energy that should have gone into milk and/or weight gain. The calf nursing on her here has to deal with an udder covered in mud along with possible bacteria and parasites from the water source that may be on it. All these factors increase the stress levels for the cow calf pair which leads to reduction in profit level due to lesser weight gains. With a non-direct watering system, these factors can be avoided.

Figure 2: Nursing beef cow covered in mud from the water source.

Types of Stationary Watering Systems

There are numerous types of stationary non-direct watering systems on the market today. Many of the provinces or states in North America that contain cattle grazing operations have documented literature about pasture watering systems for livestock on their government's agriculture web site. The problem is that there is no system that is suited to operating everywhere. The varying operation conditions, budgets, topography and type of water source in each livestock operation, will determine which kind of system is suited for the specific operation. The Alberta Government of Agriculture, Food and Rural Development has a good fact sheet (agdex644) out about some of these types of systems. The following are a few of the different types of stationary systems that could be incorporated into a portable system.

Animal operated pasture pumps

These pasture pumps are commonly called nose pumps because cattle operate them by pushing them with their noses (Figure 3). The pump provides a very low cost (i.e., \$10/cow-calf pair) pumping system and is good for about 30 to 40 cow-calf pairs.

Figure 3: Animal operated nose pump

Nose pumps supply approximately 1 litre of water for every stroke of the nose device. The pumps can lift water from a maximum of 20 vertical feet. These pasture pumps are very reliable and easy to move from pasture to pasture. However, the cattle will take a day or so to learn how to operate the pump. The herd manager for Maclaren Farms at the Duck Unlimited cattle watering demonstration site in Lefieve, Ontario found that if the cattle had access to an open water source, they would drink from it instead of using the nose pump. This type of system would not work as a portable system on to supply 200 calf pairs due since there would be several units required and that the set may be near an accessible water source.

Wind Power Pumps

Wind can pump water in one of three ways. It can produce electric energy by turning a turbine to run an electric water pump, by rotating a wind propeller linked directly to a water pumping unit or the wind can turn the shaft of an air-compressor unit that power a compressed air pumping system. All of these system work well as long as they are in an area where there is enough wind velocity to power them. In a portable system the set up location is not always known. It could be easily protected from the wind. So using wind power as the primary pumping source would not be very reliable. The only way to incorporate wind into a portable system is to use it to charge a battery backup system in windy locations.

Gas-power water pumps

Figure 4: Gas-powered electric generator used to run an electric water pump.

Gas-powered pumping systems are a low cost alternative for pumping water to larger herds of livestock. There are two types of gas-powered systems. One is where a gas motor directly powers a water pump. The other is where a gas-powered generator is used to run an electric water pump (Figure 4). They both work well in combination with an elevated reservoir system, containing enough storage for a few days. The pumps are very portable and can be moved easily from one water source to the next. These systems can be automated to start on a float switch device located in a stock tank or reservoir. One advantage of this type of system is that both pumps and generators can be used for other purposes on the farm. The problem with this type of system is that it requires manual labour to haul in gas and to manually run the pumping systems. During the busy cropping season, the herd manager my not have enough available time to do this.

Solar-Powered Water Pumping

Solar-powered water pumping has been around for a few decades. Newer technology has improved it and made the solar-power option more affordable. A lot of research has gone into developing systems for small rural household. These same systems are suitable to pump water to livestock. Agriculture and Agri-Food Canada has

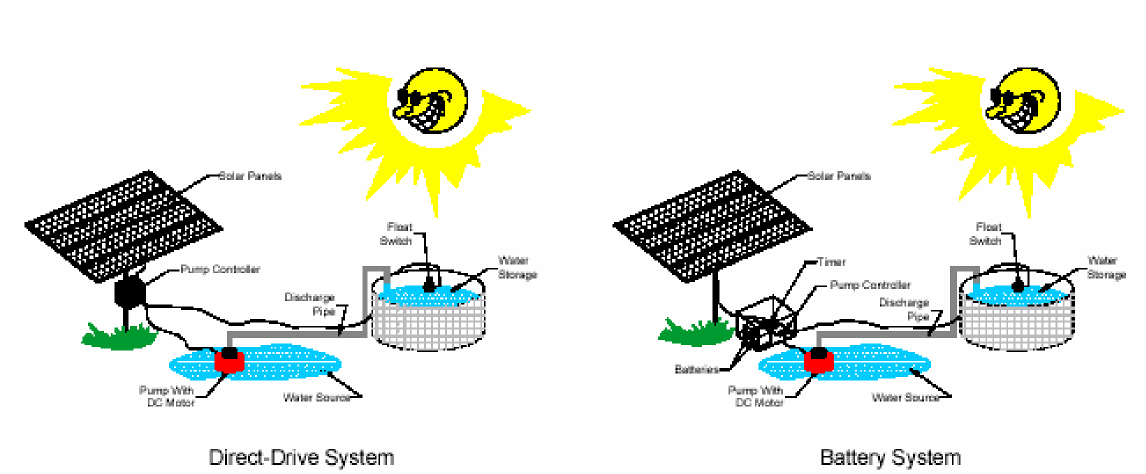


Figure 5: Two types of solar powered systems.

a well-written fact sheet about using solar-powered water pumping systems to water livestock on their web site. It explains that a solar-power system can be set up in one of two ways, a direct-drive system or a battery system as shown in Figure 5. A direct-drive system has a solar panel connected directly to a dc-powered water pump. The pump is turned on and off with a float control switch in the reservoir tank. The problem with this set up is the continuity because there may not be enough sunlight at times when there is a demand for water. The other system overcomes this factor by incorporating a battery back up system within it. The solar panels here are used to keep the batteries fully charged. In this system the water pump can run when ever there is not enough sunlight to power the panels as long as the battery is fully charged. If a watering system had large enough water reservoir to supply the cattle of their needs during the low light periods, a direct-drive system would be suitable. Otherwise the solar-power watering system should have large enough of a battery capacity to supply the animals with water during the low light periods.

Design Objective and Method

In order to supply 200 cow-calf pairs with water while they rotate from pasture to pasture on the Duck Unlimited Canada Atocas Creek conservation site, a portable watering system must be developed. By developing and using this system, the many ponds and creeks in this cattle grazing area will have reduced or it will have no more animal access. This will improve animal health within the herd and protect the aquatic environment.

Figure 6: Possible wagon to set up portable system on.

This system must be easy to move from pasture to pasture and fast to set up. Due to the rolling terrain of the land careful consideration is required for the type of wagon or trailer that is going to be used to transport this system from site to site. The wagon shown in Figure 6 is a 10- ton wagon that is going to be considered for this task. It will contain on it every thing that is needed for the portable system to work.

Figure 7: Stationary Solar-Powered and Wind Powered watering site

Figure 7 shows a current stationary solar-powered and wind powered watering site on the Ducks Unlimited Site. The main objective of this project is to take a stationary site like this one and develop it into a portable system.

The designed system must be able to supply enough water to the grazing animals at all times. The selected pump must overcome the variable elevation heads that are going to change from site to site and the friction head loss that is going to occur in the selected pipe size. This means that careful calculations must me made to make sure that the proper pump and pipe transfer system is selected.

Design

As mentioned, above the main concept behind this design is to take the stationary wind and solar powered cattle-watering site shown in Figure 7 and make it portable. Since this project may be able to use some of the parts from this existing system, this design will focus on the possibility of using these parts and how to improve this system to meet the needs of 200 cow- calf pairs. The first step in this design will look at pumping, water requirements and storage requirements for this project. After this the power requirements for the system will be determined. Followed by the wagon design to mount all of the system components on to.

Pump selection

In order to make this design easy to handle and move from water source to water source a floating submersible pump is to be used. One currently popular brand on the market is the made by Sunmotor International Ltd. They have been manufacturing D.C. powered water pumps for years. On their web site http://www.sunpump.com they have so good customer testimonials about their product. For this reason and also that I have personally used this pump and have access to one owned by Ducks Unlimited Canada.

The system design will be based on this pump. Appendix A contains all of the Specifications for this pump that are going to be used for the design.

Cattle Water Requirements

This design is to supply a 200 cow-calf pair during the pasture grazing months of the year, April-October. According to the Water Management Guide: For Livestock Production cow-calf water requirements are around 67- 135 litres per day. This requirement will vary depending on temperature and humidity and size of animal. Since this system is being designed for a red-angus cross type of beef animal that are a medium size animal they will not require the higher value. A more realistic value that I will design will beat the lower range around *70 litres per day*. This value is closer to what other sources state like the pump manufactures and facts sheets from the University of Nebraska.

In studies on cow watering habits, by myself and the farmer managers' observations, cows tends to drink about 4- 6 times a day. Therefore in order to supply the whole herd at once, the tank reservoir must be equal to the total herds daily consumption rate/ 4 drinking times per day. The Water Management Guide: For Livestock Production also recommend that this reservoir must have a refill time of about 1-2 hours on hot days.

Minimum Tank Reservoir tank size calculation

70 liters /day/animal x 200 animals / 4 **= 3500 liter reservoir**. (approx **1000 us gallon**)

Reservoir Tank Selection

Since this reservoir has to be lightweight and portable, a plastic style tank is the only option. There are a number of different styles of plastic tanks on the market. Diverse Plastic Tanks Inc. have a good selection of plastic tanks that could be used for this purpose and can be seen on their website, www.plastictanks.ca. They have two model types that could suit this design. One type is called the "Horizontal Leg Tank".. The closest size they have to my minimum volume requirement is 1200 US gallons. It measures 55'' in Diameter and is 125'' long and costs $2250 Canadian. Another tank style is the "Commercial Grade Vertical Tank". In this style the shortest tank that will suit my volume requirement is 1100 US gallons model measuring 57" height with an 86'' diameter costing $890 Candian. Since the height difference between the two tanks is only a 2'' difference, the height factor for the pumping head does not have to be considered therefore the price is the deciding factor. Therefore I will use the 1100 US gallon commercial grade Vertical tank in this design.

Maximum Total Pumping Requirements and Calculations

One of the largest factors to consider here is the total pumping head that the pump has to overcome. Since this is a floating submersible pump that goes directly in the reservoir there are only two major factors to the pumping head. One is the line loss and the other is the actual elevation difference between the pump in the water source and inlet at the top of the tank. Appendix A shows tables for the amount of friction loss in 1", 1.5" and 2" plastic pipe sizes. What is shown here is that there is significant amount of line losses for the small diameter pipes in the higher flow rates. Since this design is going to require a high flow rate of around 50 to 75 l/m. This design will have to use a 2'' pipe to minimize the friction loss in the line.

The maximum total elevation difference between the top of the reservoir tank and the pump will be a total elevation head of 6 meters (20 feet). This number comes from a total tank height of 57" sitting on a wagon height of approx 24'' totalling approximately 7 feet leaving a 13 foot drop for the ground level at the wagon to the water source. At the location that this system is being designed for the maximum elevation difference between the wagon ground level and water source level is approx 10 feet therefore there is a 3-foot safety factor.

Sample Calculations used in Friction loss Tables in Appendix A

Velocity, v (m/s) = flow/pipe area., pipe diameter 2'' =0.05m

For a flow of 75 l/minute x 1 m^3 /1000 l x 1 minute/ 60 seconds = 0 .00125m^3/s

0.00125m^3/s /(0. 05^2 * Π /4)m^2 = **0.637 m/s = v**

Reynolds number, Re= Velocity X diameter/ Kinematic viscosity = vd/ ν

Kinematictic viscosity of water @ 10°C = 1.3088 x 10^{-6} m^2/s = ν

Re = 0.637 m/s x 0.05m / 1.3088 x 10^{-6} m^2/s = **24335**

Friction factor, f is found from the moody diagram.

For Re = 24 335 and smooth pipe roughness = 0.0025 **f = .025**

Total friction loss in line hL (m) = 4fLv^2/(d2g), L= line length = 30m, g = 9.81m/s **hL**= .025*30/0.05*0.637^2/(2*9.81) = **1.24 m**

Total elevation difference between water source and top of tank reservoir = **6m**

Maximum total Head for pump to overcome with a 2” pipe and a 6m elevation difference between the pump and the tank inlet **= 7.24m, 23.7 feet**.

