MINISTRY OF
INDUSTRY AND TRADE

EU - VIET NAM SUSTAINABLE ENERGY
TRANSITION PROGRAMME (SETP)

Global Gateway

Funded by
the European Union

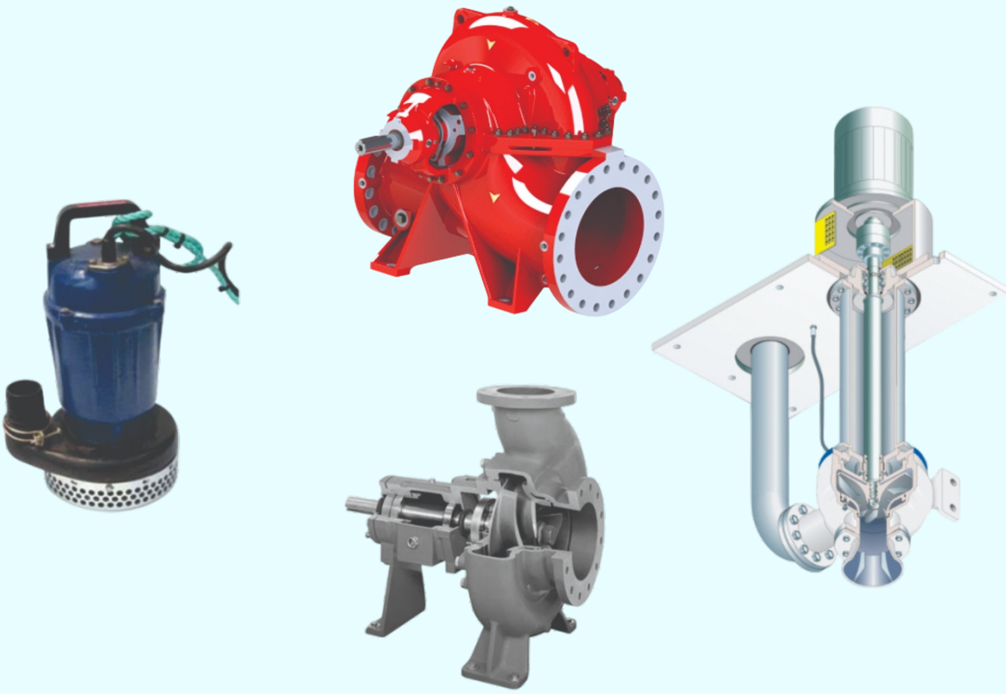
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Project "Accelerating energy efficiency (EE) in large industries through energy management system, system optimisation and the promotion and adoption of EE in SMEs" (IEEP)

EXPERT TRAINING PROGRAMME

PUMP SYSTEMS OPTIMISATION (MODULE 2)

Ha Noi, 20 - 23/01/2026



AGENDA

Expert Training on Pump Systems Optimisation (PSO)
20 - 23 January 2026

At: - Hoa Binh Hotel, 27 Ly Thuong Kiet, Hoan Kiem, Ha Noi
- Thieu Nien Tien Phong Plastic JSC., Hai Phong province
- Menrva Hotel, 4 Tran Hung Dao, Hai Phong province

Day 1 (Hoa Binh Hotel)

Time	Contents	Speakers
8.00-8.30	Registration and welcome	
8.30-8.45	Opening speech	Representative of MOIT/ IEEP Project Office
8.45-9.00	Pump and System Basics	Lecturer
9.00-9.30	Introduction to ASME Standards and Pump system assessment process	Lecturer
9.30-10.00	Field Observation: Identifying signs of non-optimal systems	Lecturer
10.00-10.15	**Tea-break**	
10.15-10.45	Case Study: Data collection and analysis	Lecturer
10.45-11.15	Case Study: Identifying savings opportunities	Lecturer
11.15-12.00	Operation and maintenance issues	Lecturer
12.00-13.15	**Lunch at the hotel**	
13.15-13.45	Variable Frequency Drive (VFD) issues	Lecturer
13.45-14.15	Case Study: VFD in a Paper Mill	Lecturer
14.15-15.00	Data Collection: On motors and fluid properties Data Collection: On pumps	Lecturer
15.00-15.15	**Tea-break**	
15.15-16.00	Key parameters to measure: flow, pressure, power	Lecturer
16.00-16.30	Measurement tools and techniques	Lecturer

Day 2 (Thieu Nien Tien Phong Plastic JSC.,)

Time	Contents	Speakers
8.00-8.30	Registration	
8.30-9.00	Welcome and Introduction	IEEP Project & Thieu Nien Tien Phong Plastic Company
9.00-9.30	Plant overview & welcome by top management	Management of Thieu Nien Tien Phong Plastic Company
9.30-9.40	Safety briefing	Lecturer
9.40-10.00	Training objectives & group division	Lecturer
10.00-10.15	**Tea-break**	
10.15-11.00	Review of pump systems	Lecturer
11.00-12.00	Site visit – preliminary system inspection	All the class
12.00-13.15	**Lunch at the hotel**	All the class
13.15-14.00	Pump system assessment session 1	All the class
14.00-15.00	Pump system assessment session 2	All the class
15.00-15.15	**Tea-break**	
15.15-16.00	Pump system assessment session 3	All the class
16.00-16.30	Analysis of observations and data	All the class

Day 3 (Menrva Hotel)

Time	Contents	Speakers
8.00-8.30	Registration	
8.30-9.30	Analysis of observations and data	All the class
9.30-10.00	Introduction to MEASUR software	Lecturer
10.00-10.15	**Tea-break**	
10.15-12.00	MEASUR software user guide	Lecturer
12.00-13.15	**Lunch**	All the class
13.15-15.00	Applying MEASUR to model energy saving projects	All the class
15.00-15.15	**Tea-break**	
15.15-16.00	Applying MEASUR to calculate project parameters for PSO	All the class
16.00-16.30	Preparation for presentation to the top management of Thieu Nien Tien Phong Plastic Company	All the class

Day 4 (Thieu Nien Tien Phong Plastic Company)

Time	Contents	Speakers
8.00-8.30	Registration	
8.30-9.15	Summary of findings & opportunities	All the class Lecturer
9.15-9.30	**Tea-break**	
9.30-12.00	Reporting to the top management of Thieu Nien Tien Phong Plastic Company	All the class
12.00-13.15	**Lunch**	
13.15-15.00	Reporting to the top management of Thieu Nien Tien Phong Plastic Company	All the class
15.00-15.15	**Tea-break**	
15.15-16.00	Reporting to the top management of Thieu Nien Tien Phong Plastic Company	All the class
16.00-16.30	Next steps – Exercises and online webinars	Lecturer
16.30-17.00	Closing speech	Representative of IEEP Project Office

Two Day
Expert Pump System Optimization Training

Harry Rosen

UNIDO International Energy Efficiency Expert

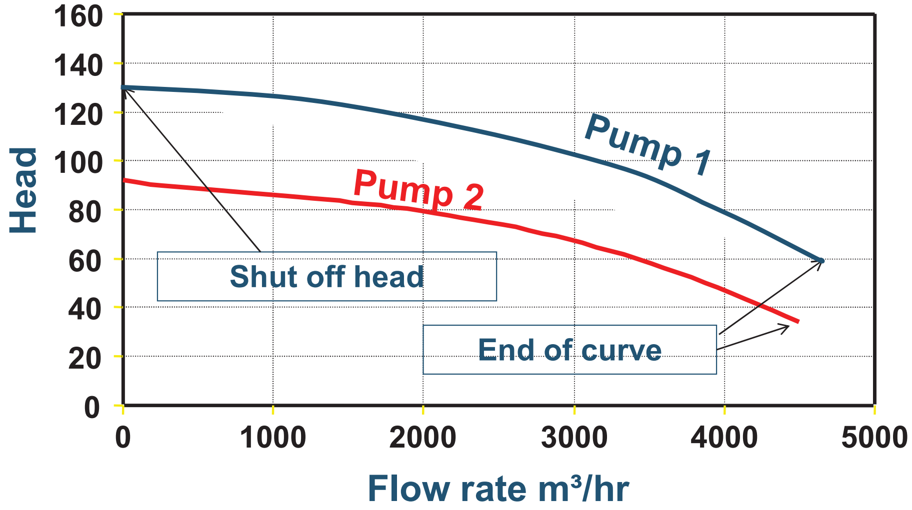
Based on the contents of the UNIDO Expert PSO Training Manual

Viet Nam
2026

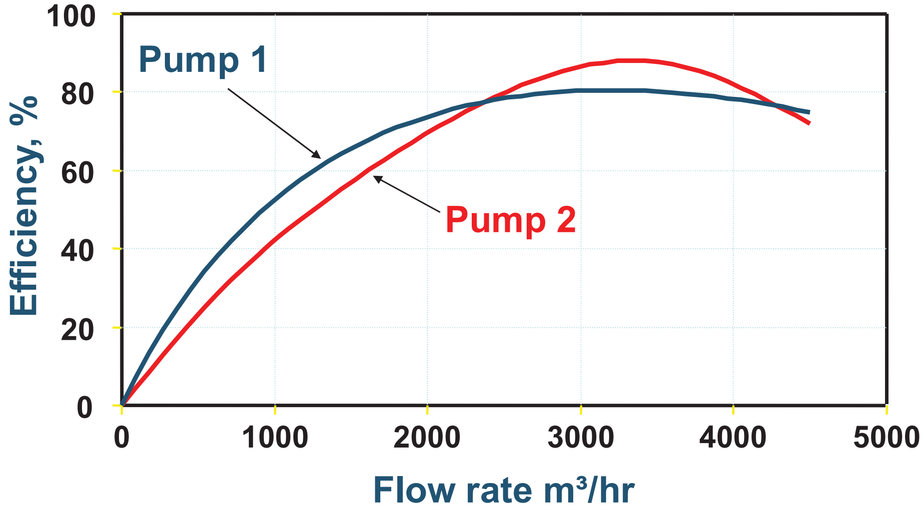
Pump and System Basics

2

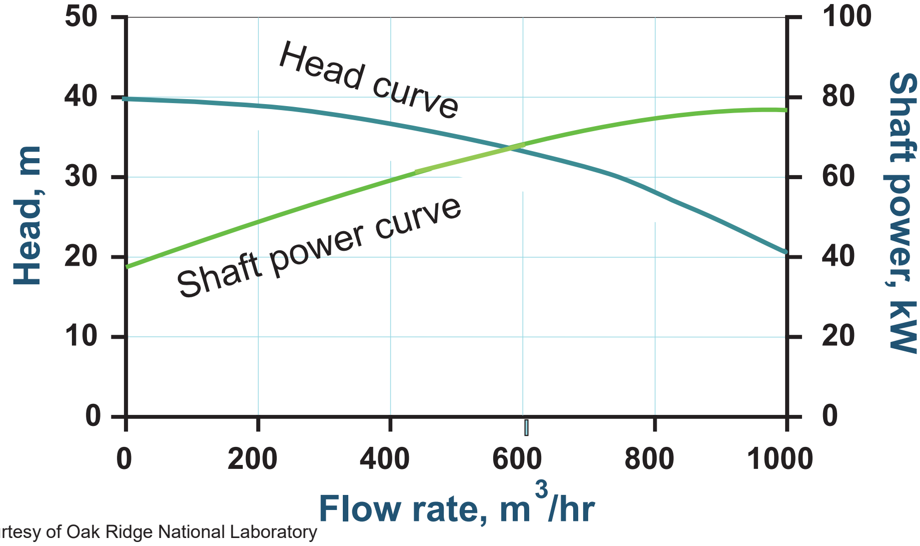
Pump curve shapes vary: Head curves for two pump designs



And finally, efficiency curves for the two pumps

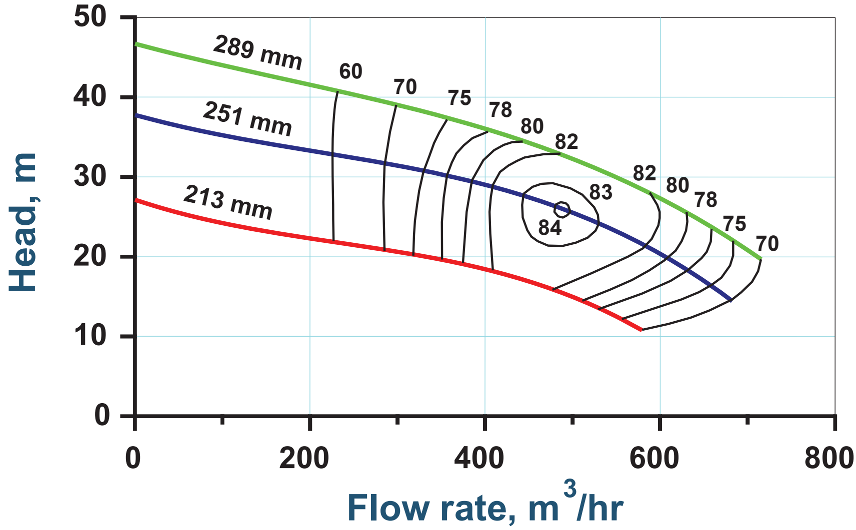


Another characteristic curve of interest is the shaft power as a function of flow rate



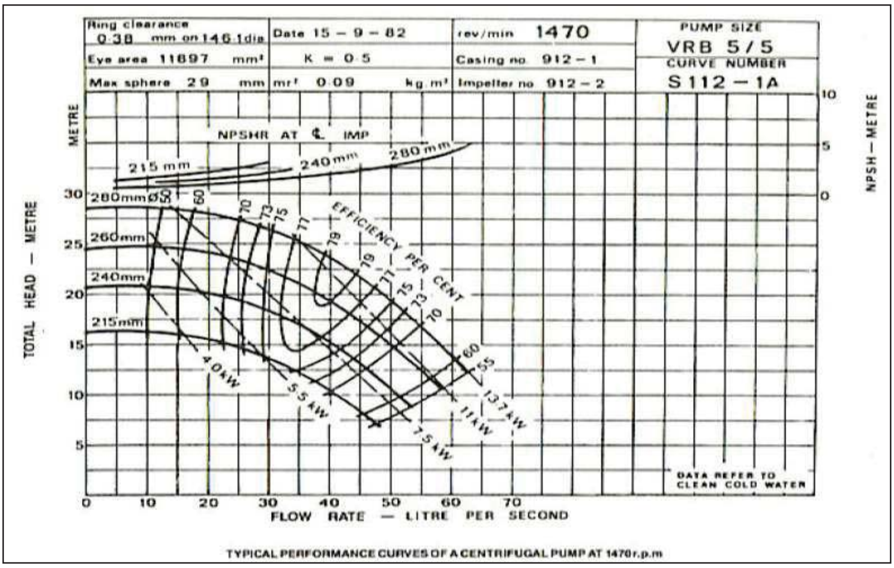
Slide Courtesy of Oak Ridge National Laboratory

ISO-efficiency lines are frequently overlaid onto head-capacity curves for multiple impeller diameters

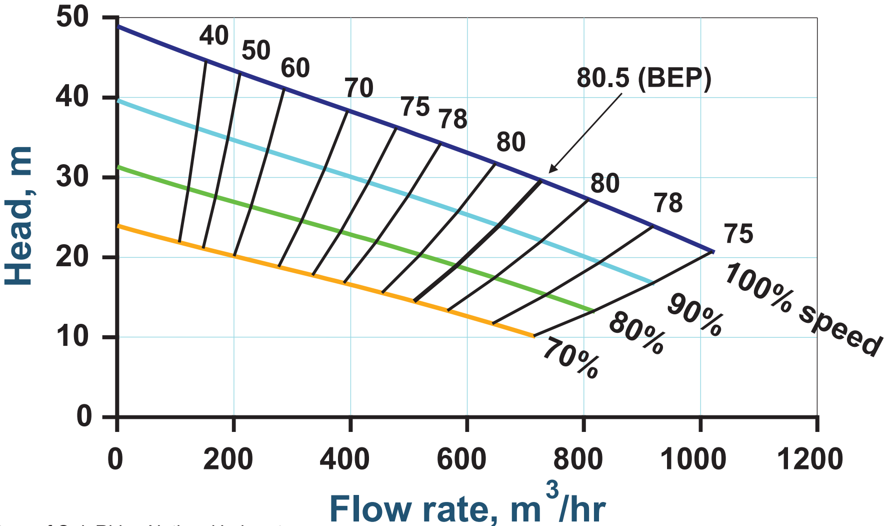


Slide Courtesy of Oak Ridge National Laboratory

Typical performance curves, trimmed imp.



For speed changes, the efficiency lines have a different pattern



Slide Courtesy of Oak Ridge National Laboratory

Nameplate data applies to one particular operating point

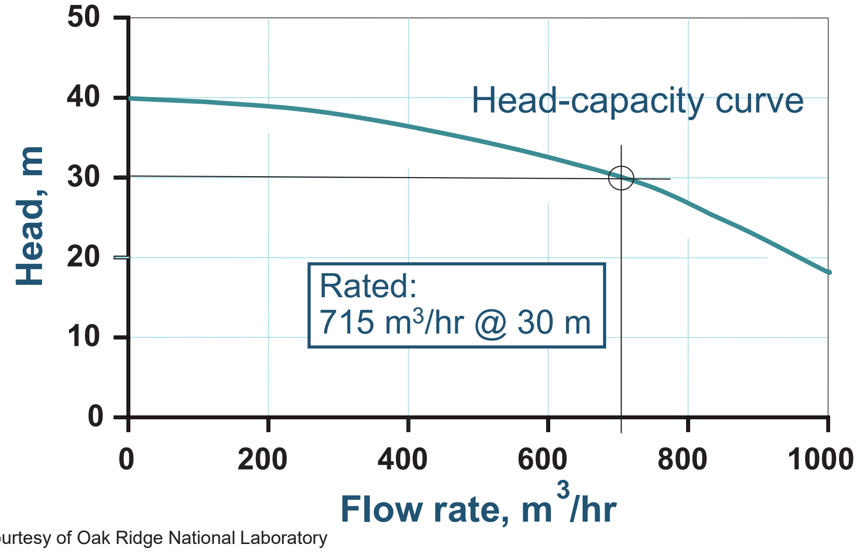
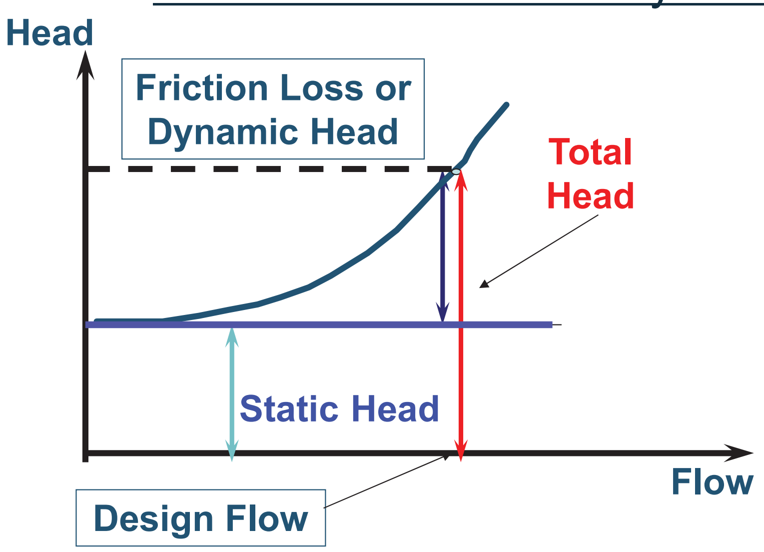


Figure Courtesy of Oak Ridge National Laboratory

Two Components of System Curves: Static and Friction or Dynamic Head

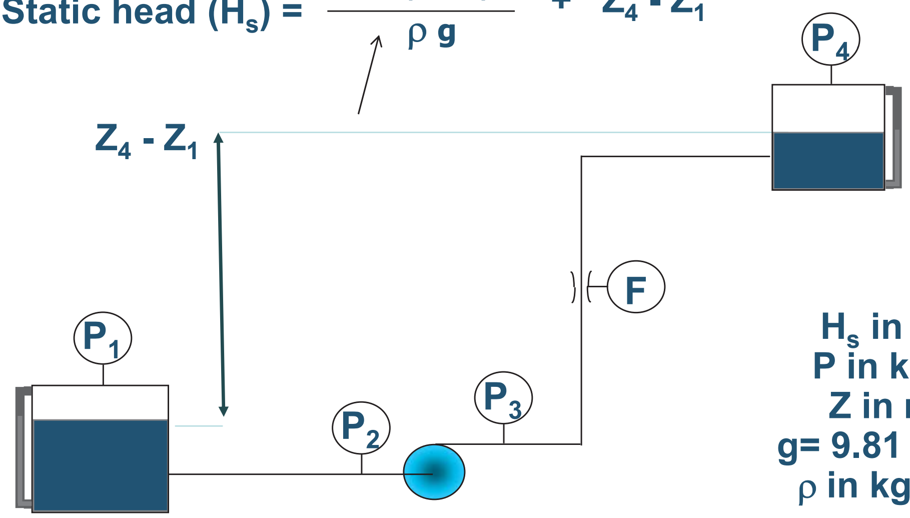


Friction head varies with approximately the square of the flow rate

Static head is the sum of pressure + elevation head differences from start to finish

The static head is made up of elevation, and sometimes pressure components

$$\text{Static head } (H_s) = \frac{(P_4 - P_1)}{\rho g} + Z_4 - Z_1$$



H_s in m
P in kPa
Z in m
g= 9.81 m/s²
ρ in kg/m³

System head curve for all static system

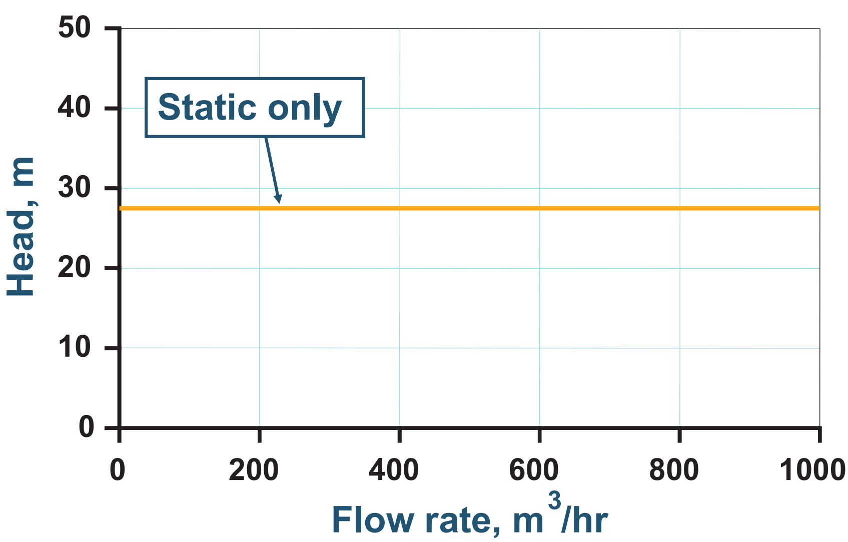
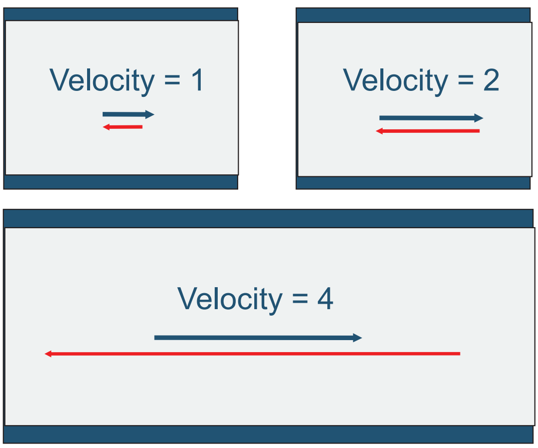


Figure Courtesy of Oak Ridge National Laboratory

As is the case for all motion, movement of fluids is resisted by friction

The friction magnitude is approximately proportional to the square of the fluid velocity



$$\text{Friction head loss} = K\frac{V_2^2}{2g}$$

For piping, K is often defined by a pipe friction loss-estimating method called Darcy-Weisbach.

For fittings and components such as valves, elbows, and tees, K is called the "loss coefficient". More on that later.

