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USING THE CHAT FUNCTION………

WHO IS YOUR FAVORITE SUPERHERO….AND

WHY????

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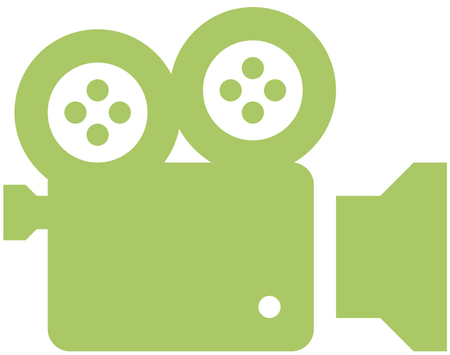
1

Recording



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Using Zoom!

Mute yourself!
Have a question?
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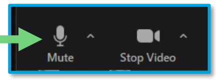

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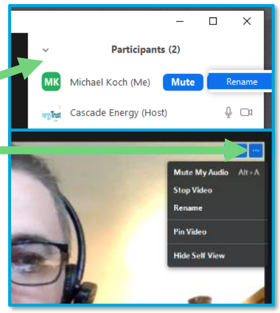
Right click on your picture or 3 dots
OR
Controls accessed at the right after clicking 'Participants' at bottom.



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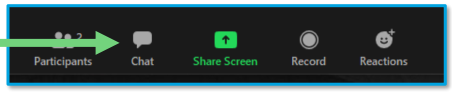

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VIRTUAL WASTEWATER INPLT SESSION 2

MOVING DAY - BOD & Pumping

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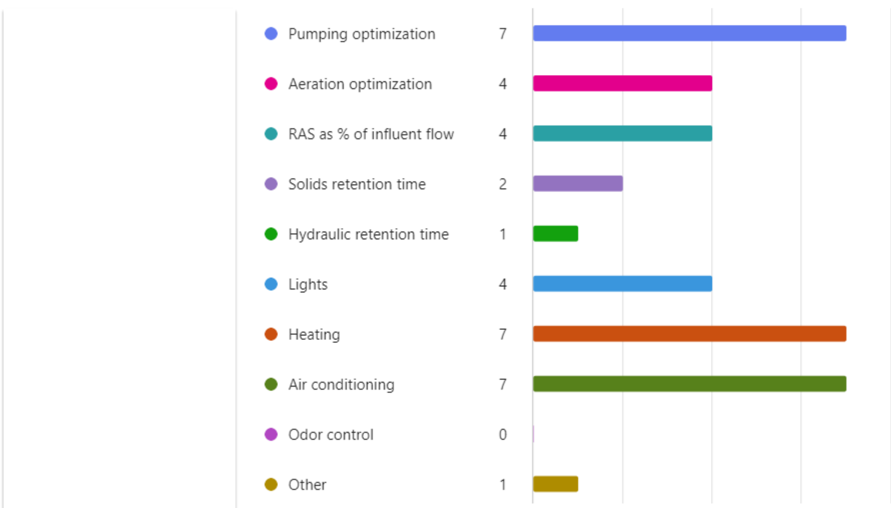
17. Which processes are automatically controlled at the facility?

10 Responses



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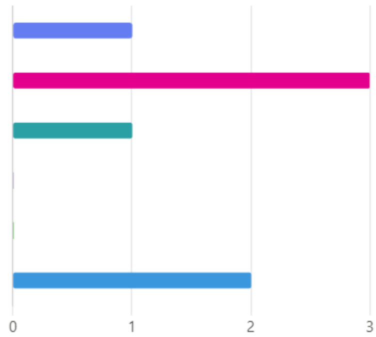
22. Do you track any energy key performance indicators?

5 Responses

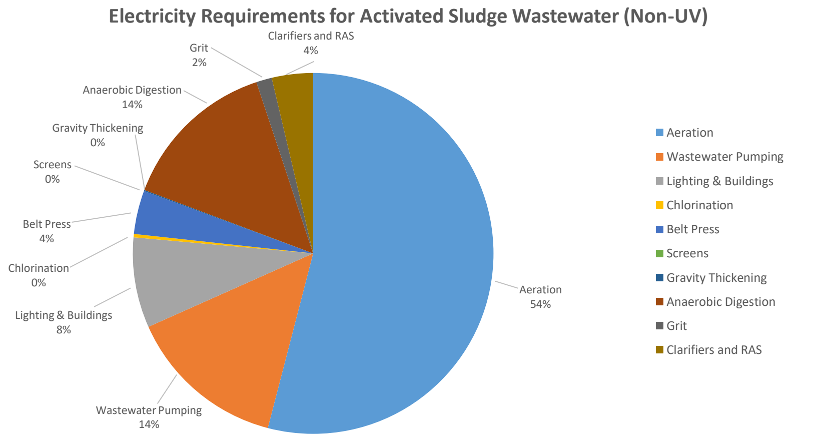
kW/MG	1
kWh/MGD	3
kWh/pounds of BOD	1
blower power kW/blower flow scfm	0
blower flow scfm/blower power kW	0
Other	2



Today's Agenda

- Intros & Welcome
- Follow the BOD
- Pumping Systems Part 1 - Head
- Break
- Pumping Systems Part 2 - Curves
- Energy Maps
- Wrap-up
- Q&A

Plant Process Electricity Use Overview



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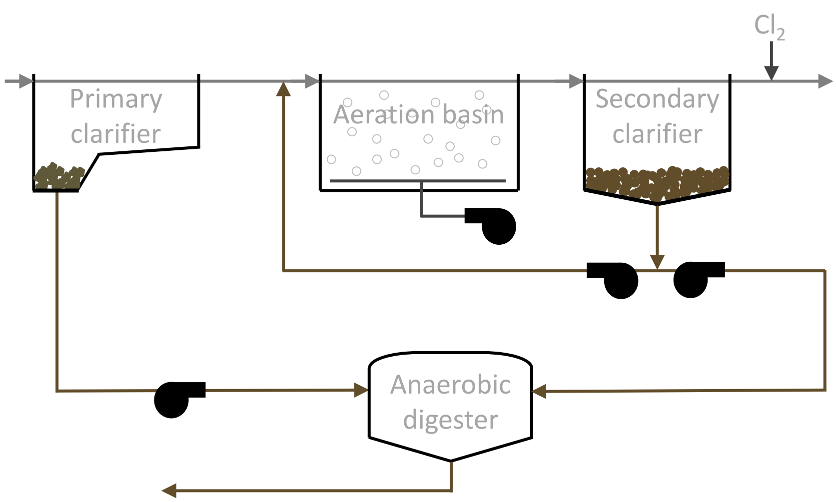
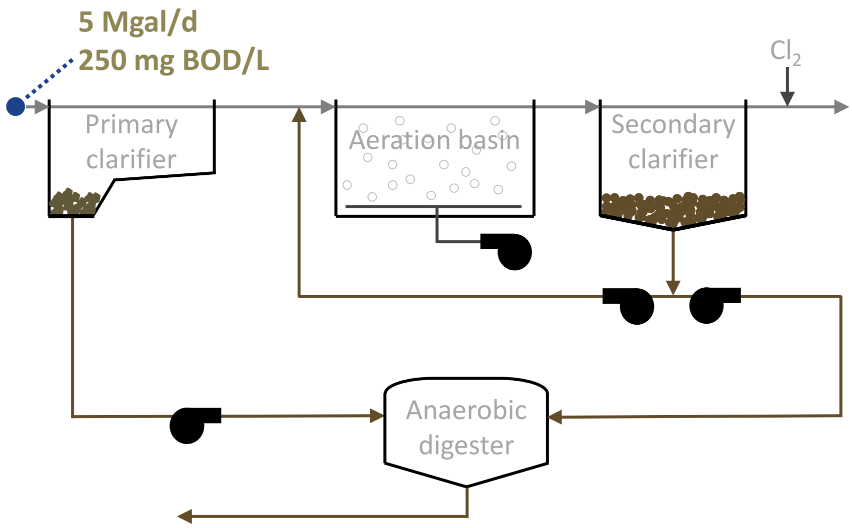
Where Does Most of the “Treatment” Occur?



