The Irrigator – Team 1 Prototype Description November 20, 2000

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Design Description:

Team 1's goal is to design a double-acting human-powered piston pump, according to the specifications given (Table 1). The Team 1 design is simply a pump, crank, and a chair attached to a baseboard. The adjustable seat is located at one end of the baseboard, and the pump located at the other, while the crank is in between (Figure 4). The pump is designed to use lower body power to move the piston. A person's lower body can create more force and tires out much more slowly than the upper body.

CHARACTERISTICS	SPECIFICATIONS
Cost	Less than $150
Power	Human Power and/or 9V or AA Batteries
Assembly/Disassembly Time	15/10 Minutes
Kit Size	Minimize
Accomodations	3 Different People, 1 Female
Flow Rate	Maximize
Performance	Move Water 8 Feet High
Measurement Method	Accuracy of Measurement at Instantaneous Flow Rate

Table 1 -- Design Requirements

Design Details:

The wooden seat is held down by bolts that go through a 14" piece of angle iron (Figure 3; Seat Base Bracket), with holes 6 inches apart (Figure 4; Item 5). This makes an adjustable distance between the pedals and the operator. A bicycle crank and pedals push the shaft (Figure 4; Items 2 & 8). The link piece to the shaft consists of two pieces of 1" flat bar welded into a T-shape for strength (Figure 3; Pedal-Shaft Linkage). The link is attached to a bicycle pedal on one end and the piston shaft on the other (Figure 4; Item 3). A bearing prevents the piston shaft from any unwanted motion (Figure 4; Item 7). The pedals are secured to the baseboard using 2" pieces of 1" angle iron (Figure 3; Pedal Base Bracket). The pump is elevated above the baseboard, equally level with the pedals. This maximizes force by allowing the operator to push directly on the piston. The pump is attached to a pump stand using band clamps to stop unwanted motion.

The pump uses oscillating movement to move water on both sides of the piston in the cylinder. The cylinder is 4" PVC, where the size is based on Equation 1:

$$r=\sqrt{(f)/(p*\pi)} \qquad (1)$$

where r = radius, f = force on piston (about 50 lbs), p = pressure (3.47 psi) (Dally 81). The piston is attached to a steel shaft (with one threaded end) using a piece of rubber squeezed between two circular pieces of steel with nuts to make an adjustable seal (Figure 4 Detail B). The piston travels 13 inches.

The design uses two one-way check valves on each side of the piston to create a directed flow. Each set of valves contains an "in" valve and an "out" valve. On the side opposite of the shaft, the check valves attach to a threaded T-fitting, placed in the center of the cylinder. On the shaft side, the valves run 90° to the shaft, as close to the cap as possible (Figure 4 Item 6).