System head curve for all frictional system

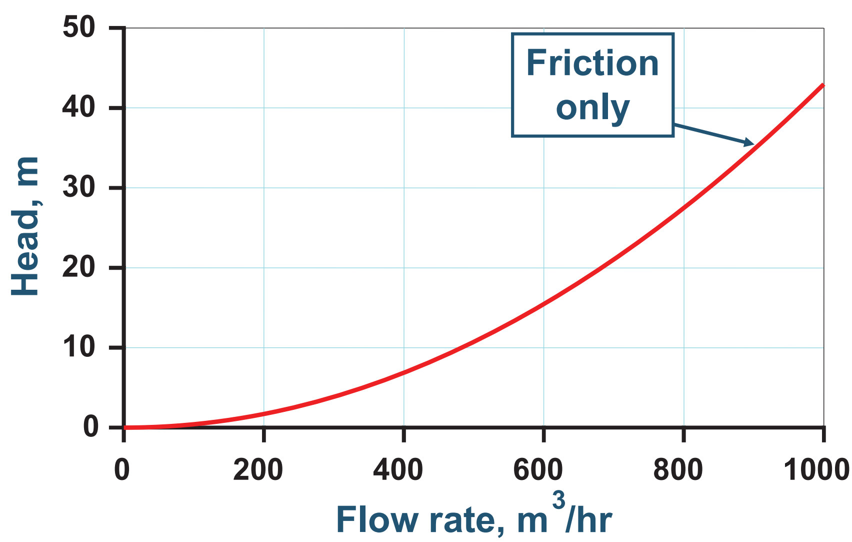


Figure Courtesy of Oak Ridge National Laboratory

The effect on the system head curve when the static head changes

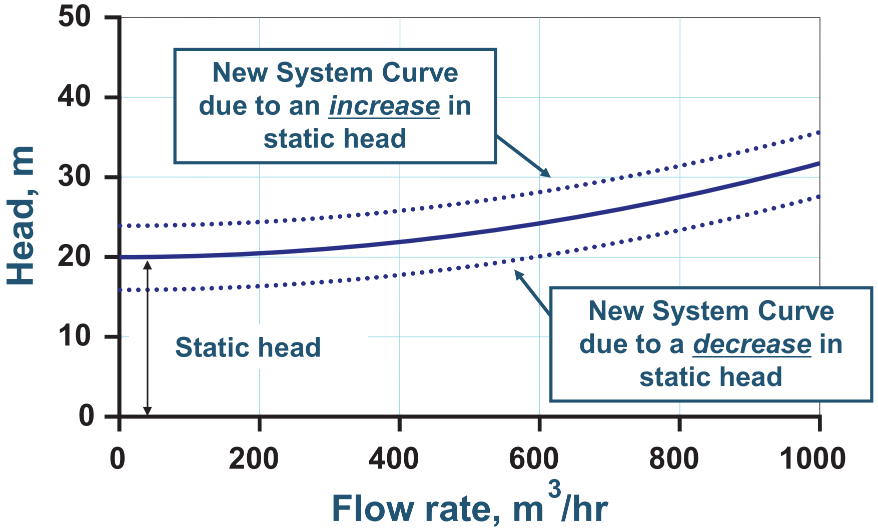


Figure Courtesy of Oak Ridge National Laboratory

The effect on the system head curve when system friction changes

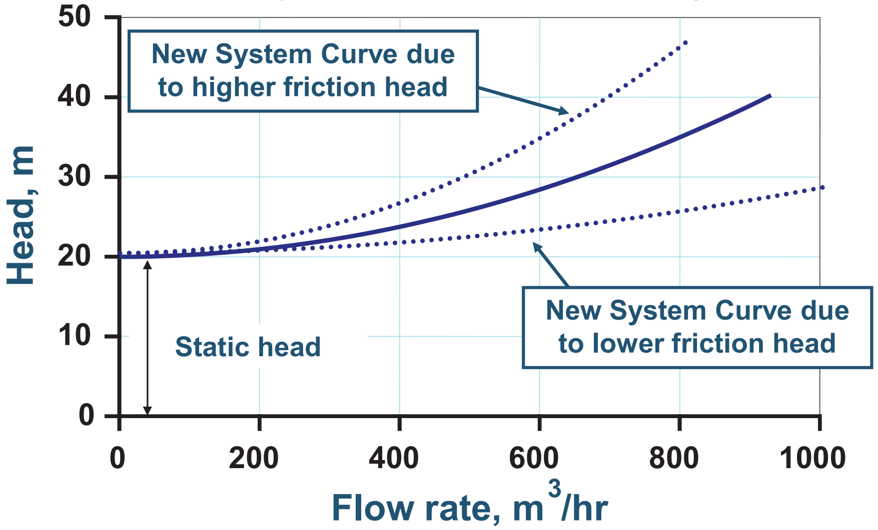
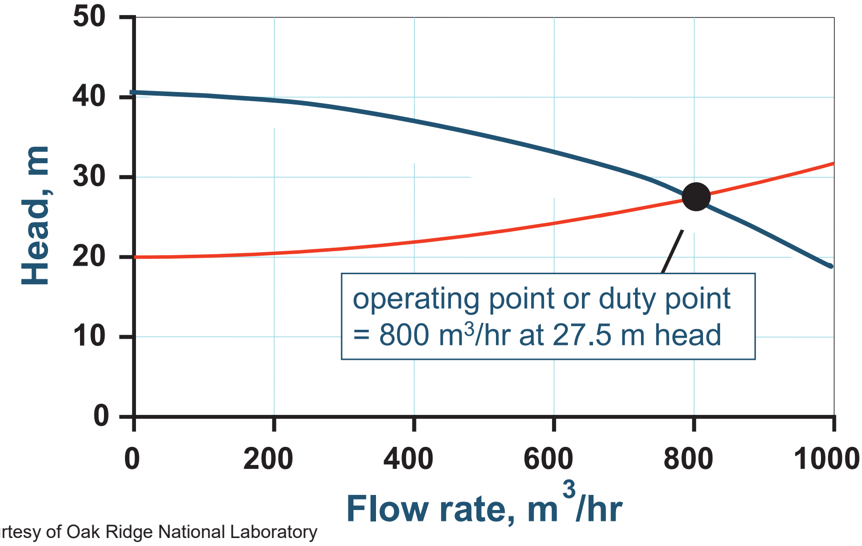


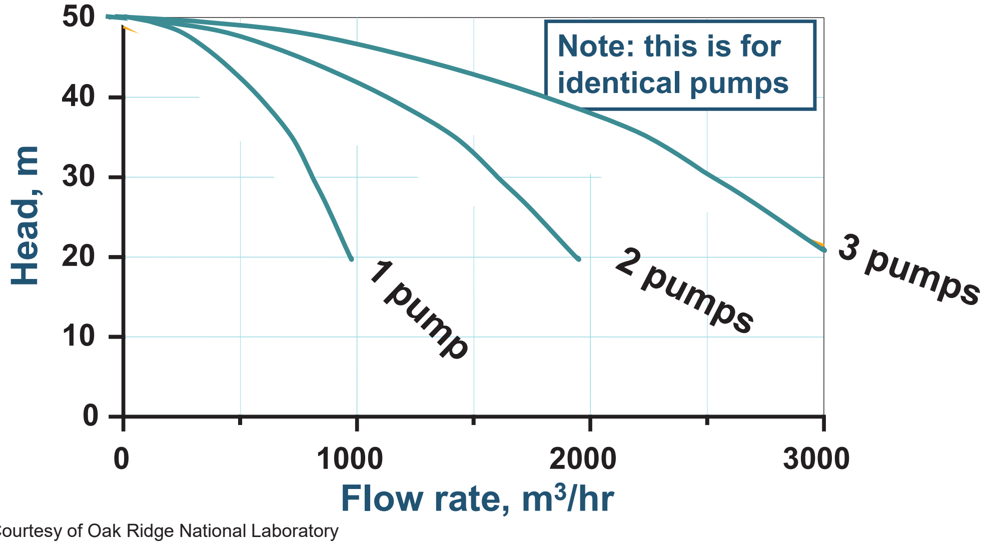
Figure Courtesy of Oak Ridge National Laboratory

The intersection between the pump and system head capacity curves defines the operating point



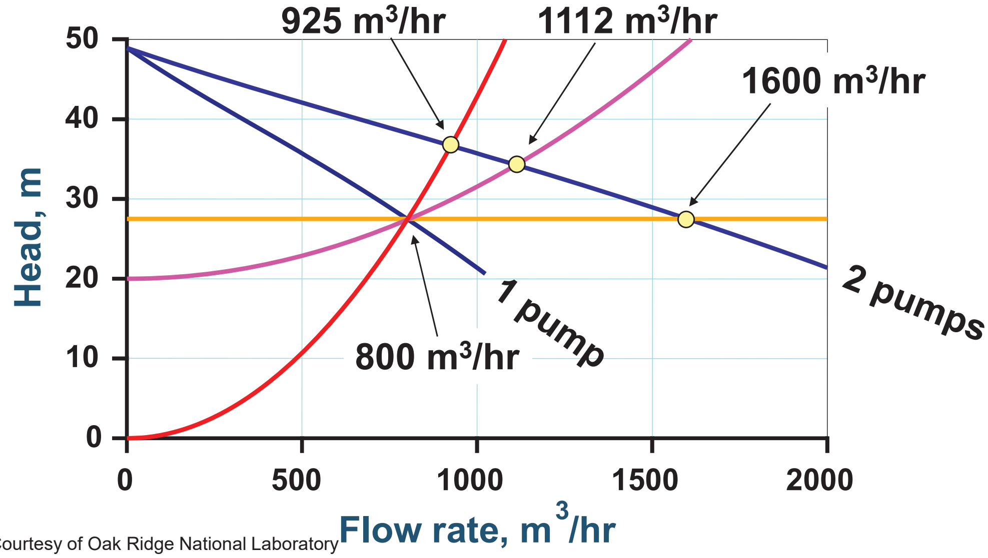
Slide Courtesy of Oak Ridge National Laboratory

Parallel pumps can help adapt to changing system requirements and provide redundancy



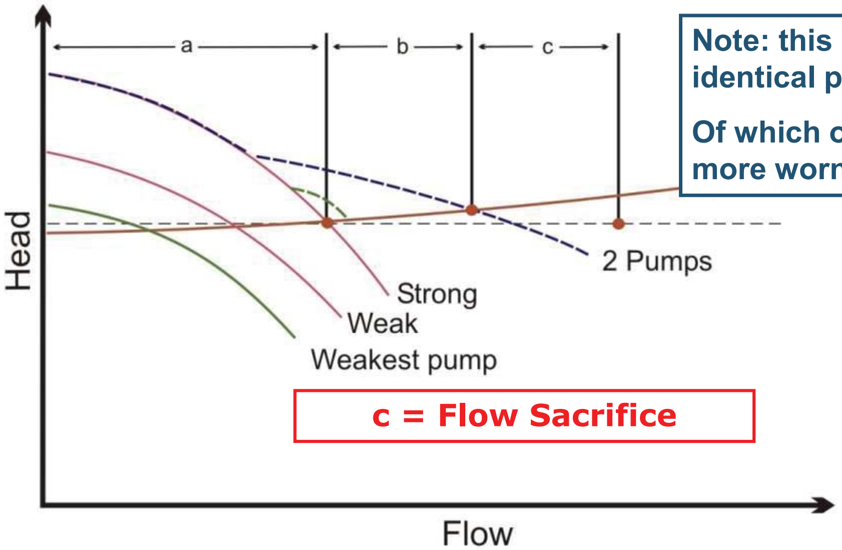
Slide Courtesy of Oak Ridge National Laboratory

Parallel pump operation with different system types



Slide Courtesy of Oak Ridge National Laboratory

Worn pumps operating in parallel One pump will dominate the other



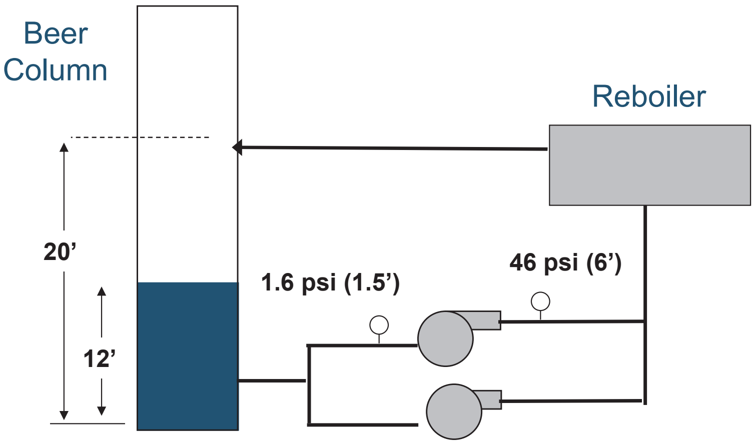
Note: this is for identical pumps

Of which one is more worn

c = Flow Sacrifice

Pumps in Parallel
Ethanol Plant Example

Reboiler Pumps #1 and #2

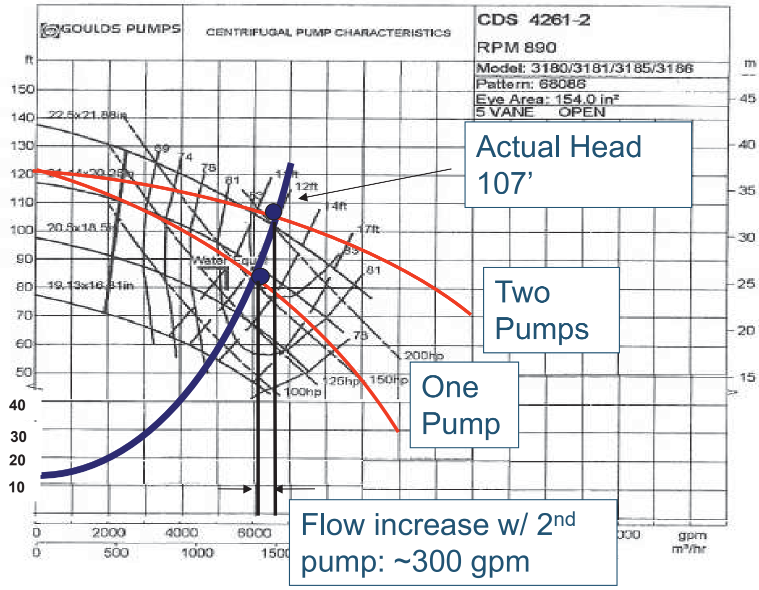


BC Boiler Pump Energy Use #1 (119.6 kW), #2 (120.4 kW)

Pump #2 Energy Use: 120.4 kW * 8,500 hours =1,023,400 kWh

Reboiler Pump Curves

Operating two pumps instead of one only increases flow by 6% *but increases system annual energy costs by $56,287*

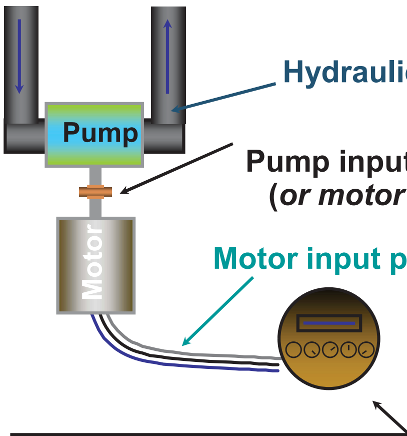


Standard efficiency definition

$$\text{Motor efficiency} = \frac{\text{Motor shaft power out}}{\text{Motor electric power in}} \qquad \frac{\text{Pump fluid power out}}{\text{Pump shaft power in}} = \text{Pump efficiency}$$

24

From the water or hydraulic power, the equation can be extended to include the pump system components to determine kW



Hydraulic power $= \dfrac{\text{l/s} \cdot \text{m} \cdot \text{relative density}}{102}$

Pump input power (kW) (*or motor output*) $= \dfrac{\text{Hydraulic power}}{\text{Pump efficiency}}$

Motor input power (kWe) $= \dfrac{\text{Motor output power}}{\text{Motor efficiency}}$

And finally, the cost of running the motor =
Motor input power · operating hours · per unit electricity cost

Slide Courtesy of Oak Ridge National Laboratory

Expanding the Power Equation…

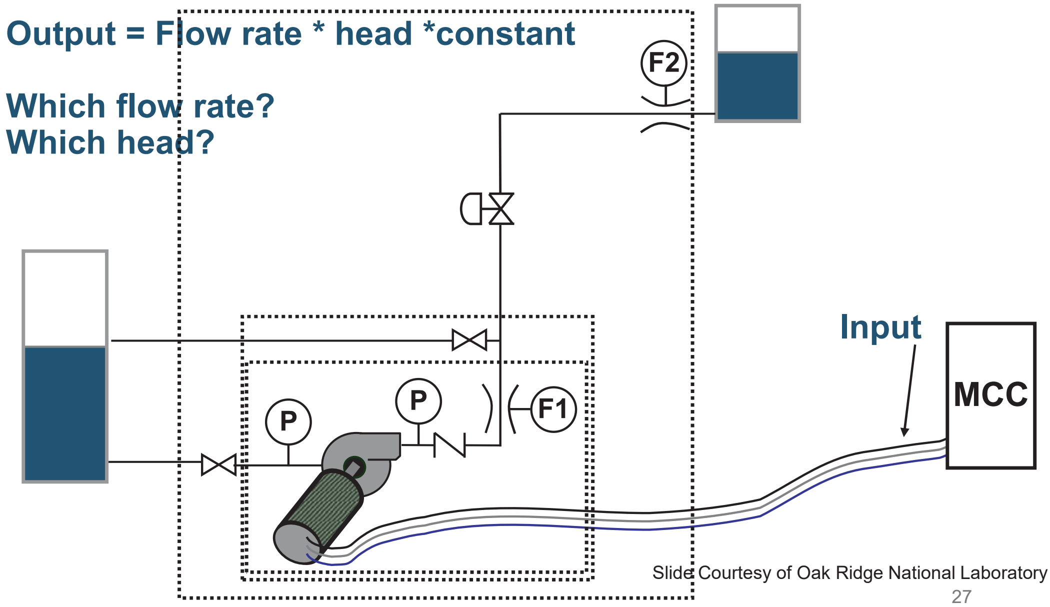
$$\text{kW} = \frac{\text{Flow (l/s)} * \text{Total Head (m)} * \text{Relative Density}}{102 * \eta_p * \eta_m * \eta_{vfd}}$$

Flow
Total Head
} **System-level Opportunities**

η_p = pump efficiency
η_m = motor efficiency
η_{vfd} = VFD efficiency
} **Component-level Opportunities**

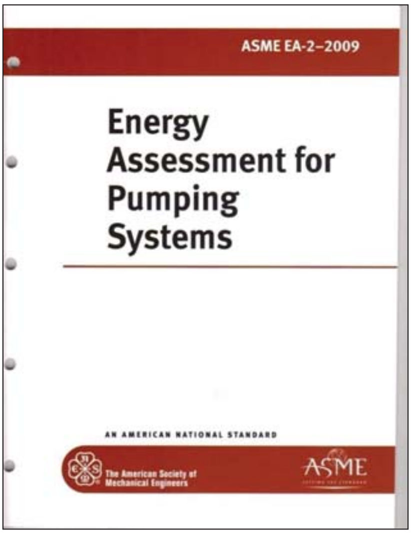
kWh = kW * Hours

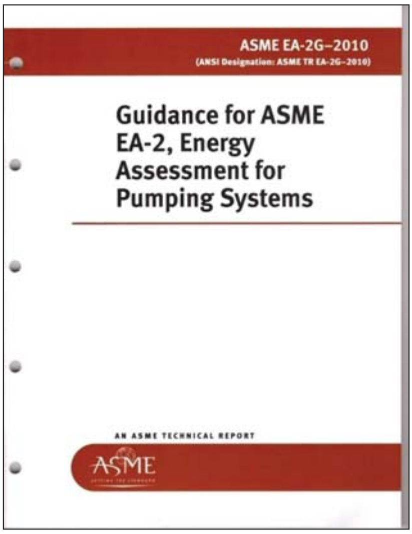
Pump System Optimization
Defining the system



Slide Courtesy of Oak Ridge National Laboratory

ASME Pump Assessment
Standard & Guidance Document





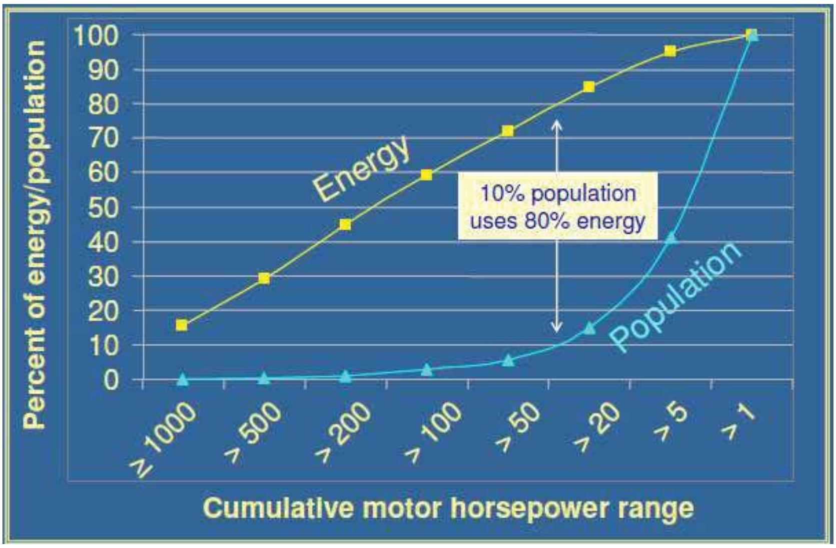
What is Pump System Optimization?

- Pump system optimization is a systematic approach to evaluate high energy use pumps to identify energy savings opportunities.

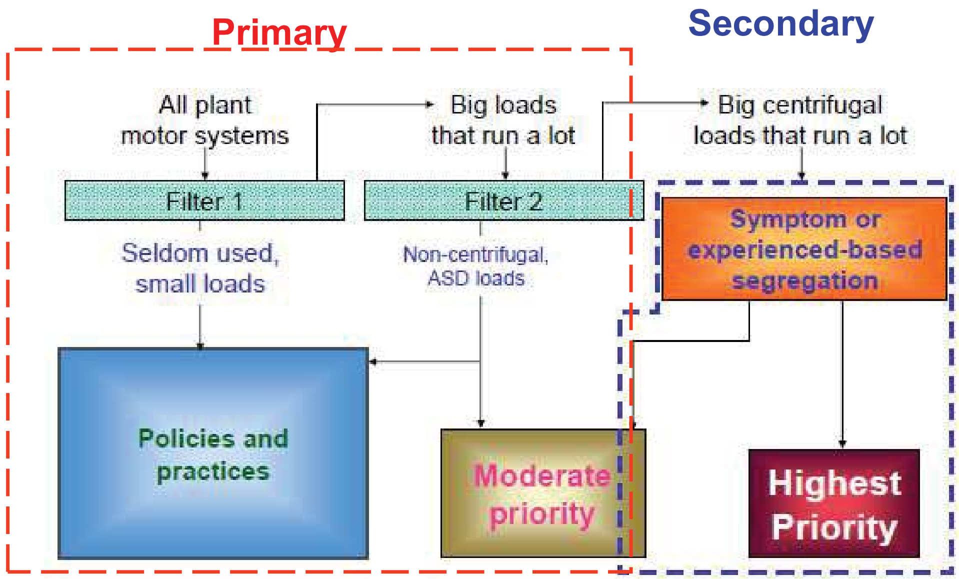
- After prescreening pump systems, potential savings of the selected pumps are determined by measuring, pressure, flow and power in the field. This data is combined with pump system operational data to determine an energy use baseline and the true system requirements.

- The DOE PSAT software tool can be used to provide a preliminary savings analysis. If there is a good opportunity, a more advanced analysis can be performed to determine the most cost effective improvement for pump system optimization.

