Savings With Pump Efficiencies

Energy Management Initiative

Tennessee Wastewater Utility Partnership

Wave Five

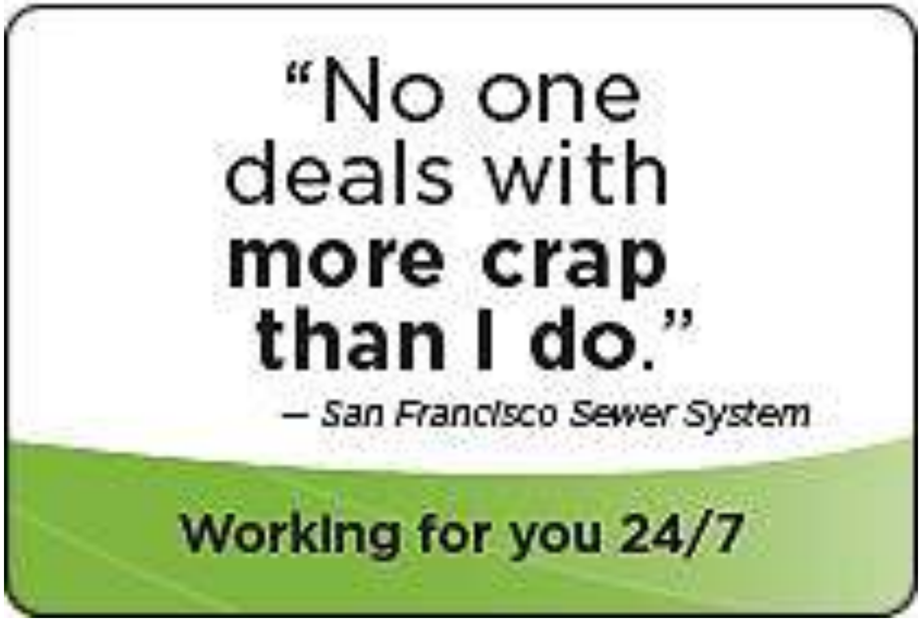
November 14, 2017

Jim Grassiano – Alabama Department of Environmental Management

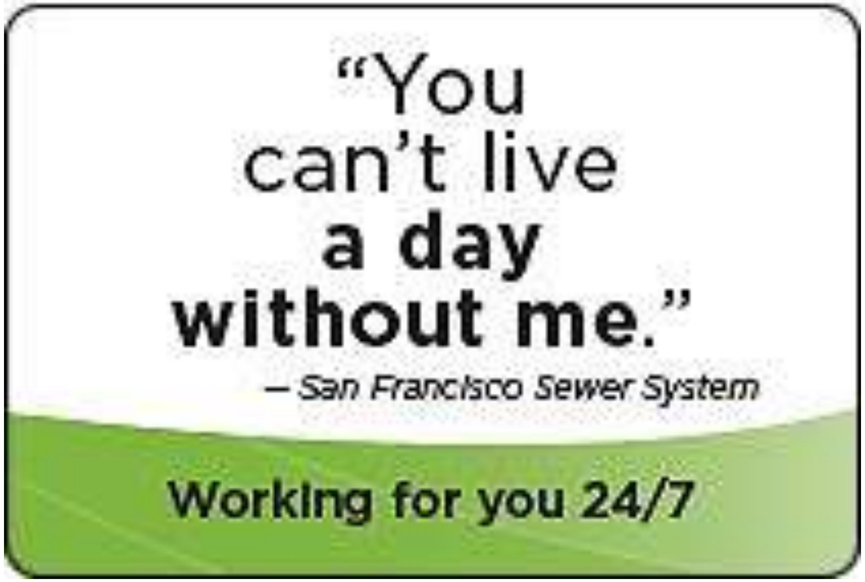
Our Main Job…?


LIFE ON EARTH
by Ham
UNISEX NAMES FOR BACTERIA
BRINGING UP BACTERIA
PROBLEM BACTERIA
HAM

San Francisco Public Utilities PR Campaign



San Francisco Public Utilities PR Campaign



ADEM

The SFPUC Ads Appeared…

- On bus stops
- In and on city buses
- 14 neighborhood papers
- In Chinese & Spanish
- Larger City-wide papers:
  - *San Francisco Examiner*
  - *San Francisco Bay Guardian*
- Facebook

