NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics, and Applied Sciences

Memorandum

Design4Practice (D4P) Program

To: Dr. David Trevas

From: Aaron Curley

Due: 10/11/20

Re: Individual Analytical Analysis

Introduction

Our capstone team has been tasked with building a small scale residential vertical farming system. The system should occupy the least amount of space and provide owners with a supply of healthy nutritious vegetables. Vertical farming systems have the potential to revolutionize farming because the amount of crops that can be produce per land area is unprecedented. Our main design is a vertically stacked aquaponics system.

Aquaponics combines aquaculture and hydroponics to grow fruits and vegetables. The nutrient film technique will be used to provide plants with the nutrients they need. In this method plant roots are soaked with a thin layer of water flowing at the bottom of a tube or trough. The water is filled with oxygen and nutrients which are absorbed by the plant.

The results of last semester's technical analysis were three system head curves that could be used to select pumps to meet the flow rate demands. The design has now changed and the MATlab code used to calculate the system head curves needs to be changed. Design changes include the inside diameter of the tubing used, the amount of water held in the grow troughs, and the number of troughs.

Equations

The fundamental equation used to select pumps is the energy equation expressed in terms of head. This equation defines conservation of energy within a fluid. In our calculations we set P_1, P_2, v_1, v_2, and H_T equal to zero because the water at points one and two are held in tanks, exposed to the atmospheric pressure, and there is no turbine in the system.

$$\frac{P_1}{\rho G}+\frac{v_1^2}{2G}+z_1+H_P=\frac{P_2}{\rho G}+\frac{v_2^2}{2G}+z_2+H_T+H_L \qquad \text{Eq 1}$$

Equation 1 Energy equation [1]

Table 1 Energy equation variables

Variable	Description
P	Pressure
v	Velocity
ρ	H20 Density (62.4 lbs/ft^3)
G	Gravity (32.2 ft/s^2)
z	Height
H_P	Pump head
H_T	Turbine head
H_L	Total head loss

Project schematic

Figure 1 diagram of the team's design from last semester. The system had three subsystems used to move water. The first (orange) will move water to a manifold at the top which will distribute water to the seven troughs below it. The second (green) will move water to 4 troughs below the fish tank. The water will then drain into a tank at the bottom and then subsystem 3 (blue) will move the water back into the fish tank.