Pumping Volume Check to Recommended Refill Time Requirements

According to the data just found with a maximum pumping head is 0.31 meters. The M-20 pump will supply about 50 litres per minute with 24 volts D.C. and 70 litres per minute with 30 volts of power supply according to the pump curve for the 2’’ pipe in Appendix A.

*Calculations for 24 volts (4 * 6 volt battery back-up system)*

Q= 50 litres / min. Time to fill reservoir = 4160 l / 50 l/min = **83.2 mins.**

Total daily pumping time to meet cattle’s daily needs = 200 cows * 70 litres/day / 50 l/m = 280 pumping minutes per day = **4.7 hours per day**

Therefore both voltage-pumping systems meet the recommended reservoir refill time of approx 1-2 hours on hot days. Since this will have a battery back-up, it will be designed for a 24- volt system.

Power Calculations

This design system will have two sources requiring power. One is the pump as discussed above and the other is an electric fence charger. The following calculations will determine the daily power requirements for the whole system.

Maximum Daily Power Requirement for 24-volt System:

Pumping operating for 4.7 hours / day, pumping 50 liters/min drawing 5.4 amps. (As per pump manufacture specs in appendix A)

Total daily pump power requirement = 4.7 hours * 5.4 amps = **25.38 amp hours**

Daily Power Requirement for 24-volt System Electric fence Charger:

For this design, a large enough battery operated electric fence charger. It can power the surrounding fences. One brand that Maclaren Farm's currently uses is "Speedrite" model Viper 5000. This model will power up to 50 km of fence. According to the manufactures brochure in Appendix B, this unit consumes between 300mA and 600ma of current. For this design I will use the maximum rate of 600 mA to be safe.

Daily Electric Fence Power use = 0.6 amps * 24 hours = **14.4 amp hours**

Maximum Daily Total System Power Requirement= 25.4 + 14.4 = **39.8 amp hours**

System Battery Sizing

Deep cycle batteries are rated by there voltage and amp hours they contain. Deep-Cycle batteries should never be fully discharged. Fully discharging a deep cycle battery will cause plate damage and will significantly reduce the life of the battery. Most battery manufactures recommend discharging only to about 60 to 80 % of their rated capacity.

To determine the number of batteries need and size, the following formula is used:

# of battery amp-hours needed = daily amp hours of system * # of continuous cloudy days in a row / maximum discharge level * battery temperature multiplier.

For this design, the maximum number of cloudy days will be 4, the battery discharge rate will be 80% and the battery temperature multiplier will be 1.11 to take in to effect to the colder days at the beginning of the grazing period. This value and the formula can be found @ www.solar4power.com.

# of battery amp-hours needed = 39.8 amp hours * 4 days / .8 *1.11 **= 220 amp-hours**

Now that the amp-hours is known, a battery or combination of batteries must be chosen to obtain this value for a 24- volt system. For this design I will use **4 – 6 volt** Trojan 105 deep cycle batteries rated at 225 amp-hours each. This combination connected together in series will give **24 volts with 225 amp hours.** (Note: battery amp hours only accumulate when they are connected together in parallel.) Voltage accumulates when they are connected together in series. (See Figure 8)

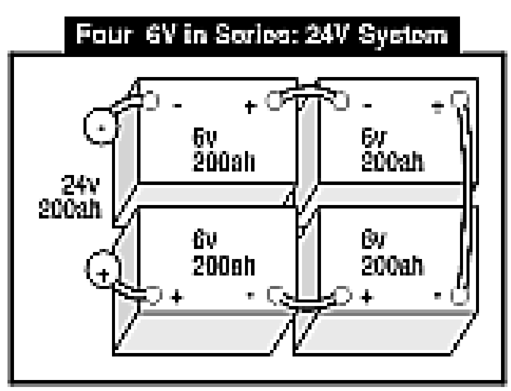


Figure 8: 4-6 V batteries in series

Charging the system

To charge this system I will look at using photovoltaic cells, a windmill or a combination of both. Currently there are two 50 -watt Kycorea photovoltaic panels and one Rutland 913 windmill available to power this system. Due to the fact that they are available I will use the data given by the manufacturers (Appendix C) to determine if they can power this system.

Solar power option:

The following worksheet was found at a Solar4Power website www.solar4power.com. It has a very easy step by step procedure to help determine the number of photovoltaic panels that is required for a system. Using the data determined above and the manufacturer specification for the Kyocera KC50 photovoltaic modules (Appendix C). The following information is generated:

1. Total amp hours per day from the System Loads	39.4
2. Multiply line 1 by 1.2 to compensate for loss from battery charge/discharge.	47.28
3. Average sun hours per day in your area.	8
4. Divide line 2 by line 3. This is the total solar array amps required.	5.9
5. Optimum or peak amps of solar module used. See module specifications.	3.0
6. Total number of solar modules in parallel required. Divide line 4 by 5.	1.97
7. Round off to the next highest whole number.	2
8. Number of modules in each series string to provide DC Battery voltage:	2

DC Battery Voltage # of Modules in Each Series String

12	1
24	2
48	4

9. Total number of solar modules required. Multiply line 7 by 8. 4

This means that if solar panels are going to be the only power source, four Kyocera KC50 modules will be needed, connected together in series and parallel to meet the power requirement. The only other option is to use two higher power panels that have at least 5.9 amp of rated maximum output power together in series. When it comes down to the difference in costs between four smaller modules or two larger ones they are about the same according to the prices found @ www.wholesalesolar.com/solar-panels. The only consideration will be that if the smaller panels are used more mounting space will be needed.

Windmill Option:

Windmill power output is dependent upon wind speed. The placement of a windmill can determine how much wind it can receive. Geographic location, height of windmill and surrounding obstacles will determine how much wind a windmill is to receive. According to the Canadian government website http://collections.ic.gc.ca/stlauren/environ/en_clima.htm, the geographic area that this

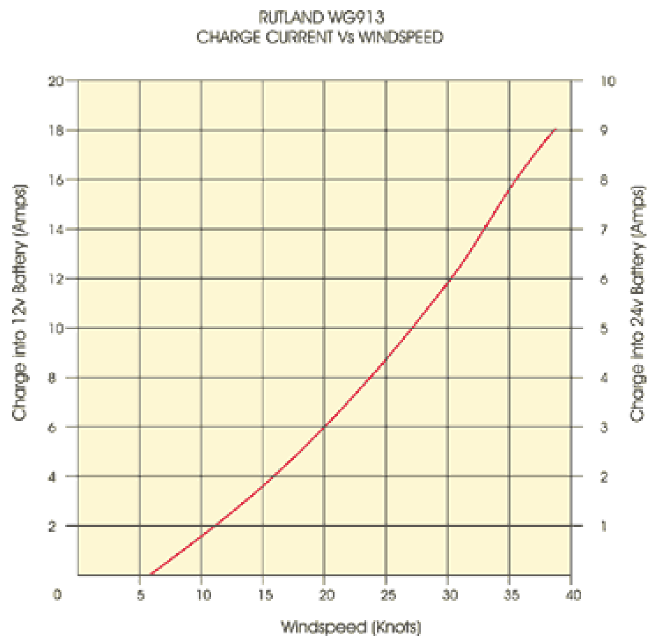


Figure 9: Rultland 913 charging curve
www.marlec.co.uk

system is being designed for has a yearly average wind speed of about 4.2 m/s (8 knots, 15 km/h). With this value and making the assumption that this wind mill will be mounted high enough so that there will not be any wind interference from other obstacles, the daily power output can be determined using the data from Figure 9.

Daily power output = 0.75 amps * 24 hours = **18 amp hours per day.**

This value is a conservative one, but it is safe. In order to supply this system the average daily wind speed would have to be around 8m/s (15 knots, 28 km/hr) to obtain required average of the require of 39.8 amp hours per day with battery system back-up good for 4 days without wind. Therefore this size of windmill alone is not enough to run/charge the whole system. It would probably be all right to run just the electric fence system or water for a much smaller herd of cattle.

Combination of both systems:

If the two types of systems are combined, the wind mill would definitely help the solar panels charge the batteries on the cloudy days, on these days chances are that the wind speed would be high enough to provide enough of a charge to make up for one set of panels (2 –50w in series) to provide enough charge. The problem with the combination would be as follows:

- On sunny and windy days, both systems would charge up the batteries very fast. Then once the batteries are charged, both systems would be shut off by the charge controller making the rest of there charging time useless.
- Cost of Rutland 913 windmill and its charge controller is around $2000.00 that has only a 2- year warranty. Also the maintenance on the windmill would be high

since the brushes in its generator tend to wear out ever two years. The cost to replace this system with solar panels with 20-year maintenance free warranty would be much cheaper. Two 50 Watt panels costing approximately $450.00 Canadian. This amount is more than half the windmill cost.

Considering the above facts, the combination of both charging systems is not the best scenario for the design location. The preferred more reliable option will be to go with the solar power only option.

Combination of System into a Portable Unit

In order to make this system into one easily portable unit, everything is to be placed on a custom-built wagon rack that will sit on any standard farm 8 -ton wagon frame. The material options that are available to build this rack are wood and steel. After discussing the two options with farm manager, He and I determined that steel would be

Figure 10: **Hay Wagon**

the preferred material due to the extra durability and life expectancy it has. Therefore this design concept will be similar to the basic steel flat rack hay wagon seen in Figure 10. This wagon frame consists of two 9x3, 20’ long square steel tubes as the main support beams with 3x2, 8’ long square tubes spaced about 24’ apart, centre to centre, welded onto the main supports. This tubing on top is covered with ¾’ expanded metal top to make up the floor. Due to the fact that I need to get the same elevation to get the top deck over the wagon wheels, I will use the same steel dimensions in my design. Also since the expanded metal comes in 4' x 8' sheets the upper floor support beams will have to be spaced also 24" apart so the edges of the expanded metal sheets can be welded and have minimal material waste.

My original idea for a water trough was to use a fairly large one. It would be either towed in behind or emptied and lifted on to the wagon when moving between sites. When discussing this concept with the farm manager he suggested that water troughs could be built right into the sides of the wagon, making it easy to move. He also suggested using a furnace oil tank, since he had just made a water trough out of one and it was very inexpensive. With these idea's the following design was put together.

Frame Decking Layout

In order to design the frame, I used AutoCAD to draw the basic wagon set-up. I first started with the 16' by 10' box and drew in the main frame beams and cross beams to represent the wagon deck, I then placed the wagon under it to determine where the wheels would be, after this I placed my water tank and water troughs. After doing this I concluded that I only needed 8' wide wagon, so I adjusted the drawing. Drawing #1 in Appendix D shows this layout in the top view. After I had determined the lay out I then made the fabrication drawings for the frame deck shown in drawing # 2, Appendix D. Following this drawing in the same appendix is the fabrication drawing for each water trough and frame to weld onto the mainframe beams.

Beam Size Analysis

Since this design was based on a steel wagon which was already designed for similar loads, I did a basic loading and beam analysis to make sure that the material would be sufficient for the job. Since the basic steel dimensions were already set, the only changes that could be made are with the thickness of the material. The basic calculations for this are shown in Appendix E.

When I looked into getting the steel prices for this project. I was told by my supplier that he was unable to get the 9 x 3 square tubing for the main beams, so he suggested that I use 9 x 3 channel. With this information I re-adjusted my calculations for this material.

Final System Layout

When all of the major parts mentioned above are put together, there were some other minor system parts to consider. One is the water distribution to the side tanks. Another is the wiring and controllers needed for the system. And finally the battery box and electric fence storage box.

For the water distribution and the two side water troughs, the layout will consist of the following.

- The main outlet of the large water tank is of 2” diameter. It will face towards the back of the wagon and be plumbed with the following pieces in order. 2” to 1” reducer, 1” gate valve, 1” threaded to barbed fitting, short piece of 1” hose, 1- 1” tee adapter, 2 lengths of 1” hose each going to a side tanks, and finally a float valve mounted at the top of each tank.