PR Campaign Intended to foster support for…

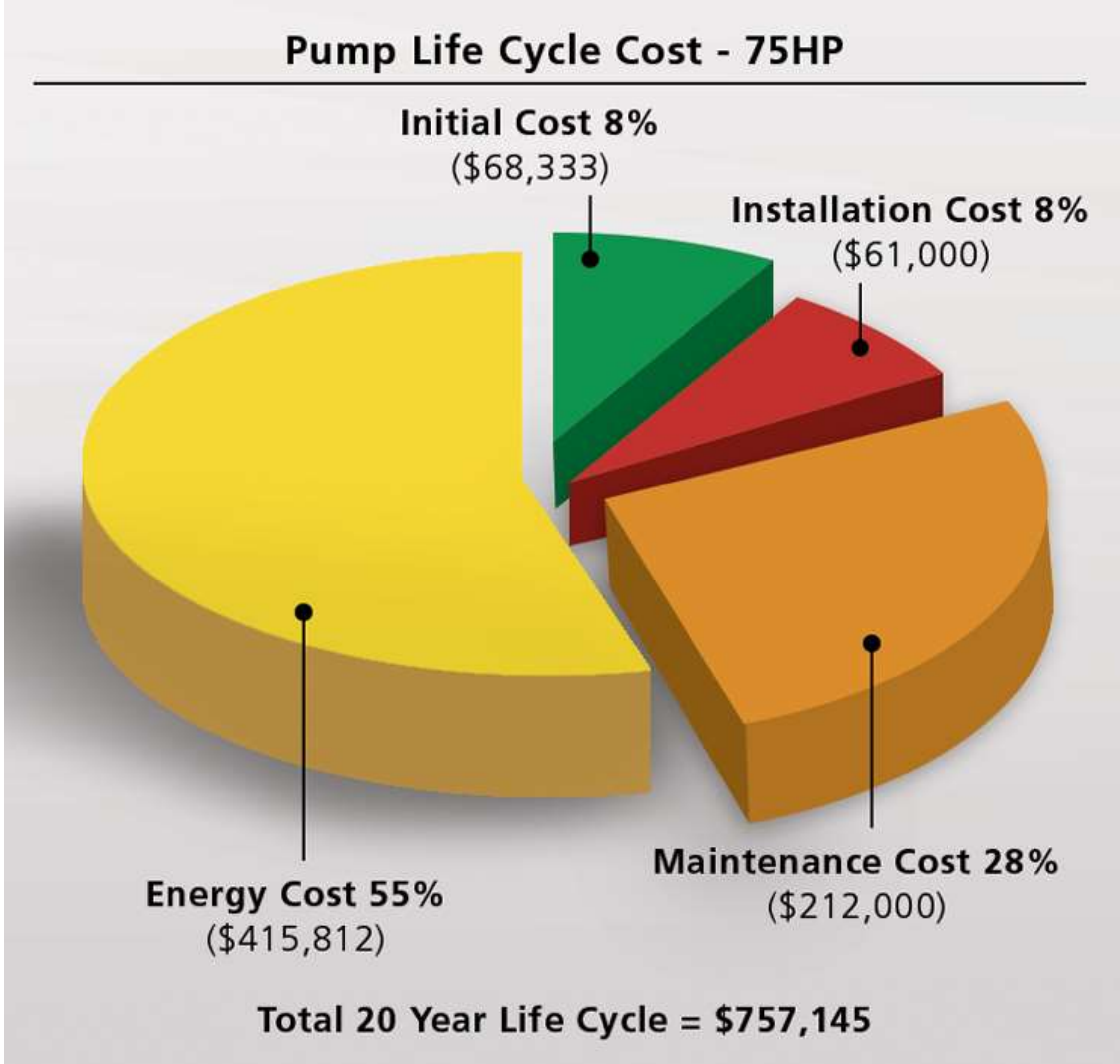
- $2.7 billion dollar, 2-yr upgrade of City WWTPs

(So you think you have budget problems..!)

Goals of Presentation

- Identify ways to save energy costs with pumping
- Discuss some interesting case study examples
- Introduce you to DOE’s Pumping Assessment Tool

Typical Life Cycle Costs for a Pump



First, the Pumping System Assessment Tool

- PSAT is a free on-line software tool developed by DOE
- Primarily intended for industrial operations, but can be helpful for water & wastewater utilities

ADEM

PSAT

- Uses hydraulic institute standards & measured pump performance data to identify areas where pump efficiencies can be improved

PSAT

- Specifically, PSAT uses pump and motor performance data from Hydraulic Institute standard ANSI/HI-1.3 and MotorMaster+ database info to estimate existing, achievable performance

(MotorMaster+ is an earlier DOE motor efficiency tool)

PSAT

- Requires field measurements or estimates of flow rate, pressure, and motor power or current

So, PSAT…

- Assesses your current pump system operating efficiency by comparing field measurements of power delivered to the motor with the fluid work (flow & head) required by the application

ADEM

PSAT

- Can identify the operational cost savings from installing a new pump/pump system

PSAT – for instance

- Is your pump properly sized?
- Is your pump service degraded?
- Do you have an old, inefficient motor?
- Is the pump just operated ineffectively?
- Would installing/modifying a check or control valve change system efficiency?

PSAT

- Gives you an optimization rating of your existing pump compared to equivalent top line equipment at peak efficiency (i.e., vs a pump with a rating of 100)
- Provides annual energy use and energy costs for existing and revised pump equipment

	Condition A	Condition B
	Multistage boiler feed	Multistage boiler feed
Pump, fluid		
Pump rpm	3560	3560
Drive	Direct drive	Direct drive
Units	gpm, ft, hp	gpm, ft, hp
Kinematic viscosity (cS)	1.00	1.00
Specific gravity	0.944	0.944
# stages	5	5
Fixed specific speed?	YES	YES
Motor		
Line freq.	60 Hz	60 Hz
HP	3000	3000
Motor rpm	3560	3560
Eff. class	Energy efficient	Energy efficient
Voltage	4160	4160
	Estimate FLA	Estimate FLA
Full-load amps	355.6	355.6
Size margin, %	15	15
Duty, unit cost		
Operating fraction	1.000	1.000
$/kwhr	0.0618	0.0618
Field data		
Flow rate, gpm	2639	2639
Head tool / Head, ft	2645	2155
Load estim. method	Power	Power
Motor kW	1600.0	1600.0
Voltage	4160	4160

Retrieve defaults | Set defaults | Copy A > to B > | Copy B < to A < | Background information

System curve tool: select below

STOP

	Condition A Existing	Condition A Optimal	Units	Condition B Existing	Condition B Optimal	Units
Pump efficiency	80.8	86.2	%	65.8	86.5	%
Motor rated power	3000	2250	hp	3000	2000	hp
Motor shaft power	2058.5	1930.0	hp	2058.5	1566.4	hp
Pump shaft power	2058.5	1930.0	hp	2058.5	1566.4	hp
Motor efficiency	96.0	96.3	%	96.0	96.2	%
Motor power factor	89.2	90.0	%	89.2	89.5	%
Motor current	249.1	230.5	amps	249.1	188.4	amps
Motor power	1600.0	1494.5	kW	1600.0	1214.7	kW
Annual energy	14016.0	13091.4	MWh	14016.0	10640.5	MWh
Annual cost	866.2	809.0	$1000	866.2	657.6	$1000
Annual savings potential, $1,000		57.1			208.6	
Optimization rating, %		93.4			75.9	

Log file controls: Create new log | Add to existing log | Retrieve log entry | Delete log entry

Summary file controls: Create new summary file

Existing summary files: CREATE NEW

Documentation section

Condition A Notes

Facility: Westvaco | System: Boiler FW Pumps | Date: Nov 25, 2015

Application: Boilers 6 and 7 | Evaluator: Cunningham

General comments:

Feedwater pump discharge pressure is ~1100 psig. The boiler pressure is maximum of 650 psig. when the pumps are replaced the discharge pressure could be dropped by at least 200 psi, or 490 ft of head. Condition A is the current operation.