10

5 Mgal/d Used to be Economy-of-Scale Cutoff for Anaerobic Digesters



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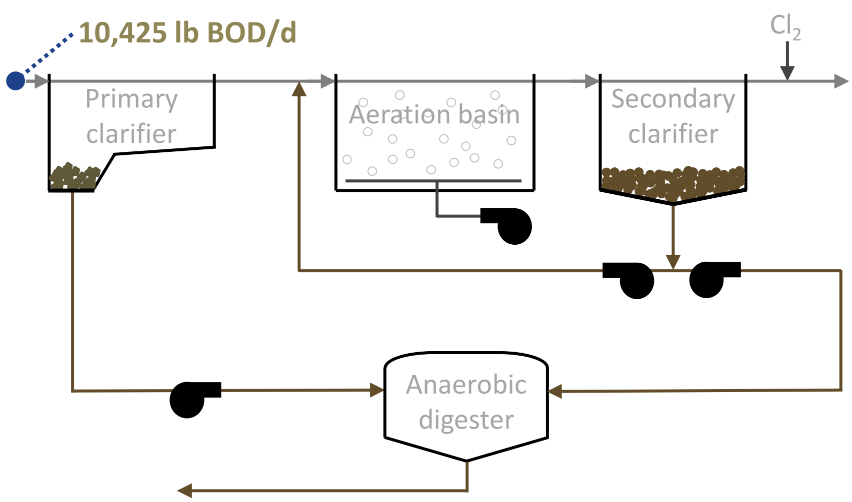
BOD Load to Plant



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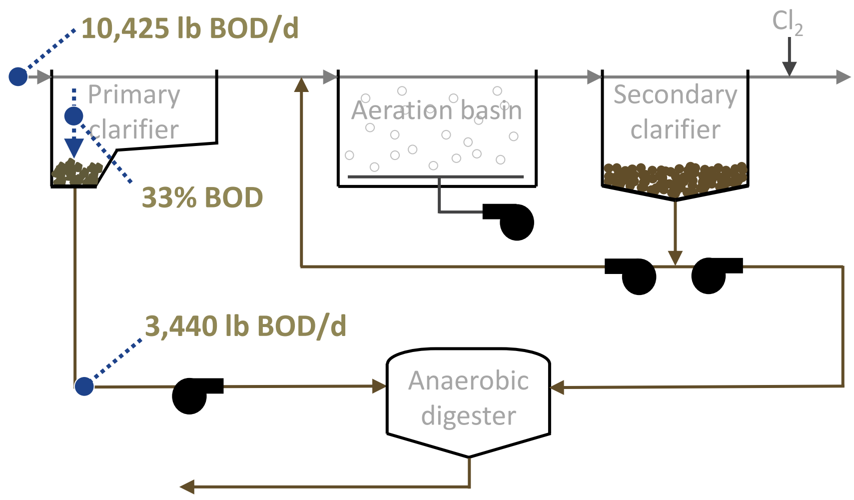
Assume 33% BOD Removal in Primary Clarifier



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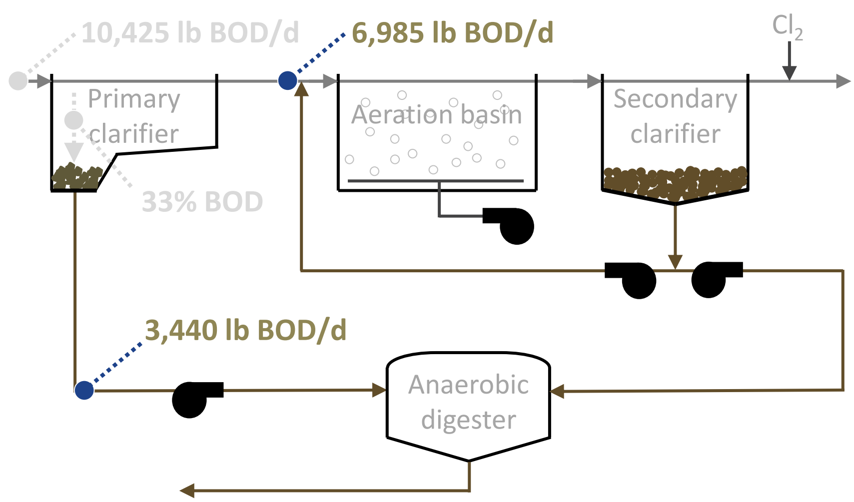
The Remaining BOD Goes to the Aeration Basin



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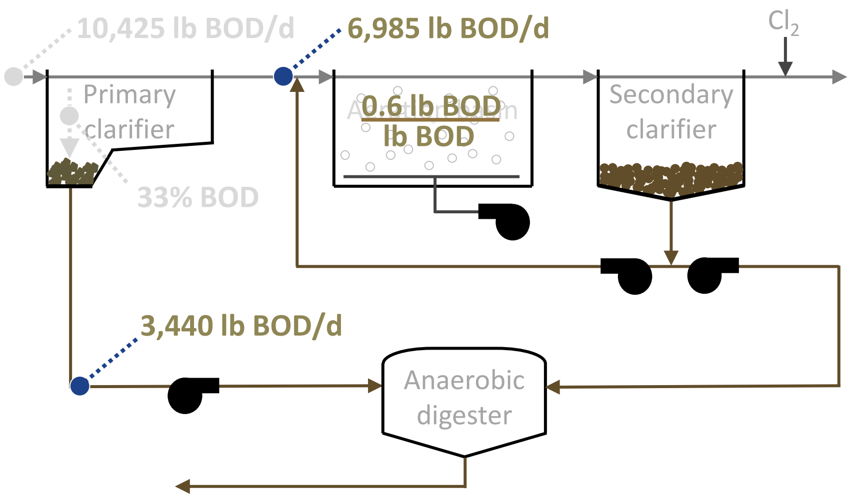
Assuming a Yield of 0.6 lb Biomass (measured as BOD) per lb BOD…



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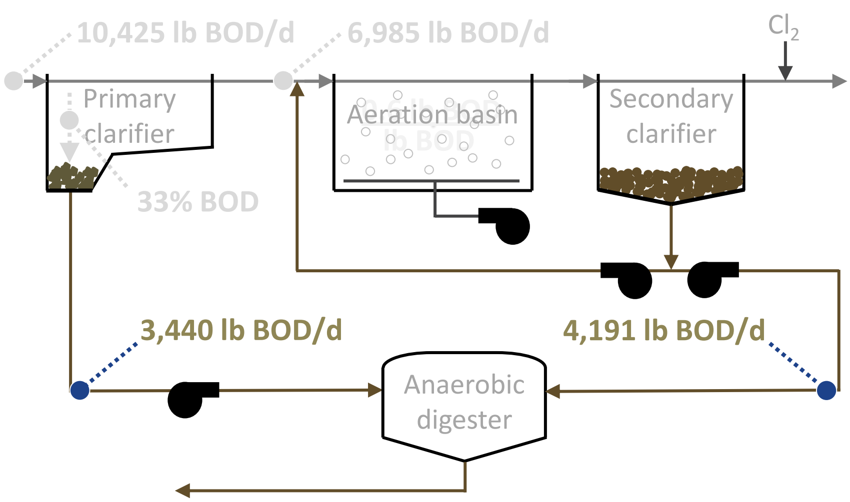
…Means 4,191 lb BOD/d Must be Removed in the WAS



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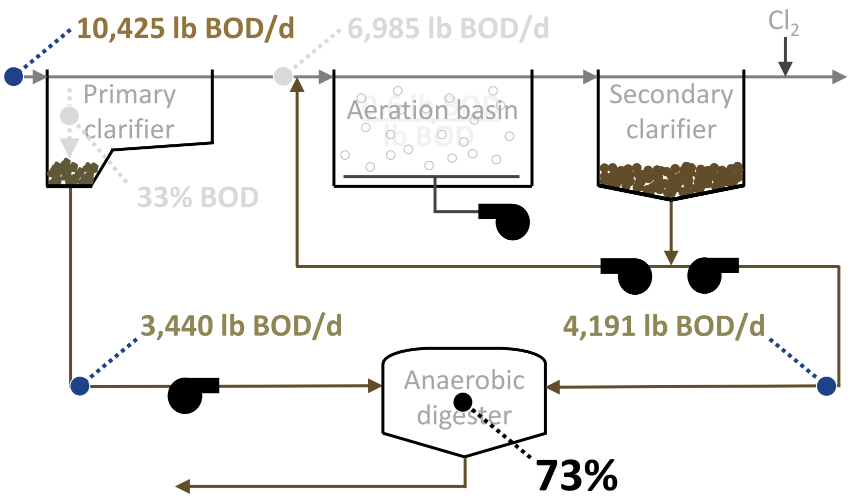
Nearly ¾ of the Influent BOD Ends Up in the Digester



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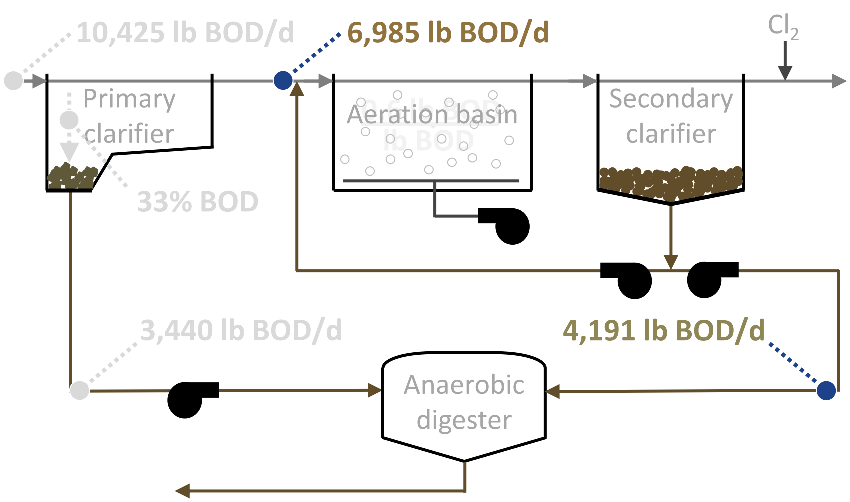
Difference Between These is 2,794 lb BOD/d Where Does That BOD Go?