A small portion of the motors are responsible for most of the energy consumption



Primary & Secondary Prescreening



Slide Courtesy of Oak Ridge National Laboratory

Identifying Potential Savings Opportunities

Four common causes of less than optimal pump system performance

- Installed components are inefficient at the typical operating condition
- The efficiency of the pump system components have degraded
- More flow or more head is being provided than the system requires
- The pump is being operated when it is not required by the system

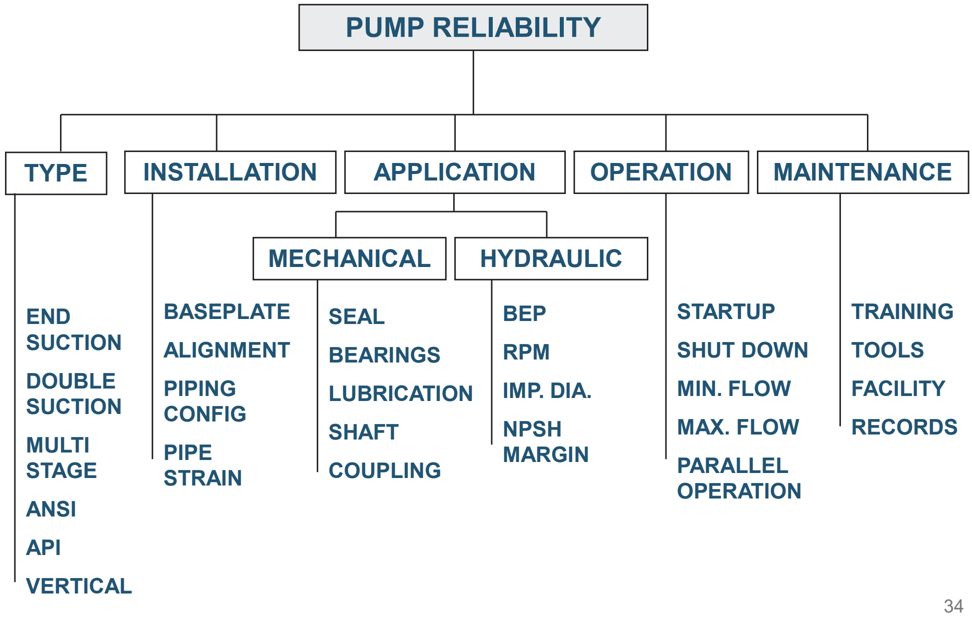
Slide Courtesy of Oak Ridge National Laboratory

Field Observations to Identify Potential Savings Opportunities

- Valves throttled to control flow
- Bypass (re-circulation line) normally open
- Multiple parallel pump system with same number of pumps always operating
- Constant pump operation for a batch process
- Cavitation noise (at the pump or elsewhere in the system)
- High system maintenance
- Systems that have undergone a change in function

Slide Courtesy of Oak Ridge National Laboratory

Factors that influence pump reliability



Standard/Guidance Document Sections

ASME EA-2-2009 Energy Assessment
Pump Systems Sections:

1. *Scope & Introduction*
2. *Definitions*
3. *References*
4. *Organizing the Assessment*
5. *Conducting the Assessment*
6. *Analyzing the Data*
7. *Reporting & Documentation*

Areas to be discussed

ASME Standard

Chapter 6:

Data Analysis

Pumping System Assessment Standard

6. Analysis from the Data of the Assessment

6.1 Common Causes and Remedies for Excessive Energy Use

6.1.1 Reduce System Head

6.1.2 Reduce System Flow Rate

6.1.3 Ensuring that Components Operate Close to BEP

6.1.4 Change Pumping System Run Time

6.2 Basic Energy Reduction Opportunity Calculations

6.2.1 Comparing Existing and Optimal Energy Use

6.2.2 Excess System Energy Use

Solutions to Excessive Energy Use

Reduce System Head:

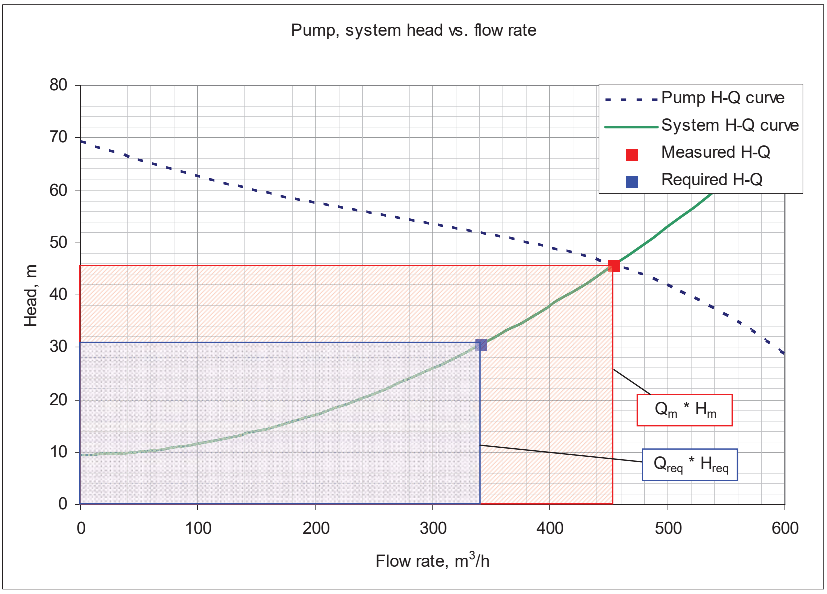
- Remove / reduce unnecessary throttling
- Clean fouled or partially blocked components
- Isolate unnecessary flow paths
- Replace old or corroded piping
- Up-size piping
- Reduce number of valves and fittings
- Increase suction tank level

Solutions to Excessive Energy Use

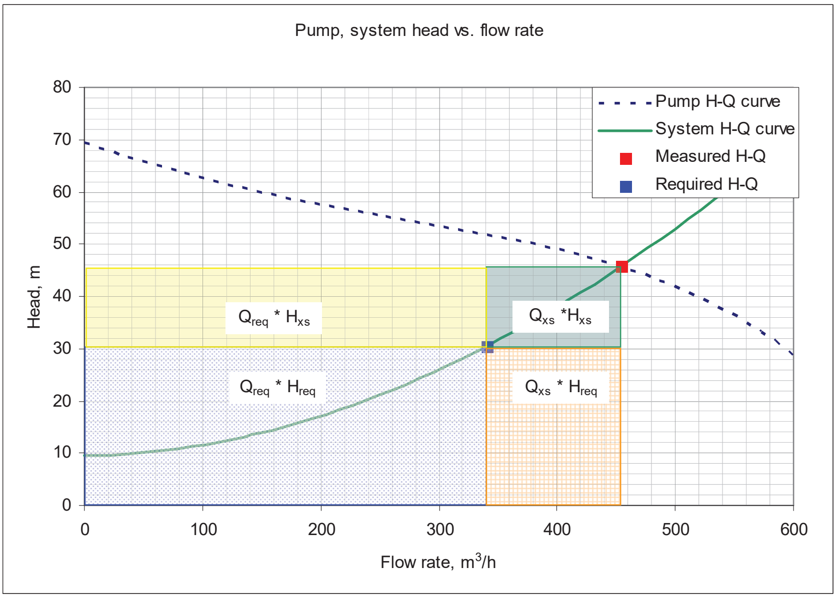
Reduce System Flow Rate:

- Maintain appropriate heat exchange differential temperatures by reducing cooling water flow.
- Isolate unnecessary flow paths.
- Extend batch process fill and drain times.
- Turn off/reduce flow when not needed.

Measured versus Required H-Q



The excessive power(s) delivered



ASME Standard

Chapter 7:

Reporting & Documentation

Pumping System Assessment Standard

7. Reporting and Documentation

7.1 Introduction

7.2 Report Contents

7.2.1 Executive Summary and Project Summary Table

7.2.2 General Facility Information

7.2.3 Assessment Goals & Scope

7.2.4 Description of Systems

7.2.5 Data Collection Methods

7.2.6 Data Analysis

7.2.7 Energy Baseline

7.2.8 Savings Opportunities Identified

7.2.9 Implementation Recommendations

7.2.10 Appendices

Pumping System Assessment Standard

7. Reporting and Documentation

7.3 Provision for Third Party Review

7.4 Review of Final Report by Assessment Team Members

Executive Summary

- Summary of existing energy use
- Presentation of identified energy saving projects with annual kWh savings, cost savings, estimated project cost and simple payback. Projects typically presented as:
  - OMMs – Operational Measures
  - ECMs – Energy Conservation Measures
  - ESMs – Energy Supply Measures
- Summarize percent savings and environmental benefits.

	Proposed Cost saving Measures	Annual Energy Savings (kWh)	First Year Annual Dollars ($)	Initial Cost ($)	Simple Paybacks (yrs)
	OPERATIONAL MEASURES				
OM1	Initiate Efficiency Management Program	--	--	--	--
OM2	Install New Flow Meter at Scenic Station	--	--	$2,000	--
OM3	Lochrem Well Speed Adjustment	59,953	$3,573	--	--
OM4	Tutt Pump Speed Adjustment	9,665	$1,011	--	--
OM5	Scenic Pump Speed Adjustment	48,646	$3,069	--	--
OM6	Install Low Temperature Thermostats	--	--	--	--
	ENERGY CONSERVATION MEASURES				
ECM1	Airport Well #1 Pump/VFD Replacement	58,897	$3,616	$30,800	8.5
ECM2	Airport Well #2 Efficiency Improvements	150,650	$9,250	$19,800	2.1
ECM3	Union Street Pump Improvements	72,024	$7,764	$25,300	3.3
	ENERGY SUPPLY MEASURES				
ESM1	Prevent Two Pump Operation at Tutt	--	$3,194	--	--
ESM2	Switch Rate Schedules	--	$17,585	--	--
	Electric Energy Cost and Savings	**399,835**	**$45,841**	**$77,900**	**1.7**

Present General Facility Information

Pump stations feeding a waste water plant

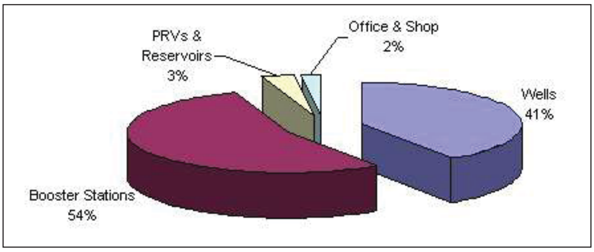
The top 5 stations were assessed

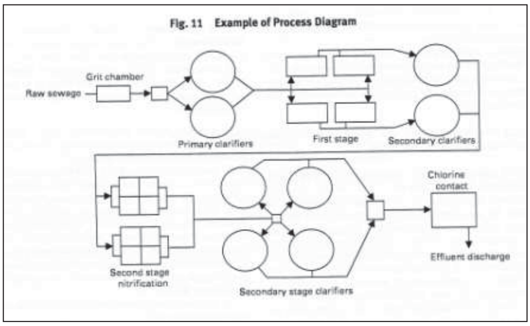
Electric Acct #	Location	Station Name	2009 Cost
3734550273	Corner of Old Vernon/Hwy 97	Airport Wells	$60,355
8400427215	1595 Glenmore Rd	Tutt Pump Station	$30,806
8626205671	2141 Quail/Lochrem Rd	Lochrem Well	$25,888
3438735241	Scenic Rd	Scenic Booster Station	$19,228
8437034171	1850 Union Rd	Union Road Booster Station	$19,084
8784406113	Postill Lake	Postill Pump Station	$14,120
2028257738	Country Club Drive	Quail Pump Station	$13,971
7196445516	2052 Dewdney Rd	OK Lake Pump Station	$10,160
37892		Ellison Well	$9,181
137025		istrano Booster Station	$6,285
353290		cKinley Pump Station	$5,310
639285		Intake Screen	$3,904
6829572527	M#555504 Rojem Rd	Bulach Bstr Pump Station	$3,508
8493235872	445B Glenmore Rd	Office	$2,922
4217787985	47192 Country Club Drive	UBCO Reservoir	$2,473
5303004369	833 Big Rock Court	Big Rock Booster Station	$2,380
2325753172	445A Glenmore Rd	Shop	$1,497
3280893061	McKinley Rd	Arthur Court Reservoir & Pump Station	$1,213
4616000173-4	2329 Rojem	Bulach Bstr Station Aux	$743
5700429059	540 Reynolds Rd	Cook Dom Pump Station	$635
6409641365	550 Valley Rd	Raisenen Rd PRV	$632
2448745798	800 Packinghse Rd	Scenic Reservoir	$522
3203030962	1248 Reynolds Rd	Cooks Irr Pump Station	$451
6081212108	2635 Dry Valley Rd	Dry Valley PRV	$241
4710548990	70877 Rifle	Rifle Rd Pump Station	$221
5286062985	127205 Sexsmith Rd	Sexsmith Road Well	$194
4366273409	1210 University Way / Concass	Vector Well #1	$0
Total			**$235,924**

The highest energy use stations representing 66% of GEID 2009 energy costs were reviewed to evaluate potential energy savings.

Present General Facility Information

Distribution of energy usage for pumping within a municipality





Layout of the waste water treatment plant

Site Description, example

- The site has a large integrated cooling water system.
- There are six cooling tower sites with multiple cooling towers on the site which are interconnected with a cooling water supply and return loops.
- There are 20 pumps in the cooling water system.
- Approximately 13 pumps (300-600HP each) are running at any given time to supply the necessary cooling water flows.
- The circulation rate is approximately 150,000 gpm.

Assessment goal and scope, example

- The assessment should focus on the water cooling system at the plant.
- The cooling system consists of a number of inter- connected systems.
- There are 6 operating Cooling Towers (CT) with two or five cells.
- At each CT there is a pump station with usually 3 pumps of which 2 are operating and the third kept in reserve.
- CT 4, however, has only two 600 HP pumps.
- All the systems are interconnected so it is difficult to get a full understanding of what is going on in the system.
- CT4 is chosen as the primary target of the ESA (=Energy Saving Assessment)

Example: Assessment goal and scope

Assessment of a cooling system. What to look for:

- Pump efficiencies
- Motor efficiencies
- Regulation methods
- Throttling and/or by-pass losses
- Cooling tower operation
- Cooling needs for served processes
- Supply equals demand?
- Cooling tower operation
- Water levels
- Fans
- Assess the system and suggest improvements

ESA Activities, example

During the ESA the following tasks will be performed:

- Review the operation of the water cooling systems
- Estimate energy use at different pump installations
- Assessment will be based on gathered field data
- Review energy use and pump reliability issues

Data collection methods, example

- Measurement of pressures and amperage was done on the chosen systems. This turned out to be a bit of a challenge due to lack of pressure taps, but the plant people were very helpful.

- The ESA expert worked closely with the plant personnel involved in the ESA to examine and input the data collected into PSAT and the valve tool.

- In all cases except one, where pump curves were not available, the results were compared to pump curves and the flow estimated from power and pressure measurements.

Data Analysis

- Performed field measurements of power and pressure to identify sources of energy loss

- Cooling tower 4 (CT4) was chosen as a primary target for the investigation

- Used the DOE PSAT tool to quantify the opportunity

- Developed a plan to test assumptions made after analyzing field data from CT4

Energy baseline

The Pumps at CT4 are running continuously using 216.9 kVA each

Identified Saving Opportunities

Results:

- Saving opportunity approximately $200 000 per year at no cost by turning one pump off.
- Net 216.9 kVA reduction in cooling water system power consumption (90 A at 2410 V);
- Overall system pressure not affected
- Throttling valves at other pump stations were adjusted to accommodate for the change

Example Recommendations

The proposed and executed change was:

- Shut down one of the 600HP water pumps at CT4
- Increase flow from the other pump at CT 4 by opening up the throttling valve
- Assess load increase on the other pumps connected to the plant cooling system

Simple Drawing with Elevations

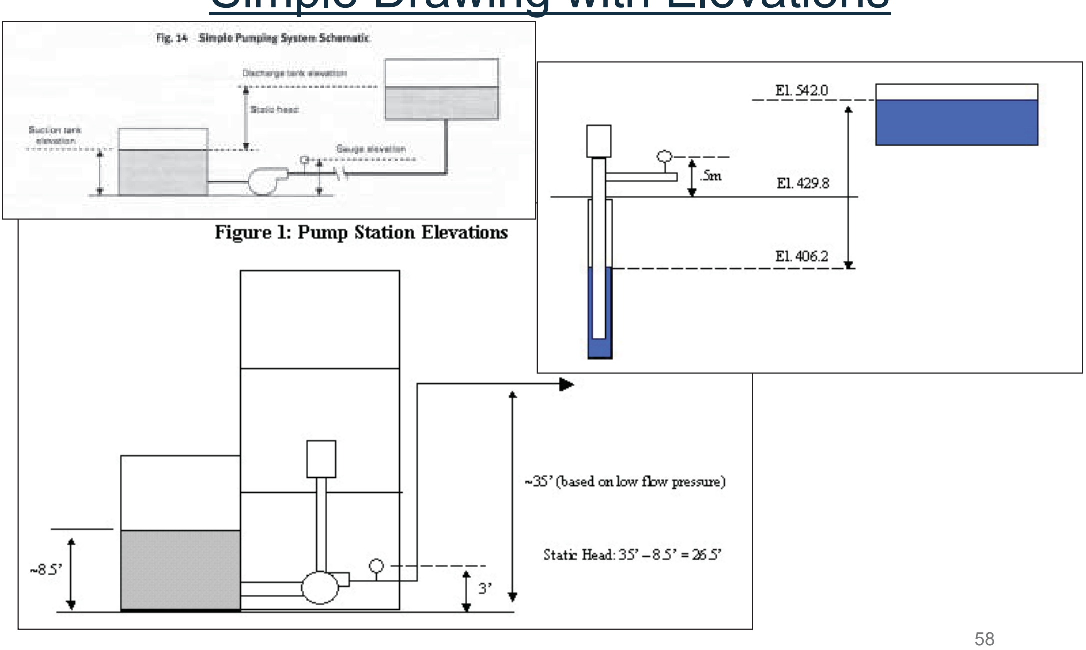
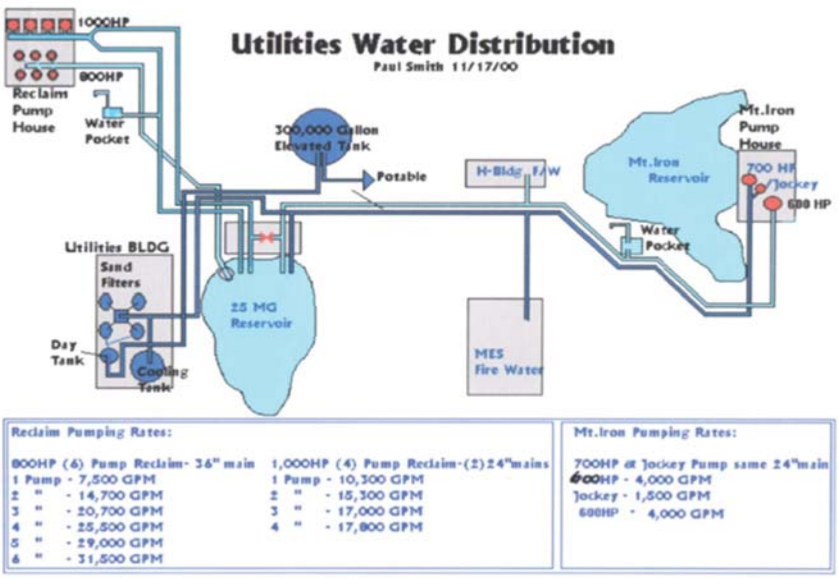
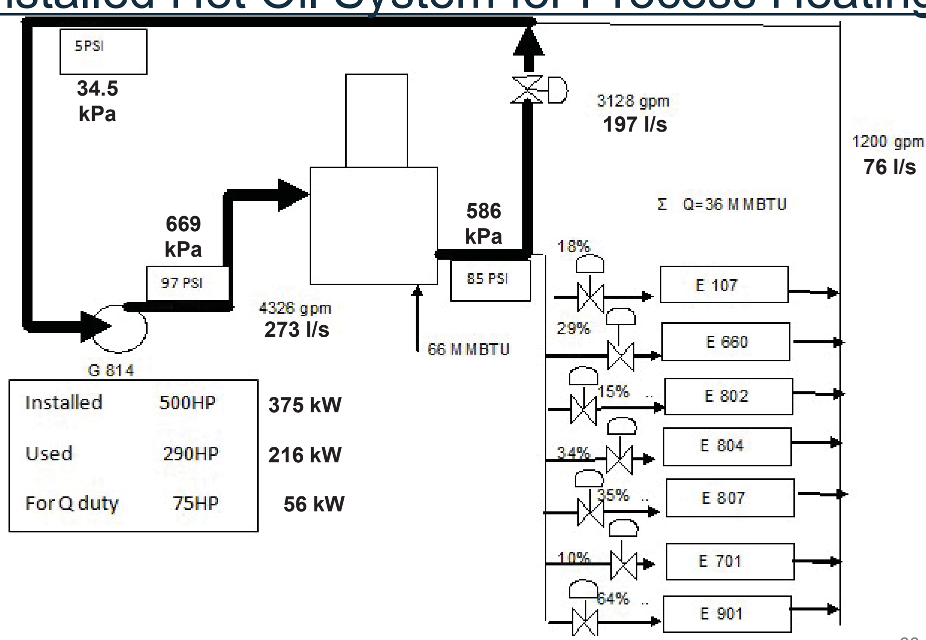


Figure 1: Pump Station Elevations

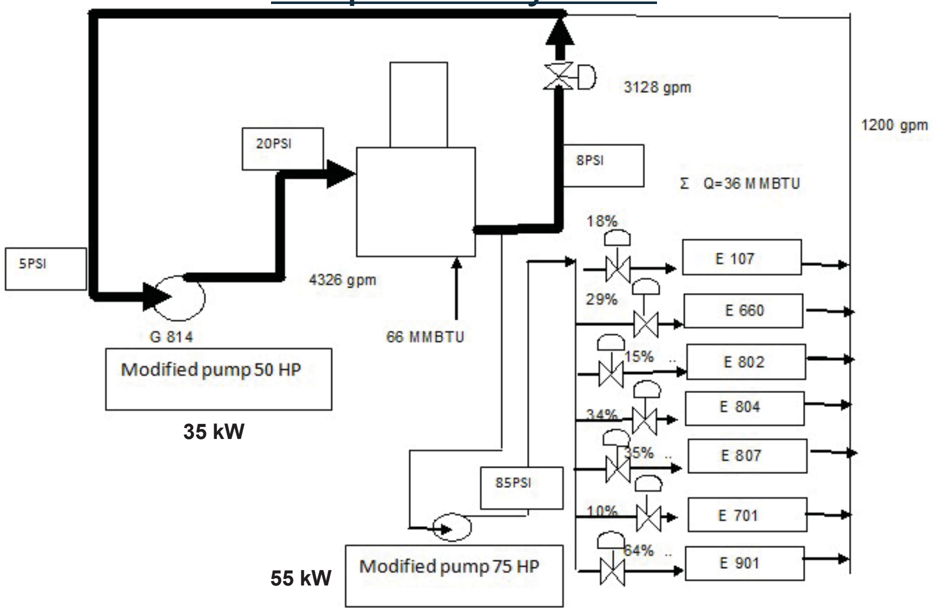
Overall System Layout



Installed Hot Oil System for Process Heating



Proposed System



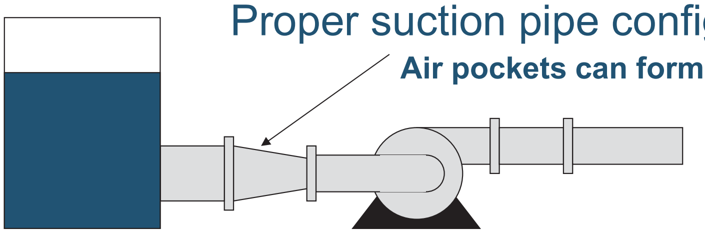
Importance of Proper Installation

- Pump installation is critical to long term pump system reliability and efficiency. Standards for each of the areas below should be reviewed to insure a proper installation
  - Motor/pump coupling alignment
  - Pump hold down bolts, mounting, grouting, bedplate construction
  - Proper piping size, component installation (ANSI/HI 9.6.2)

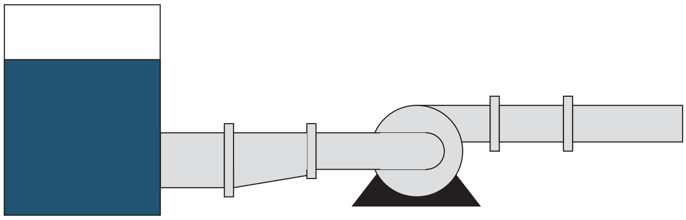
- One company realized a 10 fold increase in reliability by instituting new installation specifications relating to Base-plate, piping, and grouting.

Piping Configurations

Proper suspect pipe configurations



Incorrect installation



Correct installation

Pump Operation

The following charts and graphs shown provide an indication of how pump system reliability is compromised when pump flow rate increases or decreases away from the BEP due to higher (or lower) system pressures.

When a variable speed drive is used, care has to be taken, since the forces inside the pump generally are reduced and seal face speed is lower, **but if the pump is operating in a high static head application these forces could increase and lead to shaft failures.**

Pump Operation / Reliability

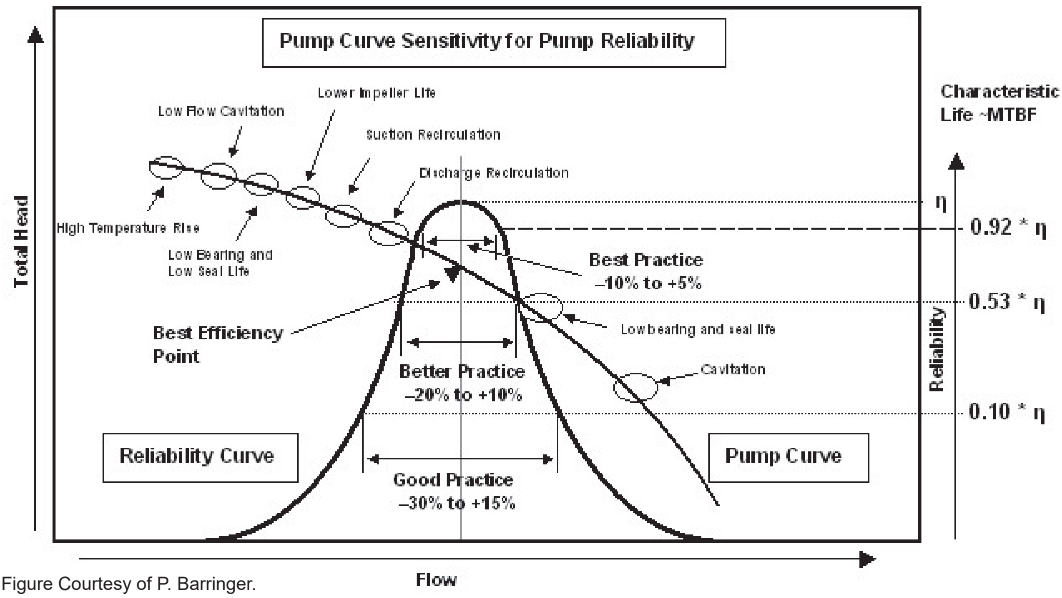
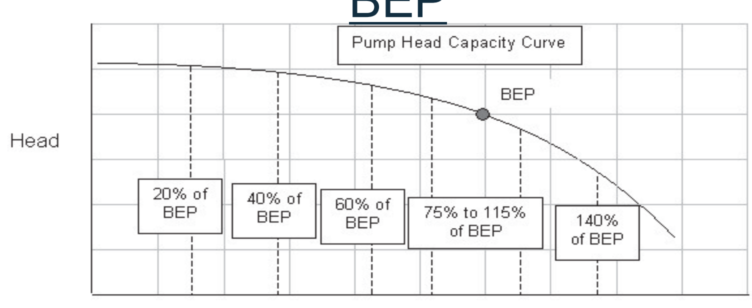


Figure Courtesy of P. Barringer.

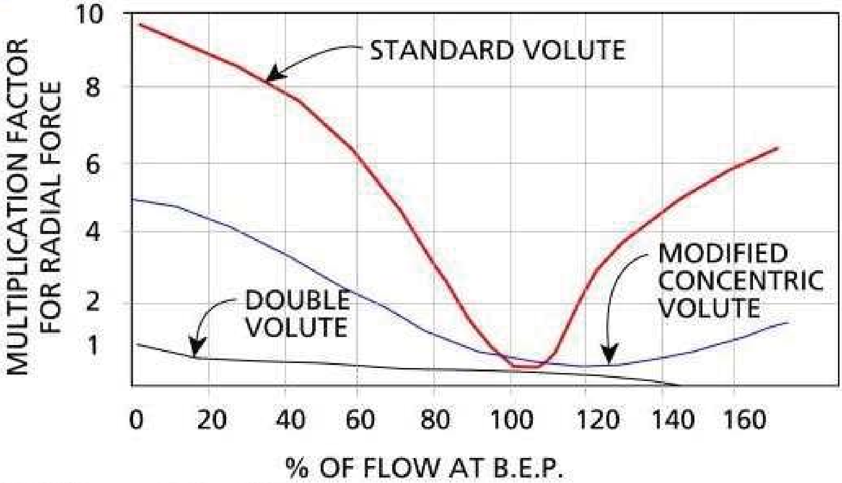
Maintenance Costs Relative to Distance from BEP



	%of BEP	20%	40%	60%	75-115%	140%	$/Failure	
Seals:	Life	2 Months	4 Months	1 Year	2 year	2 months	$1,000	Parts
	Failure/Year	6	3	1	0.5	6	$500	Labor
	Cost/Year	$9,000	$4,500	$1,500	$750	$9,000		
Bearings:	Life	1 Year	3 Year	4 Year	5 Year	1 Year	$500	Parts
	Failure/Year	1	0.33	0.25	0.2	1	$500	Labor
	Cost/Year	$1,000	$333	$250	$200	$1,000		
Casing/Impeller:	Life	2 Year	5 Year	7 Year	10 Year	2 Year	$2,000	Parts
	Failure/Year	0.5	0.2	0.014	0.1	0.5	$0	Labor
	Cost/Year	$1,000	$400	$285	$200	$1,000		
Total Cost/Year		$11,000	$5,230	$2,040	$1,150	$11,000		

Table Courtesy of J. Hodgson.