For the wiring of the system the following items are needed.

- 100’ of pump power cable to go from the pump to the control box (comes with pump).
- Float control switch and wire to go from storage tank to control box (comes with pump). This switch will turn off the pump when the reservoir tank is full.
- Main power switch to turn off complete system.
- Approximately 70 ‘ of 12 awg size electrical wires and various connectors to connect solar panels together and bring their power to the batteries panels.
- Charge controller, 24 V/16 amps, to place between the solar panels and the batteries to prevent overcharging.
- Approximately 3’ of 2 awg size wire and connectors to connect to batteries together in series.

The battery box and electric fence box will be made out of 1’’ thick plywood. It will be custom made to fit all of the switches, charge controllers and batteries together in a neat organized manner. Also this box will contain enough space to place the electric fence charger and various electric fence parts in to box. It will be mounted towards the back of the wagon as seen in drawing #1 in Appendix D.

Costs Analysis

The following table shows the total costs to build this system. The new costs column shows the costs if this complete system to be built with all new material. The current column shows the extra costs that will be acquired if the current stationary system in use is to be modified into this designed portable system.

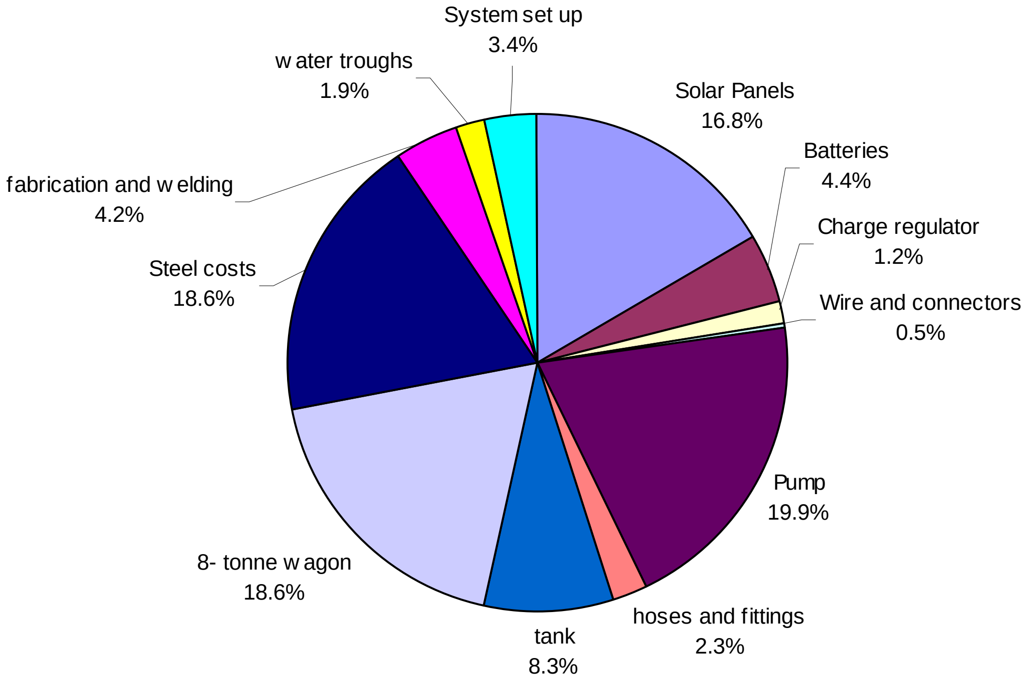
System Costs Note: Prices in current column are the extra amounts needed to make existing system portable

Pumping System	Details	New	Current	Source
Solar Panels	4- 50 watt panels @ $450 each	$ 1,800.00	$ 900.00	SPS energy Solutions
Batteries	4 - Trojan 105 @ $119 each	$ 476.00	$ 476.00	Total Battery
Charge regulator	1- ASC 24 volt/ 16amp	$ 125.00		SPS energy Solutions
Wire and connectors	estimate	$ 50.00	$ 50.00	Barrete Electric
Pump	Sunmotor M-20	$ 2,138.00	$ -	SPS energy Solutions
hoses and fittings	100' of 2' hose and connectors	$ 250.00	$ 250.00	Low's plumbing
tank	1100 U.S. gallon	$ 887.00		Diverse Plastics Tanks
subtotal		**$ 5,726.00**	**$ 1,676.00**	
Wagon				
8- tonne wagon	new horst 8- tonne wagon	$ 2,000.00	$ 500.00	Rosemount Equipment
Steel costs	See steel costs sheet in appendix E	$ 2,000.00	$ 2,000.00	Metec
fabrication and welding	10 hours @ $45/ hour	$ 450.00	$ 450.00	Geordie Maclaren
water troughs	Furnace oil tank with ends cut off	$ 200.00	$ 200.00	Low's plumbing
subtotal		**$ 4,650.00**	**$ 3,150.00**	
Other				
System set up	8 hours @ $45/ hour	$ 360.00	$ 360.00	Geordie Maclaren
Total		**$ 10,736.00**	**$ 4,826.00**	

Table 1: Total system costs

The following figure shows the cost break down for all off the major components in the system if it were to be built from all new materials. It can be clearly seen that the four largest major costs are associated with the solar panels, the pump and the wagon costs.

Figure 10: Cost break-down for Portable Watering System



Economic Analysis

The cost of this system seems expensive at first. But when the total cost is divided between the 200 cows over a ten-year period, and compared to the estimated saving, the system seems to pay for itself, especially when factors like increased weight gains in calves due to a cleaner water source and animal stress reduction are considered. Also with increasing environmental regulations about keeping animals out of water ways, this low maintenance system may look very attractive in the future to farmers and environmentalists.

The following is the economic payback calculation:

Factors:

Cost per cow = $10 736.00/ 200 cows = **$53.68/ cow**.

Estimated calf weight gain per year = 10 lbs x $1.00/lb = **$10.00/yr**

Estimated annual interest rate = **8%**

Estimated annual maintenance cost = %2 x $10 736.00 = $ 215.00

Estimated annual maintenance cost/cow = $ 215.00/200 = $1.08

Payback Calculation

Table 2 shows how the initial $56.38 per cow cost can be paid back over 8.5 years. The solar panels and the wagon should last 20 years. The things that are going to wear out are the pump, tank and hoses. This wear factor is considered in the annual maintenance cost.

Table 2:Payback Schedule per Cow

Year	Savings	Cost	Real cost with accumulating int.	Amount to pay back
1	$ 10.00	$ 1.60	$ 57.98	$ 49.06
2	$ 10.00	$ 1.60	$ 52.99	$ 44.07
3	$ 10.00	$ 1.60	$ 47.59	$ 38.67
4	$ 10.00	$ 1.60	$ 41.77	$ 32.85
5	$ 10.00	$ 1.60	$ 35.48	$ 26.56
6	$ 10.00	$ 1.60	$ 28.68	$ 19.76
7	$ 10.00	$ 1.60	$ 21.34	$ 12.42
8	$ 10.00	$ 1.60	$ 13.41	$ 4.49
9	$ 10.00	$ 1.60	$ 4.85	$ (4.07)

Conclusion

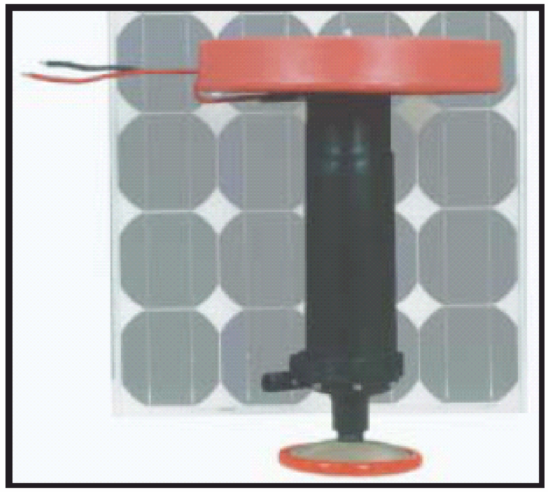
This portable watering system design will benefit Maclaren Farms and the Ducks Unlimited demonstration site. Cattle will no longer have to go into the water sources to drink. This will improve the water quality and the aquatic environment of the water sources. Animal health will be improved due to the cleaner drinking water that will in turn increase the animal weight gains. This system will be easily portable from pasture to pasture. All the farm manager will have to do is take the pump out of the water source and coil up its power cable and hose onto the rack mounted on the wagon for it, then move the wagon to the next pasture with a tractor or truck. With its steel frame design and solar panels warranty for 20 years, the most of this system should last for many years. With the estimated increase in weight gain in the calves, this system should pay for its self in ten years. In all this system design will save the farmer time, money and also reduce the negative effects that direct cattle watering has on the environment.

Appendix A- Pump Specifications and Performance Charts

SUNMOTOR

MODEL M20 FLOATING SOLAR PUMP

Designed to pump from surface water sources, such as ponds, dams, canals and streams.

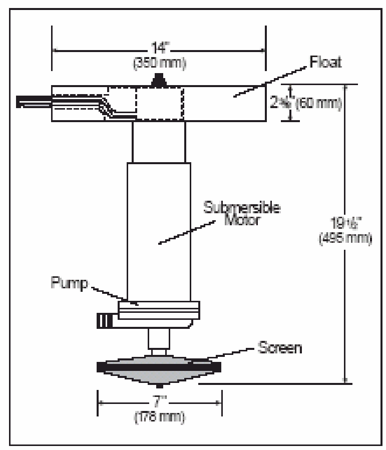


FEATURES

- Operates on solar panels or batteries
- Low power requirements
- Simplicity of design
- Magnetic drive
- Long life
- Serviceable
- Converts to automatic sump pump

PERFORMANCE CHART

Pumping Head Vertical Lift		24.0 volts			30.0 volts		
		Current	Flow		Current	Flow	
Meters	Feet	Amps	L/min.	US gpm	Amps	L/min.	US gpm
1	3.3	5.6	86.8	22.9	8.7	102.0	27.0
2	6.6	5.5	77.0	20.3	8.6	92.6	24.5
3	9.8	5.5	74.9	19.8	8.6	86.3	22.8
4	13.1	5.4	69.0	18.2	8.5	86.0	22.7
5	16.4	5.4	61.7	16.3	8.5	82.0	21.7
6	19.7	5.4	51.0	13.5	8.5	78.0	20.6
7	23.0	5.4	42.7	11.3	8.3	74.0	19.5
8	26.2	4.7	34.0	9.0	8.0	69.0	18.2
9	29.5	—	0.0	0.0	7.9	64.0	16.9
10	32.8	—	0.0	0.0	7.4	58.0	15.3
11	36.1	—	0.0	0.0	7.2	54.0	14.3
12	39.4	—	0.0	0.0	7.0	49.0	12.9
13	42.6	—	0.0	0.0	6.6	35.0	9.2
14	45.9	—	0.0	0.0	6.2	20.0	5.3



SUNMOTOR M20 CAPACITY VS ARRAY WATTS

Pumping Head		Typical volume on a clear sunny day when powered by a 175 watt solar array		Typical volume on a clear sunny day when powered by a 350 watt solar array	
Meters	Feet	Liters	Gallons	Liters	Gallons
2	6.6	15,000	4,000	30,000	8,000
4	13.1	11,000	3,000	28,000	7,400
6	19.7	8,000	2,000	25,000	6,600
8	26.2	—	—	22,000	5,800
10	32.8	—	—	19,000	5,000
12	39.4	—	—	16,000	4,200
14	45.9	—	—	6,500	1,700

SUNMOTOR INTERNATIONAL LTD.

5037 – 50th Street
Olds, Alberta, Canada
T4H 1R8

Phone: (403) 556-8755
Fax: (403) 556-7799

Email: sunmotor@telusplanet.net
www.sunpump.com

980105-M20.qxd

SPECIFICATIONS AND OPERATING INSTRUCTIONS FOR SUNMOTOR MODEL M20 FLOATING SUBMERSIBLE PUMP

DESCRIPTION

The SUNMOTOR model M20 submersible pump is designed to operate on any direct current power source from 24 to 32 volts. Capacities at various voltages are shown in Figure 1.

