MET 330

Test 2

10/30/24

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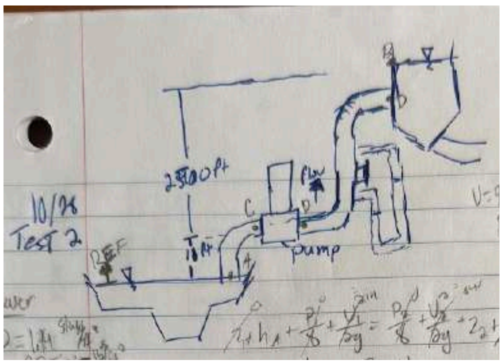
A

Purpose:

Determine the required pump power (in HP), assuming a pump efficiency of 60%. As well as compute the pressure at the pump inlet and at the pump outlet.

Diagram:



Sources:

Applied Fluid Mechanics, 8th edition, 2021

Design Considerations:

Based on the description, I assumed:
Water @ 60°F
Incompressible fluid

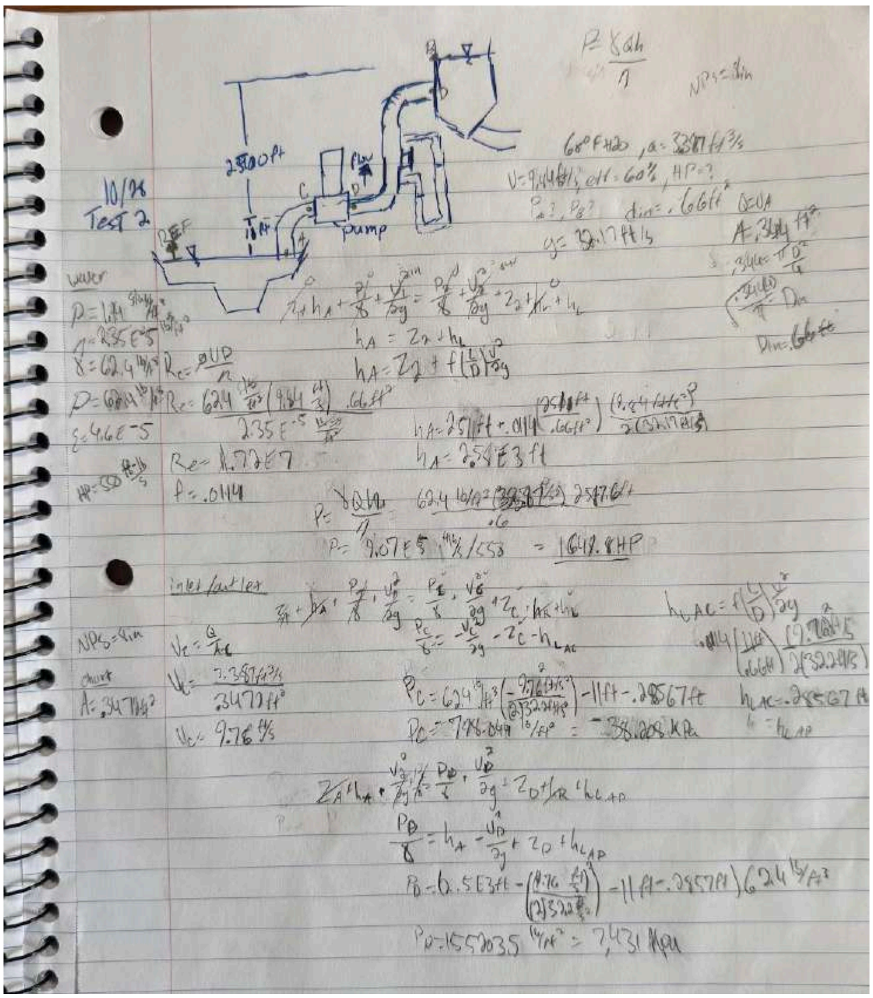
Data and Variables:

NPS 8in
Q = 3.38 ft^3/s
G = 32.2 ft/s^2
V = 9.84 ft/s^2
D = .66 ft
A = .334 ft^2
Density = 62.4 1b/ft^3
Gamma = 62.4 1b/ft^
h a-c = 11ft
h a-b = 2511ft