Condition B Notes

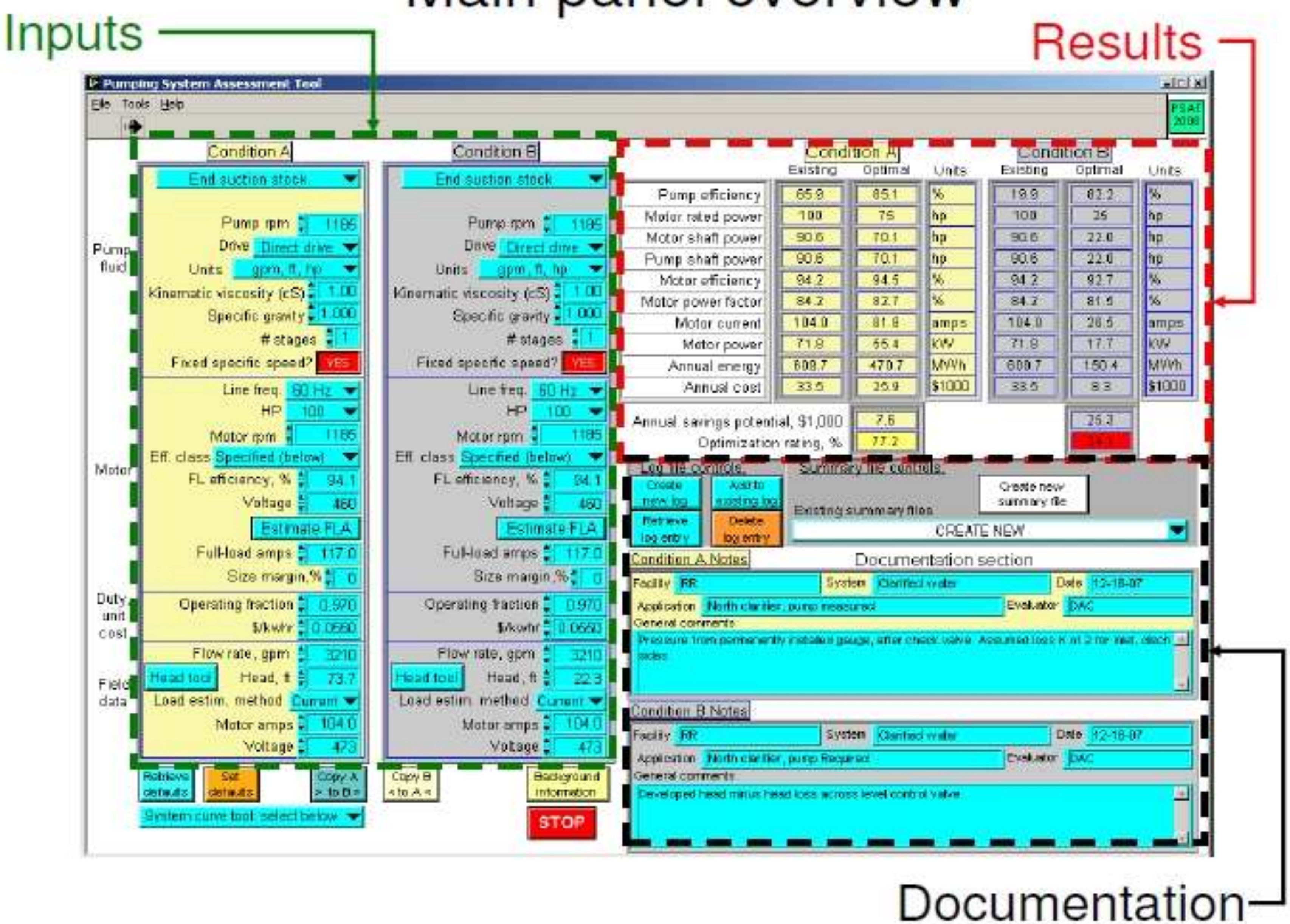
Facility: | System: | Date:

Application: | Evaluator:

General comments:

The pump head is reduced by 200 psi, or 490 ft of head. The optimal condition is used as the after project condition. Savings are $208,600/year. This is a costly project and will only be done when the pumps require major maintenance.

Main panel overview



Doing a PSAT Study can be tricky

- Assemble the right team of people to work on this project

For assistance with PSAT: Team up with these folks

- TVA's Comprehensive Services Program – Jason Snyder
- Dr. Glenn Cunningham -Tennessee Tech University
  gcunningham@tntech.edu
- EPA Region 4 – Brendan Held

Work as a team with your Utility electrician

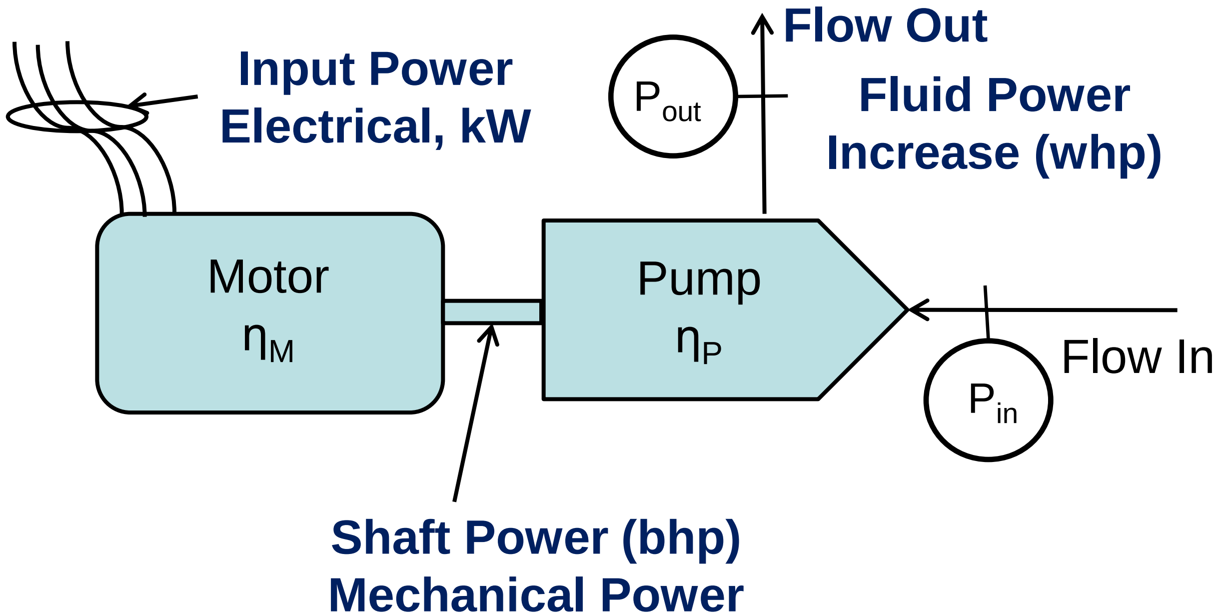
Five Basic Causes of less than optimal pumping system operation