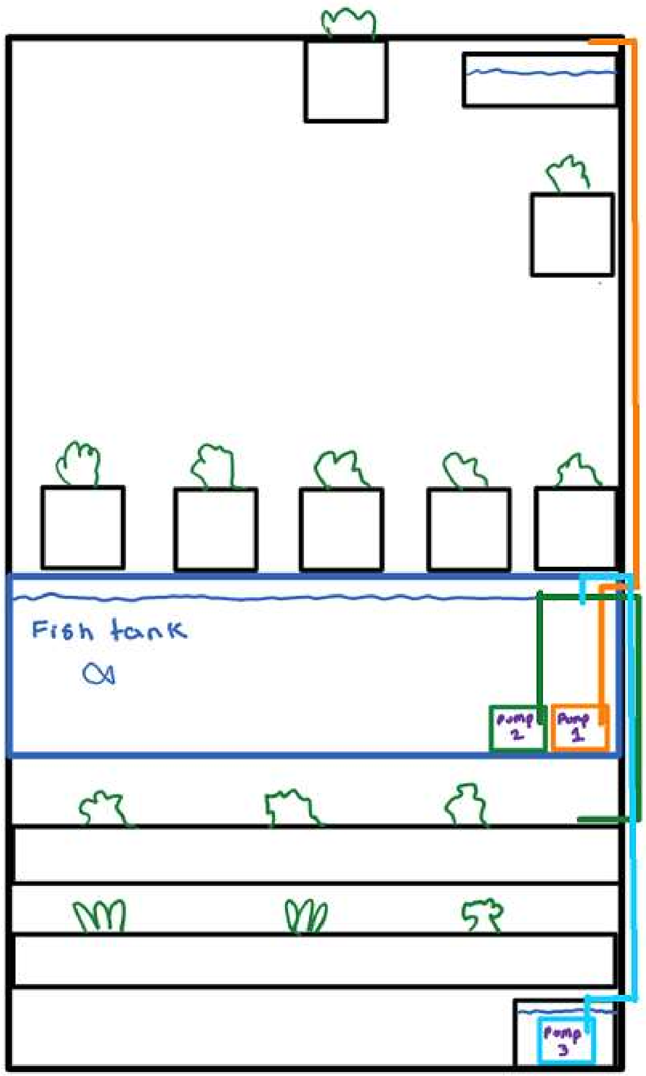

Figure 1 Right Side view of aquaponics design

Figure 2

Figure 2 is the updated current design. The updated design only uses subsystem 1 from the previous design. The lower grow troughs were removed and the number of troughs on top was increased from seven to ten. The size of the grow troughs was also decreased. The width was decreased from 4.5 inch to 4 inches. The inside diameter of the tube carrying the water up to the troughs has also changed from .5 inches to .75 inches.

All troughs in the system will hold ¼ inch of water used to feed and water the plants. The dimensions of the troughs are 48”x4”x”’ The top troughs are all the same size and will each hold .207 gallons of water. This is a reduction from .23 gallons calculated in the first semester. The water will be recirculated every five minutes which will produce at flow rate of 2.492 gallons per hour (Gph). A good flow rate for the leafy greens we plan on growing is 5 gallons per hour [2]. To get the total flow rate required 2.492 Gph is multiplied by the number of troughs (10). The total flow rate required is 24.92 gallons per hour. This is an increase from 19.63 calculated in the last semester. Figure 3 below shows that the pump selected last semester, the Ponics pumps PP-291xx, will still provide the head and flow rate necessary.