WARNING: THIS PUMP MUST BE IN WATER TO LUBRICATE AND COOL ITS CERAMIC BEARINGS. DO NOT OPERATE THE PUMP DRY.

INSTALLATION

1) The M20 pump is supplied with a short section of flexible discharge hose to prevent bending loads on the outlet port. An adapter is included to connect to 1 1/2 inch hose or plastic pipe.
2) After connecting the discharge hose and pipe, place the pump in the water and anchor it with a rope (see Figure 2).
3) The pump is supplied with 50 feet of submersible cable already attached. Once the pump is submerged in water connect the cable to the d.c. power source (red to +). Water flow should occur when power is available.
4) The quick connect cable junction included provides easy disconnect between the pump and the power source.

OVERLOAD PROTECTION

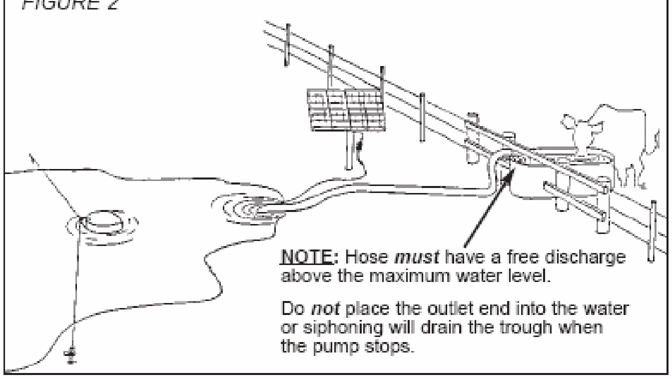
The M20 has a built in overload protection device in the form of a magnetic coupling between the pump impeller and the motor. This system will decouple automatically if the motor becomes overloaded, either from too high a voltage (over 36v) or from an obstruction in the pump impeller. If decoupling occurs the motor will continue to operate but the pump impeller will stop until the problem is corrected. To recouple the magnetic drive, simply disconnect the power supply for a few seconds. No harm is caused by decoupling of the magnetic drive.

M20 PERFORMANCE CHART

Pumping Head Vertical Lift		24.0 volts			30.0 volts		
		Current	Flow		Current	Flow	
Meters	Feet	(A)	L/min.	US gpm	(A)	L/min.	US gpm
1	3.3	5.6	86.8	22.9	8.7	102.0	27.0
2	6.6	5.5	77.0	20.3	8.6	92.6	24.5
3	9.8	5.5	74.9	19.8	8.6	86.3	22.8
4	13.1	5.4	69.0	18.2	8.5	86.0	22.7
5	16.4	5.4	61.7	16.3	8.5	82.0	21.7
6	19.7	5.4	51.0	13.5	8.5	78.0	20.6
7	23.0	5.4	42.7	11.3	8.3	74.0	19.5
8	26.2	4.7	34.0	9.0	8.0	69.0	18.2
9	29.5	—	0.0	0.0	7.9	64.0	16.9
10	32.8	—	0.0	0.0	7.4	58.0	15.3
11	36.1	—	0.0	0.0	7.2	54.0	14.3
12	39.4	—	0.0	0.0	7.0	49.0	12.9
13	42.6	—	0.0	0.0	6.6	35.0	9.2
14	45.9	—	0.0	0.0	6.2	20.0	5.3

FIGURE 1

FIGURE 2



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SUNMOTOR INTERNATIONAL LTD.

5037 – 50th Street
Olds, Alberta, Canada
T4H 1R8

Phone: (403) 556-8755
Fax: (403) 556-7799

Email: sunmotor@telusplanet.net
www.sunpump.com

Friction loss in 1" Plastic P.E. Pipe with 6m of static head

H_2O @ 10 °C   V=   1.3088E-06 m^2/s (kinetic viscosity)

Pipe length L	Flow l/m	Flow m^3/s	pipe Dia. D (m)	velocity v (m/s)	Reynolds number Re	friction f	Friction head (m) hL= f*L/D*V2/2g	Friction head + 6m elev. hL= f*L/D*V2/2g+6
5	10	0.00017	0.025	0.340	6489.5	0.035	0.16	6.16
5	15	0.00025	0.025	0.509	9734.2	0.032	0.34	6.34
5	25	0.00042	0.025	0.849	16223.7	0.0275	0.81	6.81
5	50	0.00083	0.025	1.698	32447.5	0.023	2.70	8.70
5	75	0.00125	0.025	2.546	48671.2	0.021	5.55	11.55
5	100	0.00167	0.025	3.395	64895.0	0.019	8.93	14.93
10	10	0.00017	0.025	0.340	6489.5	0.035	0.33	6.33
10	15	0.00025	0.025	0.509	9734.2	0.032	0.68	6.68
10	25	0.00042	0.025	0.849	16223.7	0.0275	1.62	7.62
10	50	0.00083	0.025	1.698	32447.5	0.023	5.41	11.41
10	75	0.00125	0.025	2.546	48671.2	0.021	11.11	17.11
10	100	0.00167	0.025	3.395	64895.0	0.019	17.86	23.86
		0.00000						
20	10	0.00017	0.025	0.340	6489.5	0.035	0.66	6.66
20	15	0.00025	0.025	0.509	9734.2	0.032	1.35	7.35
20	25	0.00042	0.025	0.849	16223.7	0.0275	3.23	9.23
20	50	0.00083	0.025	1.698	32447.5	0.023	10.81	16.81
20	75	0.00125	0.025	2.546	48671.2	0.021	22.21	28.21
20	100	0.00167	0.025	3.395	64895.0	0.019	35.72	41.72
30	10	0.00017	0.025	0.340	6489.5	0.035	0.99	6.99
30	15	0.00025	0.025	0.509	9734.2	0.032	2.03	8.03
30	25	0.00042	0.025	0.849	16223.7	0.0275	4.85	10.85
30	50	0.00083	0.025	1.698	32447.5	0.023	16.22	22.22
30	75	0.00125	0.025	2.546	48671.2	0.021	33.32	39.32
30	100	0.00167	0.025	3.395	64895.0	0.019	53.59	59.59

Friction loss in 1.5" Plastic P.E. Pipe with 6m of static head

H_20 @ 10 °C V= 1.3088E-06 m^2/s (kinetic viscosity)

Pipe length L	Flow l/m	Flow m^3/s	pipe Dia. D (m)	velocity v (m/s)	Reynolds number Re	friction f	Friction head (m) hL= f*L/D*V2/2g	Friction head + 6m elev. hL= f*L/D*V2/2g+6
5	10	0.00017	0.038	0.147	4269.4	0.039	0.02	6.02
5	15	0.00025	0.038	0.220	6404.1	0.035	0.05	6.05
5	25	0.00042	0.038	0.367	10673.5	0.031	0.11	6.11
5	50	0.00083	0.038	0.735	21347.0	0.026	0.38	6.38
5	75	0.00125	0.038	1.102	32020.6	0.023	0.75	6.75
5	100	0.00167	0.038	1.470	42694.1	0.022	1.27	7.27
10	10	0.00017	0.038	0.147	4269.4	0.039	0.05	6.05
10	15	0.00025	0.038	0.220	6404.1	0.035	0.09	6.09
10	25	0.00042	0.038	0.367	10673.5	0.031	0.22	6.22
10	50	0.00083	0.038	0.735	21347.0	0.026	0.75	6.75
10	75	0.00125	0.038	1.102	32020.6	0.023	1.50	7.50
10	100	0.00167	0.038	1.470	42694.1	0.022	2.55	8.55
20	10	0.00017	0.038	0.147	4269.4	0.039	0.09	6.09
20	15	0.00025	0.038	0.220	6404.1	0.035	0.18	6.18
20	25	0.00042	0.038	0.367	10673.5	0.031	0.45	6.45
20	50	0.00083	0.038	0.735	21347.0	0.026	1.51	7.51
20	75	0.00125	0.038	1.102	32020.6	0.023	3.00	9.00
20	100	0.00167	0.038	1.470	42694.1	0.022	5.10	11.10
30	10	0.00017	0.038	0.147	4269.4	0.039	0.14	6.14
30	15	0.00025	0.038	0.220	6404.1	0.035	0.27	6.27
30	25	0.00042	0.038	0.367	10673.5	0.031	0.67	6.67
30	50	0.00083	0.038	0.735	21347.0	0.026	2.26	8.26
30	75	0.00125	0.038	1.102	32020.6	0.023	4.50	10.50
30	100	0.00167	0.038	1.470	42694.1	0.022	7.65	13.65

Friction loss in 2" Plastic P.E. Pipe with 6m of static head

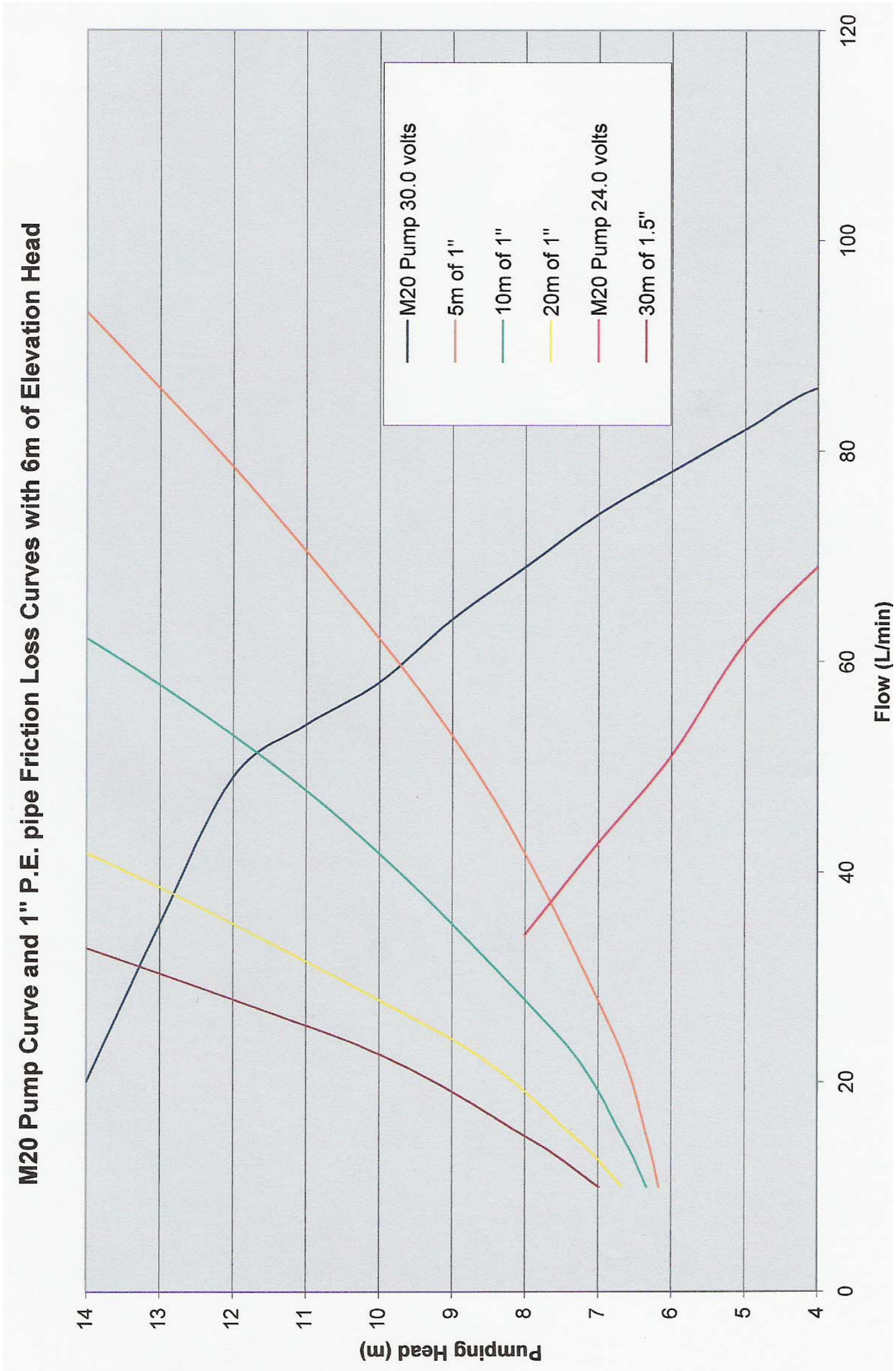
H_2O @ 10 °C V= 1.3088E-06 m^2/s (kinetic viscosity)