BEARING LIFE



BEARING LIFE

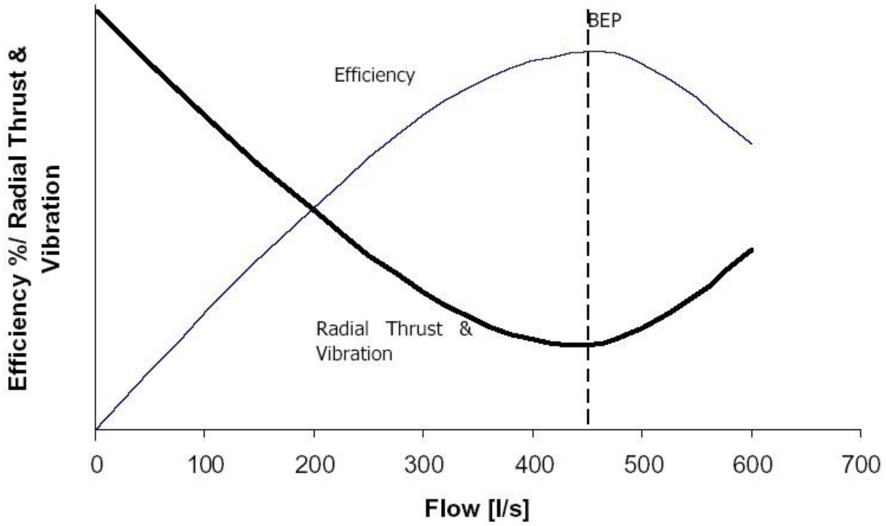
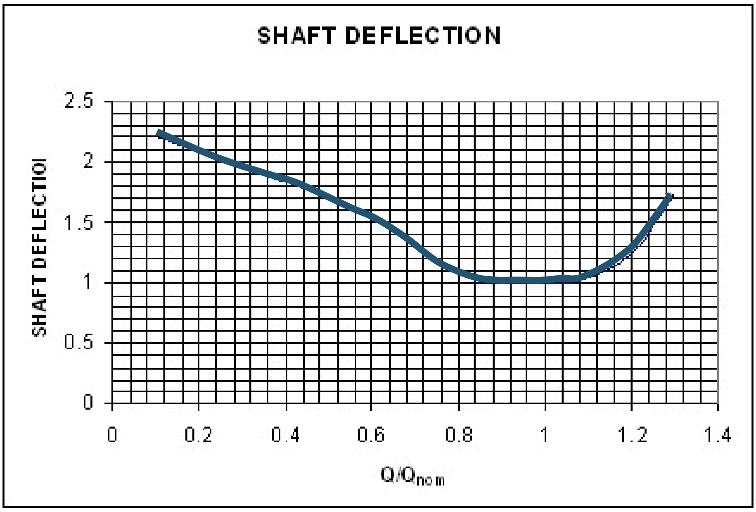


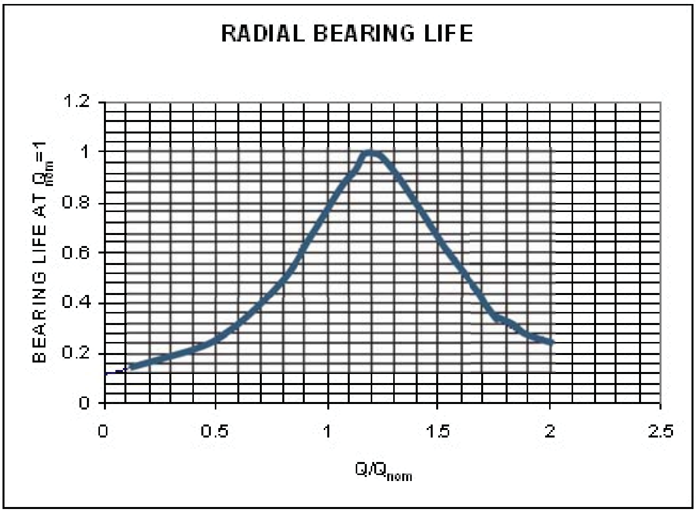
Fig 17: Radial Thrust and Vibration Increases as Pump Operation Moves Away From BEP

Operating away from the design point can create stresses on the shaft and seals



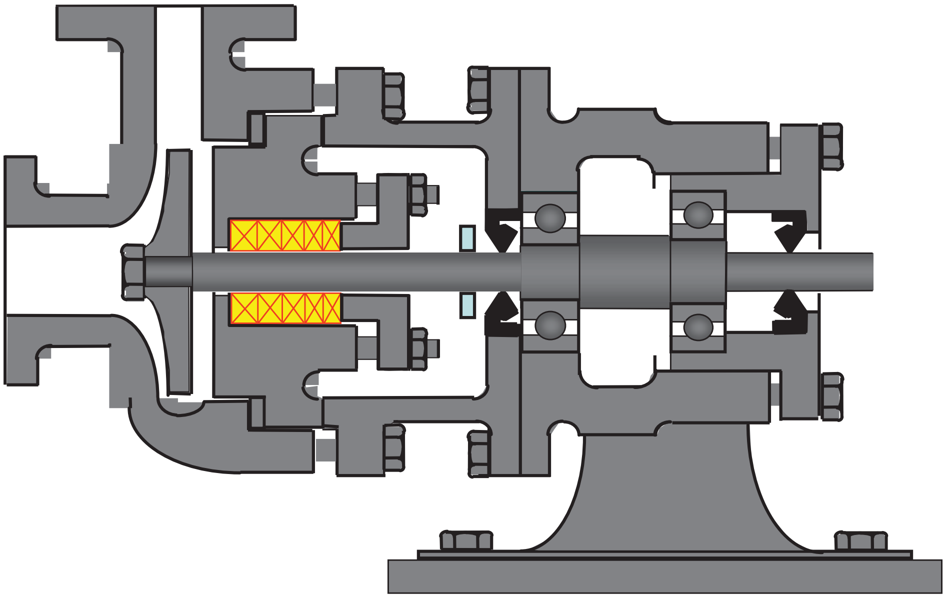
The further the pump is operated away from design flow (Qnom) versus the actual flow (Q) the greater the staff deflection and stress on the seals (for a full speed pump)

Operating away from the design point also creates stresses on the bearings



The further the pump is operated away from design flow (Qnom) versus the actual flow (Q) the greater the stress on the bearings (for a full speed pump)

SEAL LIFE

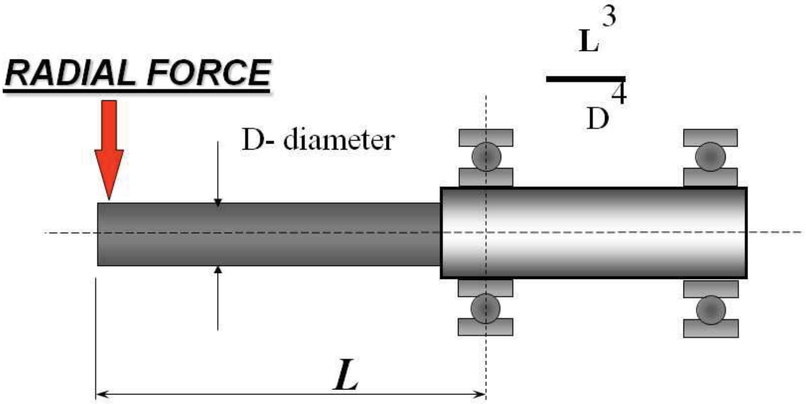


SEAL LIFE

- Increased radial load and shaft deflection
- 50% increase in radial load
- Angular misalignment exceeds 0.05 mm
- Exponential deterioration of seal life
- Less than 6 months life

SEAL LIFE

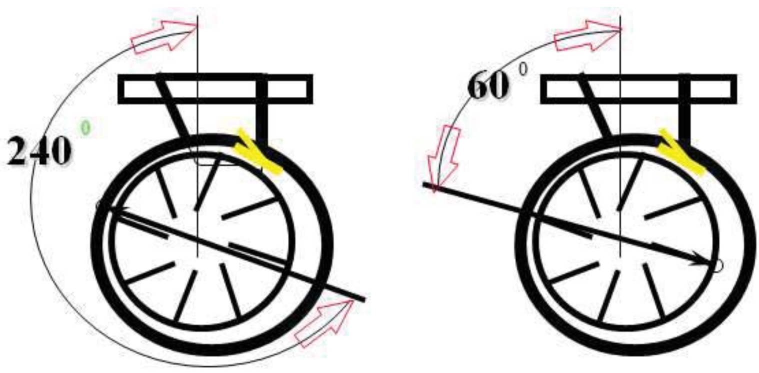
Shaft Deflection



SEAL LIFE

Throttled Discharge

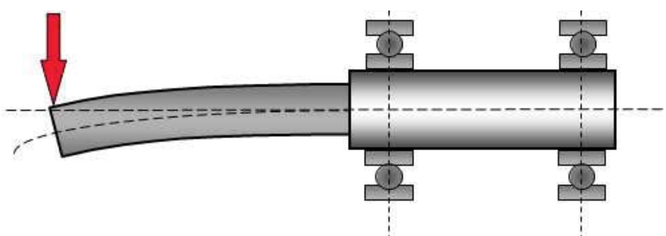
Too much Capacity



SEAL LIFE

Shaft Deflection

Throttled Discharge

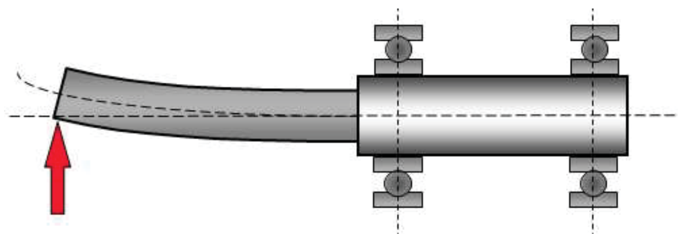


Springs operating 3000 x Min. to keep the faces together.

SEAL LIFE

Shaft Deflection

Maximum Discharge
Too much Capacity



Springs operating 3000 x Min. to keep the faces together.

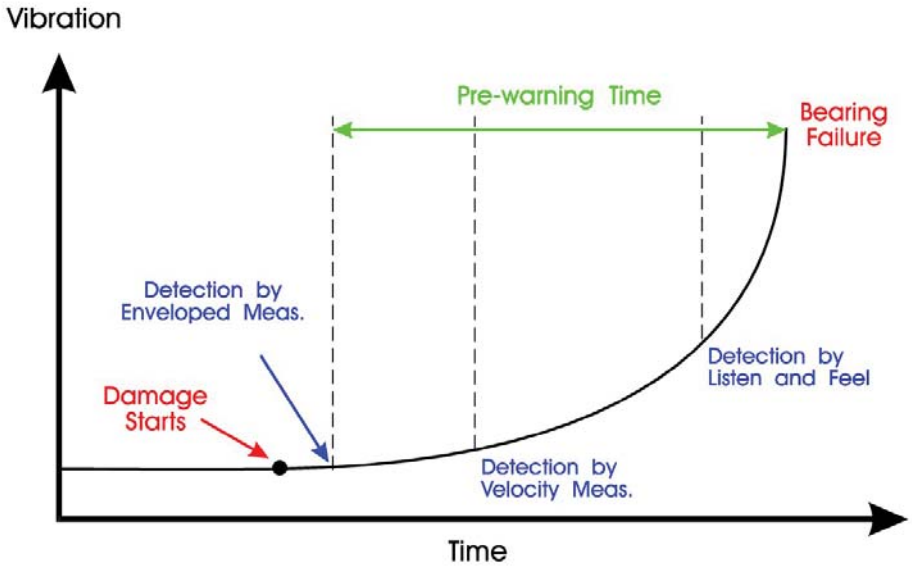
Maintenance Practices

➢ Five levels of maintenance operating practices

- *Lowest Level:* fix it when it breaks, few maintenance records or spare parts, lack of training/capabilities
- *Third Level:* short range fixes, better maintenance records, some spare parts maintained
- *Second Level:* planned preventive maintenance, routine inspections, lubrication and adjustments made, good maintenance records, input from operations and engineering for maintenance problem solving
- *Top Level:* predictive maintenance techniques used (vibration, thermography), problems are anticipated, computerized maintenance management system fully utilized

Typical Condition Monitoring

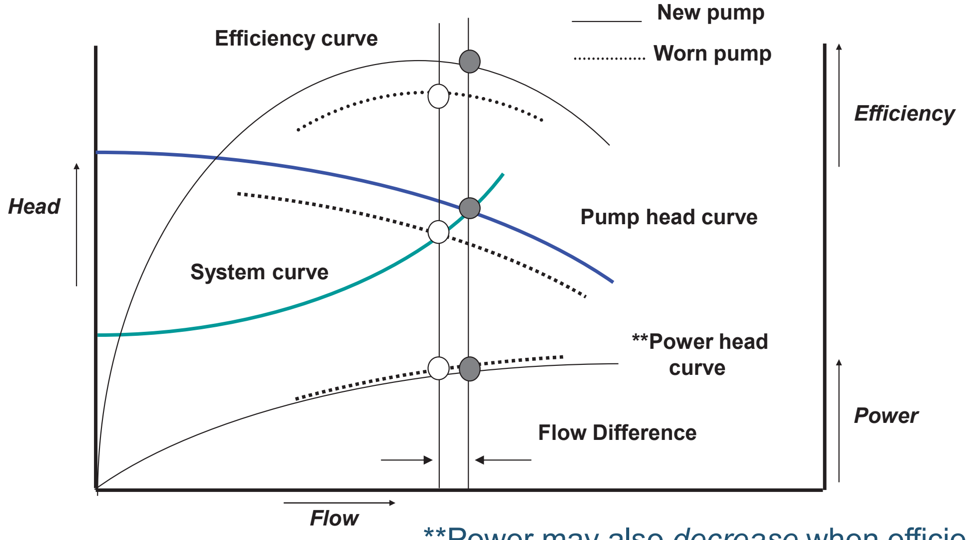
Describe advantage of performance monitoring



Effect of Wear on Pumps

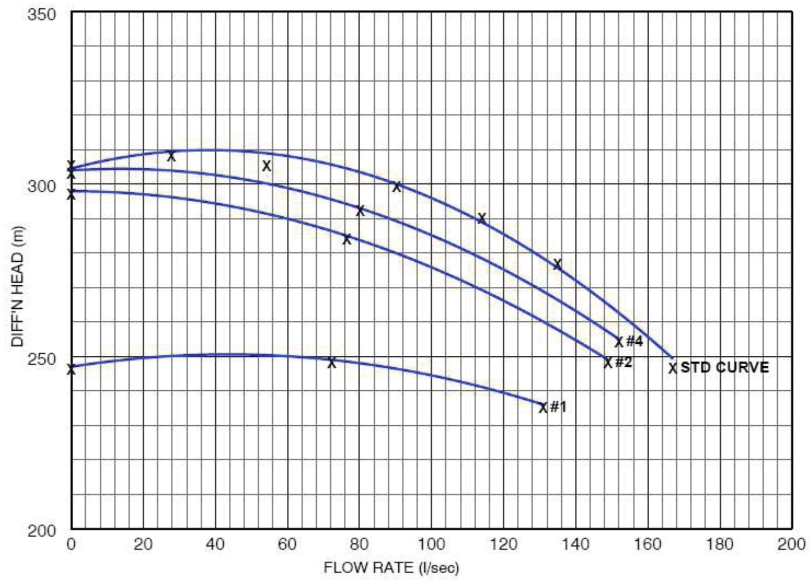
Wear rings are used in many centrifugal pumps to provide proper clearances – over time these clearances increase and the pump becomes less efficient due to recirculation of the pumped fluid from the high pressure side of an impeller to the low pressure side.

How pump wear can impact pump performance



**Power may also *decrease* when efficiency is reduced – but will also produce less flow

Drop off in pump performance due to wear



Making clearance adjustments to improve pump efficiency

Pump efficiency can be improved by adjusting impeller clearances for hollow shaft motors with semi-open impellers

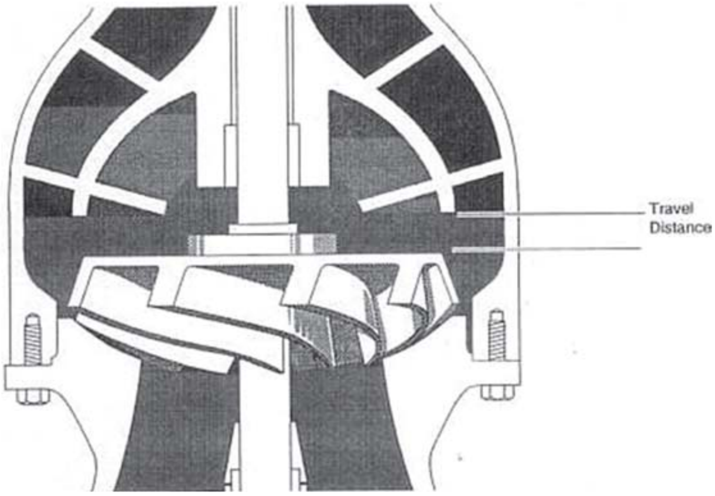


Figure Courtesy of ACR Publications

De-rating due to slurries

DEVIATIONS FOR SLURRY CURVES

- Slurry De-rating Factors

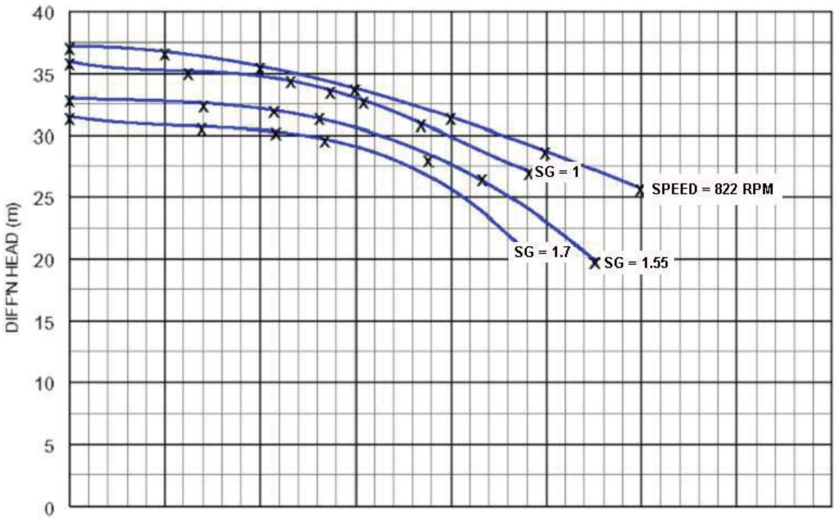
$$\text{Head Ratio} = \frac{\text{Total head developed on slurry}}{\text{Total head developed on water}}$$

$$\text{Efficiency Ratio} = \frac{\text{Pump efficiency on slurry}}{\text{Pump efficiency on water}}$$

- **Theoretical Data**
- Density of solids
- Particle size distribution
- Average particle size D50
- Concentration of solids in slurrc, CV
- Impeller diameter

ACTUAL SLURRY PERFORMANCE

➢ Determining Head and Efficiency Ratios Through Testing



De-rating due to viscous effects

VISCOUS LIQUID CORRECTION FACTORS

$$Q_{Viscous} = C_Q \cdot Q_{Wat.}$$
$$H_{Viscous} = C_H \cdot H_W$$
$$\eta_{Viscous} = C_\eta \cdot \eta_{Water}$$

$$P_{Viscous} = \frac{P_{Water}}{C}$$

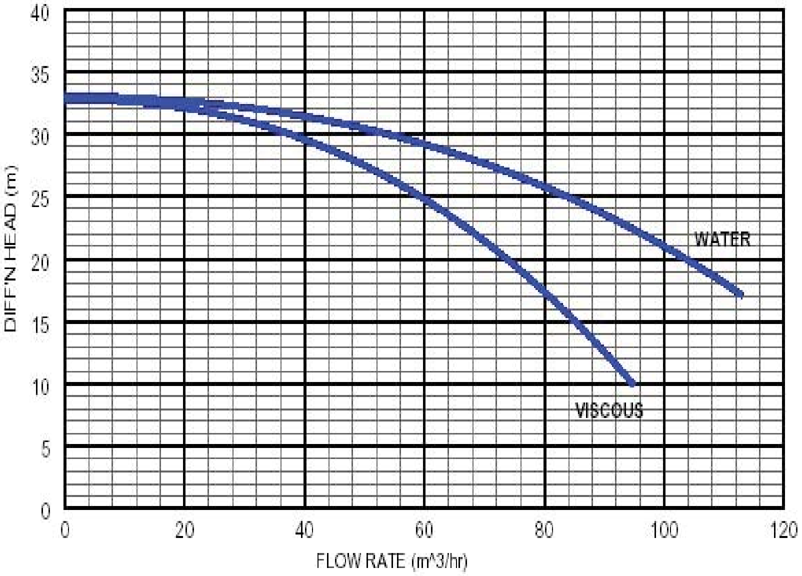
This gives you a point on the pump curve for the viscous fluid, with:

- $Q_{Viscous}$ = Capacity of the pump using viscous fluid
- $H_{Viscous}$ = Head of the pump using viscous fluid
- $eta_{Viscous}$ = Efficiency of the pump using viscous fluid
- $P_{Viscous}$ = Pumping power using viscous fluid

- C_Q = Capacity correction factor
- C_H = Head correction factor
- C_{eta} = Efficiency correction factor

- Q_{Water} = Capacity of the pump for water
- H_{Water} = Head of the pump for water
- eta_{Water} = Efficiency of the pump for water
- P_{Water} = Pumping power for water

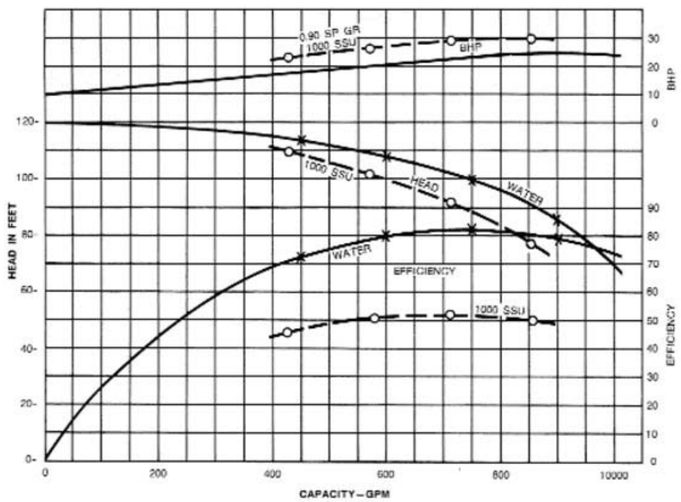
VISCOUS LIQUIDS



VISCOUS LIQUID CORRECTION FACTORS

Section D -- Properties of Liquids

D-4 Viscosity Corrections for Capacities of 100 GPM or Less Fig. 6 Sample Performance Chart

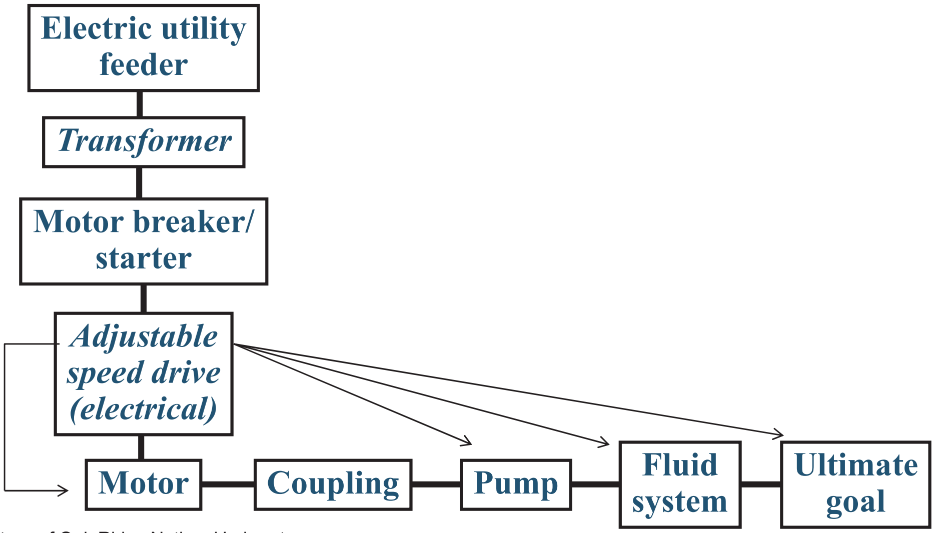


Role of an Adjustable Speed Drive (ASD)

- The true value of an ASD is the ability to precisely match motor and pump output to process requirements.

