Design of an Educational Water Feature for the Botanical Gardens of the Ozarks

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Introduction

The Botanical Gardens of the Ozarks was created by the Botanical Garden Society of the Ozarks (BGSO), a self described homegrown, grassroots organization established in 1994. The Botanical Gardens are located on 100 acres of property at the south east edge of Lake Fayetteville.

The Botanical Gardens provides lifelong learning with workshops, lectures, and classes. The local school children are offered programs at school and at the Garden including a broad array of garden-related topics, with wild plants, animals in the garden, health and wellness, sustainability, and garden and floral design. The Little Sprouts is offered for younger children.

Entrance to the Botanical Gardens

The Project

The goal for our senior design team on this project was to involve kids in learning about the production of energy. We introduce the basics of hydroelectric power, and propose alternative energy sources. In pursuing this goal, we must keep in tune with the aesthetic values of the Botanical Gardens where it is to be displayed.

In the United States, the primary source of fuel for electricity generation is fossil fuel. However, alternative forms of energy generation are gaining ground as a legitimate alternative to fossil fuel energy generation. If fossil fuel is to be largely replaced by alternative energy, the public must be aware of and support the efforts made towards that change. One method of accomplishing this is with an interactive, educational, alternative energy generator. With the input of Gerald Kilngaman at the Botanical Gardens of the Ozarks and Dr. Costello and Steve Green of the University of Arkansas, an alternative energy display was developed that uses human power as the initial input, and finally produces electricity.

In the final design, a child will ride a stationary bicycle that is directly connected to a positive displacement pump. Pedaling the bicycle will cause the pump to deliver water through a system of pipes that releases the water into a reservoir above a wooden water wheel.

When the water is released, the force of the water contacting the water wheel will cause the wheel to turn which will turn a generator. This generator will then power a series of lights to allow the children to see their muscle power manifest as electricity.

System Components

The first part of the system employs three power components:

1) Human

Power in → kilocalories=813 kcal/day

Power out → Joules per second (watts)=63.01 Watts of energy available as calculated.

From the estimated energy available* - 813 kcals/day, with 20% usable for 2 minutes at a time, we get:

$$\left(162.6\,\frac{\mathrm{kcal}}{\mathrm{day}}\right)\left(\frac{\mathrm{day}}{3\ \mathrm{hr}}\right)\left(\frac{\mathrm{hr}}{60\ \mathrm{min}}\right)(2\ \mathrm{min}) = 1.8066\ \mathrm{kcal}$$

$$(1.806\ kcal)\left(\frac{4.185KJ}{kcal}\right)\left(\frac{\mathrm{min}}{60\ \mathrm{sec}}\right)\left(\frac{1000\mathrm{J}}{\mathrm{KJ}}\right) = \frac{315\mathrm{J}}{\mathrm{sec}} = 63.01\ \mathrm{W}$$

2) Bicycle

The human energy is converted to mechanical energy losing 5% efficiency, when the child pedals the bike.

Power in → 63.01Watts

Power out → 63.01Watts x 95% eff. = 59.86Watts

The low estimate for revolutions per minute (RPM) input to the pedals is 40 RPM from the child, with a gear ration of 34:39 so, the RPM of the tire, as equal to the rear gear, calculates as,

(40 RPM) (39/34) = 45.88 RPM

Using the power equation P=Tω, where P=power; T=torque, ω=angular momentum, and T=Force x distance, the force between the tire and the pump is found as:

$$\mathrm{P} = \mathrm{T}\omega = \mathrm{F} * \mathrm{d} * 2\pi\left(\frac{\mathrm{RPM}}{60}\right)$$

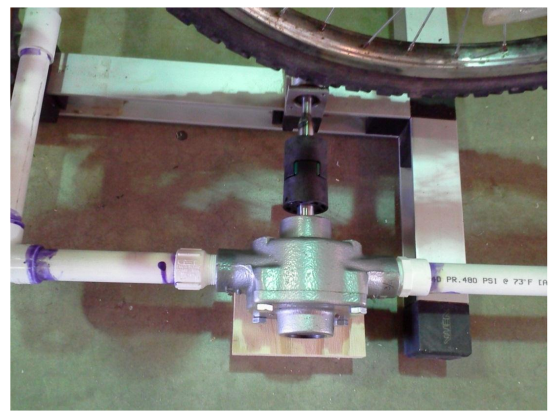
Insert substitutions and rearrange,

$$\mathrm{F} = \frac{\mathrm{P}}{\mathrm{d} * 2\pi\left(\frac{\mathrm{RPM}}{60}\right)}$$