- Installed *components* are inherently inefficient at <u>normal</u> operation conditions
- Installed *components* have <u>degraded</u> in service
- More flow is being provided than the *system* requires
- More head is being provided than the *system* requires
- Equipment is being run when not required by the *system*

Opportunities for Pump Savings

- Throttle valve-controlled systems
- Bypass (recirculation) line normally open
- Multiple parallel pump system with same number of pumps always operating
- Constant pump operation in a batch environment or frequent cycle batch operation in a continuous process
- Cavitation noise (at pump or elsewhere in the system)
- High system maintenance
- Systems that have undergone change in function
- Pumping at higher flow rates than are necessary for shorter periods of time

Pumping Power Diagram



Shaft Power (bhp) = Motor Input Power * (η_M)

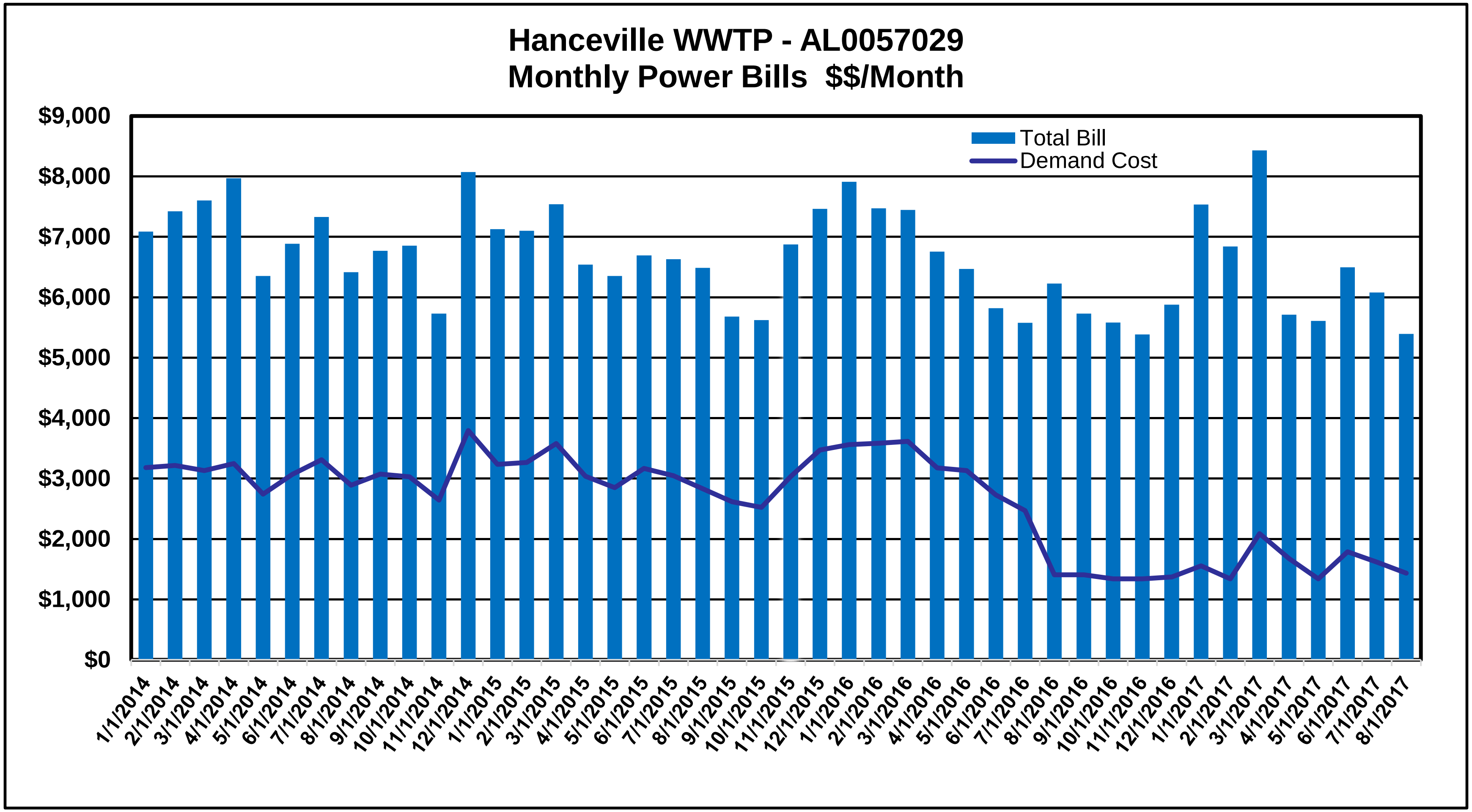
Fluid Energy Increase (whp) = Shaft Power (bhp) * (η_P)

(1 HP = 0.746 kW)

Power Costs are Increasing

- Case in Point: One Alabama utility reduced power usage by 38% in 2017 but only saw a 9% cost savings because power costs increased $49% since 2014..!!