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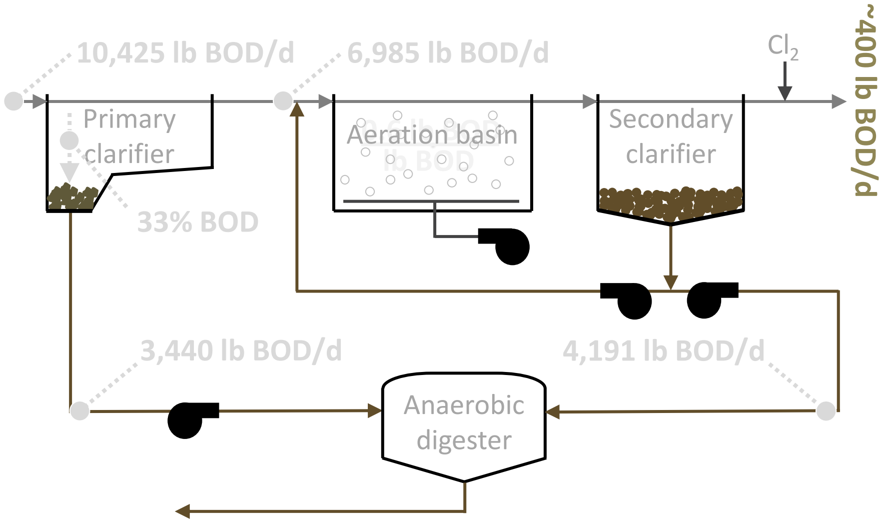
Not the Effluent



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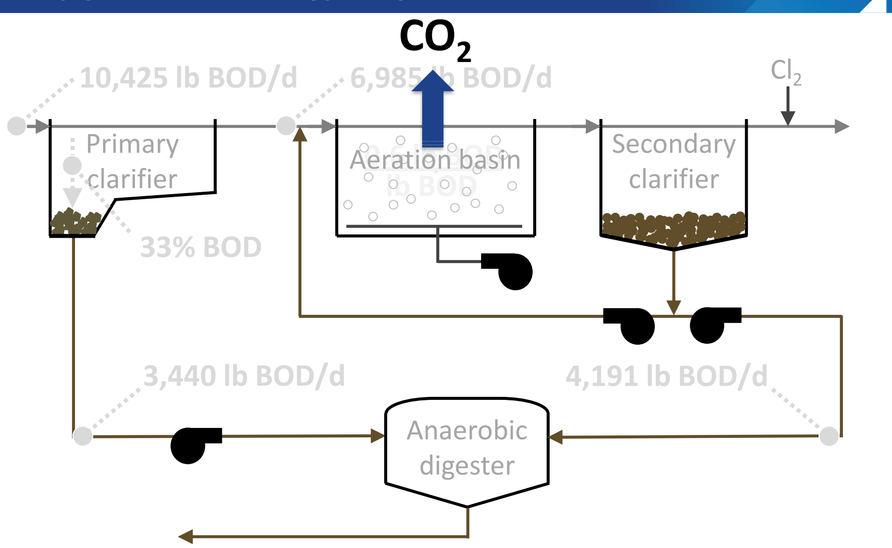
~2,394 lb BOD/d Respired as CO_2 at Tremendous Oxygen and Energy Expense



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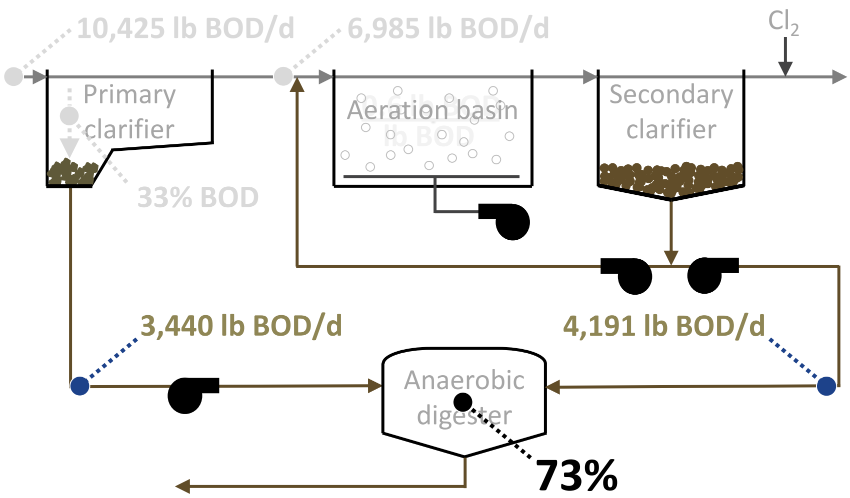
All BOD (VS) is not Created Equal



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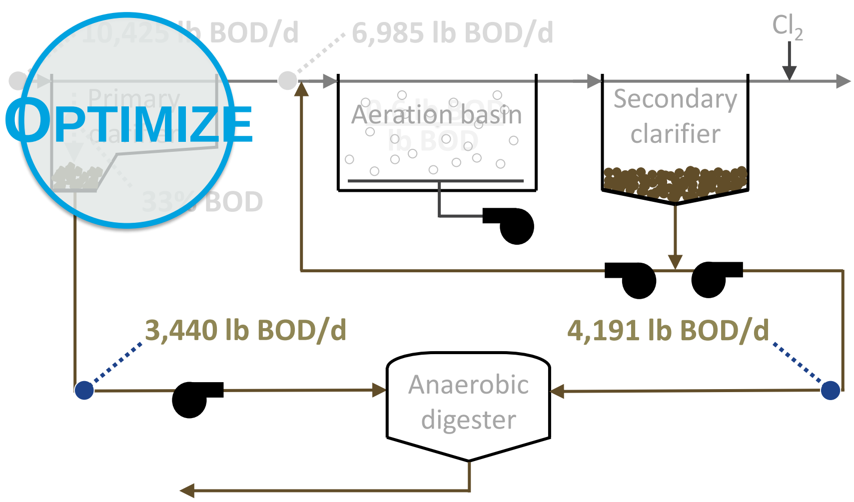
An Optimized Primary Clarifier is an Optimized Plant = Least Cost Operation



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Homework (Assume: PI = 10,425 lb BOD/d, Yield = 0.6 lb BOD/lb BOD, Eff = 400 lb BOD/d)

Primary clarifier BOD removal (%)	BOD_{PS} (lb BOD/d)	BOD_{PE} (lb BOD/d)	BOD_{WAS} (lb BOD/d)	$BOD_{RESPIRED}$ (lb BOD/d)	BOD_{PS}/BOD_{WAS}
23					
33	3,440	6,985	4,191	2,394	0.82
43					
53					

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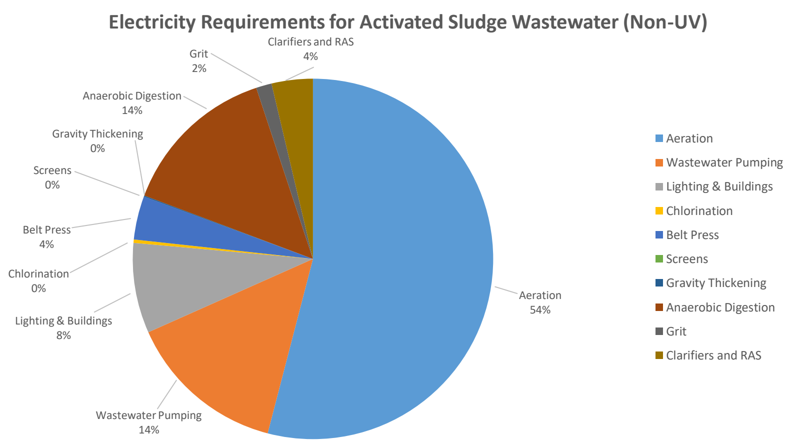
Anaerobic Digestion (tied with Wastewater Pumping) is Second Largest Electricity User



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Practice Problem Set 2, Question 4

Anaerobic Digester Mix Pump 3A pumps 1,175 gal/min against a total dynamic head of 48 ft. It was designed to run continuously. From the manufacturer's literature, the pump is 74% efficient and the motor is 92% efficient. The average cost of electricity is $0.1012/kWh. The CPO conducted a study and found no deterioration in performance—measured in terms of VSR, gas production and gas composition—when turning the mix pump off for 20 minutes every 30 minutes (i.e., 10 min *on*, 20 min *off*). Calculate the annual electrical cost savings realized with this new operation, ignoring demand charges.

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This Is What I'm Talking About

Anaerobic Digester Mix Pump 3A pumps 1,175 gal/min against a total dynamic head of 48 ft. It was designed to run continuously. From the manufacturer's literature, the pump is 74% efficient and the motor is 92% efficient. The average cost of electricity is $0.1012/kWh. **The CPO conducted a study and found no deterioration in performance—measured in terms of VSR, gas production and gas composition—when turning the mix pump off for 20 minutes every 30 minutes** (i.e., 10 min *on*, 20 min *off*). Calculate the annual electrical cost savings realized with this new operation, ignoring demand charges.