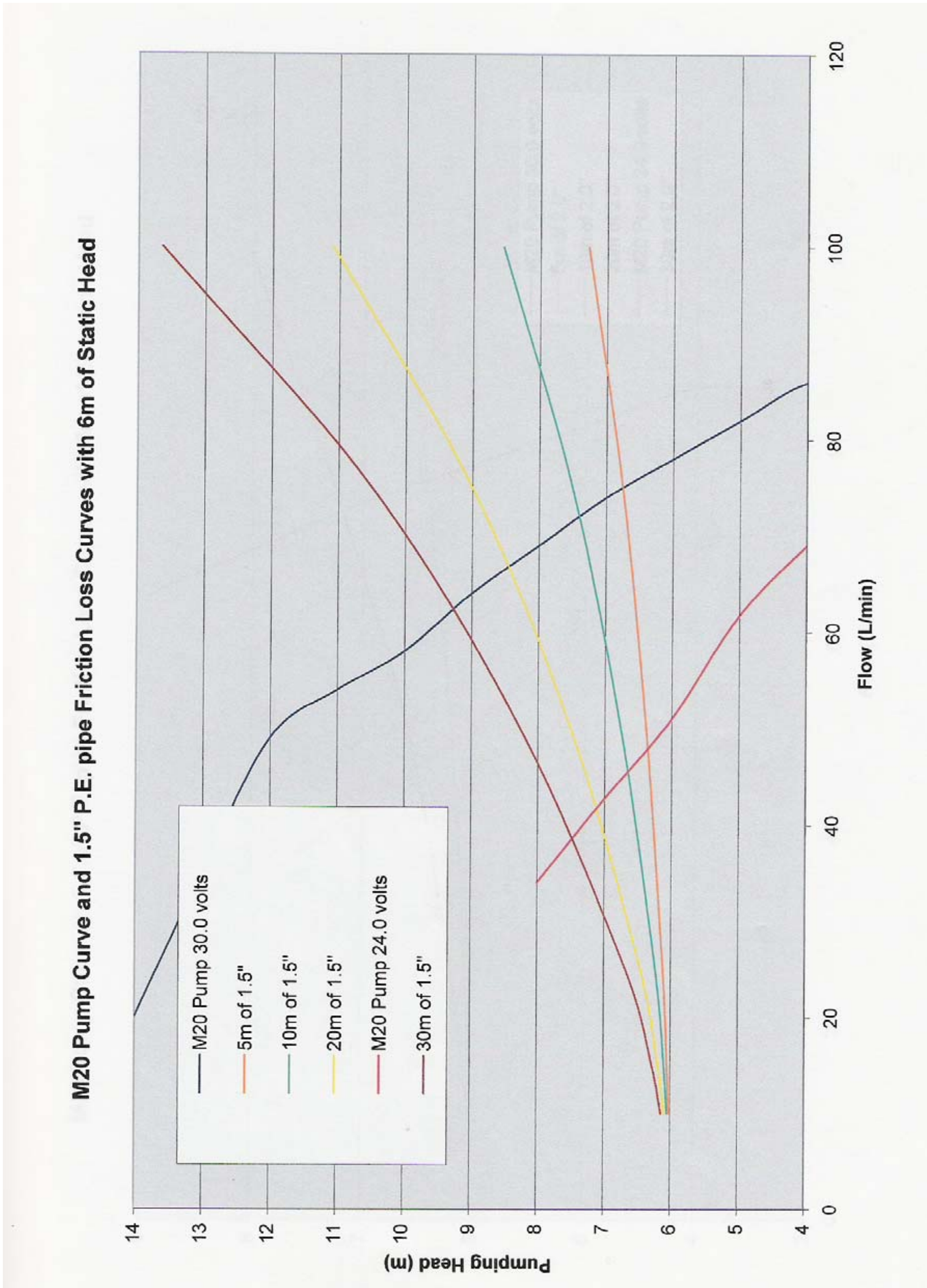
Pipe length L	Flow l/m	Flow m^3/s	pipe Dia. D (m)	velocity v (m/s)	Reynolds number Re	friction f	Friction head (m) hL= f*L/D*V2/2g	Friction head + 6m elev. hL= f*L/D*V2/2g+6
5	10	0.00017	0.05	0.085	3244.7	0.0197	0.00	6.00
5	15	0.00025	0.05	0.127	4867.1	0.037	0.01	6.01
5	25	0.00042	0.05	0.212	8111.9	0.033	0.03	6.03
5	50	0.00083	0.05	0.424	16223.7	0.026	0.10	6.10
5	75	0.00125	0.05	0.637	24335.6	0.025	0.21	6.21
5	100	0.00167	0.05	0.849	32447.5	0.023	0.34	6.34
10	10	0.00017	0.05	0.085	3244.7	0.0197	0.01	6.01
10	15	0.00025	0.05	0.127	4867.1	0.037	0.02	6.02
10	25	0.00042	0.05	0.212	8111.9	0.033	0.06	6.06
10	50	0.00083	0.05	0.424	16223.7	0.026	0.19	6.19
10	75	0.00125	0.05	0.637	24335.6	0.025	0.41	6.41
10	100	0.00167	0.05	0.849	32447.5	0.023	0.68	6.68
20	10	0.00017	0.05	0.085	3244.7	0.0197	0.01	6.01
20	15	0.00025	0.05	0.127	4867.1	0.037	0.05	6.05
20	25	0.00042	0.05	0.212	8111.9	0.033	0.12	6.12
20	50	0.00083	0.05	0.424	16223.7	0.026	0.38	6.38
20	75	0.00125	0.05	0.637	24335.6	0.025	0.83	6.83
20	100	0.00167	0.05	0.849	32447.5	0.023	1.35	7.35
30	10	0.00017	0.05	0.085	3244.7	0.0197	0.02	6.02
30	15	0.00025	0.05	0.127	4867.1	0.037	0.07	6.07
30	25	0.00042	0.05	0.212	8111.9	0.033	0.18	6.18
30	50	0.00083	0.05	0.424	16223.7	0.026	0.57	6.57
30	75	0.00125	0.05	0.637	24335.6	0.025	1.24	7.24
30	100	0.00167	0.05	0.849	32447.5	0.023	2.03	8.03

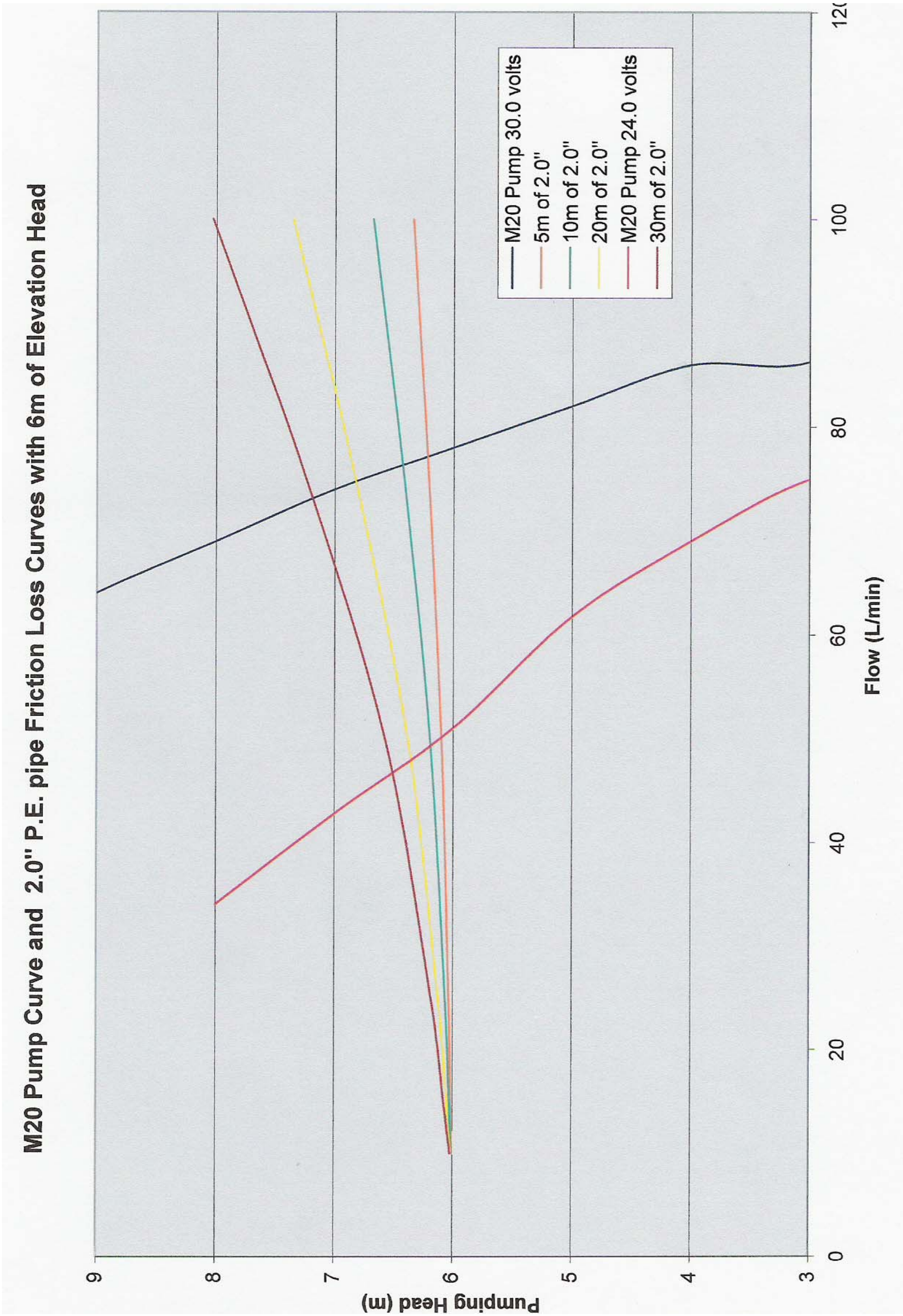
Friction loss in 3" Plastic P.E. Pipe with 6m of static head

H_20 @ 10 °C V= 1.3088E-06 m^2/s (kinetic viscosity)

Pipe length L	Flow l/m	Flow m^3/s	pipe Dia. D (m)	velocity v (m/s)	Reynolds number Re	friction f	Friction head (m) hL= f*L/D*V2/2g	Friction head + 6m elev. hL= f*L/D*V2/2g+6
5	10	0.00017	0.075	0.038	2163.2	0.0296	0.00	6.00
5	15	0.00025	0.075	0.057	3244.7	0.0197	0.00	6.00
5	25	0.00042	0.075	0.094	5407.9	0.037	0.00	6.00
5	50	0.00083	0.075	0.189	10815.8	0.032	0.02	6.02
5	75	0.00125	0.075	0.283	16223.7	0.027	0.03	6.03
5	100	0.00167	0.075	0.377	21631.7	0.026	0.05	6.05
10	10	0.00017	0.075	0.038	2163.2	0.0296	0.00	6.00
10	15	0.00025	0.075	0.057	3244.7	0.0197	0.00	6.00
10	25	0.00042	0.075	0.094	5407.9	0.037	0.01	6.01
10	50	0.00083	0.075	0.189	10815.8	0.032	0.03	6.03
10	75	0.00125	0.075	0.283	16223.7	0.027	0.06	6.06
10	100	0.00167	0.075	0.377	21631.7	0.026	0.10	6.10
20	10	0.00017	0.075	0.038	2163.2	0.0296	0.00	6.00
20	15	0.00025	0.075	0.057	3244.7	0.0197	0.00	6.00
20	25	0.00042	0.075	0.094	5407.9	0.037	0.02	6.02
20	50	0.00083	0.075	0.189	10815.8	0.032	0.06	6.06
20	75	0.00125	0.075	0.283	16223.7	0.027	0.12	6.12
20	100	0.00167	0.075	0.377	21631.7	0.026	0.20	6.20
30	10	0.00017	0.075	0.038	2163.2	0.0296	0.00	6.00
30	15	0.00025	0.075	0.057	3244.7	0.0197	0.01	6.01
30	25	0.00042	0.075	0.094	5407.9	0.037	0.03	6.03
30	50	0.00083	0.075	0.189	10815.8	0.032	0.09	6.09
30	75	0.00125	0.075	0.283	16223.7	0.027	0.18	6.18
30	100	0.00167	0.075	0.377	21631.7	0.026	0.30	6.30