- Potential benefits of precise process speed control:
  - Improved product quality
  - Improved process throughput
  - Improved process control
  - Energy savings

The adjustable speed drive, when present, will have an impact on the function of several elements.



Slide Courtesy of Oak Ridge National Laboratory

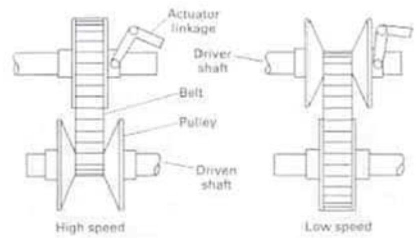
Common variable speed drive types

- Pulse Width Modulated VFD (PWM)
- Magnetic Coupling
- Mechanical Drive

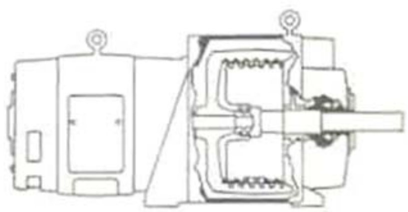
Other types:

- DC Drives
- Variable Voltage Inverter (VVI)
- Current Source Inverter (CSI)

Older types of variable speed drives



Mechanical Belt Drive VSD



Eddy Current Magnetic Clutch VSD

Figures Courtesy of Hi-Lo Manufacturing and Eaton Drives

New variable speed drives

PWM Drive

Photo Courtesy of Robicon

Magnetic Drive

Photo Courtesy of MagnaDrive

Unique behavior of variable speed drive controlled induction motors

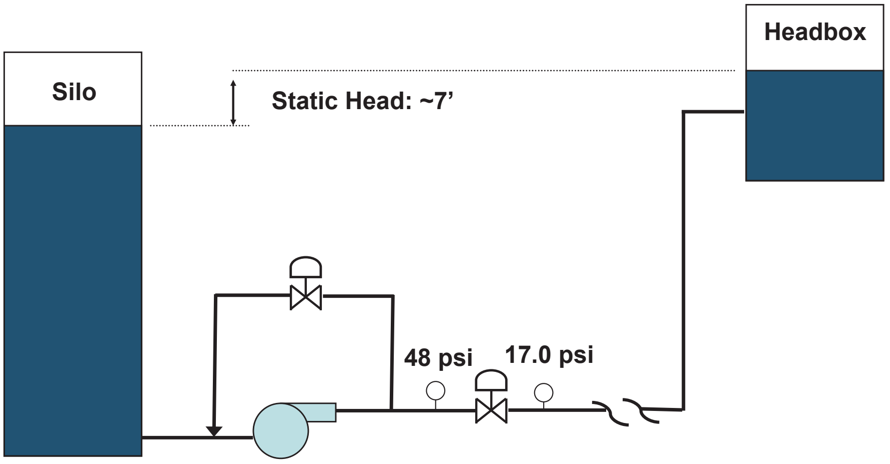
- Control of motor torque
- Control of motor speed
- Reduced starting current
- Improved power factor
- Improved efficiency over a range of operating conditions

Potential variable speed drive issues

- Harmonics could effect instrumentation
- Fault-out (equipment shut-down) when power quality varies
- Bearing currents
- Mechanical vibrations
- Increased noise (acoustical)
- Static head considerations
- May need to include a full voltage starter as a bypass control

VFD Application at Paper Mill

Overview of Fan Pump System



300 hp Fan Pump

Flow Range: (4500 to 8500 gpm)

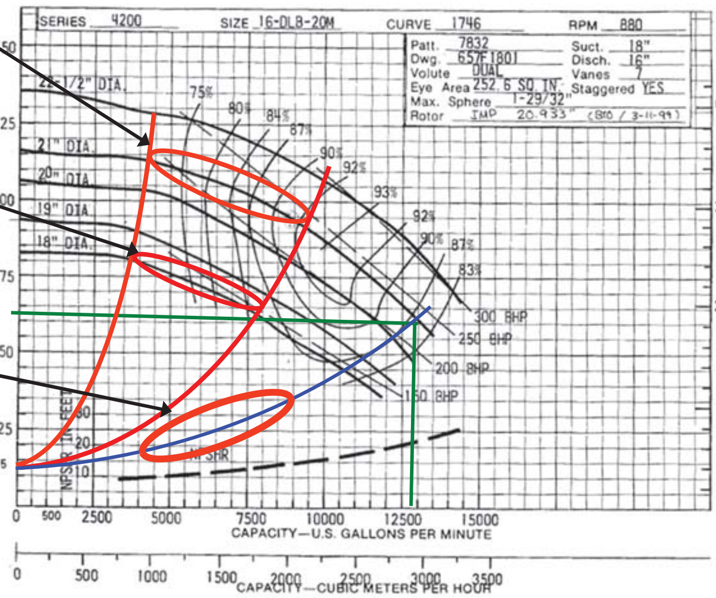
Fan Pump Curve

#7 PM FAN PUMP

Using control valve for flow range of 4500 to 8500 gpm

Trim impeller and use control valve to adjust flow

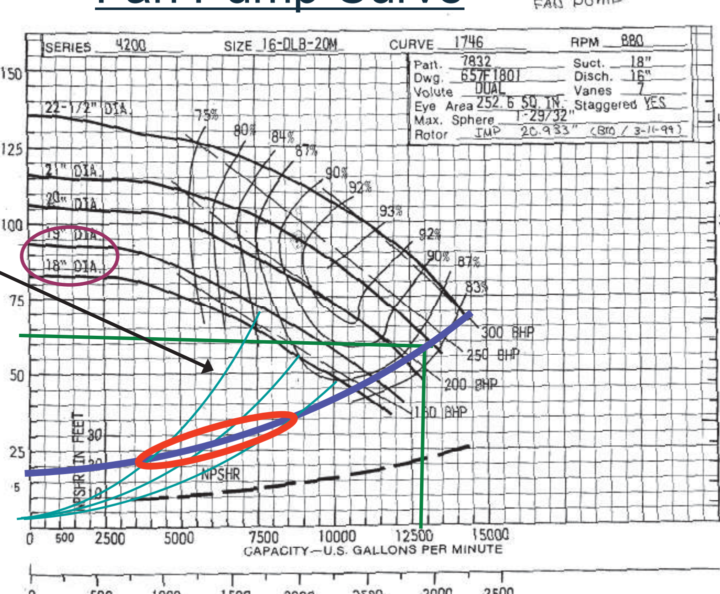
Using variable speed drive for flow range of 4500 to 8500 gpm (with control valve open)



Fan Pump Curve

#7 PM FAN PUMP

Efficiency Curves using VSD with 18" impeller



Fan Pump Savings Analysis

Interval	Hours	Flow (gpm)	TDH (ft)	Pump Eff.	VSD TDH (ft)	Trimmed Pump Eff.	AC Drive Eff.	Trimmed Impeller TDH
1	1758	4500	112	70	21	70	90	75
2	2628	5500	109	75	25.4	74	91	73
3	876	6500	106	79	28.9	80	92	70
4	3504	8500	97	90	38.1	86	92	57

Impeller Trim to 18"			
Interval	kW Existing*	kW Proposed*	Savings
1	142	96	80,868
2	158	108	131,400
3	173	113	52,560
4	182	112	245,280
Total kWh Saving			**510,108**
Annual Cost Savings			$25,505

AC PWM VSD			
Interval	kW Existing*	kW Proposed*	Savings
1	142	25	205,686
2	158	36	320,616
3	173	47	110,376
4	182	80	357,408
Total kWh Saving			**994,086**
Annual Cost Savings			$49,704

* Including assumed motor efficiency of 95%

Fan Pump Recommendations

- **Verify efficiency, flow and calculated kW data**
- **Evaluate control variation of each option**
- **Perform detailed cost estimates**

	AC Drive	Impeller Trim
Energy Savings:	$ 49,700	$ 25,505
Estimated Project Cost	$200,000	$ 15,000
Simple Payback:	4.0 years	6 months

Specific Energy Es

- The amount of energy needed to pump one unit volume through the system.

- The Specific Energy varies with flow-rate.

Some Basic Equations

Fluid Power = Head (m) * Flow (m3/sec) * specific gravity *9.8

$$E_s = \frac{P_{in} \cdot Time}{V} = \frac{P_{in}}{Q}$$

$$\frac{Energy\ used}{Pumped\ Volume} = Specific\ Energy$$

Specific Energy Es

Fluid Power = Head (m) * Flow (m3/sec) * specific gravity *9.8

$$E_s = \frac{\rho \, g \, H_S}{f_{HS} \, \eta_m \, \eta_p} = \frac{P_{el} \times \text{Time}}{\text{Pumped Volume}}$$

ρ = ***Fluid density***

g = ***Gravitational constant***

H_S = ***Static head***

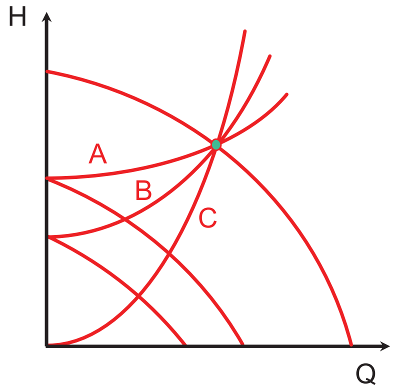
f_{HS} = ***Hydraulic System factor***

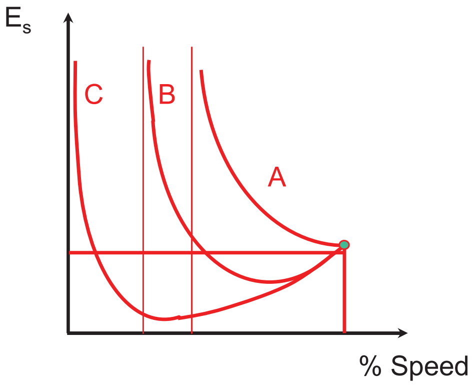
η_m = ***Motor efficiency***

η_p = ***Pump efficiency***

Where the Hydraulic System factor=Static head/ Total head

Specific Energy for three systems with variable speed pumps and different static heads





DATA TO COLLECT

Collection of Equipment and Fluid Data

- Driver information (the ASME standard focuses on motor-driven pumps)
  - Motor nameplate: type, voltage, frequency, full load amps, rated horsepower, speed, efficiency, power factor, service factor.
- Pump
  - Type, number of stages, speed, flow and head design point, impeller diameter, pump curve, maintenance records, presence of cavitation.
- Fluid Properties
  - Temperature, viscosity, density or specific gravity, presence of solids

Example of Equipment Data Collection Form

Tester		**Date**		**Time**	
Facility		**System**		**Parallel Pumps Running:**	

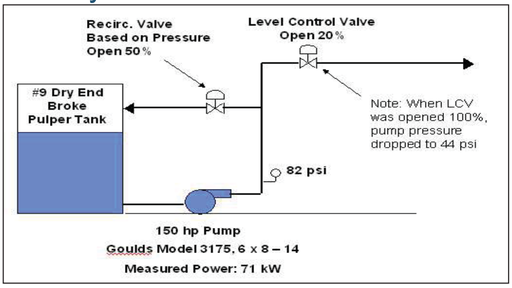
PUMP NAMEPLATE	ID / SET				
Pump Style	-				
Nameplate Pump Speed	RPM				
Number of Stages	-				
MOTOR NAMEPLATE					
Power	HP				
Full Load Speed	RPM				
Full Load Efficiency	%				
Rated Voltage	VOLTS				
Full Load Current	AMPS				
PUMP, FLUID DATA	Units				
Pump Rotational Speed	RPM				
Flow Rate	GPM				
Specific Gravity	-				
Suction Pressure	PSIG				
Suction Elevation	FT				
Suction Pipe Nom. Size	IN				
Discharge Pressure	PSIG				
Discharge Elevation	FT				
Discharge Pipe Nom. Size	IN				
ELECTRICAL DATA	Units				
Motor Rotational Speed	RPM				
kW A-B __ or A-GR__	kW				
kW C-B __ or B-GR__	kW				
kW C-GR __	kW				
Power Total	kW				

Collection of System Data

- Data gathered using installed plant instrumentation or portable instruments:
  - Motor power or voltage and current
  - Pump flow rate, suction and discharge pressure
  - Flow rates to system loads
  - Pressures at system loads
  - Fluid temperature, density, and viscosity
- Additional System Data:
  - Static head
  - Operating hours
  - Pump control method:

    VSD,Throttled valve

    By-pass or recirculation, etc



Data Collection Tips

- Determine if data collected is a representative snapshot or if the system needs to be evaluated over a longer period of time or if historical process control data is available.
- Pressure measurements should be taken with calibrated, reliable gauges or transmitters.
- Flow measurements should be taken with properly installed, calibrated meters.
  - If using portable flow meters, confirm measurement at alternative locations
  - May use dP across a component and component curve

Data Collection Tips

- Motor input power
  - Preferably measure power directly with a power meter
  - PSAT can calculate motor input power using measured voltage and current, and estimating the power factor
- Cross-validation
  - Flow rate, pressure, and power measurements may not be available but can be determined using cross-validation
  - Use pump differential pressure (total head) and pump curve to estimate flow rate
  - Use motor input power and efficiency to calculate shaft horsepower, then use pump curve to estimate flow rate
  - Use valve position, flow rate, and Cv data to estimate dP
  - Measure drawdown and fill times to estimate flow rate

Collecting Pump Data & Field Measurements

Develop a simplified flow diagram

- Capture the critical elements of the system
- How do you do that?
  - Review P&ID and piping isometrics
  - Talk with operators
  - Walk the system down (nice to have a P&ID when you do)
  - Take notes !

Slide Courtesy of Oak Ridge National Laboratory

Next… get a copy of the pump curve

Three types of pump curves:

- Generic curve for pump model - usually from a manufacturers catalog
- Certified factory curve – where the pump was tested at the factory
- Field certified curve – where the pump was tested after installed in the field.

Getting a certified factory test curve for the specific pump you're buying should be encouraged as a standard practice for pumps above 50 kW; a field certified curve should be pursued for pumps above 150 kW

Centrifugal pump curve with different impeller trims

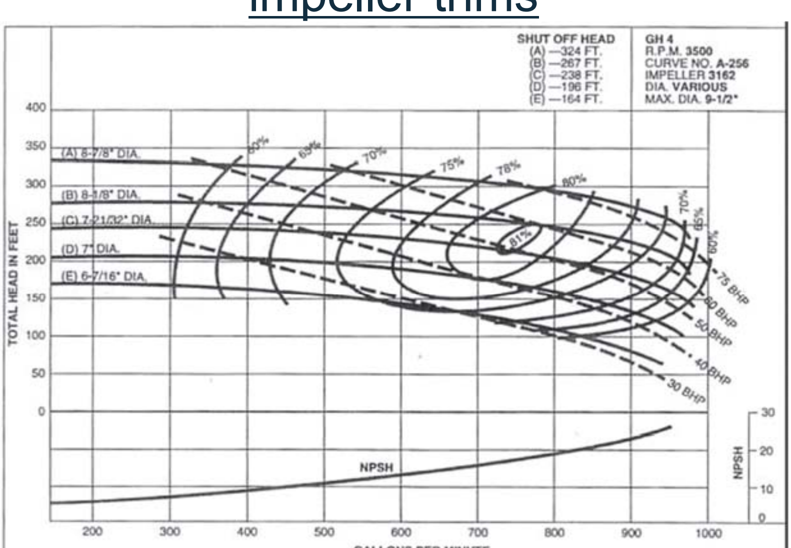
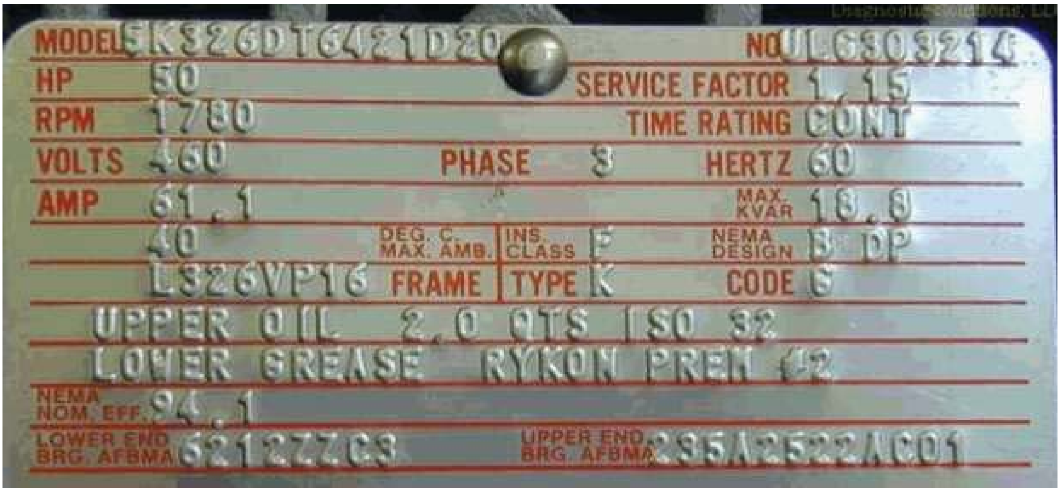


Figure Courtesy of ACR Publications

A motor nameplate



Slide Courtesy of Oak Ridge National Laboratory

Pump nameplate data

Nameplate speed here (1800 rpm) is NOT consistent with flow rate and head, it is the *nominal* synchronous speed

Slide Courtesy of Oak Ridge National Laboratory

Pumping system field measurements:

Basic principles and applications

Some questions that logically follow "Why am I doing this?"

- What do I need to measure?
- Can I actually measure what I need to measure (and what will I do if I can't)?
- What equipment should be used?
- Does the current operating condition represent the long haul?
- If not, what can I do to get a sense of the longer term circumstances?
- Do I need a snapshot or a movie?

Primary parameters of interest in pumping systems field measurements

- Flow rate
- Pressure
- Elevations
- Electric power

Next: some basic principles on the first three of those parameters

Pressure and head

Pressure is normally measured relative to the local atmospheric condition

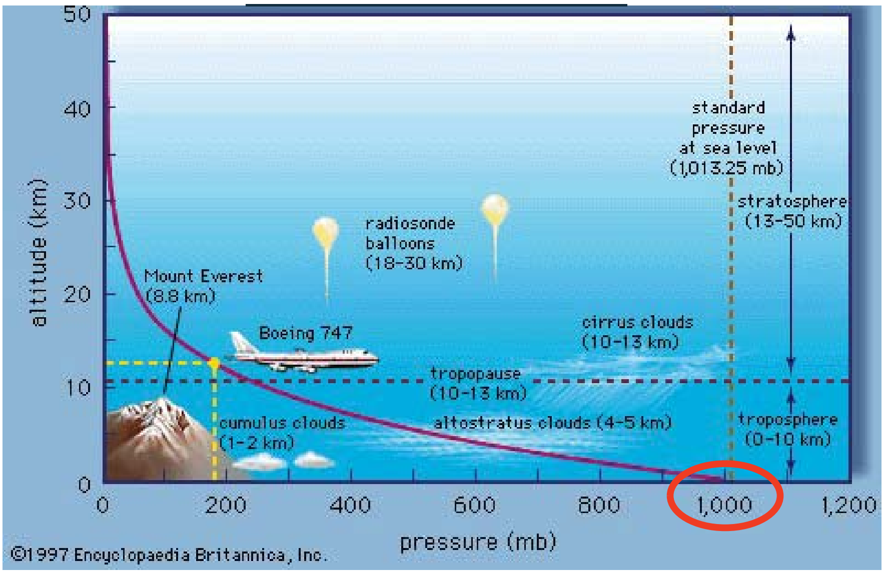
In the metric world the unit for pressure is kPa

Common U.S. units are pounds (force) per square inch gauge (psig) and inches mercury vacuum (in Hg vac)

.

Note: standard instrument practice abbreviates psig as psi

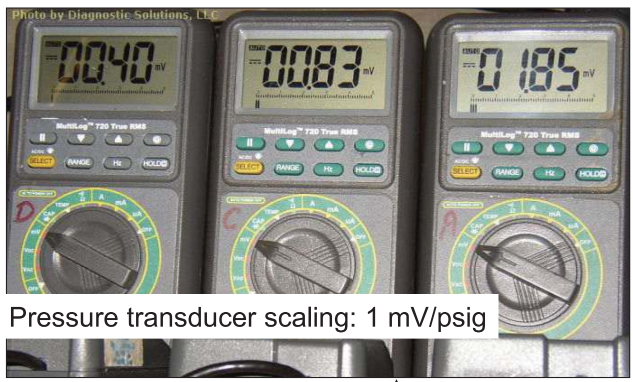
The absolute pressure in the atmosphere is a function of elevation



Gauge pressure in pumping systems is also a function of the gauge elevation

Elevations of transducers in the riser at left (above floor)

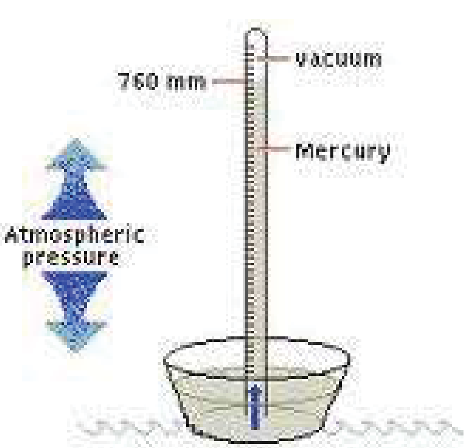
1.08 m   0.77 m   0.06 m



Pressure transducer scaling: 1 mV/psig

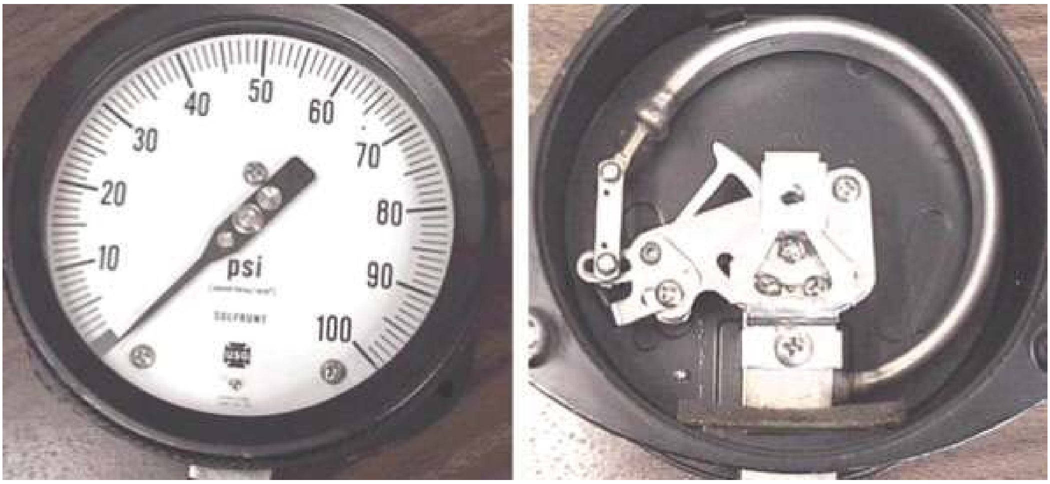
Note: pump was off during this set of measure ments

Gauge and absolute pressures



- **Average *sea-level pressure* is 101.325 kPa (1013.25 mbar, or hPa) or 760 millimeters (mmHg)** that is, the pressure of the air relative to a perfect vacuum.
- Gauge pressure measurements are always relative to the ambient atmosphere.
- Absolute pressure is an important factor in one pump performance attribute - net positive suction head. (NPSH)

The C-type Bourdon tube is by far the most common industrial pressure gauge



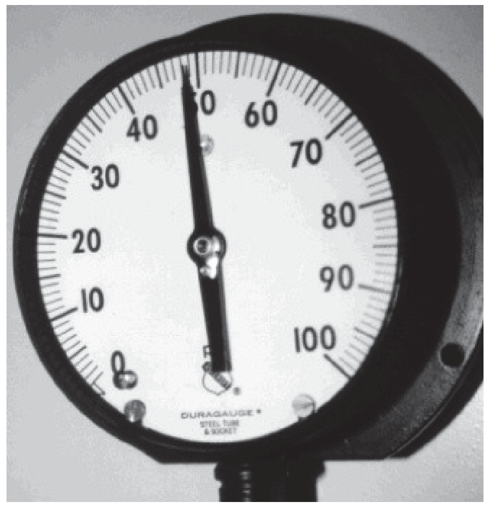
Slide Courtesy of Oak Ridge National Laboratory

Some practical considerations

- Service environment, history
  - Water hammer
  - Calibration
- Instrument range
  - Accuracy
  - Overpressure capability
- Physical location, setup
  - Process connection point
  - Accounting for sensing element elevation
  - Proper instrument line fill & vent1

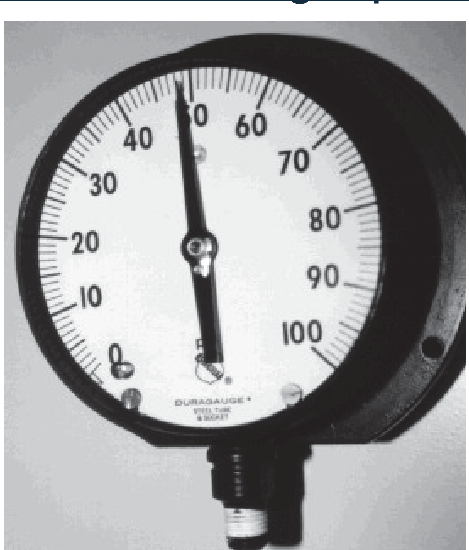
Slide Courtesy of Oak Ridge National Laboratory

What do you think the system pressure is? (note the angle from which the picture is taken)



Slide Courtesy of Oak Ridge National Laboratory

Would a little larger picture change your mind?