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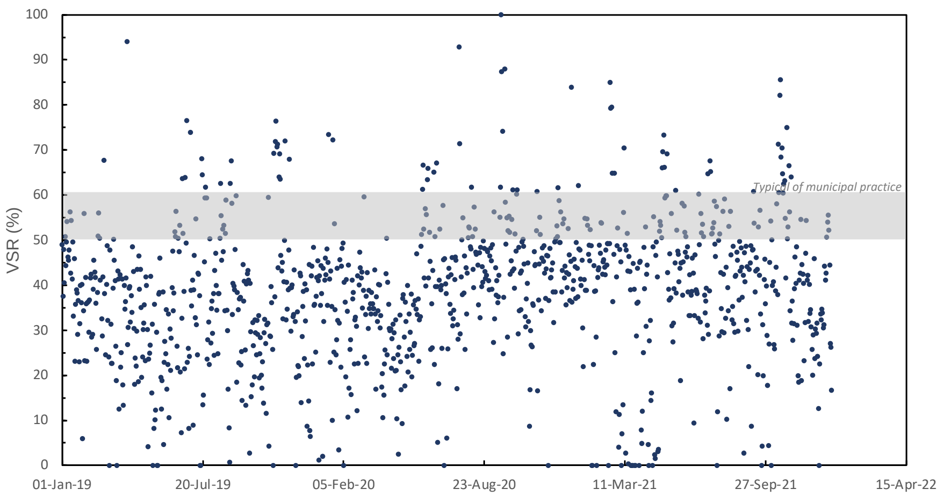
The CPO's Study Would Not Have Been Possible if the Digester Performed Like This



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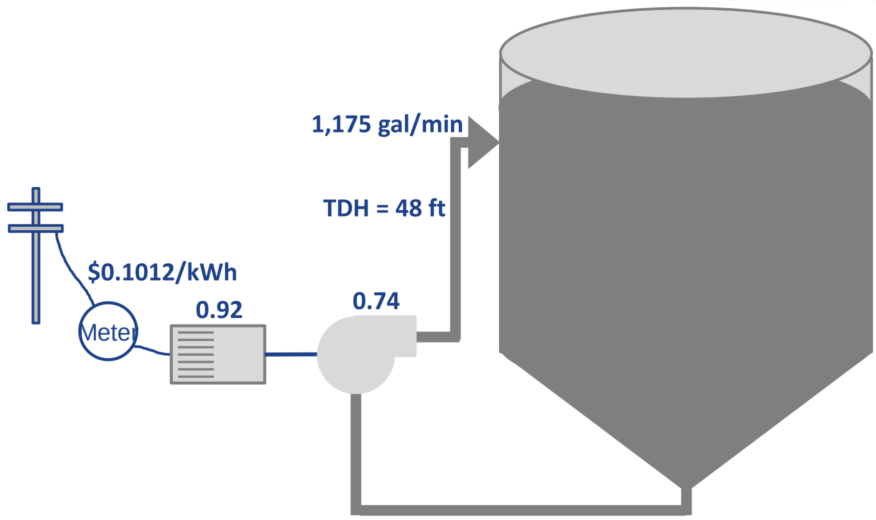
An Interesting Problem Because TDH is All Friction Head (more to come)



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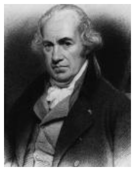
A Bit of History: Papplewick Pumping Station



Nottinghamshire, England

1882-84 until 1969

2 ea. 140 hp engines

Supplied by James ***Watt*** & Co.

Abbey Pumping Station

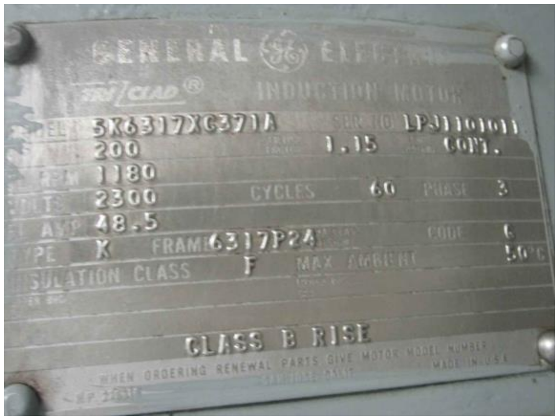
Leicester, England

1891 - 1964

4 ea. 200 hp by Gimson & Co.

12-19 RPM   4,170 GPM

What does 200 hp look like today?



Can anyone estimate the power requirement?

kW = =

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PUMPING SYSTEMS PART 1

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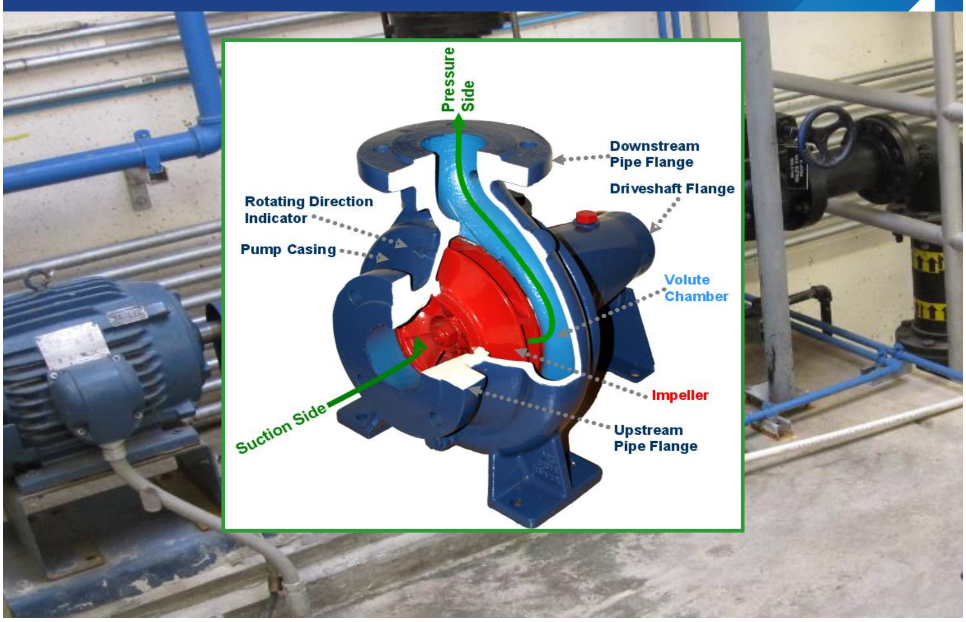

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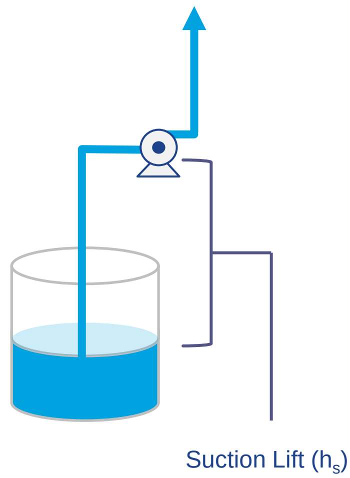
Suction Lift (h_s)

DEFINITION

When the supply is **below** the centerline of the pump.

Distance (in feet) from the center line of the pump to the level of liquid to be pumped.

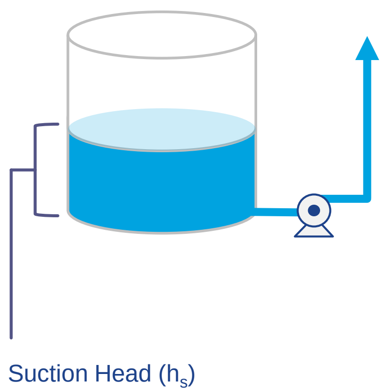


Suction Head (h_s)

DEFINITION

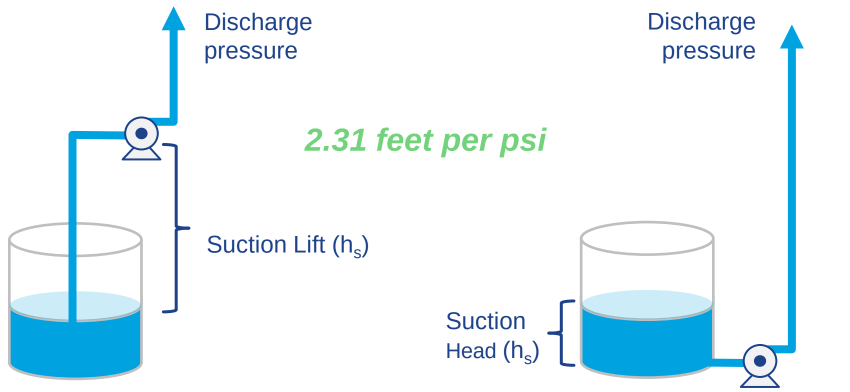
When the supply is **above** the centerline of the pump.

Distance (in feet) from the center line of the pump to the level of liquid to be pumped.