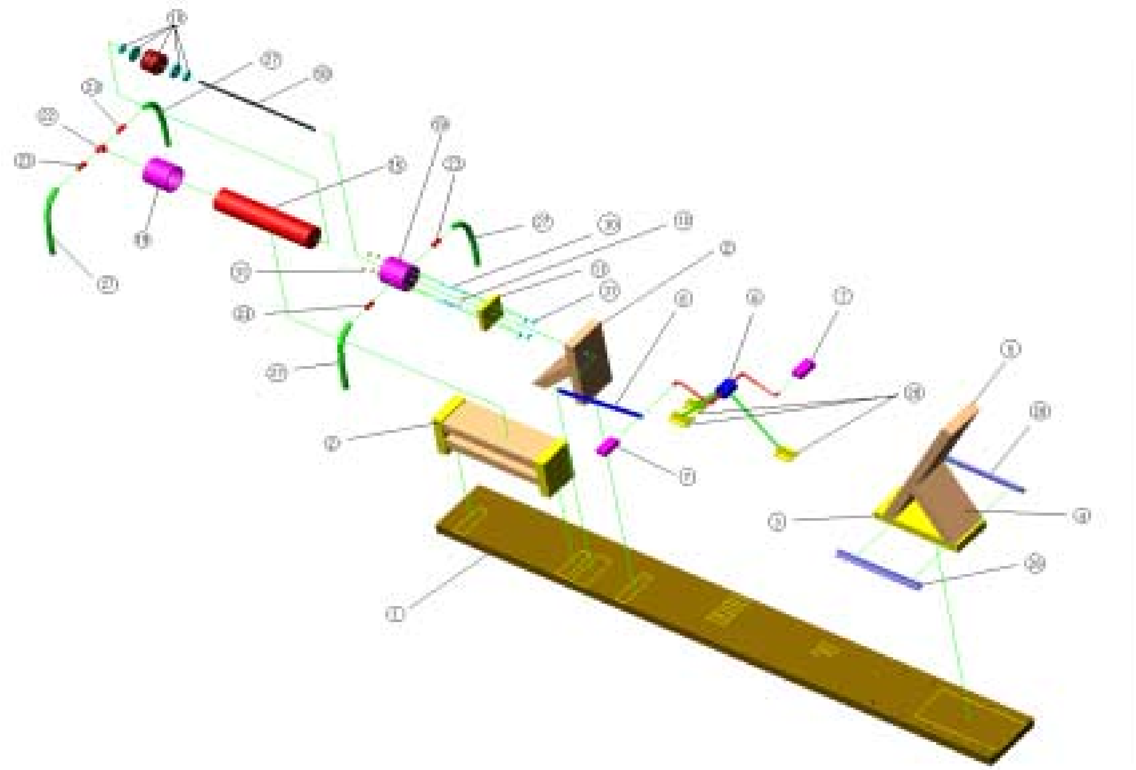


Figure 1 – Assembly Drawing

Table 2

Part #	Part Name	Description	Dealer or Loc.	Qty.	Unit Price	Total
1	Baseboard	2"x12"x10'	Home Depot	1	$ 9.24	$ 9.24
2	Chair:	2"x10"x8'	Home Depot	1	$ 6.92	$ 6.92
4	Strut	2"x10"x30"	From Part 2	1		$ -
3	Brace	2"x10"x18"	From Part 2	1		$ -
5	Back	2"x10"X40"	From Part 2	1		$ -
50	Pump Stand	2"x8"x6'	Home Depot	1	$ 3.95	$ 3.95
51	Ends	2"x8"x11"	From Part 50	1		$ -
52	Middle	2"x8"x17"	From Part 50	1		$ -
53	Top	2"x8"x20"	From Part 50	1		$ -
6	Crank	From Bicycle	Garage Sale	1	$ 5.00	$ 5.00
7	Bicycle Pedals	From Bicycle	From Part 6	1		$ -
8	Link	T-weld 1"x14"x(3/16)	Home Depot	1	$ 2.98	$ 2.98
	Shaft-Link Pin	1"x1/4"Bolt	Home Depot	1	$ 0.07	$ 0.07
10	Shaft	.5"dia x 3.5'~4' steel	Home Depot	1	$ 6.95	$ 6.95
11	Packing Ring Flange	3"o.d.,7/8"I.d.	Home Depot	1	$ 2.95	$ 2.95
12	Packing Material	.25"dia x 2'	Home Depot	1	$ 1.98	$ 1.98
19	Shaft Housing Cap	4"x Schd.40	W. Nev.Supply	1	$ 4.11	$ 4.11
19a	Shaft Housing Plug	4" Threaded Plug	W. Nev.Supply	1	$ 2.98	$ 2.98
15	Pump Housing	PVC #40 4"x2'	W. Nev.Supply	1	$ 11.66	$ 11.66
	Band Clamps	.75" x 3'	Home Depot	2	$ 1.35	$ 2.70
	Washers	.75"dia	Home Depot	2	$ 0.06	$ 0.12
18	Plumbers Plug	4" dia	W. Nev.Supply	1	$ 3.88	$ 3.88
18	Shaft Cap	.5"dia.Cap	Home Depot	1	$ 0.59	$ 0.59
19	End Housing Cap	4"x Schd.40	W. Nev.Supply	1	$ 4.62	$ 4.62
23	Brass Nipple	.75" dia.	W. Nev.Supply	5	$ 2.21	$ 11.05
22	Brass T	.75" dia.	W. Nev.Supply	1	$ 4.76	$ 4.76
23	Check Valve	.75" dia.	W. Nev.Supply	4	$ 3.95	$ 15.80
	Hose Adapter	.75"x5/8"(ribbed)	Home Depot	4	$ 0.37	$ 1.48
	Hose T	5/8"(ribbed)	Home Depot	3	$ 0.47	$ 1.41
	Hose Clamps	1"	Home Depot	10	$ 0.42	$ 4.20
	Garden Hose	5/8"x50'	Home Depot	1	$ 5.95	$ 5.95
28	Angle Iron	4'x1"	Home Depot	1	$ 2.95	$ 2.95
	Bolts (Lag)	3/8"	Home Depot	24	$ 0.37	$ 8.88
	Bolts (Carrige)	1/4"dia x 2"	Home Depot	11	$ 0.17	$ 1.87
	Wing Nuts	1/4"dia.	Home Depot	4	$ 0.08	$ 0.32
	Nuts	1/4"dia	Home Depot	13	$ 0.06	$ 0.78
	Washers	.75"dia	Home Depot	16	$ 0.06	$ 0.96
	J B Weld	Two Part Cold Weld	Home Depot	1	$ 2.96	$ 2.96
	Paint	Assorted Colors	Garage Sale	1	$ 1.00	$ 1.00
					Subtotal	$ 135.07
			Nv Sales Tax @ 7.25%			$ 9.79
					Total	$ 144.86