The effect of Demand charges



The effect of Demand charges

- So Hanceville saw a $2,100 decrease in its monthly demand charge over a 6 month period
- Some of this savings was due to installing a VFD on its main influent WWTP pumps

Laws of Affinity

- Flow is proportional to shaft speed
- Head (pressure) is proportional to the square of shaft speed
- Power is proportional to the cube of shaft speed

Laws of Affinity

$$\frac{Q_1}{Q_2} = \left(\frac{N_1}{N_2}\right)$$

Flow

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

Pressure

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

Power

Typical Pump Design

- On average, 80% of the time pumps operate at 60% of their full capacity

  [*Source: Baldor Motors*]

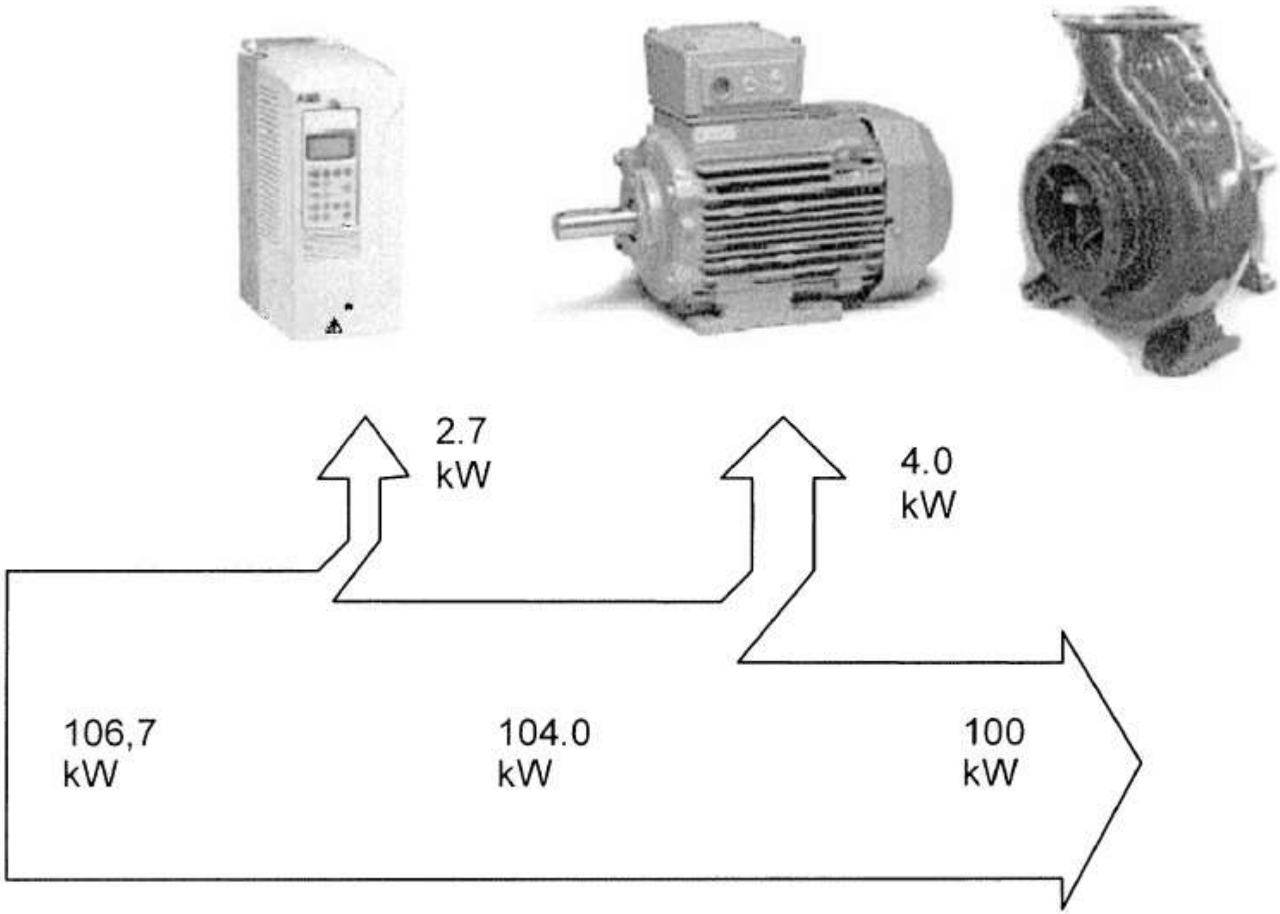
This indicates there is often an opportunity to save energy by controlling pump operation

Variable Frequency Drives

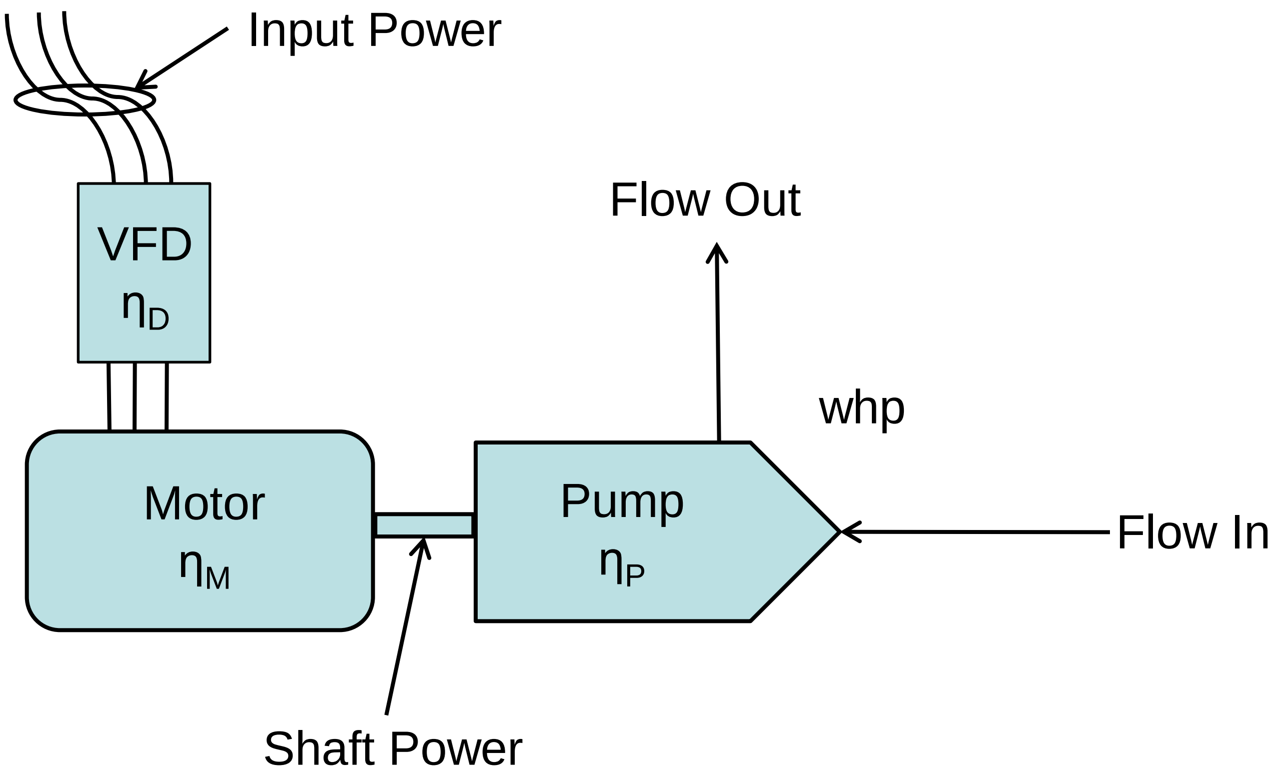
Where warranted, A VFD Can:

- **Provide improved process control**
- **Save electrical energy**
- **Reduce wear and tear on equipment**

AC Drive and Motor Losses



VFD on Pump Motor



$$\text{VFD Input Power} = \text{whp}/(\eta_D * \eta_M * \eta_P)$$

A VFD has limitations

- Generates Heat (2-3 % loss)
- Generate harmonics (current distortion)

So, a VFD adds a degree of inefficiency

BUT, overall…

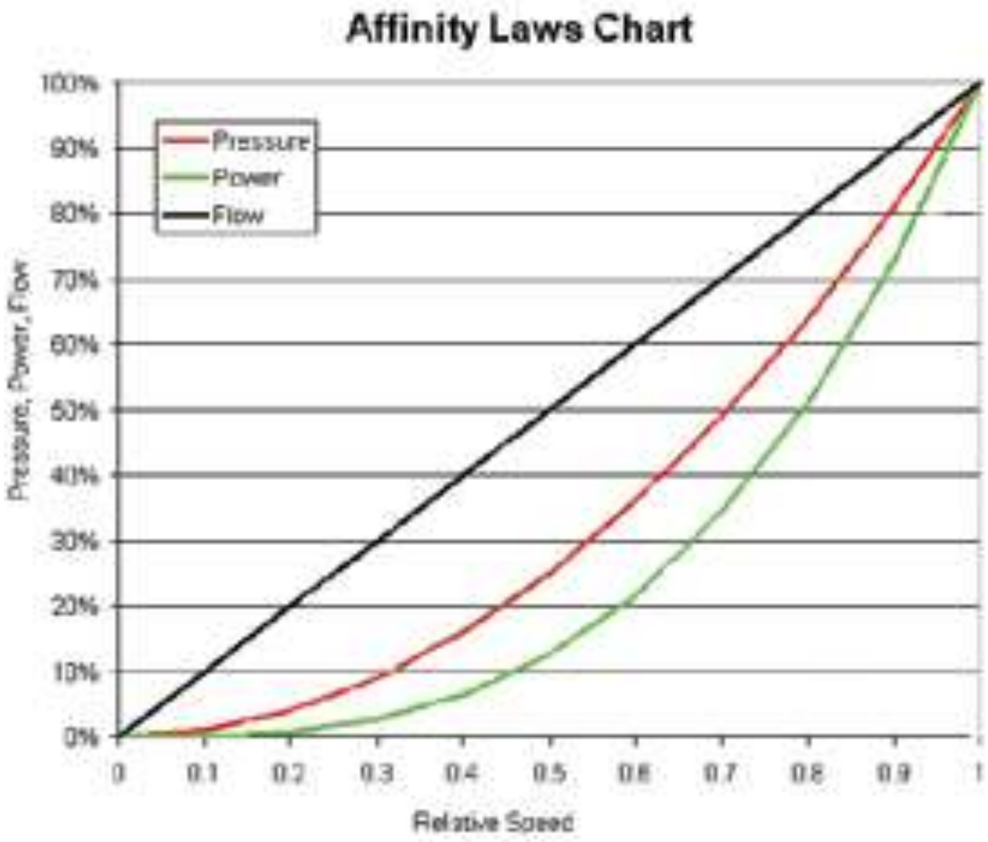
- VFDs save energy by using less overall power
  - Power a pump consumes is proportional to the cube of velocity. Theoretically, if you run a pump at 80% speed, you can save 51% of full load power)
- VFDs run at a high power factor- Results in potential cost savings and increase in motor life

Theoretical Power Savings

- **Running a pump at 60% of its operating volume requires only 22% input power**

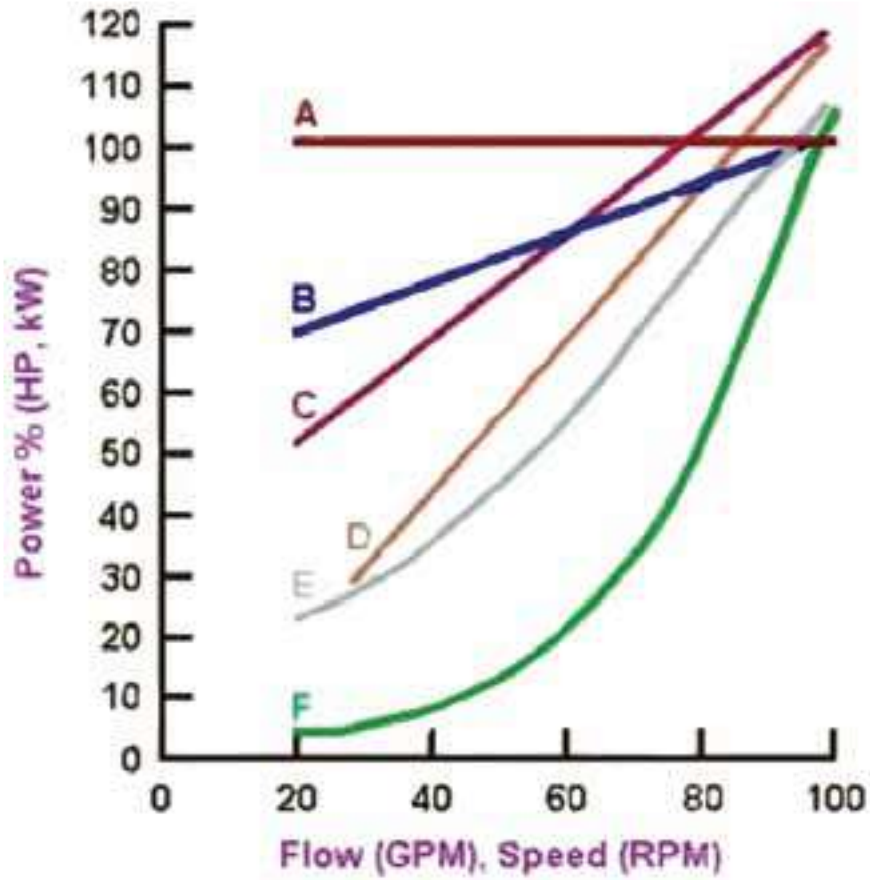
Volume	Pressure/Head	HP Required
100%	100%	100%
80%	64%	51%
60%	36%	22%
40%	16%	6%