Total Head (H)

DEFINITION



With Suction Lift

Total Head= Discharge Pressure (ft) + h_s (ft)

With Suction Head

Total Head= Discharge Pressure (ft) – h_s (ft)

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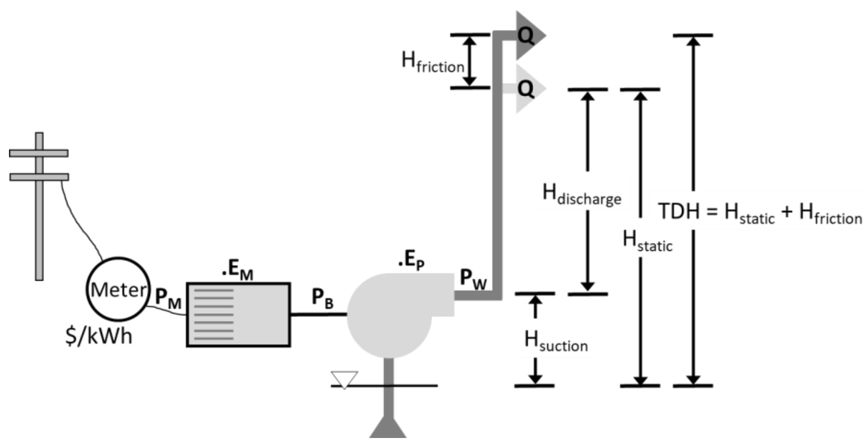
Teaching Pumping Math to Operators



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Centrifugal *Pump Power*

$$BHP = \frac{Q * H \ * s.g.}{3960 * \eta_p}$$

Opportunity Register Alert!!!

To save energy

- Decrease Flow
- Decrease Head
- Increase Efficiency
- Decrease Run hours

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Centrifugal Pump *Motor Power*

$$MotorPower(hp) = \frac{Power(BHP)}{\eta_{motor}}$$

$$\text{MotorPower(kW)} = \text{MotorPower(hp)} * \frac{0.746 \text{ kW}}{\text{hp}}$$

This is what you pay for!

BHP	Brake Horsepower
η_{motor}	Motor Efficiency (0-1.0)

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Opportunity Register

Expand or collapse steps using the +/- signs above Expand or collapse steps using the +/- signs above ↑ Expand or collapse steps using the +/- signs above ↑

Energy Projects

Energy Project		Step 1	Identify				Step 2	Prioritize					Step 3	
#	Opportunity Name		Description	Location	System*	Submitted By		Energy Impact	Energy Savings	Type of Energy Saved*	Cost/Effort Required	Decision		Next Step
1	Reduce Non-Potable Water Pressure		Average pressure is 100 psi. Pressure needed is 80 psi. Average flow is 300	Plant water pump skid	Non-potable water	Wendy		Gems	24,954	Electric	Low	Do it now		
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														

...

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PUMPING SYSTEMS PART 2 - CURVES

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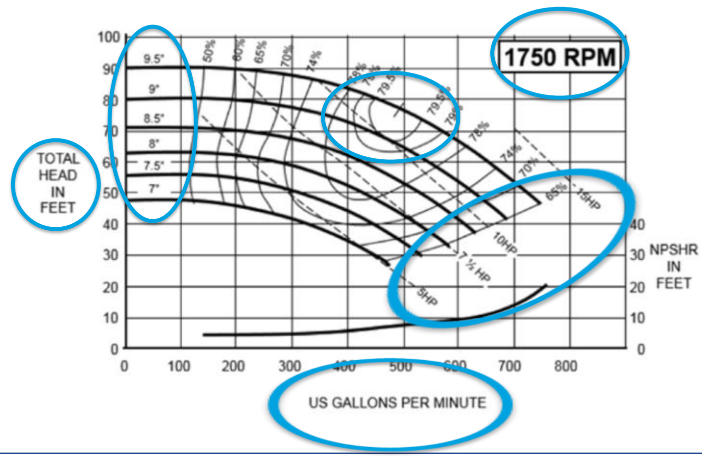
Typical Single Stage Pump Curve



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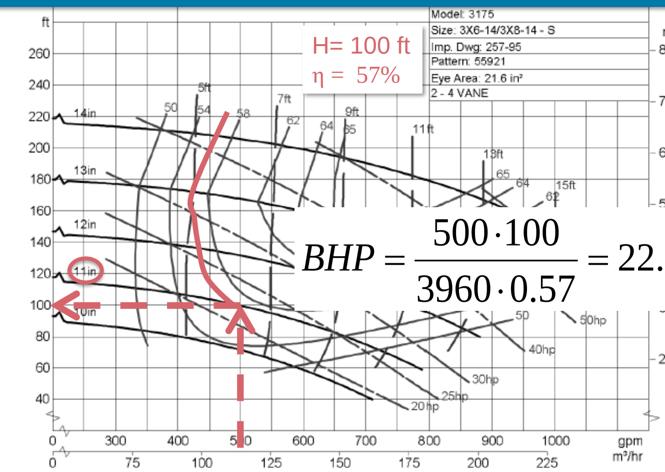
Reading Pump Curves

If the pump has a 11” impeller diameter, is pumping water, and is operating at 500 gpm, what are the other operating conditions (H, BHP, η)?



$$BHP = \frac{500 \cdot 100}{3960 \cdot 0.57} = 22.2\,BHP$$

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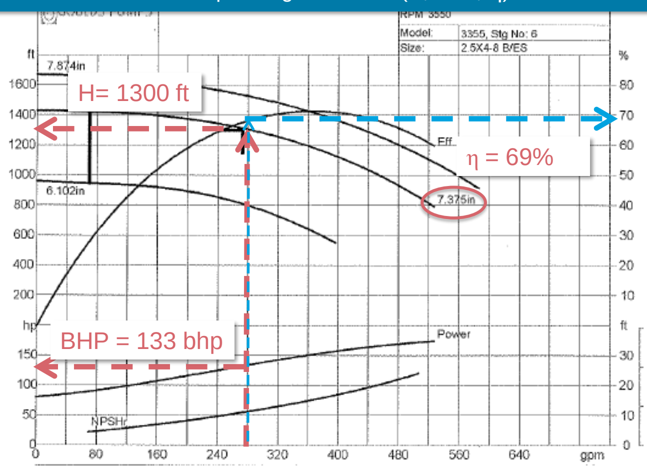
Reading Pump Curves (continued)

If the pump has a 7.375” impeller diameter (D), and is operating at 280 gpm, what are the other operating conditions (H, BHP, η)?



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BREAK

Until 6 after the hour

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PUMPING SYSTEMS PART 2 – CURVES CONTINUE..

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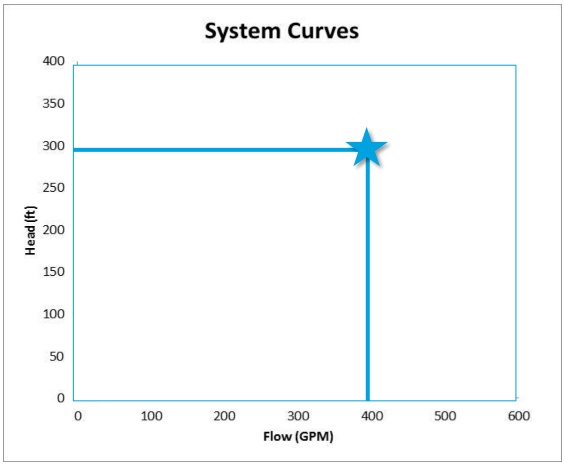
Examples of system curves for three different systems



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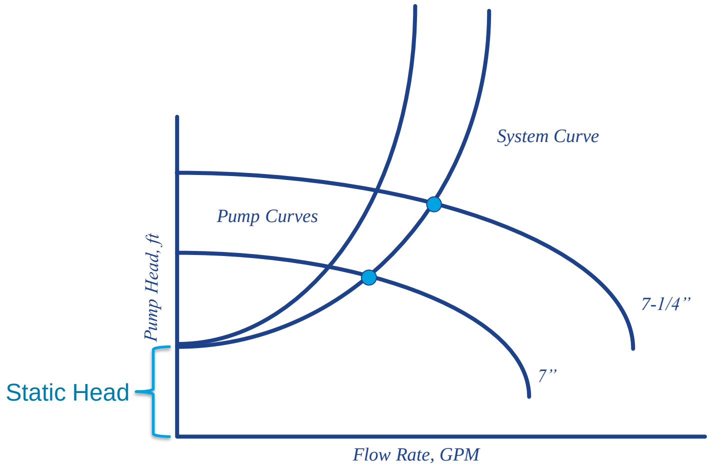
Pump and System Curves



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What affects head loss the most?