Substitute values,

$$\mathrm{F} = \frac{59.86\mathrm{W}}{(0.305\mathrm{m})(2\pi)\left(\frac{45.88}{60s}\right)} = 40.85\mathrm{N}$$

Bike set up on trainer with pump attached.



Force is applied from the tire to pump shaft.

3) Pump

We used a positive displacement pump, so the power output is directly related to the RPM turning the shaft of the pump.

Power in → 59.86Watts

Power out → 59.78 Watts (should equal power in here)

Components and Testing

To find the RPM turning the pump shaft:

For the bike wheel (30.5cm radius) to the pump shaft (19.05mm radius), with angular rotation (ω),

$\omega 1 * r1 = \omega 2 * r2$

Rearranged,

$\omega 2 = \omega 1 * r1 / r2$

So,

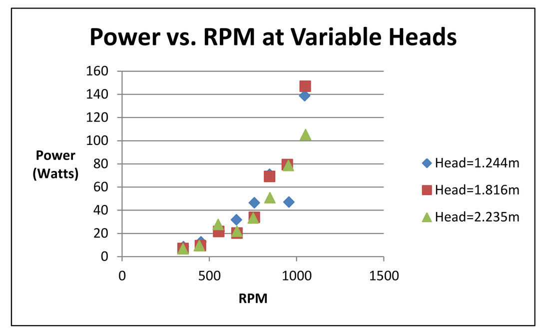
$\omega 2 = 45.88\mathrm{RPM} * 0.305\mathrm{m} / 0.01905\mathrm{m} = 734.56\ \mathrm{RPM}$

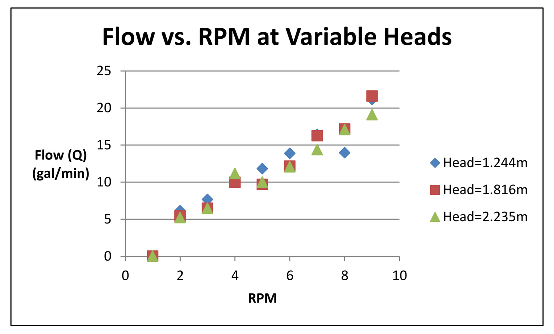
To check power output using force and RPM found:

$\mathrm{P} = \mathrm{T}\omega$

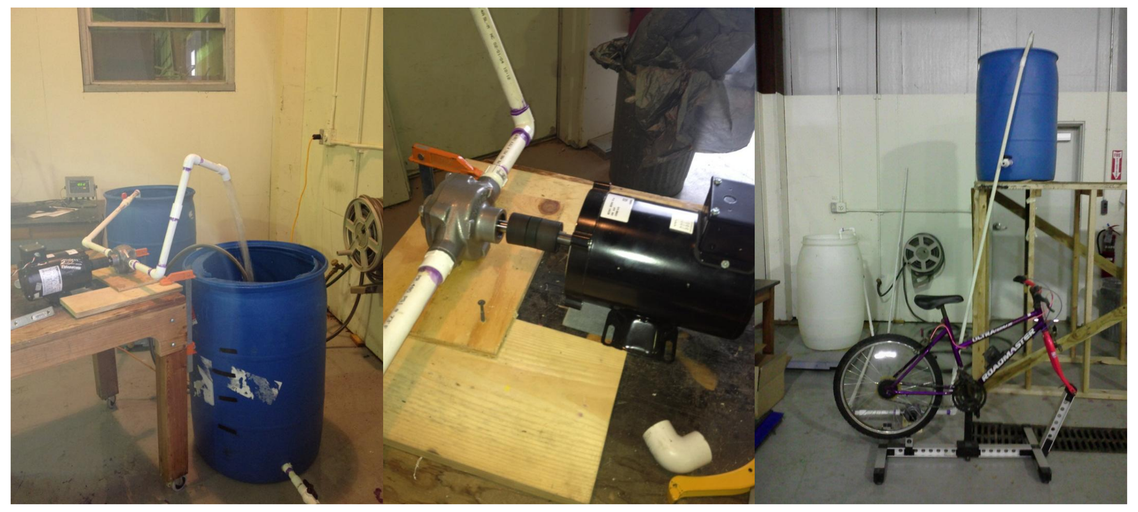
$$\mathrm{P} = (40.85\mathrm{N})(0.019\mathrm{m})(2\pi)\left(\frac{735.56}{60}\right) = 59.78\mathrm{W}$$