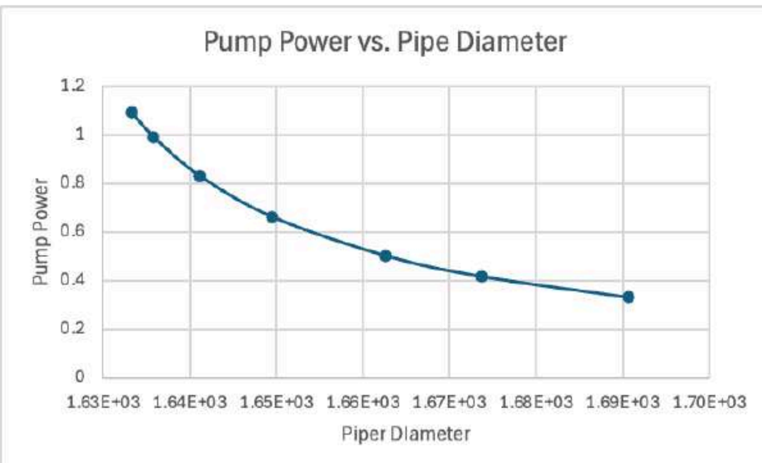
Materials:

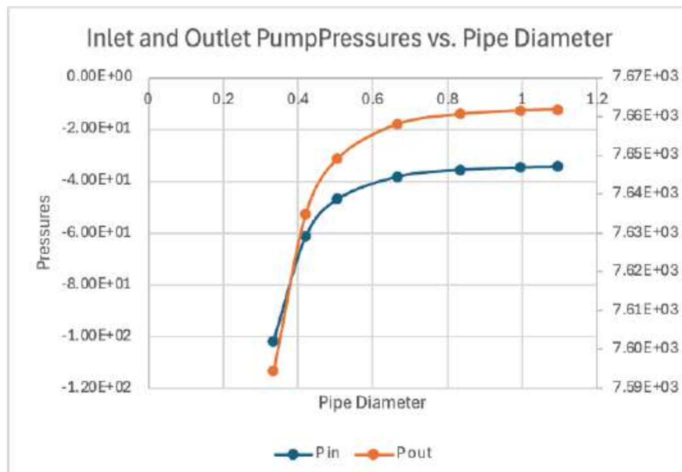
Schedule 40 steel pipes (suction and discharge)
Water
pump

Procedure/Calculations:



pipe diameters	pow (hp)	flow area	v	p in	p out
0.33355	1.69E+03	0.0884	38.31447964	-1.02E+02	7.59E+03
0.42046	1.67E+03	0.139	24.36690647	-6.13E+01	7.63E+03
0.5054	1.66E+03	0.2006	16.88434696	-4.69E+01	7.65E+03
0.6651	1.65E+03	0.3472	9.755184332	-3.81E+01	7.66E+03
0.835	1.64E+03	0.5479	6.181784997	-3.55E+01	7.66E+03
0.9948	1.64E+03	0.7771	4.358512418	-3.46E+01	7.66E+03
1.094	1.63E+03	0.9396	3.604725415	-3.43E+01	7.66E+03





Summary:

The required pump power is 1649.8 HP
The Pressure at the inlet is -38.208 Kpa
The Pressure at the outlet is 7431 Kpa

Analysis:

These results make sense due to the vertical size of the system and how high the pump actually has to move the fluids. The pressure at the inlet being negative makes sense, because it is above the water level meaning that there is a vacuum taking place which requires a negative pressure. The large size of the pressure at the outlet of the pump concerned me at first but I remembered that the pump has to move the water 2500 ft vertically which would require a large number like 7000 kpa. The selected pipe was a good choice, it has good output amongst the other pipes.

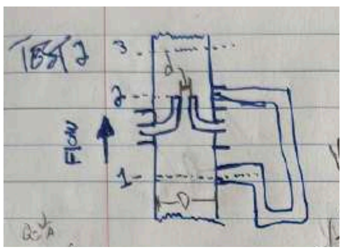
<u>B</u>

Purpose:

For a nozzle diameter to pipe diameter ratio of 0.5, determine the pressure drop across the nozzle?

With this addition to the system, would the pump power increase?