Theoretical Affinity Laws



VFD Advantages

Curve A – Diverting Valve
Curve B – Throttling Valve
Curve C – Hydrostatic Drive
Curve D – Mechanical Drive
Curve E – Eddy Current Clutch
Curve F – Variable Speed Drive



So, a VFD…

- Comes closest to achieving the theoretical maximum efficiency of a pump

Energy Cost Savings

For a centrifugal pump:

- An adjustable AC drive can save a great deal of energy if a pump is designed to operate at somewhere between 40-80 % speed
- Savings: 10 to 60 %

Power/Demand Fee Structure Trend

TVA – Lower unit power cost but higher demand charge

Southern Company – Higher unit power cost but lower demand charge

Example Usage/Demand Charge

Lift Station Pump: 200 hp, Single Speed
Centrifugal Pump

Utility Costs: $14.36/kW Demand Charge

This pump runs for ten 30-min cycles/day

Example: Energy Usage Cost

Energy Cost:

Pumping at 92% efficiency

Lift Station Pump: 200 hp, Single Speed Centrifugal Pump

Energy Consumed

Unit Cost of $0.10/kWh

Pumping at 92% efficiency

Energy Use:

200 hp x 0.746 kW/hp x 5 hr/day x 30 days/mo x 0.92 = 20,600 kWh/Mo

Energy Usage Cost

Energy Cost = 20,600 kWh/Mo x $0.10/kWh

= $2,060/Month

Example Demand Charge

For the short cycle time, the operation of this pump imparts a significant demand charge on the utility:

200 hp x 0.7457 kW/hp = 149 kW

The demand cost to run this pump:

149 kW x $14.36/kW = $2,140/Month

Example Demand Charge

So, the utility is paying:

$2,060/Month in Energy Usage

AND

$2,140/Month in Demand Charge

To run this pump

What Can be done…?

The utility can install a variable frequency drive (VFD) on the pump:

Conceivably, the pump may then begin a pump cycle at 40% speed and increase to 60% speed. It may never need to run > 85% speed or it may pump at 100% speed for < 15 min per cycle (typ SCADA-controlled).

What Can be done…?

Anything that runs < 15 minutes won’t show up as a demand charge

Note: Your Demand period may be 15 min or 30 min.

What Can be done…?

Say the average pump run speed is now 50% and the pump now operates for double the amount of time:

Drive efficiency would decrease somewhat: …say 5%

What Can be done…?

Energy Usage:

0.13 x 200 hp x 0.746 kW/hp x 10 hr/day x 30 days/mo x 0.92 x 1.05

= 5,600 kWh/Mo

Energy Cost: 5,600 kWh/Mo x $0.10/kWh

= $560/Month (73% savings)

** Efficiency roughly estimated

What Can be done…?

Demand Usage:

200 hp x 0.13 x0.746 kW/hp = 19.4 kW

(decrease from 149 kW)

Demand Charge: 19.4 kW x $14.36/kW

= $280/Month

(87% savings)

Resulting Savings from VFD Installation

So the utility is now paying quite a bit less to operate the pump from: $2,060 to $560/Month

But they have also reduced the demand cost from $2,140 to $280/month:

That's a net monthly savings of $3,360/Month

Resulting Savings from VFD Installation

A savings of 80%..!! BUT, if this electric utility only charges a demand cost for a certain kW threshold, conceivably, the entire demand cost of this pump may be eliminated: a net savings of:

$3,640/Month…!! (87% Savnings)