M20 Pump Curve and 1" P.E. pipe Friction Loss Curves with 6m of Elevation Head
Pumping Head (m)
Flow (L/min)
M20 Pump 30.0 volts
5m of 1"
10m of 1"
20m of 1"
M20 Pump 24.0 volts
30m of 1.5"
14
13
12
11
10
9
8
7
6
5
4
0
20
40
60
80
100
120


M20 Pump Curve and 1.5" P.E. pipe Friction Loss Curves with 6m of Static Head
Pumping Head (m)
Flow (L/min)
14
13
12
11
10
9
8
7
6
5
4
0
20
40
60
80
100
120
M20 Pump 30.0 volts
5m of 1.5"
10m of 1.5"
20m of 1.5"
M20 Pump 24.0 volts
30m of 1.5"


M20 Pump Curve and 2.0" P.E. pipe Friction Loss Curves with 6m of Elevation Head
Pumping Head (m)
Flow (L/min)
M20 Pump 30.0 volts
5m of 2.0"
10m of 2.0"
20m of 2.0"
M20 Pump 24.0 volts
30m of 2.0"
0
20
40
60
80
100
3
4
5
6
7
8
9

Appendix B- Electric Fencer Controller Specifications

speedrite by TRU-TEST

Home > Speedrite Battery Energizers > Speedrite Viper 5000

Know How book

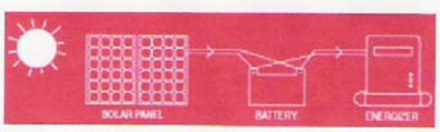
Close

BATTERY ENERGIZERS
Large to Mid-Sized

Serious animal control, where you need it.

Speedrite Viper and Delta battery energizers provide dependable power, no matter how remote the location. All models can be used with a solar panel option to create a fully self contained, low maintenance fencing solution. Speedrite battery powered energizers can be used in permanent, semi-permanent or completely portable applications.

SOLAR POWER: Speedrite offer a range of solar panels and solar kits depending on your region. To determine which Speedrite solar configuration is right for you, ask your Speedrite dealer.



All Speedrite battery energizers featured are solar compatible.

BATTERY ENERGIZERS
Portable

Intense grazing. Insense energizers.

Good pasture control means greater profit. Speedrite portable energizers are designed for

Speedrite Viper 5000
(SE103)

Designed for large farms and harsh conditions. Suitable for the control of all types of animals.

- Heavy duty energizer designed for specialised solar assisted applications
- High and low output terminals
- Two pulse speed options
- Pulse light indicates pulse and fence loading
- Light sensor reduces battery consumption at night
- Power level selection – high for training animals and low for battery conservation

intense strip grazing and small to large paddock containment. From self-contained solar to standard dry cell units, you get maximum power, maximum portability, maximum control.

UTILITY ENERGIZERS: Speedrite now offer a range of truly versatile portable energizers that, due to their large battery capacity, can be used for medium-term applications without maintenance. The SG-1 and the SG-3 allow users to electrify problem areas anywhere on the property for longer time frames as well as the traditional strip-grazing uses.

Maximum Power Factor - 50km/30 miles

	Max Pulse Output Energy	Max Pulse Stored Energy	Voltage@ Resistance 100/500Ω	Current Consumption	Maximum Power Factor	Suitable for up to
Viper 5000	5.0 J	7.0 J	4,700/7,200V	300mA/600mA	50km/30 miles	95acres/39 ha

NOTE: Distance and area recommendations are nominal and in multiple wire terms Performance will be affected by quality of fence. Voltages are maximum at given re

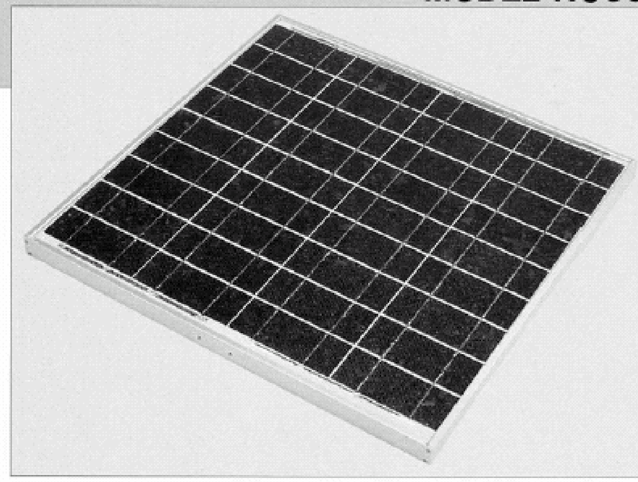
I would like to know more about the **Speedrite Viper 5000**. Add this to my Enquiry Basket.

Speedrite Viper 5000

Appendix C- Photovoltaic Module and Wind Mill Information

KYOCERA

MODEL KC50



KC50

HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE

TYPICAL OUTPUT 50 Wp

HIGHLIGHTS OF KYOCERA PHOTOVOLTAIC MODULES

Kyocera's advanced cell processing technology and automated production facilities have produced a highly efficient multicrystal photovoltaic modules.
The conversion efficiency of the Kyocera solar cell is over 14%.
These cells are encapsulated between a tempered glass cover and an EVA pottant with PVF back sheet to provide maximum protection from the severest environmental conditions.
The entire laminate is installed in an anodized aluminum frame to provide structural strength and ease of installation.

APPLICATIONS

- Microwave/Radio repeater stations
- Electrification of villages in remote areas
- Medical facilities in rural areas
- Power source for summer vacation homes
- Emergency communication systems
- Water quality and environmental data monitoring systems
- Navigation lighthouses, and ocean buoys
- Pumping systems for irrigation, rural water supplies and livestock watering
- Aviation obstruction lights
- Cathodic protection systems
- Desalination systems
- Recreational vehicles
- Railroad signals
- Sailboat charging systems

SPECIFICATIONS

■ Electrical Specifications

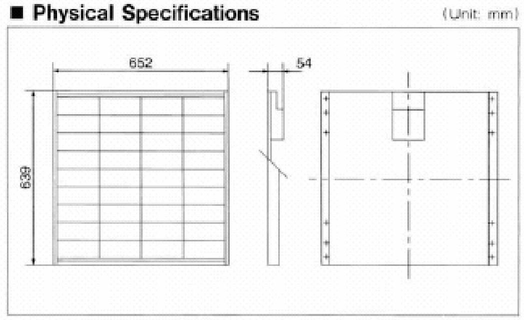
MODEL	KC50
Maximum Power	50 Watts
Maximum Power Voltage	16.7 Volts
Maximum Power Current	3.00 Amps
Open Circuit Voltage	21.5 Volts
Short-Circuit Current	3.10 Amps
Length	639mm (25.2in.)
Width	652mm (25.7in.)
Depth	54mm (2.1in.)
Weight	5.0kg (11.0lbs.)

Note: The electrical specifications are under test conditions of Irradiance of 1kW/m^2, Spectrum of 1.5 air mass and cell temperature of 25°C

Kyocera reserves the right to modify these specifications without notice.

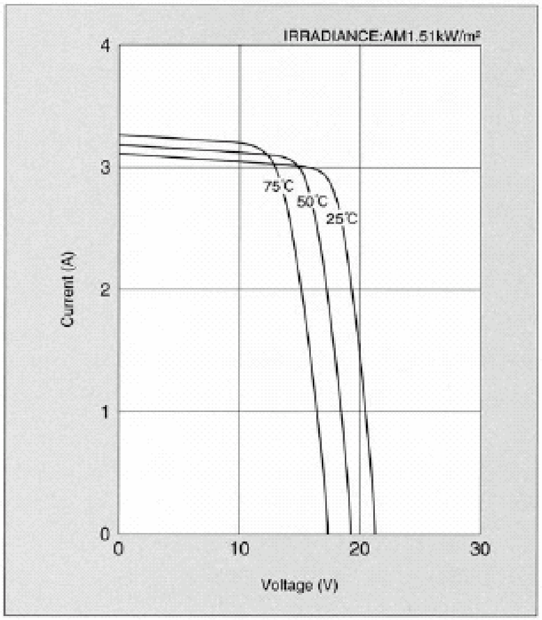
■ Physical Specifications

(Unit: mm)

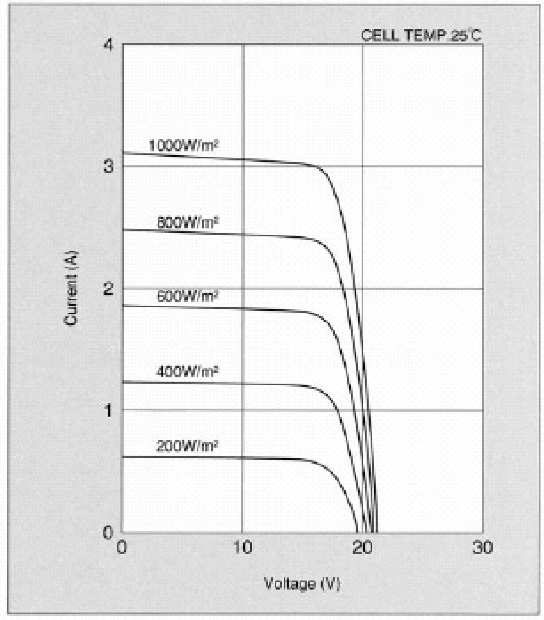


ELECTRICAL CHARACTERISTICS

Current-Voitare characteristics of Photovoltaic Module KC50 at various cell temperatures



Current-Voitare characteristics of Photovoltaic Module KC50 at various irradiance levels



QUALITY ASSURANCE

Kyocera multicrystal photovoltaic modules exceed government specifications for the following tests.

- Thermal cycling test
- Thermal shock test
- Thermal/Freezing and high humidity cycling test
- Electrical isolation test
- Hail impact test
- Mechanical, wind and twist loading test
- Salt mist test
- Light and water-exposure test
- Field exposure test

Please contact our office to obtain details without hesitation.