The power calculation estimate is consistent with the testing done on the pump at differing RPM.





Graph 1 shows power generated increasing exponentially with RPM, but not greatly affected by head at the values tested.
Graph 2 shows flow increasing linearly with RPM.
The water is pumped to a reservoir where it becomes potential energy.



Power and flow test set-up with variable RPM motor input, then set up with bike power input.

The second portion of the system employs three components also:

1) Reservoir

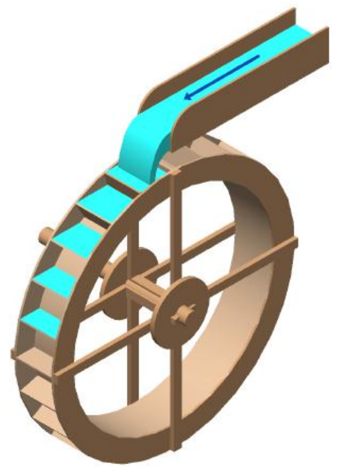
The water is pumped to the reservoir, and is considered potential energy. This can be estimated by;

PE = mass x gravity x head

We have not calculated this yet as our final location is yet undecided.

2) Waterwheel

When the sluice gate on the reservoir is lifted, the potential energy begins to create power as the forces of the water turn the wheel. The wheel transfers energy to the shaft as it rotates.

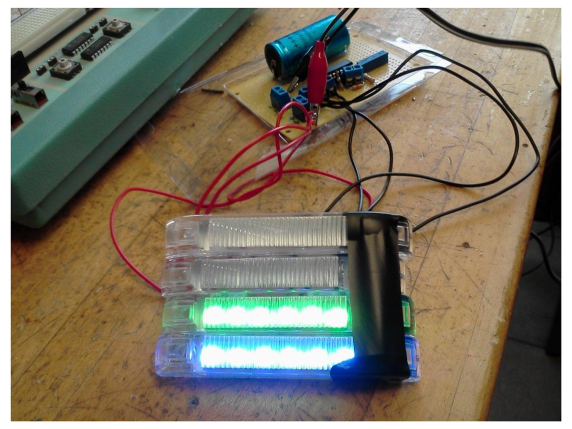


Outcomes Produced

3) Electric Power Generation

The shaft of the wheel turns the generator, lighting the LED light display.

While all the engineered components to the system have been prototyped, a complete, aesthetic design is still being finalized with input from our client.



The final outcome from the energy taken in as Calories will be an LED light display.

Future Enhancements

Our team would like to see the addition of a solar pump to fill the reservoir. We would also like to incorporate a wind turbine into the design, as we feel these additions would greatly add to the renewable energy education we wish to provide with this feature.

Sustainability

The successful completion of this project will benefit the Botanical Gardens, and it's visitors by enhancing the overall aesthetic and educational values of the Botanical Gardens which are important aspects of the Botanical Gardens' mission statement. Learning centers and community gathering places are essential to the social aspects of sustainability.

The educational value of this water feature can have ecological benefits to the managed systems by giving people a greater understanding of the amount of work required to generate even a small amount of energy. This understanding could lead to energy conservation decisions being consciously made by people who use this educational water feature.

Engineers are taught to address the sustainability of built systems while evaluating the life of their designs, and the most efficient and friendly use of the materials available.

Artistic rendition of proposed water wheel design for the Botanical Gardens.

This poster was prepared in partial fulfillment of SUST 4103 Sustainability Capstone