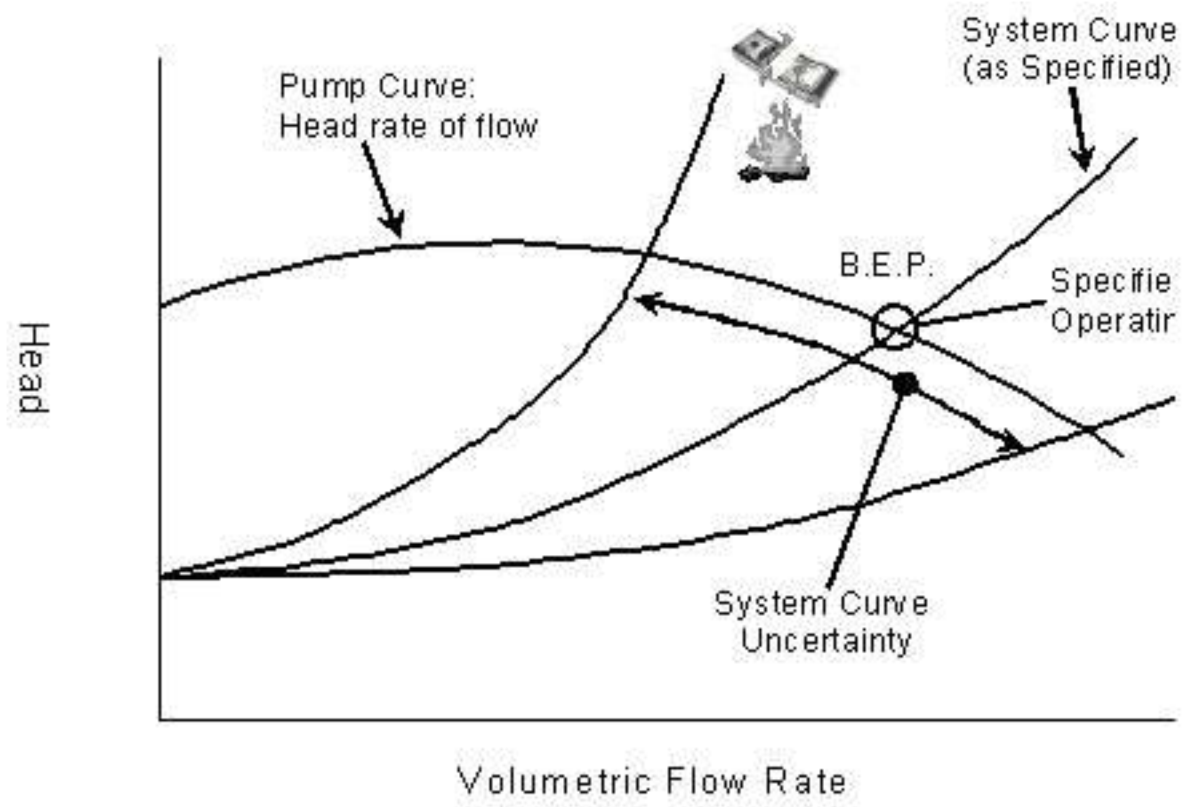
(Note: There may be a base demand charge)

VFDs can be expensive

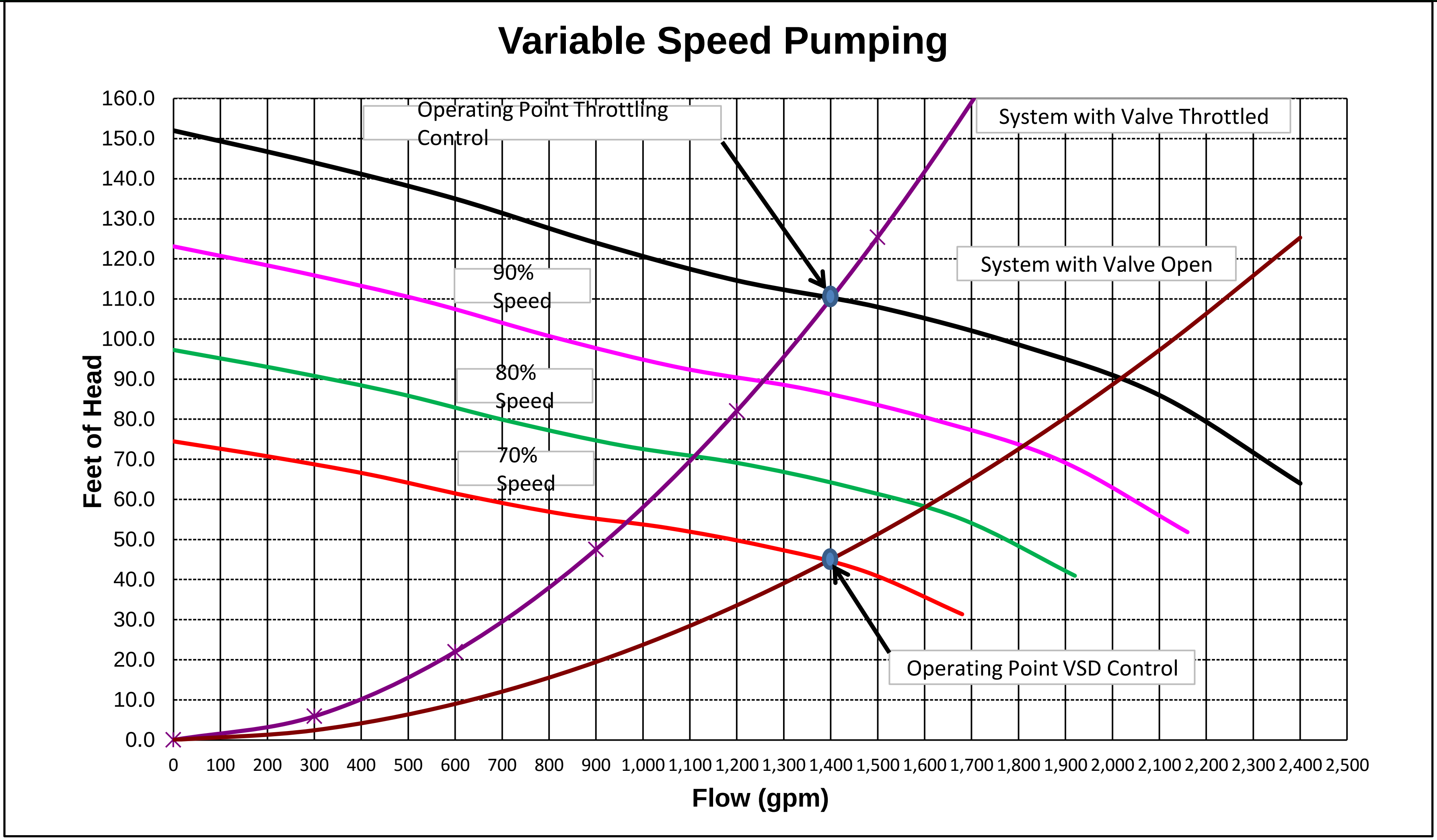
- But in many applications, the payback period is < 2 years

- And annual cost savings continue..!

Need to Check Pump System Condition



Ensure a VFD is the right "System" Solution



You need to assess each site-specific Application

Determine if the pump design and system design will facilitate reliable control & operation by using a VFD for turndown

ADEM

OK…so this is a fan company

BIG ASS SOLUTIONS

No Equal

But if you have a REALLY big pump…

It warrants a close look

Questions..?

Jim Grassiano

Chief, Compliance Assistance & Operator Certification Programs

jgrassiano@adem.alabama.gov

334-279-3071