Total Dynamic Head = Static Head + Head Loss

$$h_L = f\frac{L}{D}\frac{v^2}{2g} =$$

Head loss is most sensitive to changes in **diameter**

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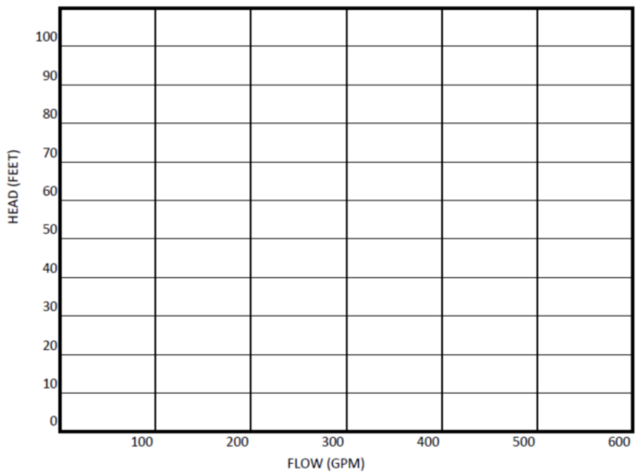
Exercise - Design Engineer for a Day!



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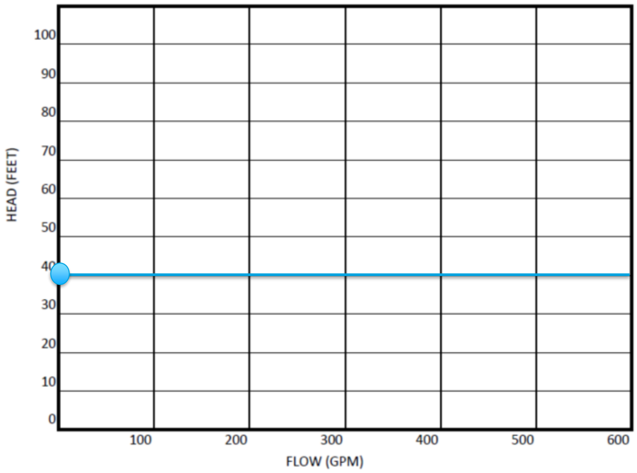
LET'S DRAW!

- You get to design a new pump station.
- Wet well water elevation is 820 feet.
- Discharge point elevation is 860 feet.

- Static head = ?

Static Head



Design flow is 350 GPM, and the pipe friction loss is estimated as follows:

100 GPM = **1 foot**

200 GPM = **5 feet**

300 GPM = **15 feet**

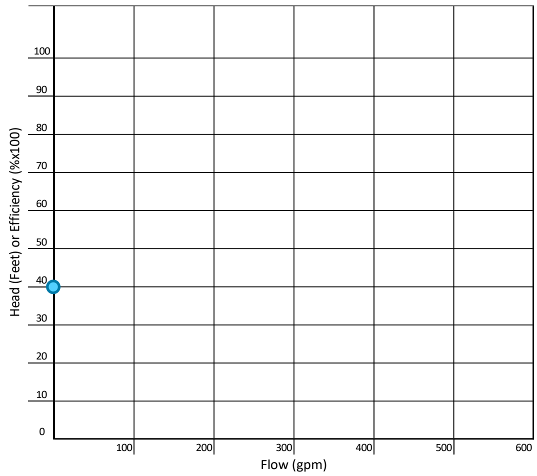
400 GPM = **30 feet**

500 GPM = **50 feet**

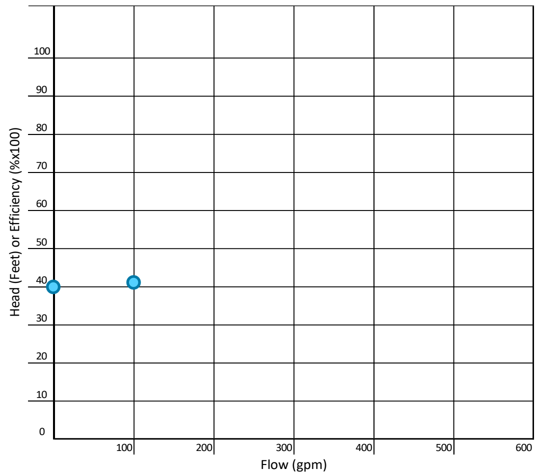
Static Head = 40 feet

- Use circles to mark the system curve points
- System curve head = static + friction at each flow point

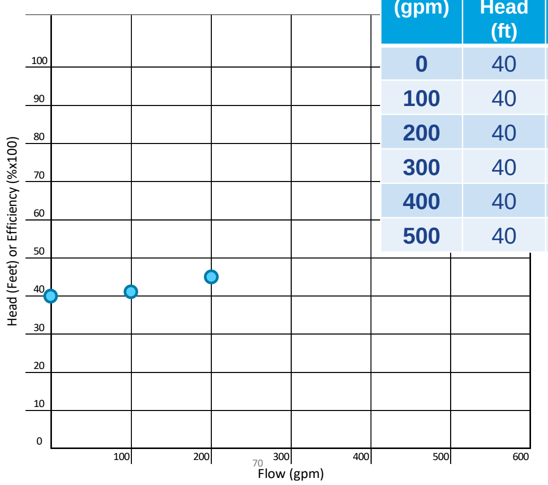
Flow (gpm)	Static Head (ft)	Friction Head (ft)	System Curve Head (ft)
0			
100		1	
200		5	
300		15	
400		30	
500		50	

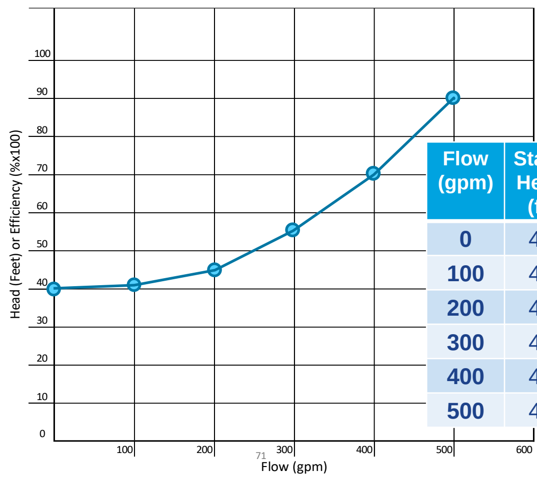


Flow (gpm)	Static Head (ft)	Friction Head (ft)	System Curve Head (ft)
0	40	0	40
100		1	
200		5	
300		15	
400		30	
500		50	



Flow (gpm)	Static Head (ft)	Friction Head (ft)	System Curve Head (ft)
0	40	0	**40**
100	40	1	**41**
200	40	5	**45**
300	40	15	**55**
400	40	30	**70**
500	40	50	**90**





Flow (gpm)	Static Head (ft)	Friction Head (ft)	System Curve Head (ft)
0	40	0	**40**
100	40	1	**41**
200	40	5	**45**
300	40	15	**55**
400	40	30	**70**
500	40	50	**90**

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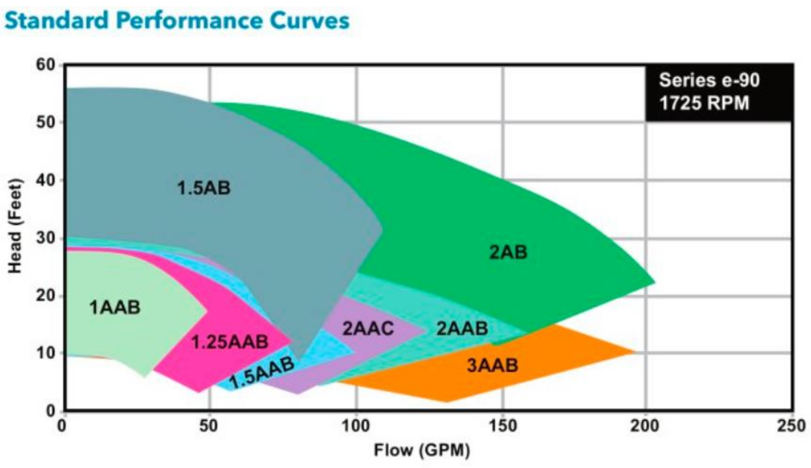
Pump Selection



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Draw the pump curve:

0 GPM = **92 feet**

100 GPM = **90 feet**

200 GPM = **85 feet**

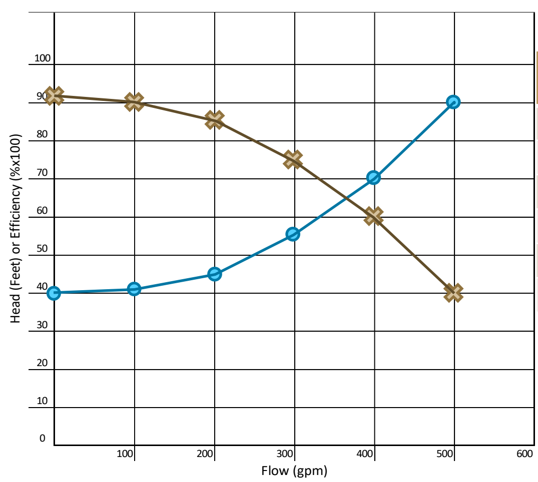
300 GPM = **75 feet**

400 GPM = **60 feet**

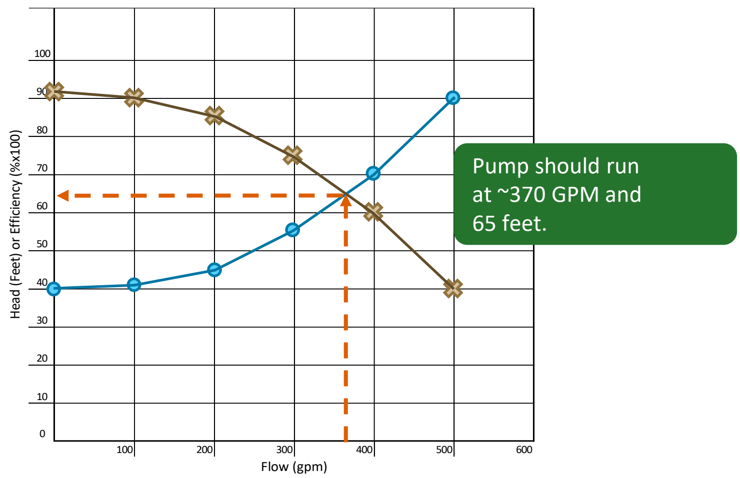
500 GPM = **40 feet**

Use Xs to mark the pump curve points

Where do the curves intersect?