Diagram:



Sources:

Applied Fluid Mechanics, 8th edition, 2021

Design Considerations:

Water @ 60°F
Incompressible fluid
I assumed variables from problem A were apart of the same system

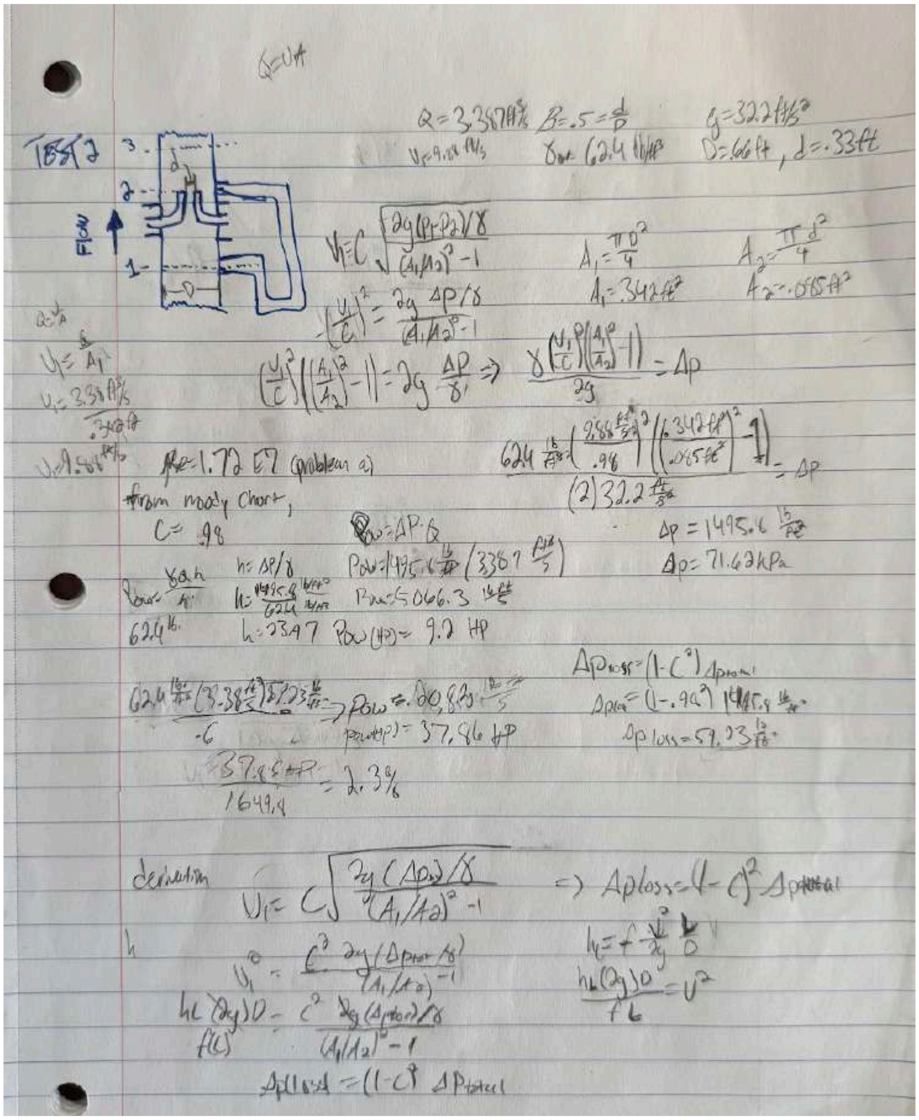
Data and Variables:

NPS 8in
Q = 3.38 ft^3/s
G = 32.2 ft/s^2
V = 9.84 ft/s^2
D = .66 ft
D = .33 ft
B = .5
C = .98
Re = 1.72
A1 = .334 ft^2
A2 = .085ft^2
Density = 62.4 1b/ft^3
Gamma = 62.4 1b/ft^
h a-c = 11ft
h a-b = 2511ft

Materials:

Schedule 40 steel pipes (suction and discharge)
Water
Flow nozzle

Procedure/Calculations:



$Q = VA$

TEST 2

$Q = 3.387\ ft^3/s$ $\beta = .5 = \frac{d}{D}$ $g = 32.2\ ft/s^2$

$V_1 = 9.88\ ft/s$ $\gamma_w = 62.4\ lb/ft^3$ $D = .66\ ft$, $d = .33\ ft$

FLOW

$V_1 = C\sqrt{\frac{2g(p_1 - p_2)/\gamma}{(A_1/A_2)^2 - 1}}$ $A_1 = \frac{\pi D^2}{4}$ $A_2 = \frac{\pi d^2}{4}$