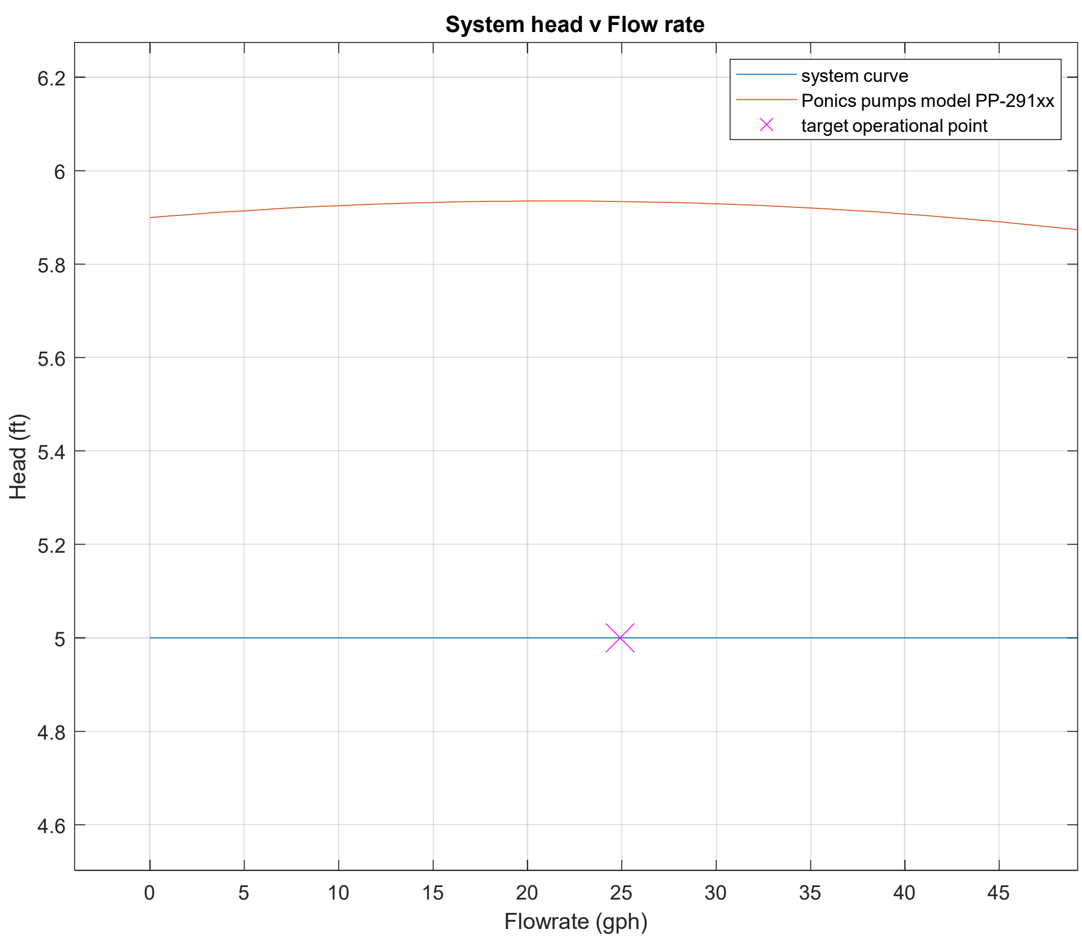

Figure 3 System head curve and selected pump performance curve.

Works Cited

[1] Çengel Yunus A. and J. M. Cimbala, *Fluid mechanics: fundamentals and applications*. New York, NY: McGraw-Hill Education, 2018.

[2] A. R. Al-Tawaha, G. Al-Karaki, and A. Rahman Al-Tawaha, "Effect of water flow rate on quantity and quality of lettuce (Lactuca sativa L.) in nutrient film technique (NFT) under hydroponics conditions," *Bulgarian Journal of Agricultural Science*, vol. 24, no. 5, 2018.

APPENDICES

Appendix A: Matlab calculations

```
%Define constants
nu=1.06e-5 %ft^2/s fox and mcdonalds Table A.7
```

```
nu = 1.0600e-05
```

```
gpm2ft3ps = .0022801;
ft3s2gpm = 448.831;
g = 32.2 %ft^2/s
```

```
g = 32.2000
```

```
%Pump 1
A1 = .00307 %ft Tube cross sectional area
```

```
A1 = 0.0031
```

```
L1 = 5.5 %ft Length of tube
```

```
L1 = 5.5000
```

```
D1 = .0625 %ft Diameter of tube
```

```
D1 = 0.0625
```

```
DelZ = 5 %ft Change in height
```

```
DelZ = 5
```

```
E1 = .000023 %ft Roughness
```

```
E1 = 2.3000e-05
```

```
%Calculate system head curve
Q_vec = [0:.1:1]*gpm2ft3ps; %ft^3/s
V1_vec = Q_vec/A1; %calculate velocities from flow rate
Re1_vec = V1_vec*D1/nu; %calculate reynolds number from flow rate
epsD1_vec = E1/D1*ones(size(Re1_vec)); %pre allocate epsilon/diamter vector
f1_vec = (.3086)./(log((epsD1_vec.*Re1_vec+25.530)./Re1_vec)-.5682).^2.22; %halland equation
solved for f to get friction factors
```

```
H_sys = DelZ+f1_vec*(L1/D1).*(Q_vec.^2./2*g*A1^2); %system head curve

%Plot system head curve
figure;
plot((Q_vec/gpm2ft3ps)*60,H_sys); %gal/hour vs ft
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
xlim([0 30])
title('System head v Flow rate')
ylabel('Head (ft)')
xlabel('Flowrate (gph)')
grid on
hold on

%Plot pump performance curve
% Ponics pumps model PP-291xx 16 watt Flow rate and Head from documentation
Q1 = [291 271 251 218 175 120 26] %gph
```

```
Q1 = 1×7

   291   271   251   218   175   120    26
```

```
H1 = [0 1 2 3 4 5 6] %ft
```

```
H1 = 1×7

     0     1     2     3     4     5     6
```

```
performance=polyfit(Q1,H1,2);
plot(0:300,polyval(performance,0:300))
xlim([0 30])

%Plot target operational point
Q_rec_gpm = .4152 %gpm 24.92GPH
```

```
Q_rec_gpm = 0.4152
```

```
Q_rec = Q_rec_gpm*gpm2ft3ps
```

```
Q_rec = 9.4670e-04
```

```
H_req = interp1(Q_vec,H_sys,Q_rec)
```

```
H_req = 5.0000 - 0.0000i
```

```
plot((Q_rec/gpm2ft3ps)*60, H_req,'mx','Markersize',20)
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
legend('system curve','Ponics pumps model PP-291xx','target operational point')
```