Flow (gpm)	Pump Head (ft)
0	92
100	90
200	85
300	75
400	60
500	40



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What Power Will It Require?

Pumping Power Equation	
Q	370 GPM
H	65 feet
s.g.	1.0 (we're pumping water)

$$BHP = \frac{s.g.* Q * H}{3960 * \eta}$$

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The pump we've selected has the following efficiency points:

0 GPM = **0%**

100 GPM = **30%**

200 GPM = **50%**

300 GPM = **60%**

400 GPM = **50%**

500 GPM = **30%**

Use Δ's to mark the pump curve efficiency points

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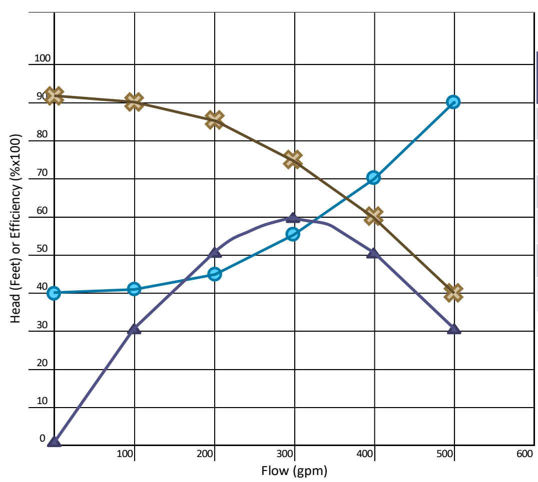

Flow (gpm)	Efficiency (%)
0	0
100	30
200	50
300	60
400	50
500	30

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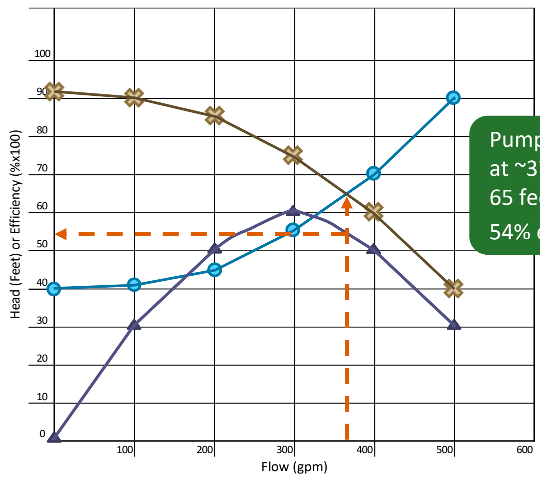

Pump should run at ~370 GPM and 65 feet and 54% efficiency.

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What Power Will It Require?

Pumping Power Equation	
Q	370 GPM
H	65 feet
s.g.	1.0 (we're pumping water)
η	54% (0.54)
BHP	

$$BHP = \frac{s.g. \cdot Q \cdot H}{3960 \cdot \eta}$$

11.2 hp x $\frac{0.75 \text{ kW}}{\text{hp}}$ = 8.4 kW

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How Much Will It Cost To Run?

Use 94% motor efficiency

$$\frac{8.4\text{ kW}}{0.94} = 8.9\text{ kW into motor}$$

$$8.9\text{ kW} \times \frac{8{,}760^{**}\text{ hrs}}{\text{year}} = \frac{78{,}000\text{ kWh}}{\text{year}}$$

$$\frac{78{,}000\ \cancel{\text{kWh}}}{\text{year}} \times \frac{\$0.06}{\cancel{\text{kWh}}} = \frac{\$\ 4{,}680}{\text{year}}$$

**Assume continuous operation

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$$BHP = \frac{s.g.\cdot Q \cdot H}{3960 \cdot \eta}$$

You install the pump, and determine that it's actually running at 450 GPM

Pumping Power Equation	
Q	450 GPM
H	______ feet
s.g.	1.0 (we're pumping water)
η	______%
BHP	_____ x 0.75 = ____ kW

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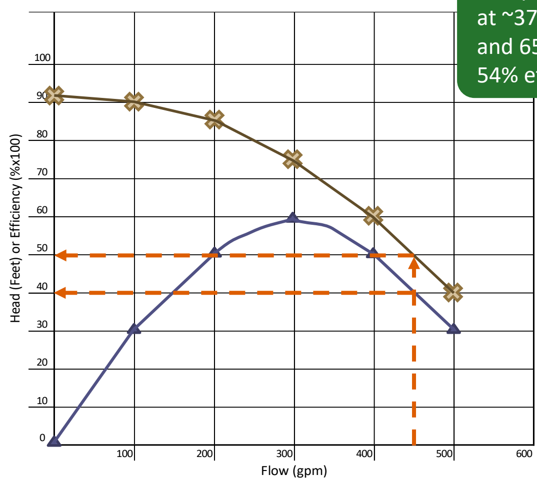
Pump should run at ~370 GPM and 65 feet and 54% efficiency.



Pumping Power Equation	
Q	450 GPM
H	50 feet
η	40 %

$$BHP = \frac{s.g.* Q * H}{3960 * \ \eta}$$

Pumping Power Equation	
Q	450 GPM
H	50 feet
s.g.	1 (we're pumping water)
Pump Efficiency η	40%
BHP	

$$BHP = \frac{450\ gpm*50\ feet}{3960 * 0.40} = 14.2\ HP$$

Pumping Power Equation	
Q	450 GPM
H	50 feet
η	40%
BHP	14.2 HP

$$\text{Motor Output} = \text{BHP} * \frac{0.75\text{ kW}}{\text{hp}} = 14.2\,\cancel{\text{hp}} * \frac{0.75\text{ kW}}{\cancel{\text{hp}}} = 10.6\text{ kW}$$

$$\text{Motor Input} = \frac{\text{Motor Output kW}}{\text{Motor Efficiency}} = \frac{10.6\text{ kW}}{0.94} = 11.3\text{ kW}$$

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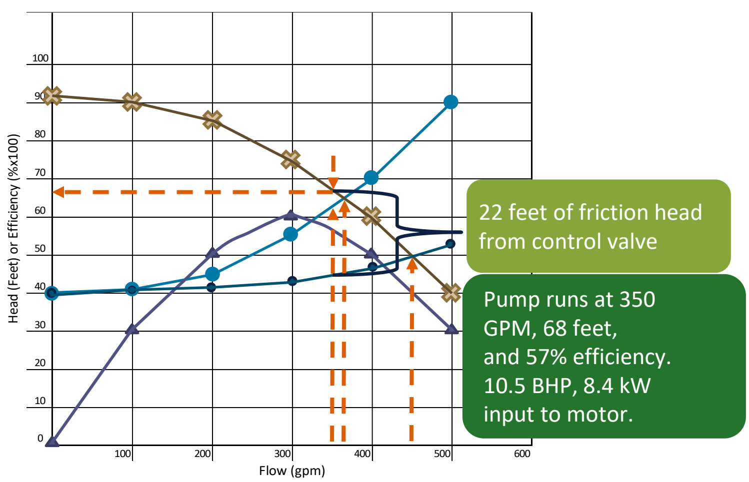
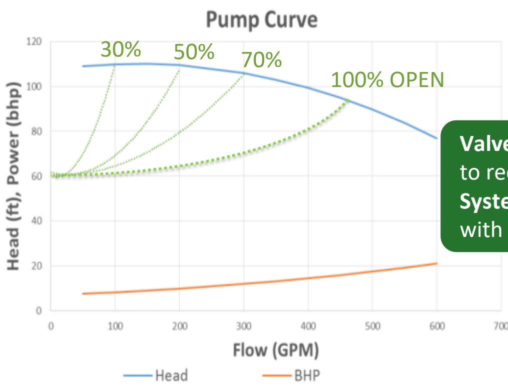


Throttled Valve



Valve is throttled back to reduce the flow. **System curve** changes with valve position.