$A_1 = .342\ ft^2$ $A_2 = .085\ ft^2$

$\left(\frac{V_1}{C}\right)^2 = \frac{2g\ \Delta p/\gamma}{(A_1/A_2)^2 - 1}$

$Q = \frac{V}{A}$

$V_1 = \frac{Q}{A_1}$

$V_1 = \frac{3.38\ ft^3/s}{.342\ ft^2}$

$V_1 = 9.88\ ft/s$

$\left(\frac{V_1}{C}\right)^2\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right) = 2g\frac{\Delta p}{\gamma} \Rightarrow \frac{\gamma\left(\frac{V_1}{C}\right)^2\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)}{2g} = \Delta p$

$Re = 1.72\ E7$ (problem a)

from moody Chart,

$C = .98$

$\frac{62.4\frac{lb}{ft^3}\left(\frac{9.88\ ft/s}{.98}\right)^2\left(\left(\frac{.342\ ft^2}{.085\ ft^2}\right)^2 - 1\right)}{(2)\,32.2\frac{ft}{s^2}} = \Delta p$

$Pow = \Delta P \cdot Q$

$\Delta p = 1495.6\ \frac{lb}{ft^2}$

$\Delta p = 71.62\ kPa$

$Pow = \frac{\gamma Q h}{A}$ $h = \Delta P/\gamma$ $Pow = 1495.6\ \frac{lb}{ft^2}\left(3.387\ \frac{ft^3}{s}\right)$

$h = \frac{1495.6\ lb/ft^2}{62.4\ lb/ft^3}$ $Pow = 5066.3\ \frac{lb\,ft}{s}$

$62.4\ lb$ $h = 23.47$ $Pow\ (HP) = 9.2\ HP$

$\Delta p_{loss} = (1 - C^2)\Delta p_{total}$

$\frac{62.4\frac{lb}{ft^3}\left(3.38\frac{ft^3}{s}\right)(57.23)\frac{lb}{ft^2}}{.6} \Rightarrow Pow = 20,829\ \frac{lb\,ft}{s}$

$\Delta p_{loss} = (1 - .98^2)\ 1495.6\ \frac{lb}{ft^2}$

$Pow(HP) = 37.86\ HP$

$\Delta p\ loss = 59.23\ \frac{lb}{ft^2}$

$\frac{37.86\ HP}{1649.4} = 2.3\%$

derivation

$V_1 = C\sqrt{\frac{2g(\Delta p_{tot})/\gamma}{(A_1/A_2)^2 - 1}}$ $\Rightarrow \Delta p_{loss} = (1 - C)^2\,\Delta p_{total}$

h

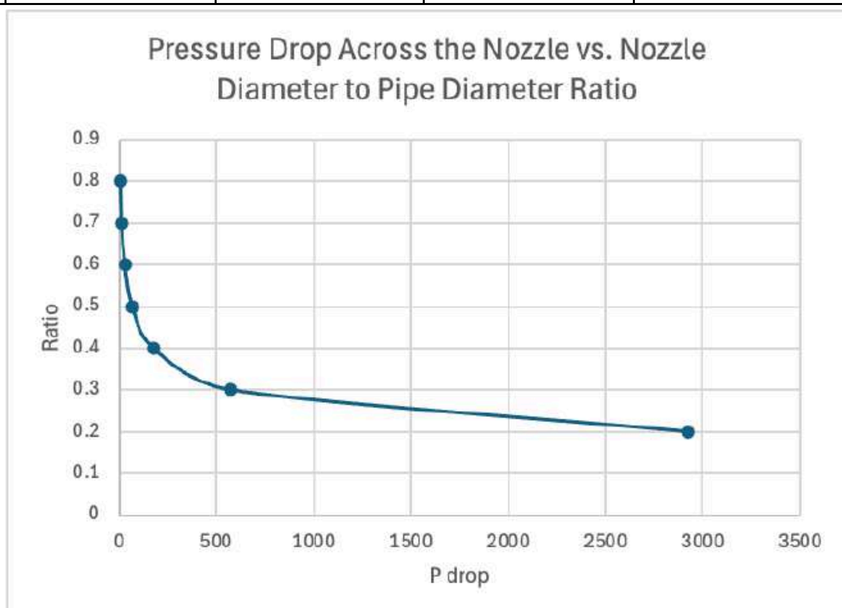
$V_1^2 = \frac{C^2\ 2g(\Delta p_{tot}/\gamma)}{(A_1/A_2)^2 - 1}$ $h_L = f\frac{V^2}{2g}\frac{L}{D}$