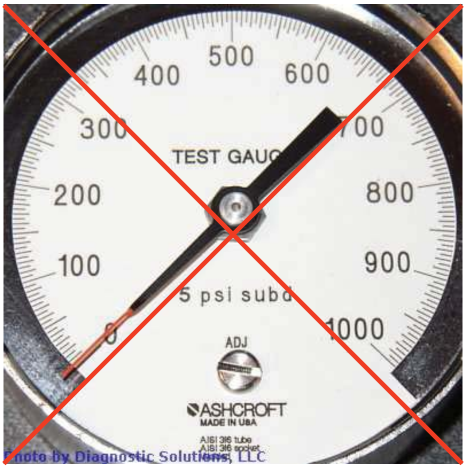


Never trust these types of pressure gauges!

Slide Courtesy of Oak Ridge National Laboratory

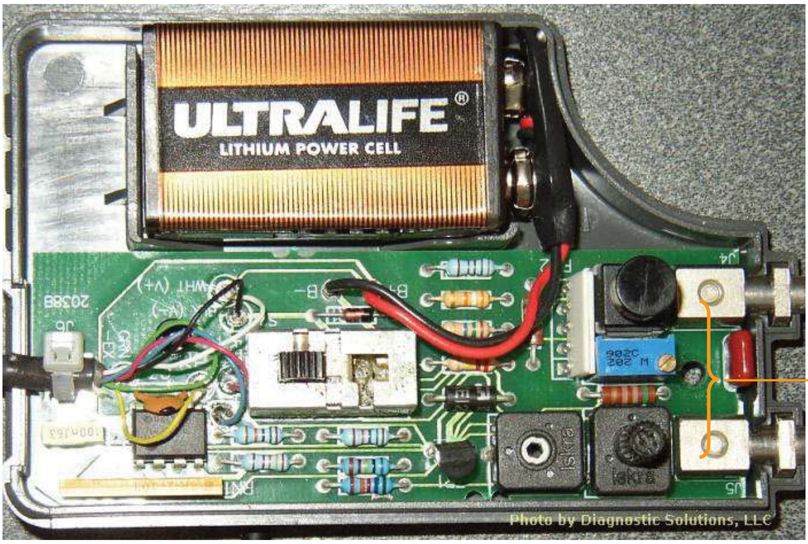
Common pressure transducers

The two most common pressure-measuring devices are the Bourdon tube and diaphragm-based strain gauge transducers



Bourdon tube gauges: mechanical linkage connected to a semi-flexible soldered /welded tube

Strain gauge signal conditioning



Span and zero adjusting potentiometers

Calibration is desirable - but not sufficient

- This gauge was removed from system to install a test gauge
- (poor camera work failed to show the end of the threads)
- Picture taken on 10/15/2004; note the calibration sticker was applied only three months before.
- The gauge is actually disconnected and still gives a reading of 70 PSI

Convenient test measurement functions: dual systems of units and easy gauge zeroing

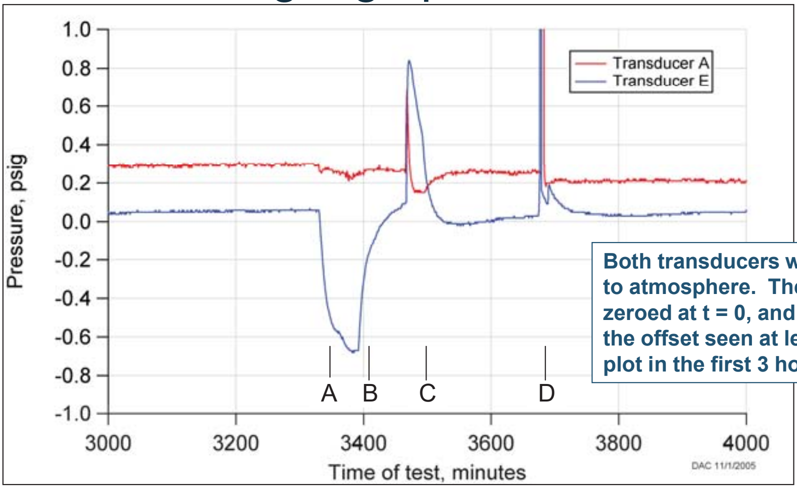
For strain gauge-based transducers, adjusting zero at installation is a good standard practice

As a part of the zeroing function, two additional practices are recommended:

1. Turn the unit on and let the signal conditioning system "warm up" for a couple of minutes ahead of time.

2. If practical, install the transducer in the system, allow it to reach stable operating temperature, then isolate and re-zero.

Example drift, thermal and transient pressure effects on strain gauge pressure transducers



Both transducers were open to atmosphere. They were zeroed at t = 0, and drifted to the offset seen at left of this plot in the first 3 hours

A: placed in refrigerator B: removed from refrigerator
C: Put in 150 deg F water D: briefly pressurized to 90 psig

Good practices for relating multiple pressure measurement points (not always practical)

- Zero all units concurrently before testing
- Cross-check the transducers under pressure
- Record a set of common pressure data for subsequent fine tune adjustments to actual test data
- For long-term situations, check offset at removal

Flow rate measurements

There are a variety of flow meter types

- Differential pressure - orifice, venturi, nozzle, elbow
- Velocity - Magnetic, ultrasonic, turbine, vortex shedding, variable area (rotameter), pitot tube
- Open flow - Weir
- Positive displacement - gear, nutating disc
- Mass

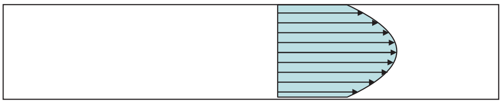
Slide Courtesy of Oak Ridge National Laboratory

Some important flow meter considerations

- Proper flow profile and installation
- Range
- Calibration
- Wear
- Corrosion, scale, foreign material
- Sensing line issues (similar to pressure)

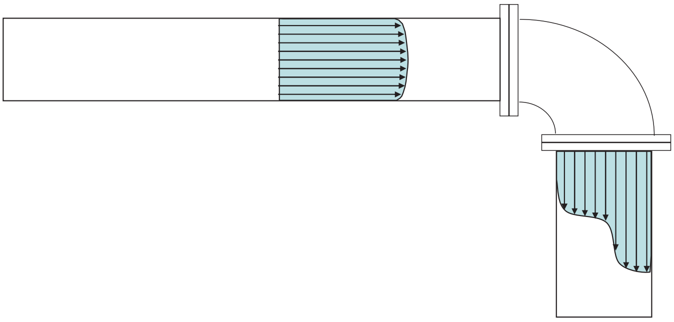
Slide Courtesy of Oak Ridge National Laboratory

The flow regime and upstream geometry affect the velocity profile



Laminar flow (very uncommon in significant energy-using pumping systems)

Turbulent flow (commonly the case in significant energy-using pumping systems)



The flow profile can be significantly distorted after disturbances, such as elbows, valves, etc.

Common industrial and municipal flow measurement devices

- Differential pressure: orifice, venturi, nozzle,
- Velocity - magnetic, ultrasonic, propeller (turbine), paddlewheel, vortex shedding
- Open flow - Weir

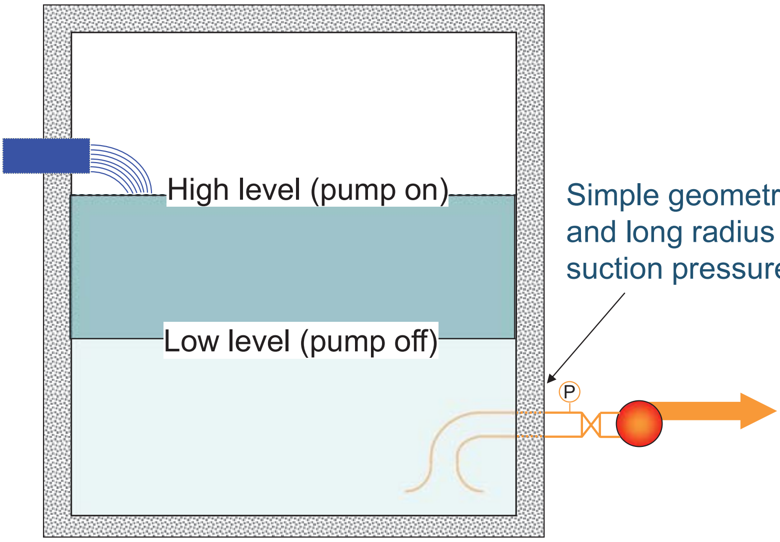
Combining ideal and real-world effects: using pressure differential to estimate flow rates

- Differential head meters rely on the basic Bernoulli principle, but make adjustments to account for real-world friction
- The basic principle is to create a pressure difference that can be converted to a flow rate estimate
- There are all sorts of devices in pumping systems that create pressure differences without even half trying
- With caution, care, and a little field calibration, we can often use them to estimate flow rate

Submersible wastewater lift pump with suction pressure tap retrofit

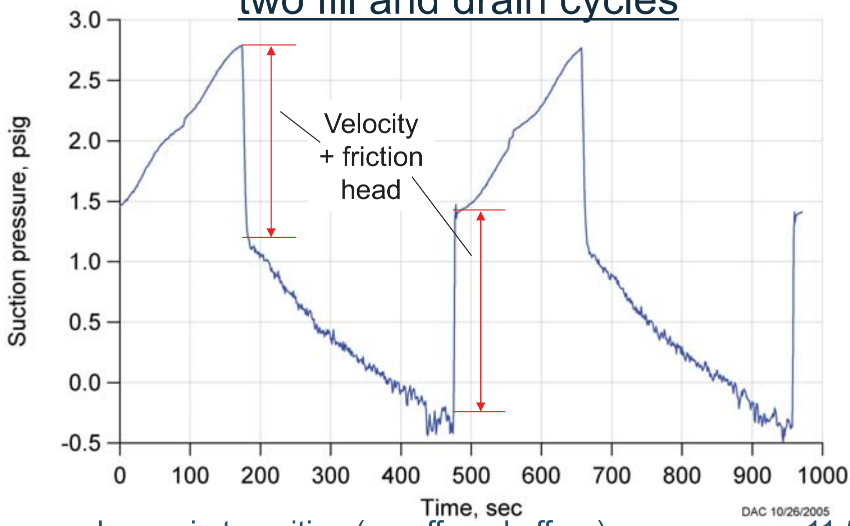
Suction pressure tap was installed for pump performance test

What effect would gas accumulation in the sensing line have?



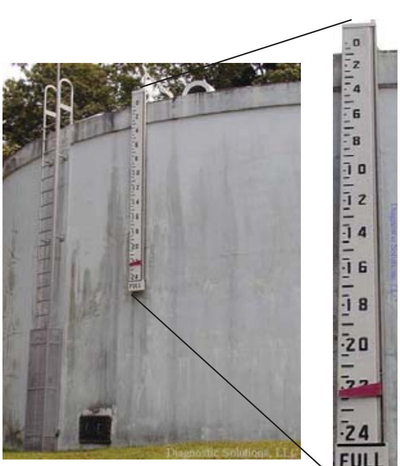
Simple geometry: bellmouth inlet and long radius elbow before suction pressure gauge

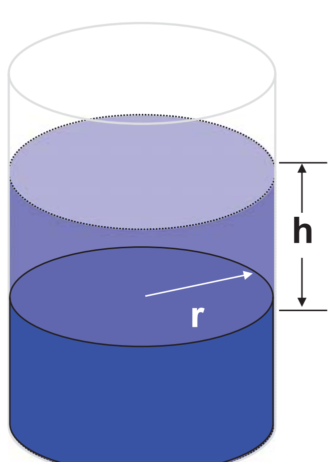
Waste lift station pump suction pressure during two fill and drain cycles



Average change in transition (on-off, and off-on) pressure was 11.5 kPa, or 1.2 m

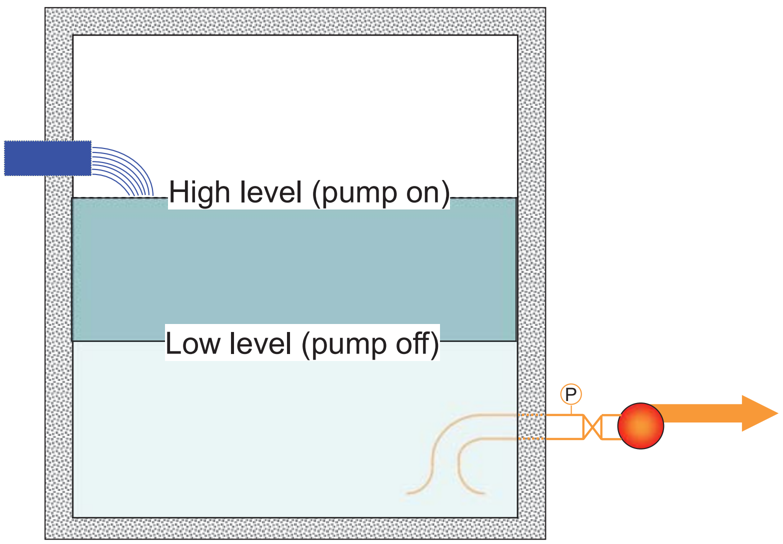
An optimal flow rate measurement method: isolated tank draw down or fill rate



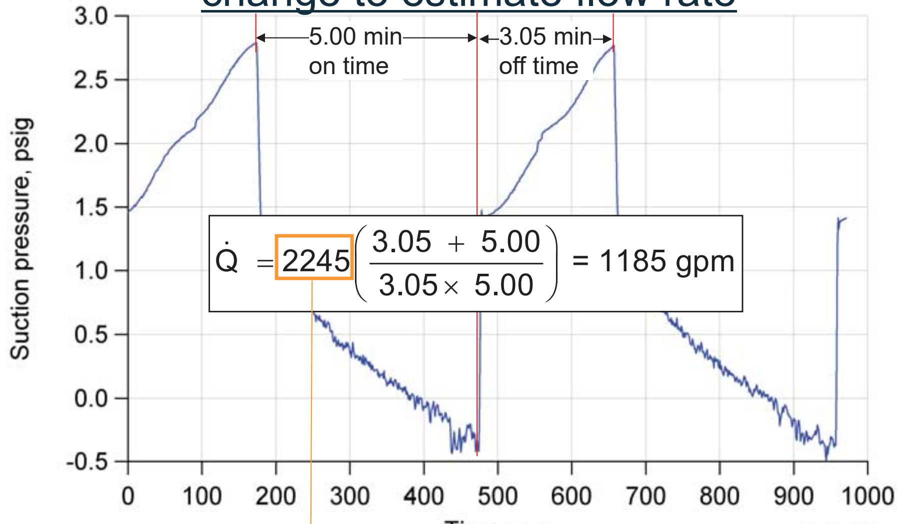


$$Q = \frac{\pi r^2 h}{t}$$

Pump flow rate can be estimated in an un-isolated tank with batch operation

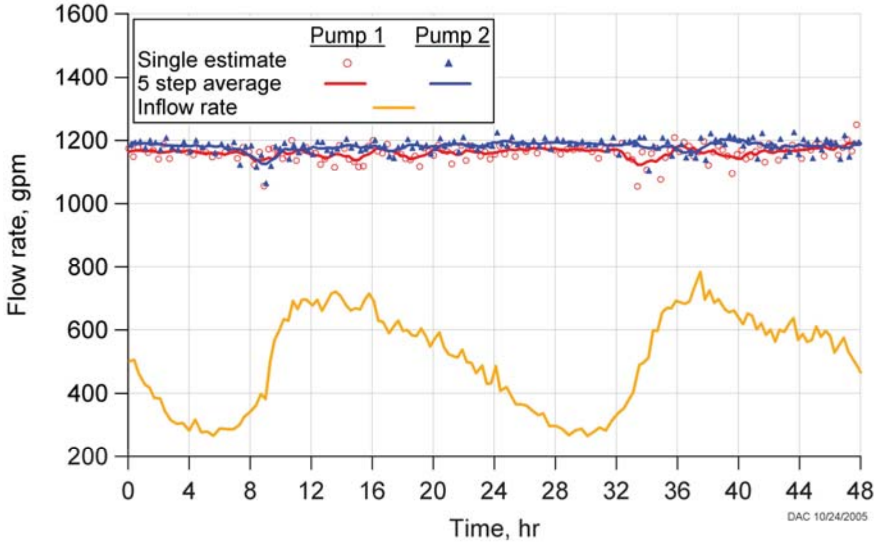


Using on and off times instead of pressure change to estimate flow rate



Volume between level switches was 8.5 cubic meters. Flow =1185gpm or 75 l/s

Tracking on/off-estimated flow rate at the same station over the course of two days



151

Pump flow rate can be estimated in an un-isolated tank with batch operation

- Measure time between on and off events
- Calculate the volume between level switches
- Incoming flow rate with pump off = volume/time
- *Assume the incoming flow rate is constant*

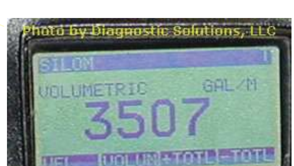
$$\dot{Q} = \frac{t_{on}\left(\frac{V_w}{t_{off}}\right) + V_w}{t_{on}} = \left[\left(\frac{V_w}{t_{off}}\right) + \left(\frac{V_w}{t_{on}}\right)\right] = V_w\left(\frac{t_{off} + t_{on}}{t_{off} \times t_{on}}\right)$$

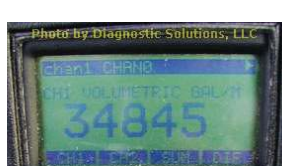
$\dot{Q}$ = Pump flow rate
t_{on} = Pump run time
t_{off} = Pump off time
V_w = Well volume

Permanently-installed ultrasonic flow meter in wastewater plant (single path)

This system measures the average velocity across the full pipe diameter; the transducers are in contact with the fluid.

Clamp-on portable ultrasonic on ductile and cast iron (top), carbon and stainless steel pipe (bottom)

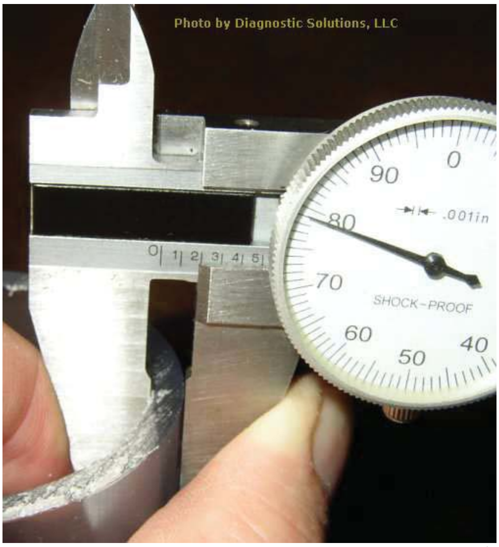




For less-than-desirable geometric conditions, 2-channel meter provides a consistency check

Note that the most upstream transducer is only about 2.25 pipe diameters downstream of the tee. The pair of ultrasonic units are set up about 90 degrees apart, circumferentially, thus sensing perpendicular velocity profiles.

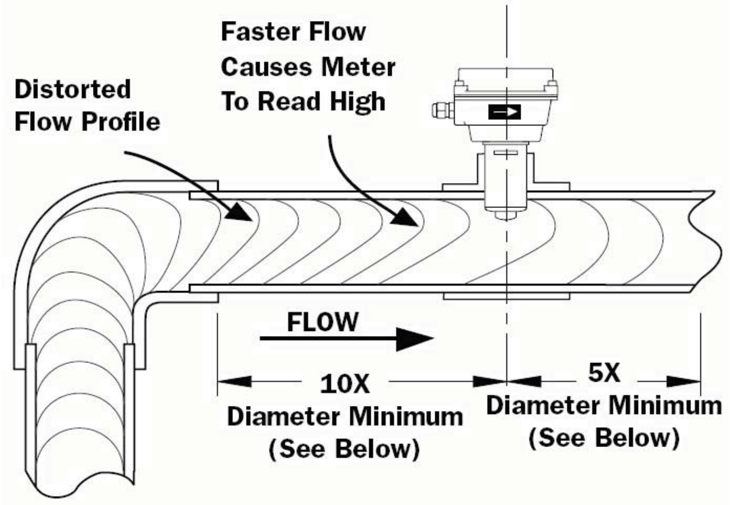
Wall thickness is a common source of uncertainty or error in all flow measurements



Problem applications for time of flight ultrasonic meters

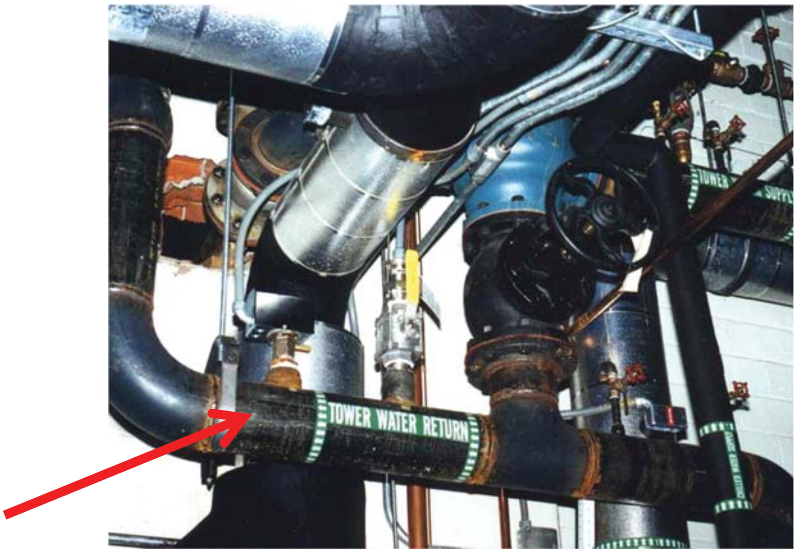
- Slurries
- Medium/high density stock
- Aerated fluid
- Considerable scale buildup
- Good quality meters give the user an alert when the meter diagnostics suggest that the data is likely to be erroneous.
- Caveat emptor: Not all meters that the author has used fit the "good quality" characterization.

Single radial point transducers are particularly susceptible to disturbed flow-induced errors

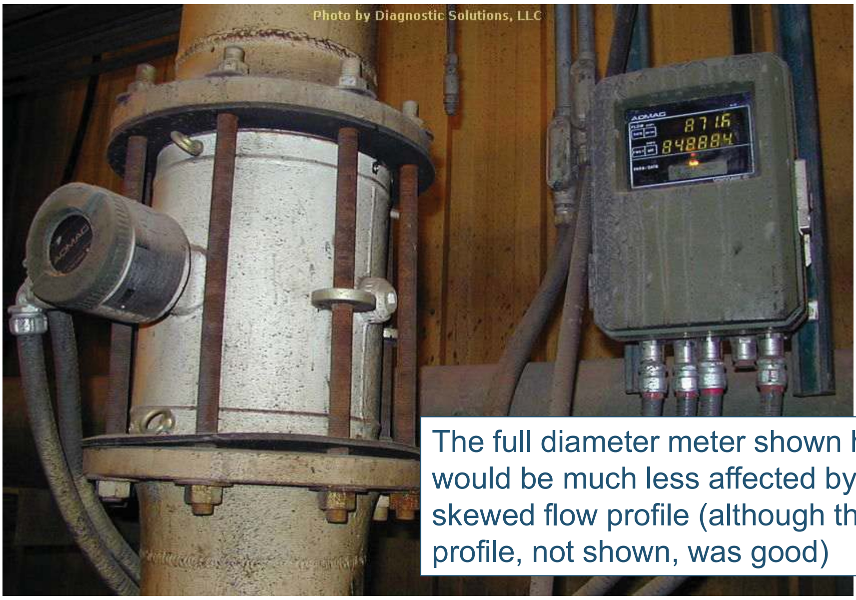


Source: SeaMetrics EX80 Series Electromagnetic Flow Sensor Instructions manual

A favorite example of an abysmal flow meter installation



Full diameter magnetic flow meter



The full diameter meter shown here would be much less affected by skewed flow profile (although the profile, not shown, was good)

Three magnetic flow meters used in a slurry application with decent pipe geometry

Power measurements

Power Measurements

Power can be measured:

- Directly
- By measuring Voltage, Amperage and estimating power factor
- PSAT has a built in power factor estimator

163

Power factor for a pair of single frequency waveforms is simple

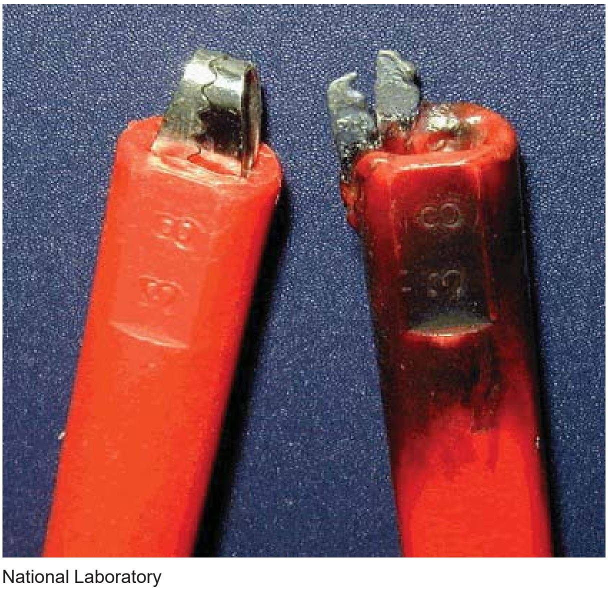
power factor = cos θ

- Where θ is the phase angle between the voltage and current waveforms
- Can we measure that phase angle? Absolutely.
- (but notice the stuff in underlined italics above)

The most important consideration in electrical measurements:

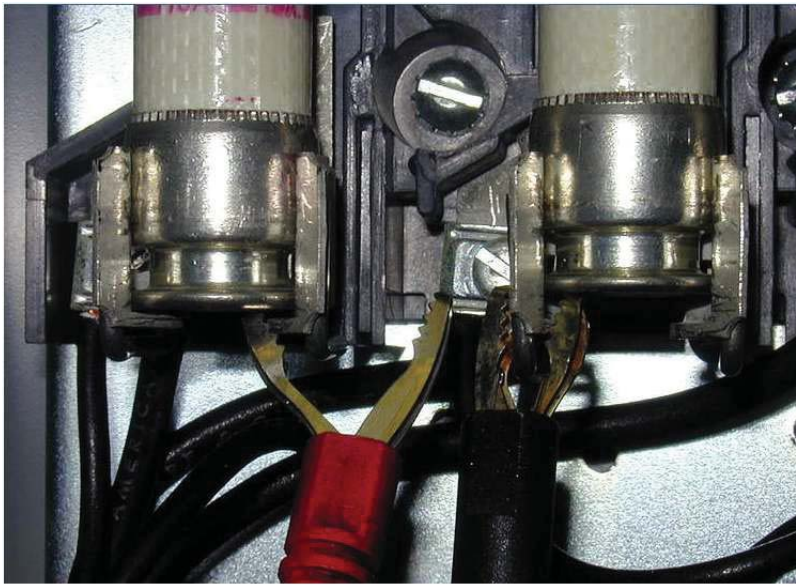
SAFETY

These two alligator clips used to look alike...