Assembly Instructions (Refer to Table 2):

Chair; use 3/8” bolts: strut (4) to back (5), back (5) to brace (3), brace (3) to strut (4), brace (3) to angle iron (20&28), assembled chair can then be lined up with appropriate predrilled holes in baseboard (1) and kept in place with four 3/8” pins (cut off bolts). Piton; on threaded end of shaft (10) attach: Plumbers’ plug (18) and shaft cap (18). Pump stand; use 3/8” bolts: attach with 4 bolts to baseboard (1). Pump; use silicon: attach end housing cap (19) to pump housing (15), brass nipple (23) to end housing cap (19), two brass nipples (21) to shaft housing cap (13), and shaft housing plug (14) to shaft housing cap (13). Crank; use precut 2” pieces of 1” angle iron and ½” bolts with washers and nuts: attach angle iron pieces (2 each) to each of 3 support rods on crank (6), attach opposite sides of six pieces of angle iron to baseboard (1). Pump-Shaft; insert assembled piston end of shaft into pump housing, place assembled shaft housing cap over shaft and secure shaft cap to pump housing using silicon. Shaft-Link; place packing material (12) in depression of shaft housing plug (14), place packing ring flange (11) over shaft and attach to shaft housing plug (14) with ¼” wing nuts and washers, place shaft support bearing over shaft and attach bottom of bearing to baseboard (1) with two 3/8” bolts, attach end of shaft (10) to link (8) with one ¼” bolt with washers and nuts. Pump-Pump Stand; wrap two band clamps (16) around pump and assembled pump stand then tighten. Link-Crank; remove one pedal (7) from crank (6) and capture link (8) between pedal axle and crank, tighten. Inlet-Outlet; attach brass T (22) to end housing cap, attach two brass nipples (21) to brass T (22), attach four check valves (23) in single direction flow at both ends of the pump to four brass nipples (21). Use 1” hose clamps to: attach four hose adapters (24) to each of four check valves (23), attach two 12” length inlet hoses to one hose T (25), repeat for outlet hoses, attach 10’ lengths of hose to outlet hose T and inlet hose T.