$\frac{h_L(2g)D}{f\,L} = V^2$

$\frac{h_L(2g)D}{f(L)} = \frac{C^2\ 2g(\Delta p_{tot})/\gamma}{(A_1/A_2)^2 - 1}$

$\Delta p_{loss} = (1 - C)^2\,\Delta p_{total}$

ratio	pipe diameters	nozzle D	a1	a2	p 1-2 (kpa)
0.2	0.33355	0.06671	0.087335648	0.003493426	2921.346228
0.3	0.42046	0.126138	0.13877749	0.012489974	573.2991698
0.4	0.5054	0.20216	0.200511891	0.032081902	178.1950974
0.5	0.6651	0.33255	0.347251038	0.086812759	70.22466895
0.6	0.835	0.501	0.547321625	0.197035785	31.4421563
0.7	0.9948	0.69636	0.776857226	0.380660041	14.81708342
0.8	1.094	0.8752	0.93951626	0.601290406	6.748151781



Summary:

The pressure drop across the nozzle is 71.62 kPa
The percent increase is 2.3%

Analysis:

This result makes sense due to the fact that the flow nozzle is supposed to help facilitate the fluids through the pipe, the Faster the liquid moves the more losses there are and the greater change in pressure. As the nozzle get smaller, the change in pressure increases, proving this theory.

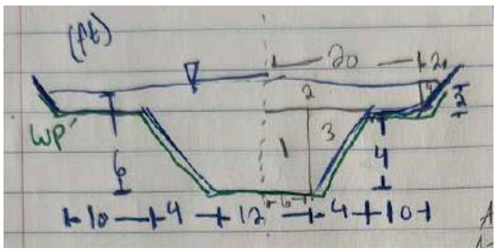
<u>**C**</u>

Purpose:

Compute the flow rate running through the lower open channel.

Compute the percentage of pumped water flow with respect to the lower open channel flow.

Diagram:



Sources:

Applied Fluid Mechanics, 8th edition, 2021

Design Considerations:

Based on the description, I assumed:
Water @ 60°F
Incompressible fluid
Open channel with light brush
I assumed variables from problem A & B were apart of the same system

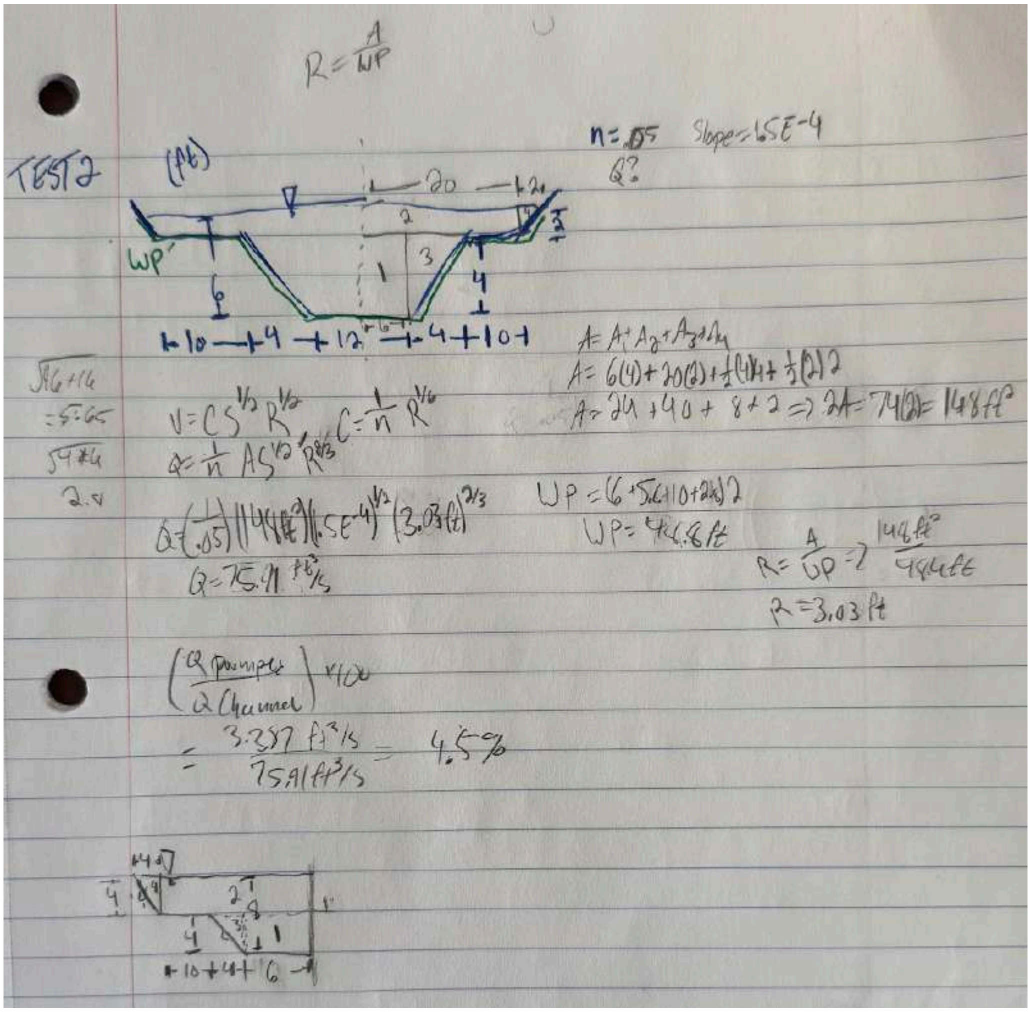
Data and Variables:

NPS 8in
Q = 3.38 ft^3/s
G = 32.2 ft/s^2
V = 9.84 ft/s^2
D = .66 ft
D = .33 ft
B = .5
C = .98
Re = 1.72
A1 = .334 ft^2
A2 = .085ft^2
Density = 62.4 1b/ft^3
Gamma = 62.4 1b/ft^
h a-c = 11ft
h a-b = 2511ft
N = .05
S = 1.5 E-4
R = 3.03 ft

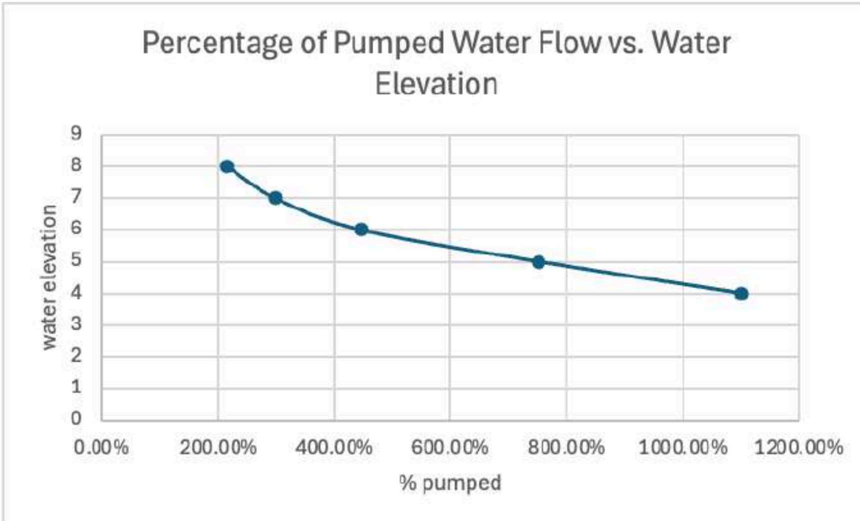
Materials:

Water
Pipes
Light brush

Procedure/Calculations:



water elevation	area	wp	r	q	%
4	64	23.3	2.746781116	3.07E+01	1101.57%
5	105	45.3	2.317880795	4.50E+01	751.89%
6	148	48.8	3.032786885	7.60E+01	445.91%
7	193	51.78	3.727307841	1.14E+02	298.02%
8	240	54.6	4.395604396	1.58E+02	214.71%



Summary:

The flow rate running through the lower open channel is 75.91 ft^3/s
The percentage of pumped water flow with respect to the lower open channel flow is 4.5%.

Analysis:

The results make sense due to the other calculations that I had computed in parts A and B. These results make sense. The only part that confuses me a little bit is the chart. I feel like it should be reversed, however I could make sense out of the fact that if less water is in the channel the ratio of water being pumped out would have to be higher than one of a full channel.