KYOCERA CORPORATION

■ KYOCERA HEAD OFFICE
SOLAR ENERGY DIVISION
6 Takeda Tobadono-cho
Fushimi-ku, Kyoto
612-8501 Japan
Phone : (81)75-604-3476 Telefax : (81)75-604-3475

● KYOCERA FINECERAMICS GmbH
Fritz Muller Straße 107, D-73730 Esslingen, F.R.G.
Phone : (49)711-9393417 Telefax : (49)711-9393450

● KYOCERA ASIA PACIFIC PTE. LTD.
298 Tiong Bahru Road, # 13-03/04/05
Central Plaza, Singapore 168730
Phone : (65)271-0500 Telefax : (65)271-0600

● KYOCERA ASIA PACIFIC LTD.
Room 803, Tower 1 South Seas Centre, 75 Mody Road,
Tsimshatsui East, Kowloon Hong Kong
Phone : (852)2-7237183 Telefax : (852)2-7244501

● KYOCERA ASIA PACIFIC LTD., TAIPEI BRANCH
Suite 501, Asia Enterprise Center,
No.142-144, Sec. 3, Min Chuan E.Road Taipei, Taiwan, R.O.C.
Phone : (886)2-2718-3595 Telefax : (886)2-2718-3587

● Kyocera Solar, Inc.
7812 East Acoma Drive
Scottsdale, AZ 85260
Phone : (480)948-8003 or (800)223-9580 Telefax : (480)483-6431

● Kyocera Solar, Inc. -Sunelco Division
100 Skeels Street
P.O.Box 787
Hamilton, MT 59840
Phone : (406)363-6924 or (800)338-6844 Telefax : (406)363-6046

● Kyocera Solar Pty, Ltd.
36 Windora Street, Unit 6
Stafford 4053
Queensland, Australia
Phone : (61)7-3856-5388 Telefax : (61)7-3856-5443

● Kyocera Solar Argentina S.A.
Mejico 2145, (16400) Martinez
Provincia de Buenos Aires
Argentina
Phone : (54)114-836-1040 Telefax : (54)114-836-0808

● Kyocera Solar do Brazil
Rua Pres. Carlos de Campos
332-Laranjeiras
22231-080
Rio de Janeiro, RJ Brazil
Phone : (55)2-1554-5554 Telefax : (55)2-1553-4894

Rutland 913

Technical Data

[Why is *The Rutland* so unique](#)

The Rutland 913 is designed for marine use on board coastal and ocean going yachts usually over 10m in length. This unit will generate enough power to serve both domestic and engine batteries on board and the RWS200 Controller is available for dual battery charging.

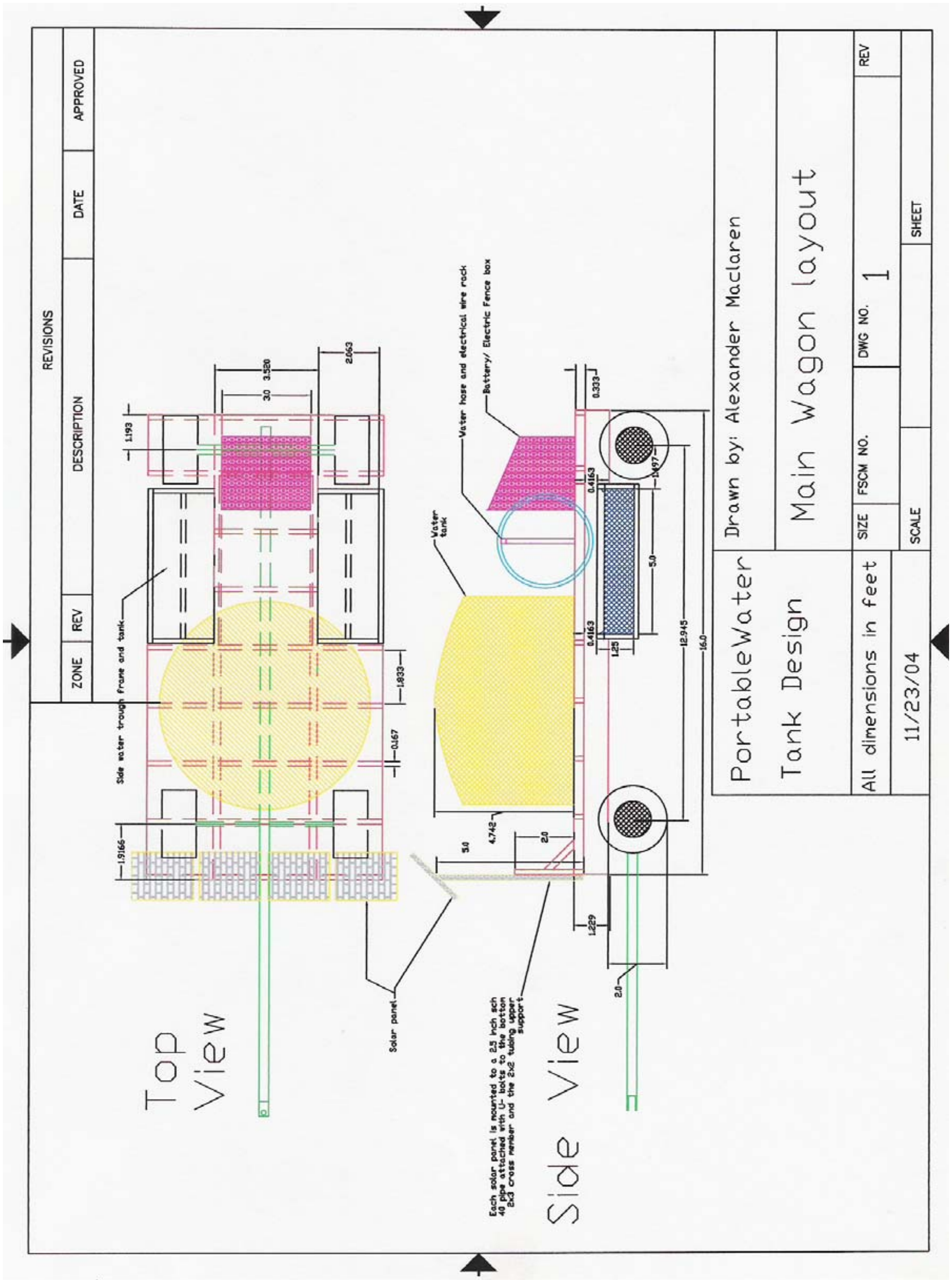
The Rutland 913 is a popular sight in marinas, thousands are in use worldwide, boat owners like it's clean, aerodynamic lines and its quiet and continuous operation. Without doubt this latest marine model accumulates more energy than any other comparable windcharger available, you'll always see a Rutland spinning in the lightest of breezes!

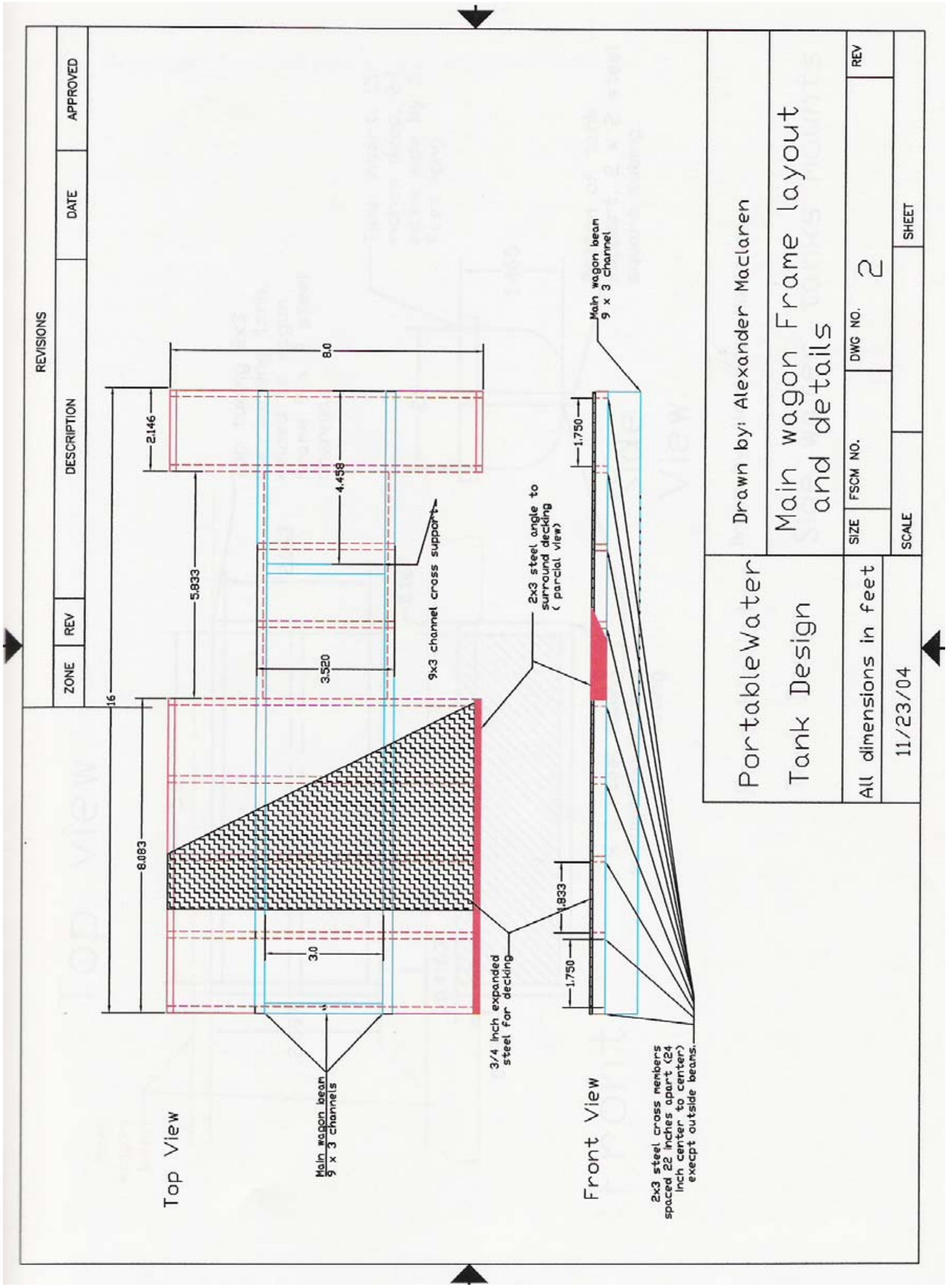
- Low wind speed start up of just 5 knots
- Generates 90w @ 19 knots, 24w @ 10 knots
- Delivers up to 250w
- One way only fit fine profile efficient aerofoil blades
- Three phase Rutland "unique" generator design
- Automatic thermostat protection in prolonged gales
- Modern, durable materials for reliability on the high seas
- No radiated interference - complies with EEC directive 89/336/EEC

Balance of System Components

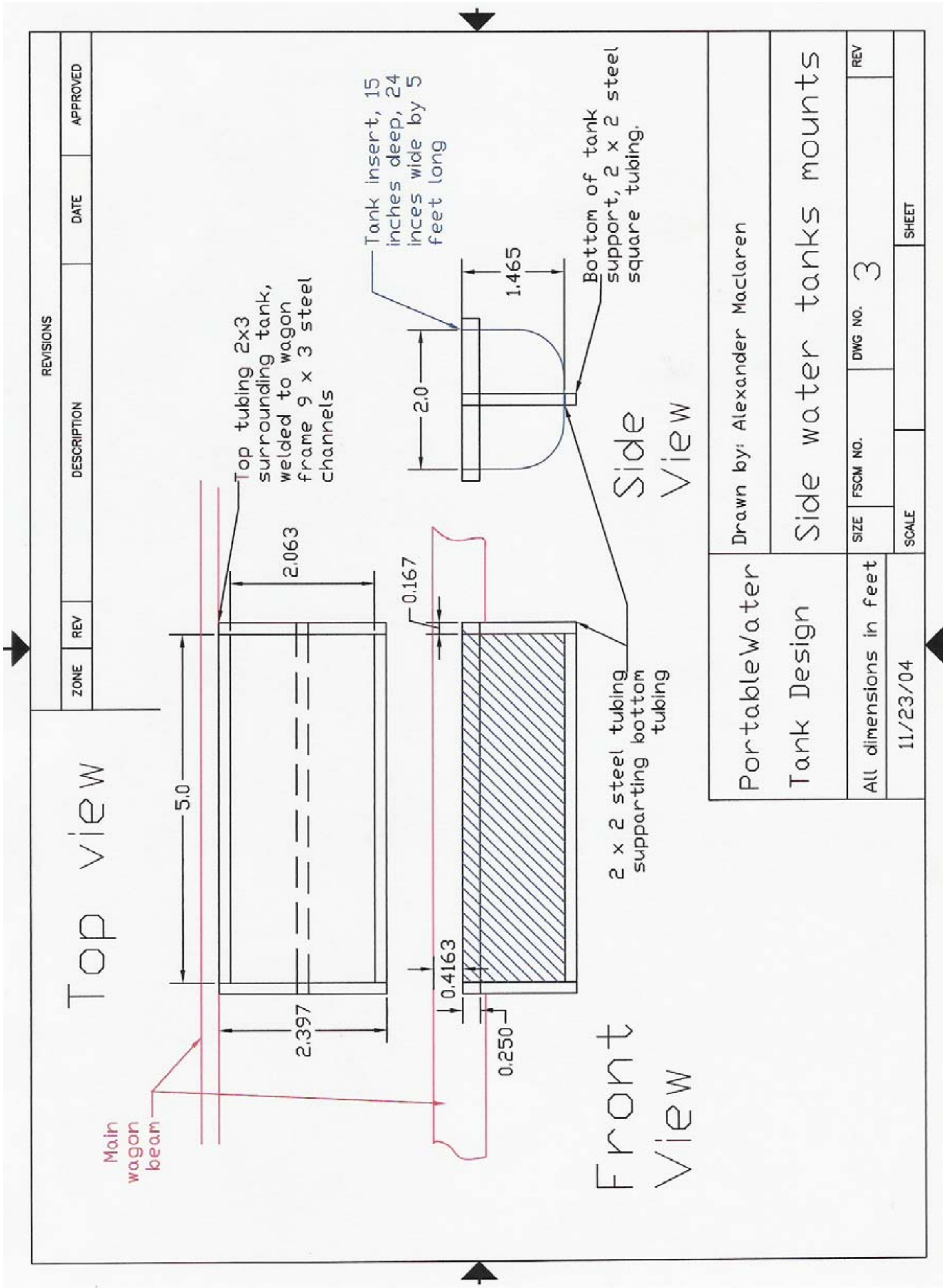
- SR200 Regulator - Shunt type voltage regulator prevents battery overcharge
- RWS200 Controller - Incorporates the SR200 Regulator, charge ammeter, dual battery voltage LED's, two battery connection terminals and switch for charging one or two battery banks simultaneously, solar panel input (maximum 50w when used in combination with Rutland 913 windcharger). Housed in attractive white case with simple to follow graphics for installation.
- Marine Mounting Kit supplied in 2 sections of stainless steel plus deck fixing and fasteners.
- Other system components Batteries, cable