Testing and Analysis:

To construct the graph of theoretical power vs. theoretical flow rate, the independent variable is power. To vary power, the number of strokes per minute must vary. For the graph, the number of strokes starts at 0 and increases in increments of 1 up to 10. To calculate power, use Equation 2:

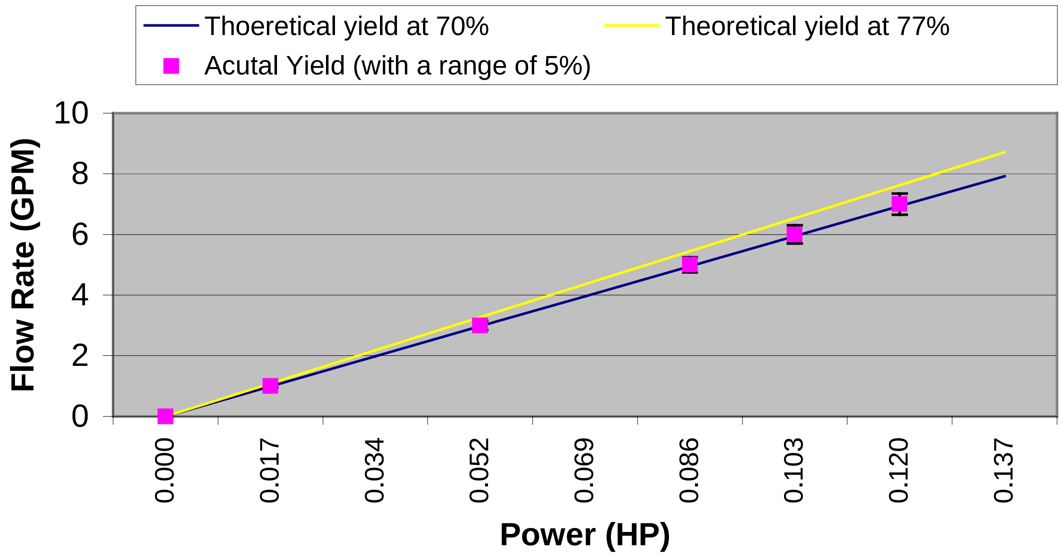
$$P=p\pi r^2dn \qquad (2)$$

where P is Power in ft·lbs/min, p is the pressure (3.47 psi) (Dally 81), r is the radius of the cylinder (2 inches), d is the stroke length (13 inches), and n is the number of strokes/minute. To convert to horsepower, divide this number by 33,000 (Dally Equation 3.8). So, the power varies from 0 horsepower to .17 horsepower by increments of .017 horsepower. The dependent variable (theoretical volumetric flow rate) was calculated using Equation 3:

$$q_v = \pi r^2dn = P(n)/3.47 \text{ psi} \qquad (3)$$

where q_v is volumetric flow rate in in^3/min. This is converted to gallons/min by dividing by 231 (Dally 80). Also shown in Equation 2 is flow rate written as a function of power.

Figure 2
Power vs. Flow Rate



The solid blue line on the graph in Figure 2 represents the theoretical yield at 70% efficiency. The solid yellow line represents the theoretical yield at 77% (Dally 82). The pink points are the actual yield values obtain from testing with an error of 5% (from measuring error and leaking). By comparing the theoretical yield to the actual yield, our pump functions at about 70% efficiency. We found the actual flow rate values by setting up our pump, priming it, and pumping the corresponding strokes/min. These values were found with two different people pumping and the data points on the graph are the medians of the data for a given power output. The amount of water was measured using a measuring pitcher. The only leakage that occurred was very minimal (about an ounce per minute) and was from the seal surrounding the shaft. We intend to solve the problem by repacking the seal. The other problem we ran into was the garden hose collapsing in on itself. This is a good sign, however, in that it demonstrates that there is plenty of pressure to push the water up eight feet and that the seal between the piston and the cylinder is strong. By fixing these problems, we should be able to reach our potential of having 77% efficiency.

Bibliography:

Dally, James W. Introduction to Engineering Design: Human Powered Pumping Systems. Book 4. College House Enterprises, LLC., Knoxville, Tennessee, 1999.