Slide Courtesy of Oak Ridge National Laboratory

How it happened



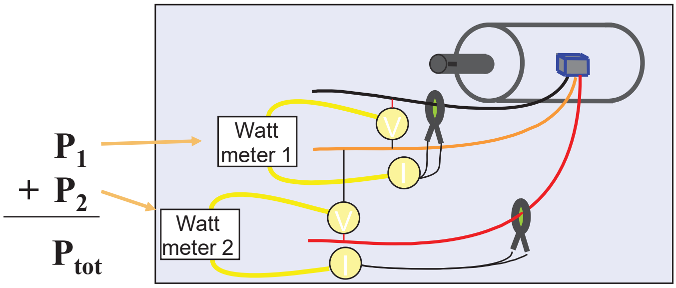
A better alternative - starter terminals

Slide Courtesy of Oak Ridge National Laboratory

Fundamental electrical power relationships: Three phase power

Balanced 3-phase power: $P = \sqrt{3} \cdot I_{rms} \cdot V_{rms} \cdot$ power factor

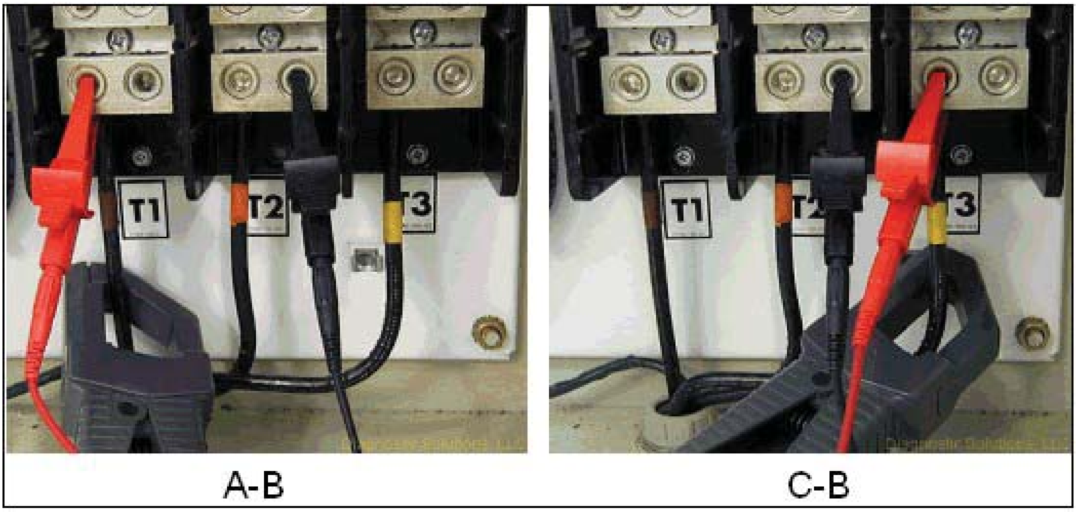
For balanced *or* unbalanced conditions, the two watt-meter method can be used:



note: the V_{rms} above is line to line voltage

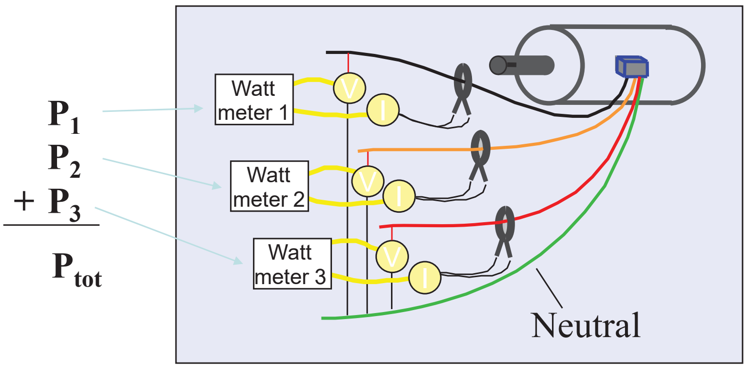
Slide Courtesy of Oak Ridge National Laboratory

The two watt-meter method being applied



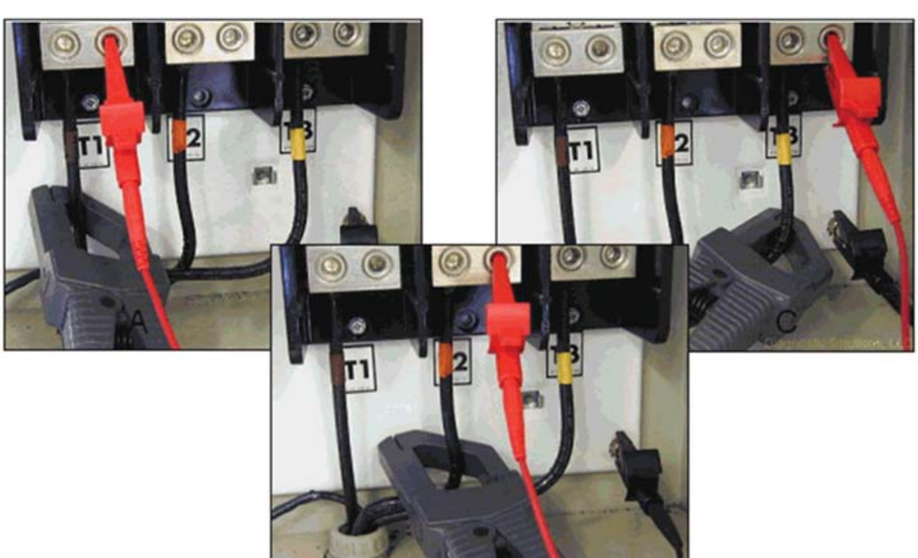
Slide Courtesy of Oak Ridge National Laboratory

An alternative method of measuring power in three-phase circuits with a neutral



Slide Courtesy of Oak Ridge National Laboratory

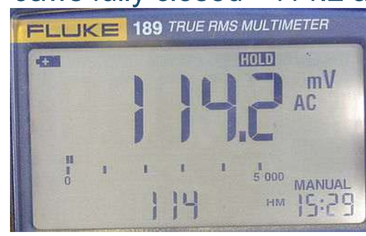
The three watt-meter method being applied



Slide Courtesy of Oak Ridge National Laboratory

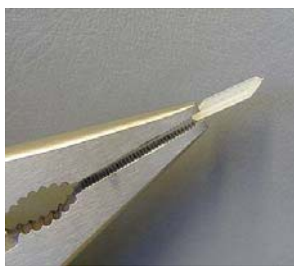
A caution about current measurements: CT jaw closure is critical

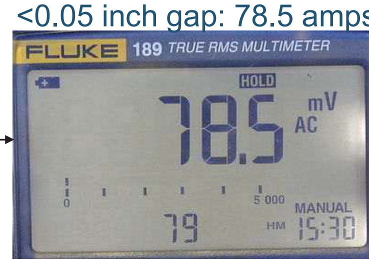
Jaws fully closed - 114.2 amps



<0.05 inch gap: 78.5 amps

Piece of tie wrap
< 0.05 in thick



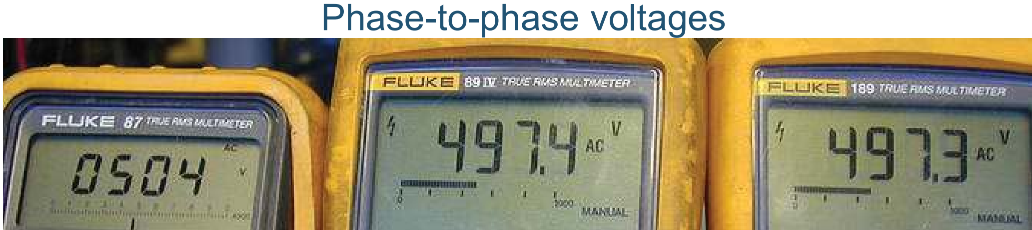


Slide Courtesy of Oak Ridge National Laboratory

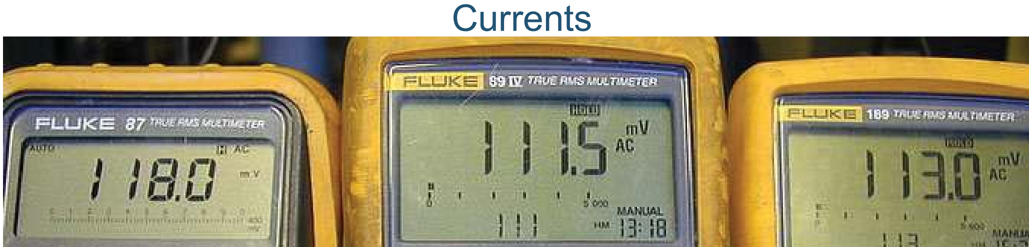
Note: CT scaling is 1 mV/amp

If possible, measure all three phases

Phase-to-phase voltages



Currents



<0.9% voltage unbalance => 3.3% current unbalance

Slide Courtesy of Oak Ridge National Laboratory

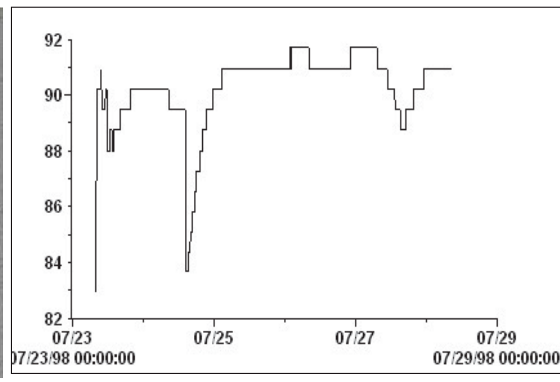
Data Logging

Data Loggers

- Data loggers can provide more insight on how a pump system operates over an hour, a day or several weeks
- Simple Data Loggers such as on/off loggers or small programmable data loggers are helpful to evaluate pump cycle times and power variations (a laptop is needed to program the units)
- Many flow and power meters also have data logging features that can be used

Multi-Channel Data Loggers

- Some data loggers can be used to log amperage, temperature or other types of data depending on the sensor attached. The data logger below is set up with an amp CT



DISCLAIMER

This document was developed within the framework of the project "Accelerating energy efficiency in large industries through energy management systems, system optimization and the promotion and adoption of energy efficiency in small and medium-sized enterprises (IEEP)", funded by the European Union (EU), managed by the Ministry of Industry and Trade (MOIT), and implemented by the United Nations Industrial Development Organization (UNIDO). The content of this document is the sole responsibility of the Project and does not necessarily reflect the views of any individual or organization.

MINISTRY OF INDUSTRY AND TRADE

EU - VIET NAM SUSTAINABLE ENERGY TRANSITION PROGRAMME (SETP)
Accelerating energy efficiency (EE) in large industries through energy management system, System optimisation and the promotion and adoption of EE in SMEs -(IEEP project)

Global Gateway
Funded by the European Union

UNIDO
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Two Day
Expert Pump System Optimization Training

UNIDO International Energy Efficiency Expert

Facilitated by:

Harry Rosen

MINISTRY OF INDUSTRY AND TRADE
Global Gateway
Funded by the European Union
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Introduction to the MEASUR Program

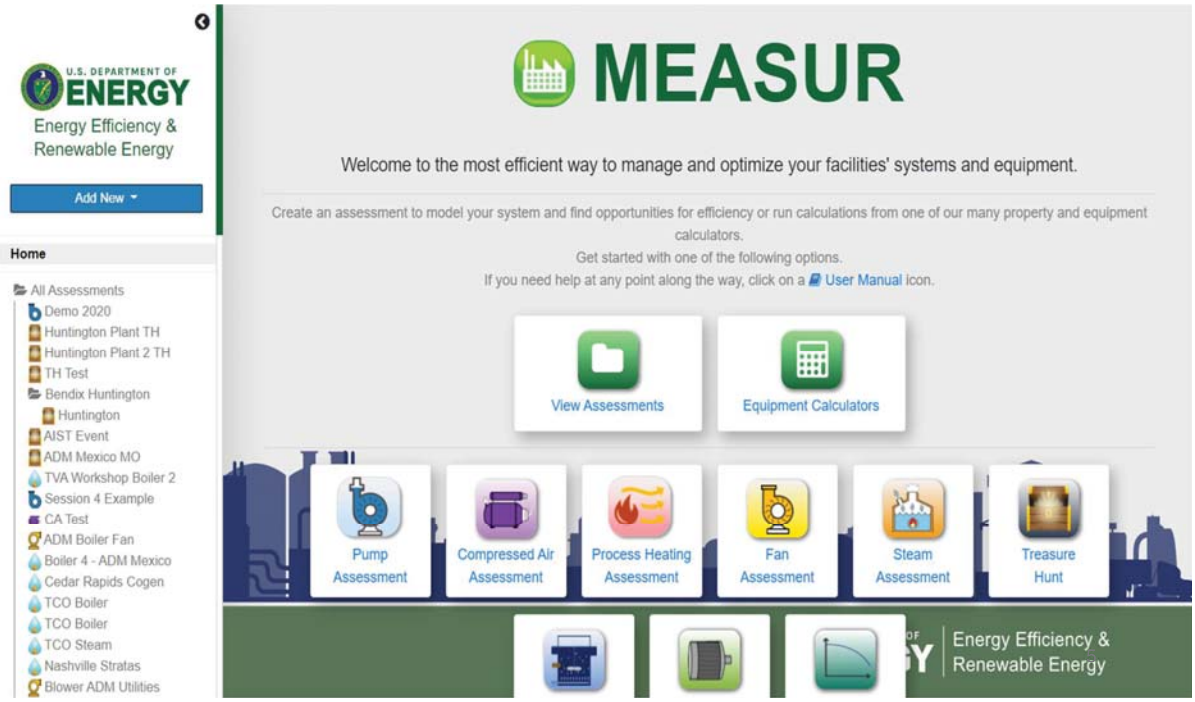
An introduction to the Pumping System Assessment Tool (MEASUR)

- Goal: to assist pump users in identifying pumping systems that are the most likely candidates for energy and cost savings
- Requires field measurements or estimates of flow rate, pressure, and motor power or current
- Uses pump and motor performance data from Hydraulic Institute standard ANSI/HI-1.3 and MotorMaster+ to estimate existing, achievable performance

MEASUR Can be used both as a component tool and as a system tool

- For a given operating point, MEASUR searches for the highest pump efficiency possible at that point
- It also searches for the highest motor efficiency available to drive the found pump at that point
- It calculates the cost of operating at the point in terms of kWh used and $
- MEASUR can also be used as a system tool if the minimum flow and pressure needed for the process are entered instead of current head and flow