Appendix D – Drawings





REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Top View
Main wagon beam 9 x 3 channels
16
8.083
5.833
2.146
8.0
3.520
4.458
3.0
1.833
1.750
9x3 channel cross support
3/4 inch expanded steel for decking
2x3 steel angle to surround decking (parcial view)
Front View
2x3 steel cross members spaced 22 inches apart (24 inch center to center) except outside beams.
Main wagon beam 9 x 3 channel
PortableWater Tank Design
Drawn by: Alexander Maclaren
Main wagon Frame layout and details
All dimensions in feet
11/23/04
SIZE
FSCM NO.
DWG NO.
2
REV
SCALE
SHEET


REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Top view
Front View
Side View
Main wagon beam
5.0
2.397
2.063
0.167
0.4163
0.250
2.0
1.465
Top tubing 2x3 surrounding tank, welded to wagon frame 9 x 3 steel channels
Tank insert, 15 inches deep, 24 inces wide by 5 feet long
Bottom of tank support, 2 x 2 steel square tubing.
2 x 2 steel tubing supparting bottom tubing
PortableWater
Tank Design
All dimensions in feet
11/23/04
Drawn by: Alexander Maclaren
Side water tanks mounts
SIZE
FSCM NO.
DWG NO.
3
REV
SCALE
SHEET

Appendix E- Load and Steel Cost Calculations

Material Cost Sheet for Water Wagon

Material	wall thichness	# of lenghts	length	lb/lin ft	Aproximate Weight (lbs)	Cost
						Quoted from Metec
Reg mat.						
3 x 2 tubing	0.25	4	80	7.11	568.8	$558.00
9 x 3 tubing	0.5	2	40	31.45	1258	n/a
2 x 3 angle	3/16	3	60	3.07	184.2	$112.00
2 x 2 tube	0.25	4	80	5.41	432.8	$448.00
					2443.8	
pipe	**size**					
Steel sch 40	2.5	2	40	7.66	**306.4**	$314.00
Aluminum sch 40	2.5	2	40			$272.00
		# sheets	Area	lb/100 ft2		
3/4 expanded						
metal	0.205	4	128	80		$276.00
9 x 3 steel Channel	0.413, 0.448 s	2	40	13.5	**540**	$400.00
Total Cost						**$2,410.00**

For: Geordie Maclaren 678-7682
fax # 613-678-3771

Weight and Beam Loading Calculations

The major weights of the system are as follows:

Water tank: Weigh of tank approximately -- 150 kg

Weight of water in tank = 1100 gallons * 3.78 kg of water/ gallon = 4158 kg

4308 kg

Total water weight * 1.2 S.F. **= 5170 kg**

Steel in Frame:

- 2 main beams 9 X 3 channel =16' * 2 * 15 lb/ ft = 480 lb /2.2 lb/kg = 218 kg
- cross members (2 x 3 tubing) = 63' * 7.11 lb/ft = 448 lb/2.2 lb/kg = 204 kg
- expanded metal decking 4- 4x8 sheet = 103 lb/2.2lb/kg = 47 kg
- angle for edge (2 x3) = 58' * 3.07 lb/ft = 178 lb/2.2 lb/kg = 81 kg

550 kg

Total frame steel weight * 1.2 S.F. **= 660 kg**

Weight of two side water troughs

- Steel frame, 2 x 3 tubing =30' * 7.11 lb/ft = 213 lb/2.2 lb/kg = 97 kg
  2 x2 tubing = 15' * 5.41 lb/ft = 81 lb/2.2 lb/kg = 37kg
- Water trough approximate weight = 35 kg
- Water in troughts = 280 l * 2 troughs * 1 kg/l = 560 kg

729 kg

Total of water troughs * 1.2 S.F. **= 874 kg**

Weight of battery box/ electric fence box

- 4 batteries @ 28 kg = 112 kg
- Box, electric fencer, regulators and other equip = approx 100 kg

212 kg

Battery box system total * 1.2 S.F. **= 250 kg**

Weight of Solar panels and Mounts

- Solar panels and bracket mounts 4 * 10 kg = 40 kg

- Aluminium pipe masts 4 * 10 kg= 40 kg
- 2 x 2 angle for upper post mount = 20' * 3 lb/ft * 2.2 kg/lb = 27 kg

107 kg

Solar panels and Mounts total * 1.2 S.F. **= 128.4 kg**

Main Beam Free Body Diagram

See the following diagram for all loads represented as point loads.

Looking at these loads the largest one is the weight of the water @ 50.7 kN.

If this main load is analyzed as a point instead of a distributed load, there will be a large moment and therefore a larger stress concentration here than the actual value. This major load will be quickly analyzed using the following handbook formula for beam loading. If the found stress load is too close to the yield strength of the steel (400 MPa), a further detailed analysis will have to be done.

To determine the load stress caused here, the following Hand book formula will be used, See next page for details.

∅ = W a b C / Z l

W= 50.7 kN, a= 3.35'=1.02m, b= 10.25' = 3.13m, l = 13.6074' = 4.15 m

Z = I/C, $I = bd^3/12 =$ 67mm * $230mm^3$/12 – 55.6mm * $209mm^3$/12 = 25.63 x 10^6 mm

C= 115 mm, therefore Z = 222 897 mm

For this point load ∅ = 174.98 MPa for both beams

There fore this stress can be divided between the two beams- 174.98/2 = 87.5 Mpa

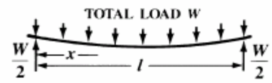
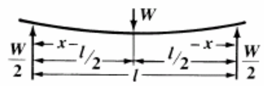
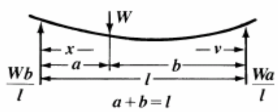
Steel has a yield stress of 400 MPa

Therefore the Safety factor here is 400/87.5 = 4.57

With this in consideration, the channel used for the main beam supports are more than sufficient to do the job, therefore a detailed stress loading analysis will not have to be done.

Handbook formula taken from Machinery's Handbook, 26 th Edition, p 239

Stresses and Deflections in Beams

Type of Beam	Stresses		Deflections	
	General Formula for Stress at any Point	Stresses at Critical Points	General Formula for Deflection at any Point[a]	Deflections at Critical Points[a]
Case 1. — Supported at Both Ends, Uniform Load				
	$s = -\frac{W}{2Zl}x(l-x)$	Stress at center, $-\frac{Wl}{8Z}$ If cross-section is constant, this is the maximum stress.	$y = \frac{Wx(l-x)}{24EIl}[l^2 + x(l-x)]$	Maximum deflection, at center, $\frac{5}{384}\frac{Wl^3}{EI}$
Case 2. — Supported at Both Ends, Load at Center				
	Between each support and load, $s = -\frac{Wx}{2Z}$	Stress at center, $-\frac{Wl}{4Z}$ If cross-section is constant, this is the maximum stress.	Between each support and load, $y = \frac{Wx}{48EI}(3l^2 - 4x^2)$	Maximum deflection, at load, $\frac{Wl^3}{48EI}$
Case 3. — Supported at Both Ends, Load at any Point				
	For segment of length a, $s = -\frac{Wbx}{Zl}$ For segment of length b, $s = -\frac{Wav}{Zl}$	Stress at load, $-\frac{Wab}{Zl}$ If cross-section is constant, this is the maximum stress.	For segment of length a, $y = \frac{Wbx}{6EIl}(l^2 - x^2 - b^2)$ For segment of length b, $y = \frac{Wav}{6EIl}(l^2 - v^2 - a^2)$	Deflection at load, $\frac{Wa^2b^2}{3EIl}$ Let a be the length of the shorter segment and b of the longer one. The maximum deflection $\frac{Wav_1^3}{3EIl}$ is in the longer segment, at $v = b\sqrt{1/3 + \frac{2a}{3b}} = v_1$

E=modulus of elasticity of the material

I=moment of inertia of the cross-section of the beam

Z=section modulus of the cross-section of the beam = *I* / distance from neutral axis to extreme fiber

W=load on beam

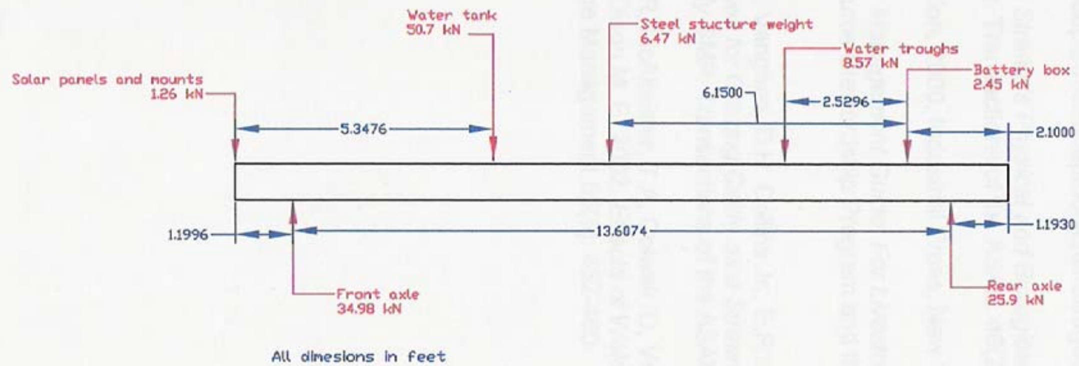
s=stress in extreme fiber, or maximum stress in the cross-section considered, due to load *W*. A positive value of *s* denotes tension in the upper fibers and compression in the lower ones (as in a cantilever). A negative value of *s* denotes the reverse (as in a beam supported at the ends). The greatest safe load is that value of *W* which causes a maximum stress equal to, but not exceeding, the greatest safe value of *s*

y=deflection measured from the position occupied if the load causing the deflection were removed. A positive value of *y* denotes deflection below this position; a negative value, deflection upward

u, v, w, x = variable distances along the beam from a given support to any point

Load Analysis for Main beams

Loads shown are total loads for both beams
Distrubuted loads are shown as point loads at there centers



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