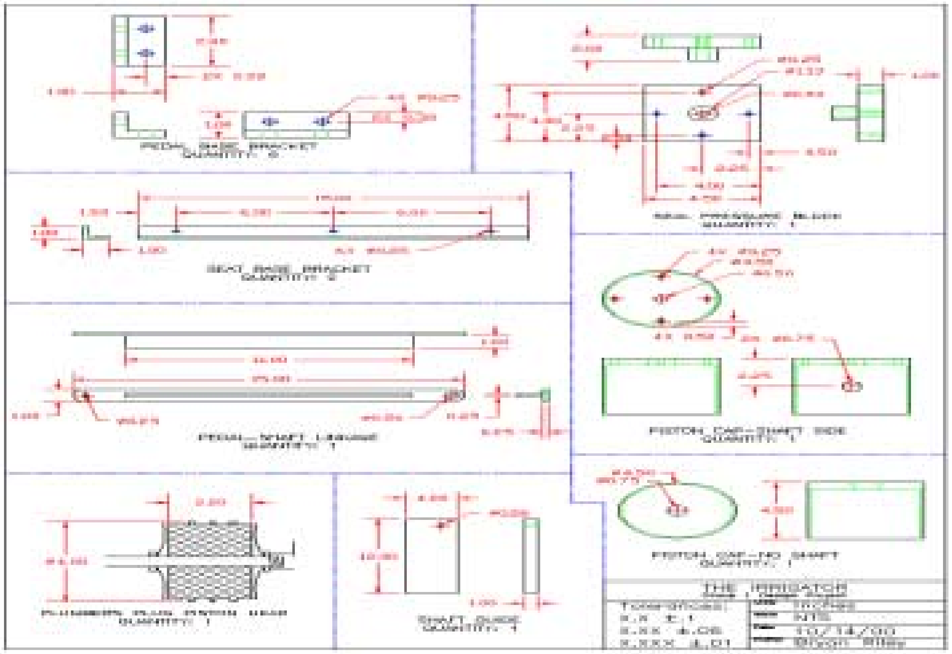


Figure 3 – Multiview Drawing 1

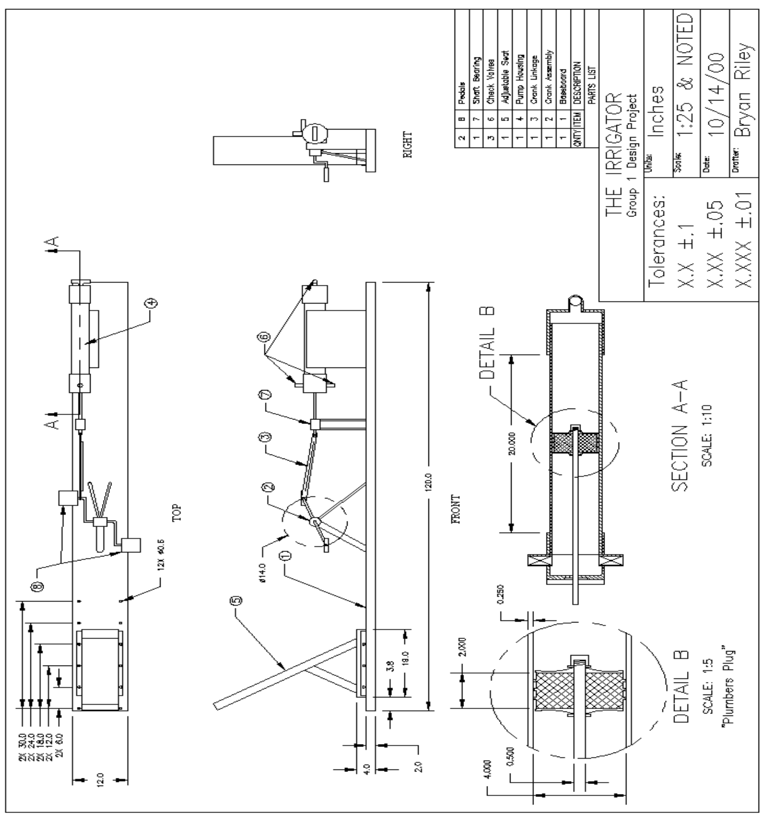


Figure 4 – Multiview Drawing 2