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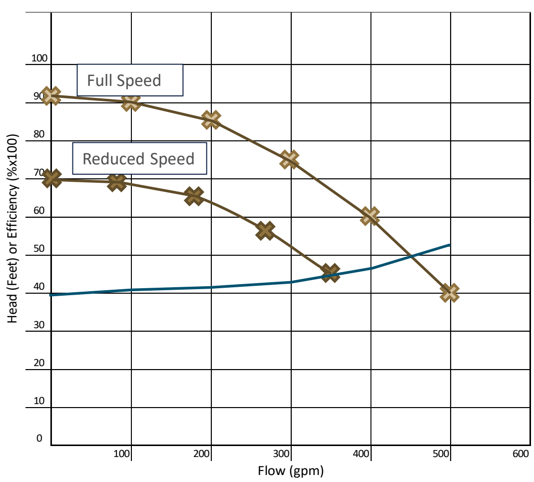

Slow pump to 78% speed for 350 gpm

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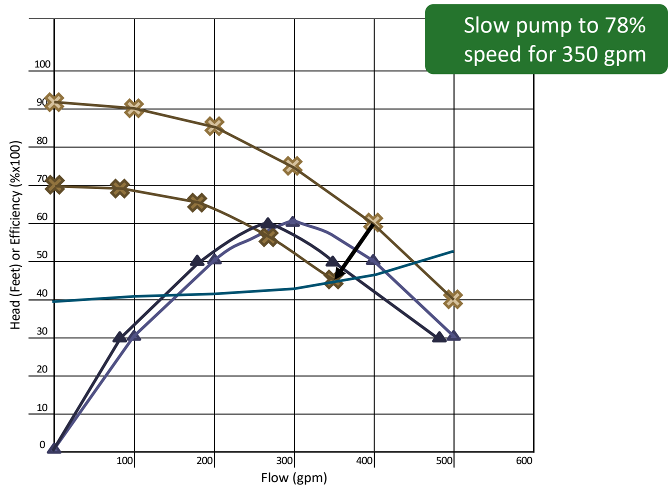
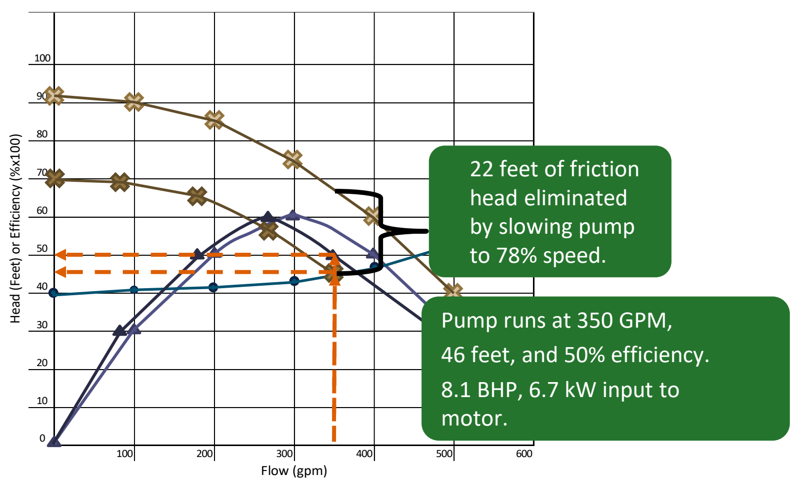
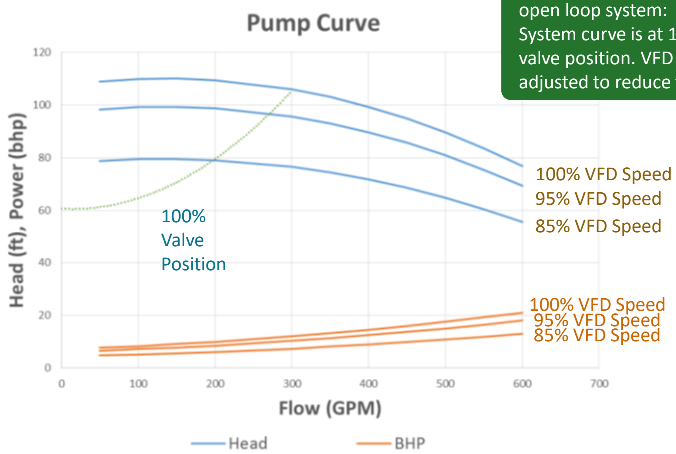

Slow pump to 78% speed for 350 gpm
Head (Feet) or Efficiency (%x100)
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
Flow (gpm)

89


22 feet of friction head eliminated by slowing pump to 78% speed.
Pump runs at 350 GPM, 46 feet, and 50% efficiency. 8.1 BHP, 6.7 kW input to motor.
Head (Feet) or Efficiency (%x100)
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
Flow (gpm)

90

System Curves: with VFD Operation



Example of system curve for open loop system:
System curve is at 100% valve position. VFD speed is adjusted to reduce the flow.

Summary

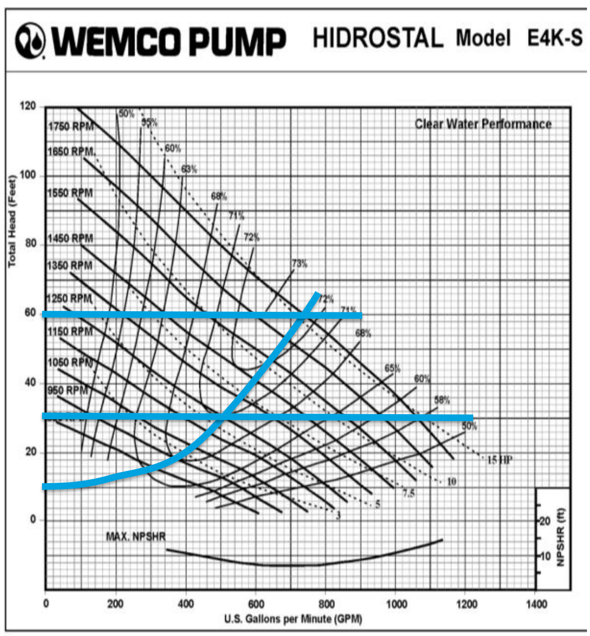
Condition	Flow (GPM)	Head (Feet)	Input Power (kW)	Annual Cost (@ $.06 /kWh)
Designed	370	65	8.9	$4,680
Installed	450	50	11.3	$5,940
Throttled	350	68	8.4	$4,420
Add VFD	350	46	6.7	$3,520

Summary

Condition	Flow (GPM)	Input Power (kW)	GPM / kW	kWh/MG Pumped
Designed	370	8.9	42	401
Installed	450	11.3	40	420
Throttled	350	8.4	42	400
Add VFD	350	6.7	52	319

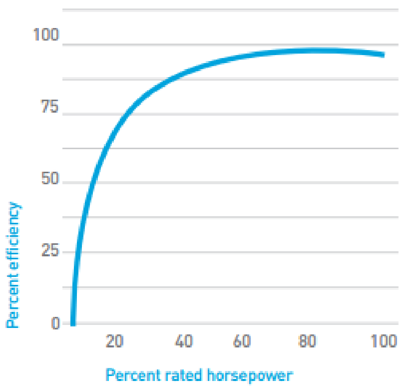
Family of Curves

- Each curve is 100 RPM step
- VFD's are not a "cure all"

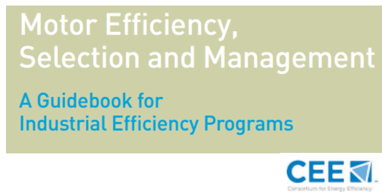


Oversize Motors Cost You $$

Figure 4: Efficiency versus Load Curve for Induction Motors



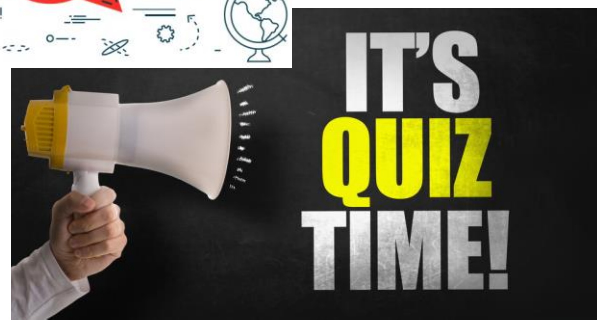
Source: Courtesy EASA. *Understanding Energy Efficient Motors*. Out of print.



http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/agriculture/industrial_guidebook.pdf

Top 10 Energy Savings Opportunities

1. Minimize loads	Decrease flow
2. Use your best part load option	Increase efficiency
3. Turn it off	Decrease run hours
4. Minimize pressure drops	Decrease head
5. Optimize pressure settings	Decrease head
6. Keep idling time to a minimum	Decrease run hours
7. Right technology	Increase efficiency
8. Right size equipment	Increase efficiency, decrease flow, decrease head
9. Remove barriers to more efficient setpoints	Increase efficiency, decrease flow, decrease head
10. Make the most of your controls	Increase efficiency, decrease flow, decrease head



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Closing

Homework:

1. Complete the table
2. Add to your opportunity register

SEE YOU NEXT WEEK!

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