Open the MEASUR Software

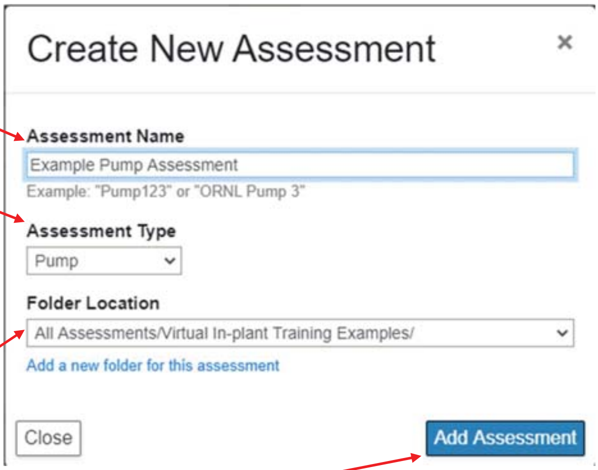


Create A New Pump Assessment

Name the Assessment

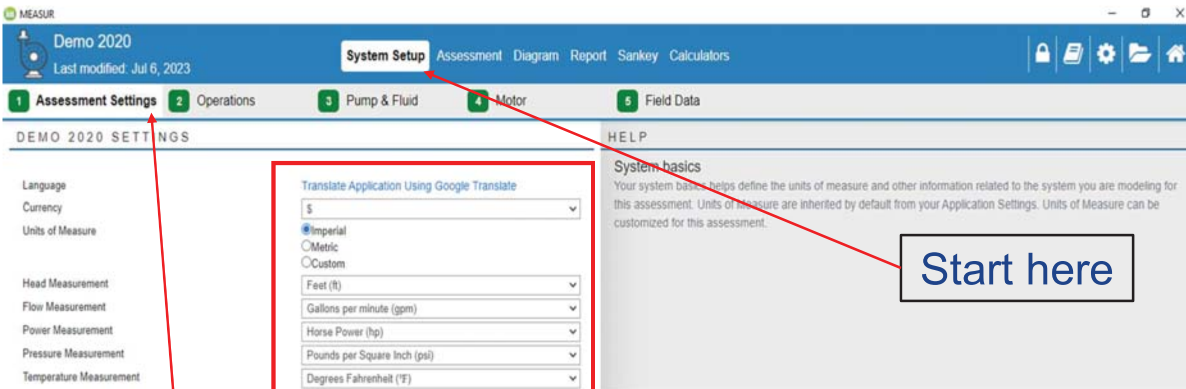
Select the Assessment Type

Select where you want the file saved on your computer



Finally, Click on Add Assessment

System Setup – Assessment Settings



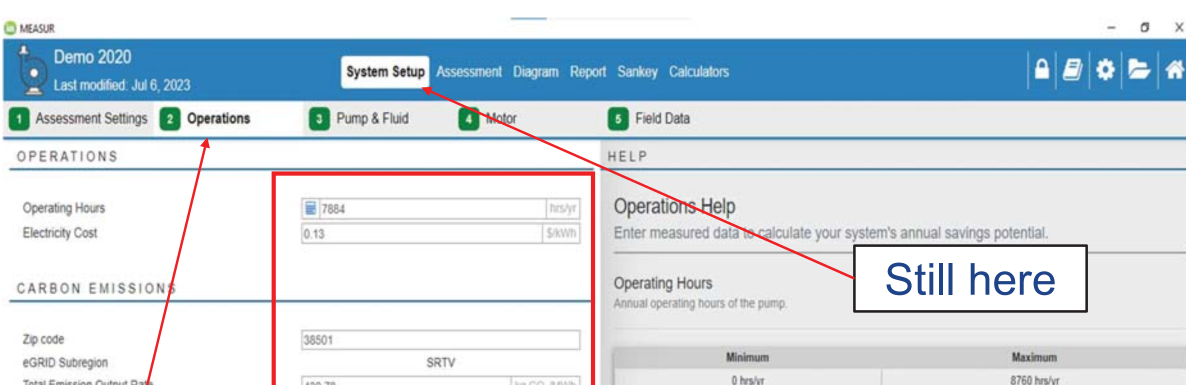
Start here

Then here

Select the language and units you want to work with

Finally, Click on Operations to continue

System Setup – Assessment Settings



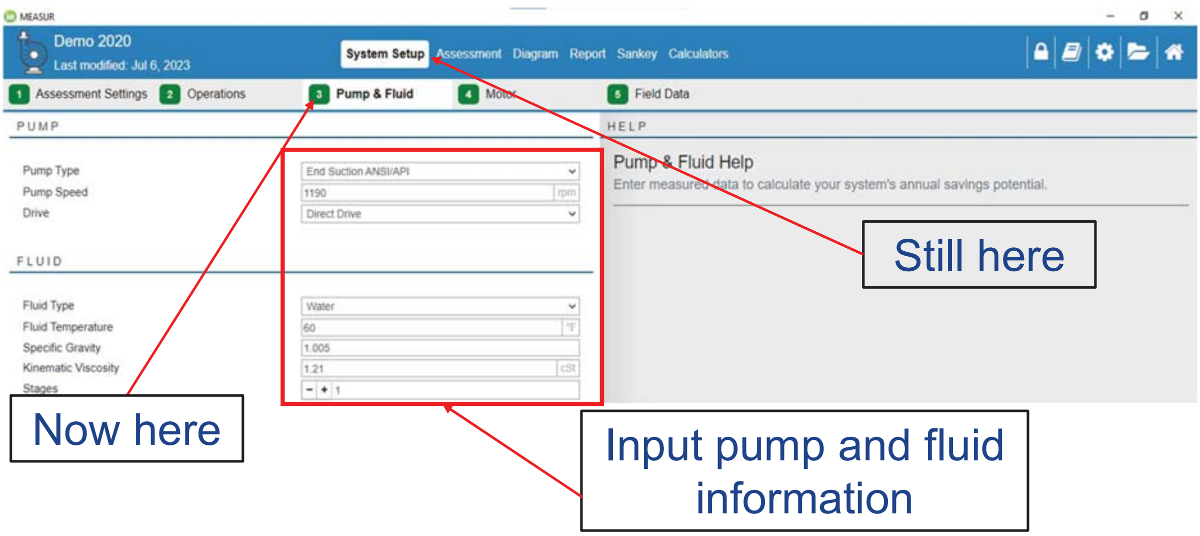
Still here

Now here

Enter Hours of Operation, Electric Cost & Zip Code

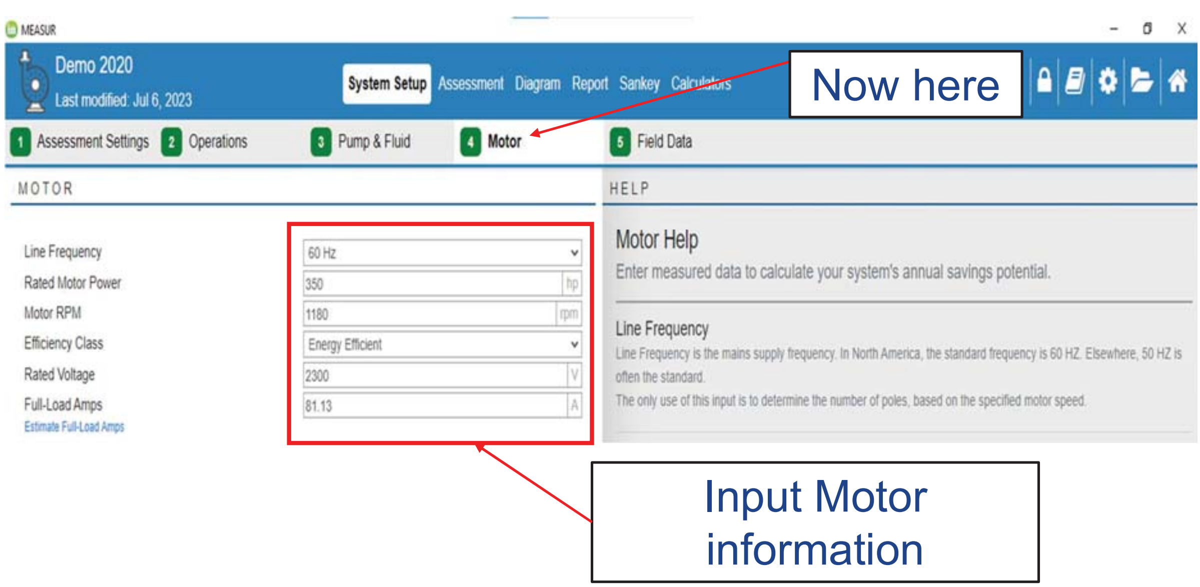
Finally, Pump & Fluid to continue

System Setup – Pump & Fluid



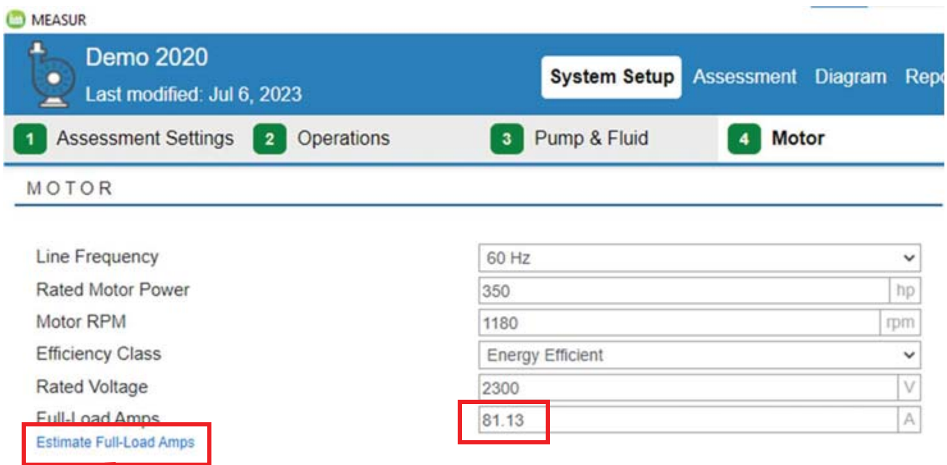
Finally, Click on Motor to continue

System Setup – Motor



Finally, Click on Field Data to continue

System Setup – Estimate Full Load Amps

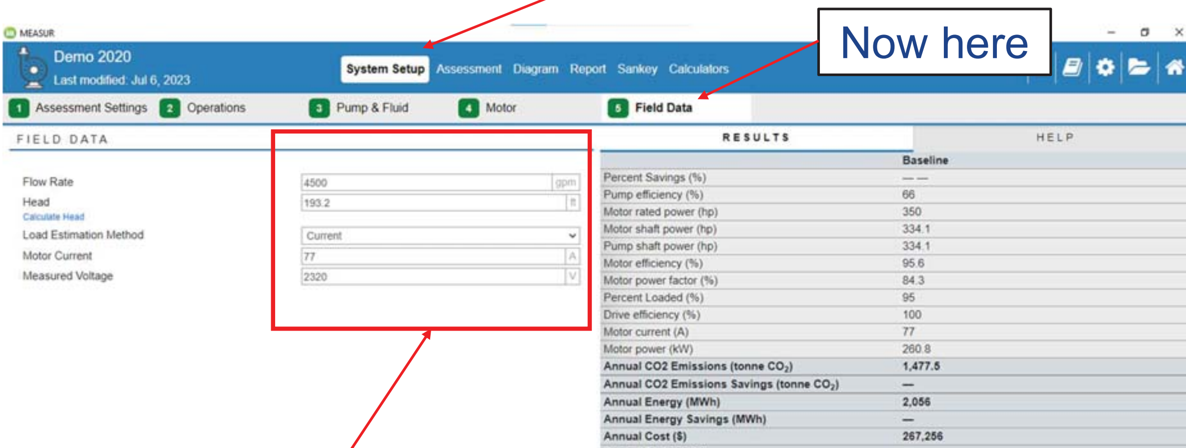


Can estimate full load motor amps by clicking here

System Setup – Field Data

Still here

Now here

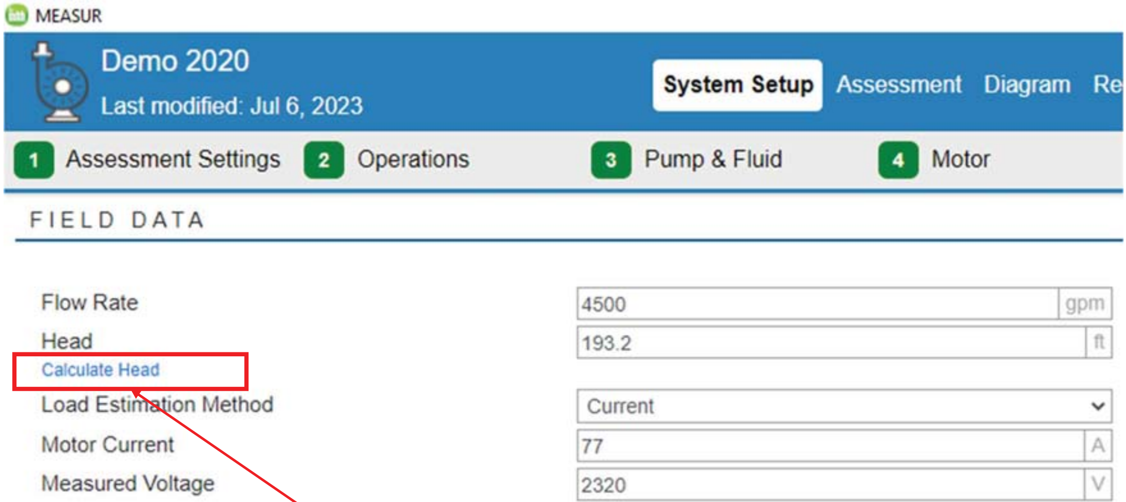


Input Field Data

Baseline Results

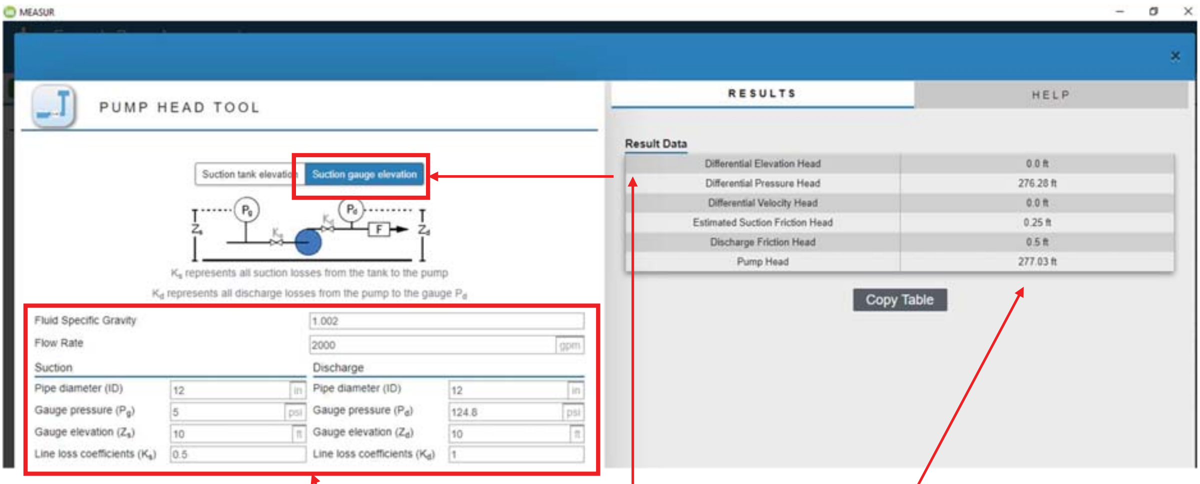
After Field Data, move on to the Assessment

System Setup – Calculate Pump Head



Go to the pump head calculator by clicking here

System Setup – Pump Head Calculator

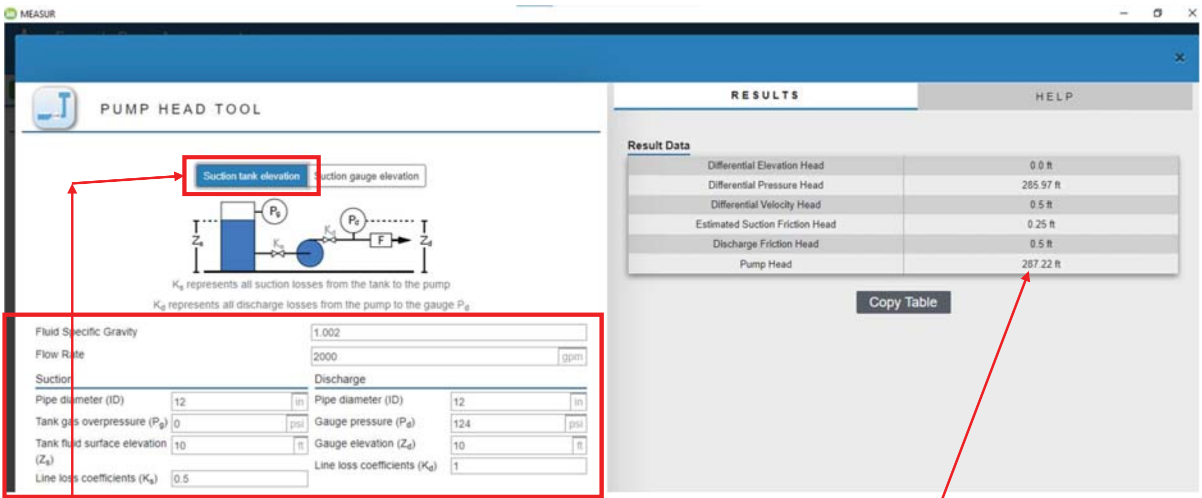


Input Field Data

Pump Head

Two Different Geometries: Suction Gauge

System Setup – Pump Head Calculator

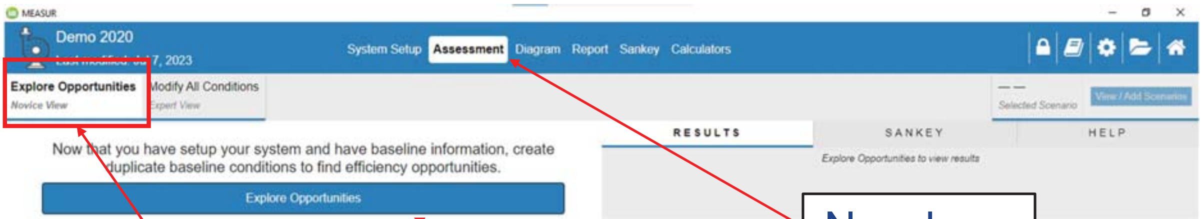


Pump Head

Input Field Data

Two Different Geometries: Suction Tank

Assessment View – Novice



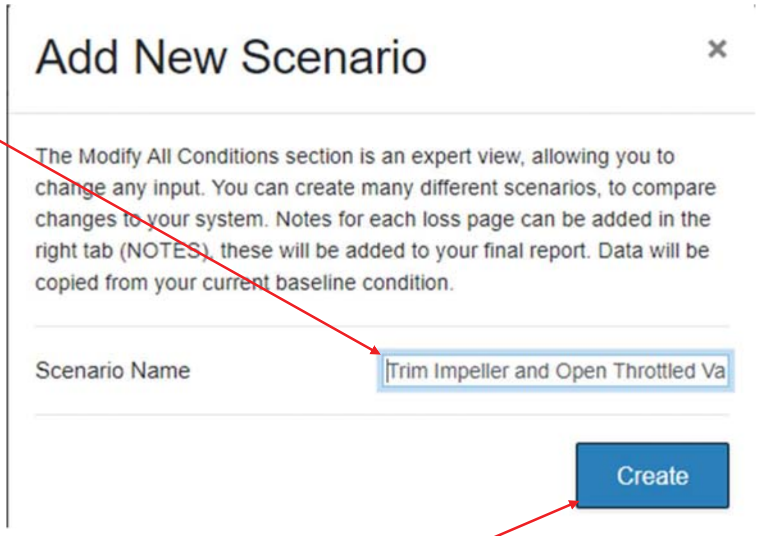
Now here

Novice View

Click Explore Opportunities to evaluate a potential project

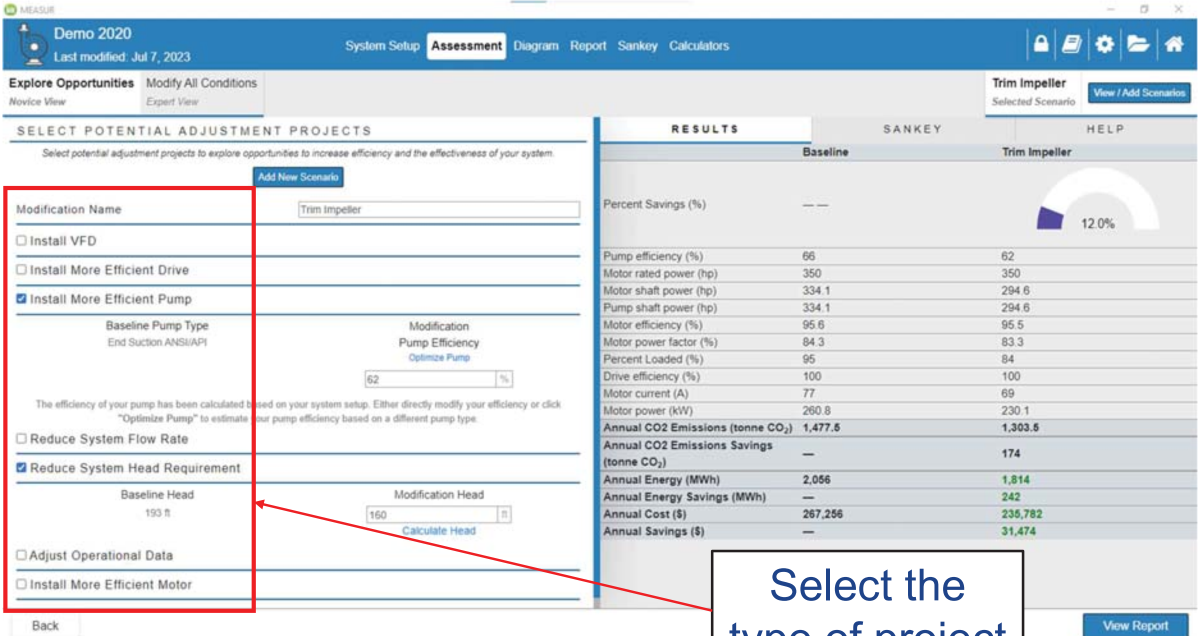
Evaluate Potential Project

Name the Opportunity



Click on Create

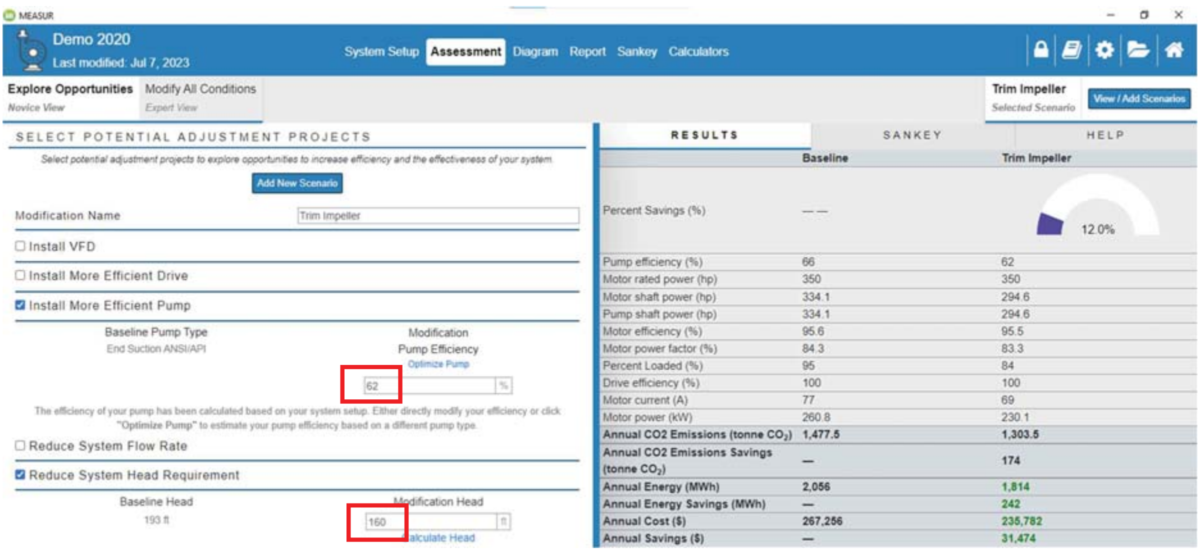
Assessment View – Novice



Select the type of project

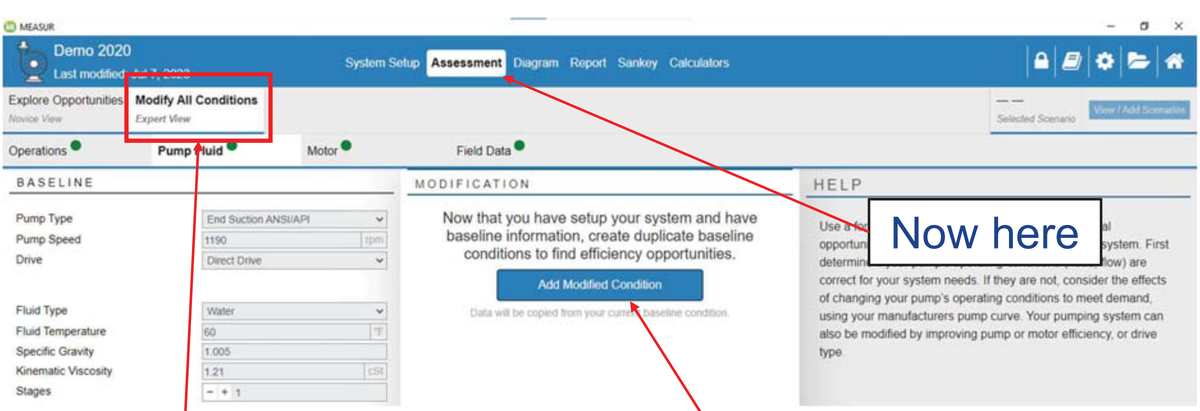
Have throttled pump with constant flow

Assessment View – Novice



Reduce Pump Head by 33 Feet by Trimming the Impeller and Opening the Throttled Valve. Pump efficiency falls by 4%.

Assessment View – Expert

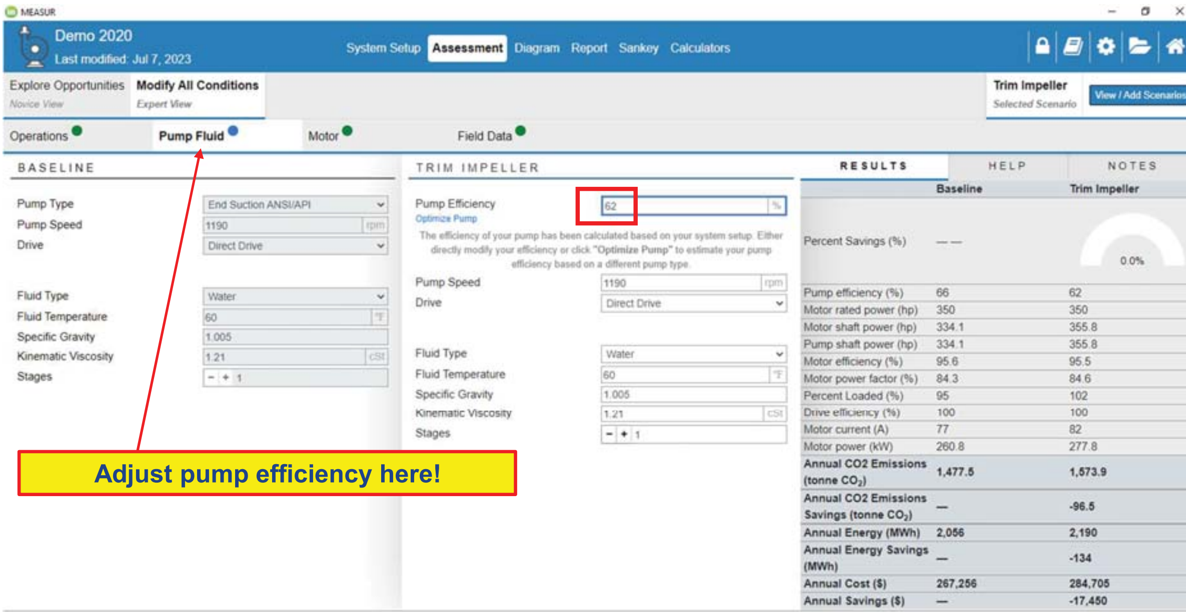


Now here

Expert View

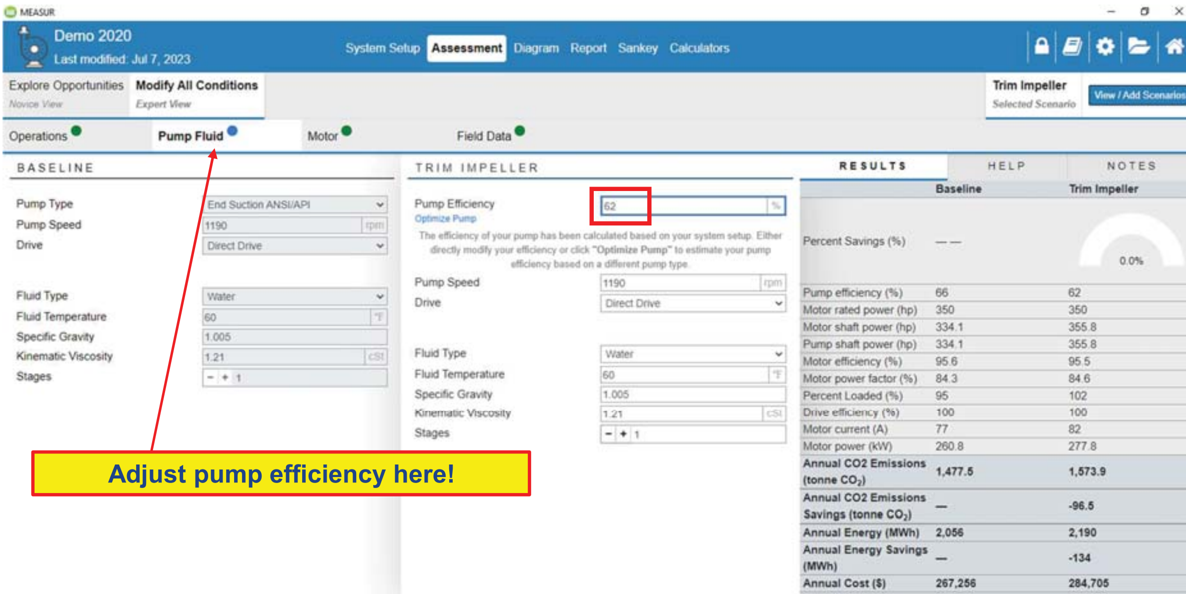
Click Modified Condition to evaluate a potential project

Assessment View – Expert



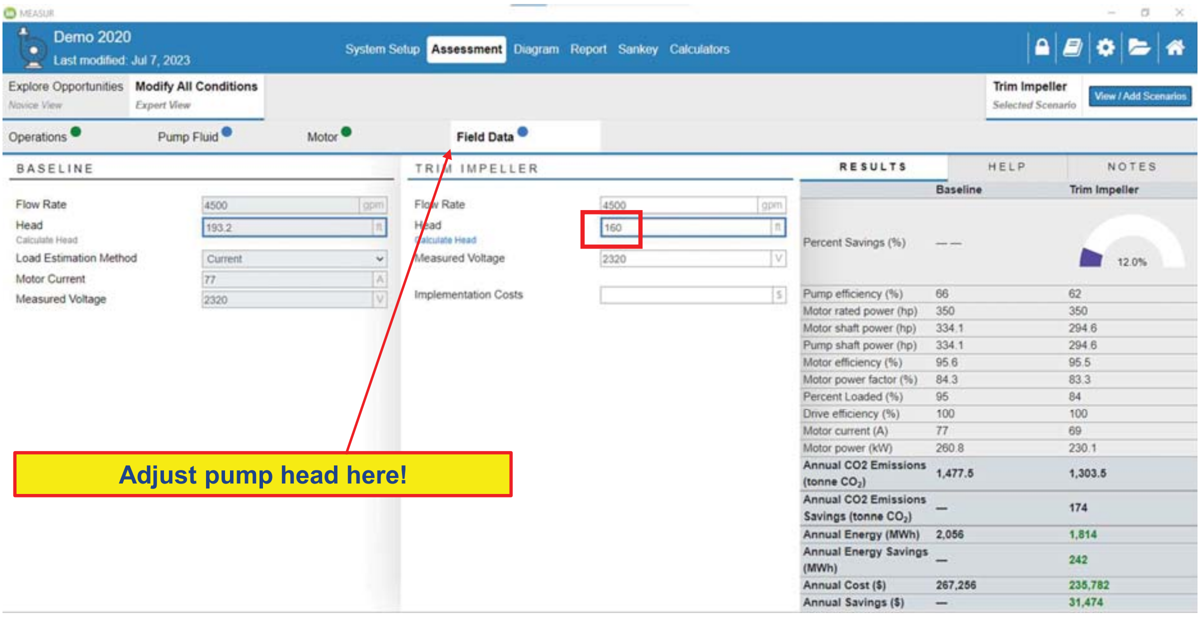
Pump efficiency dropped to 62%

Assessment View – Expert



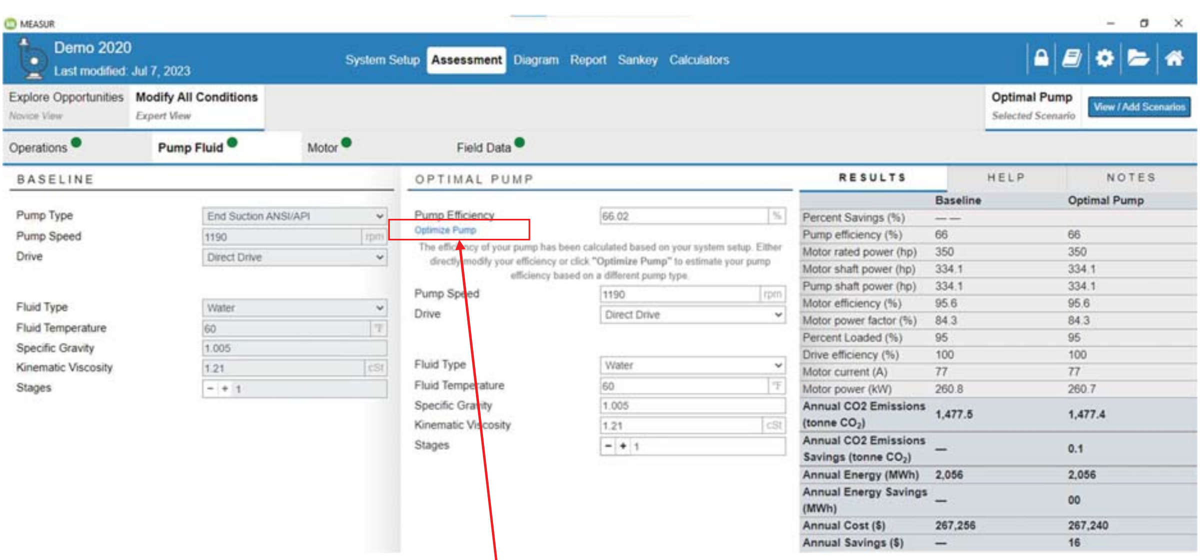
Pump efficiency dropped to 62%

Assessment View – Expert



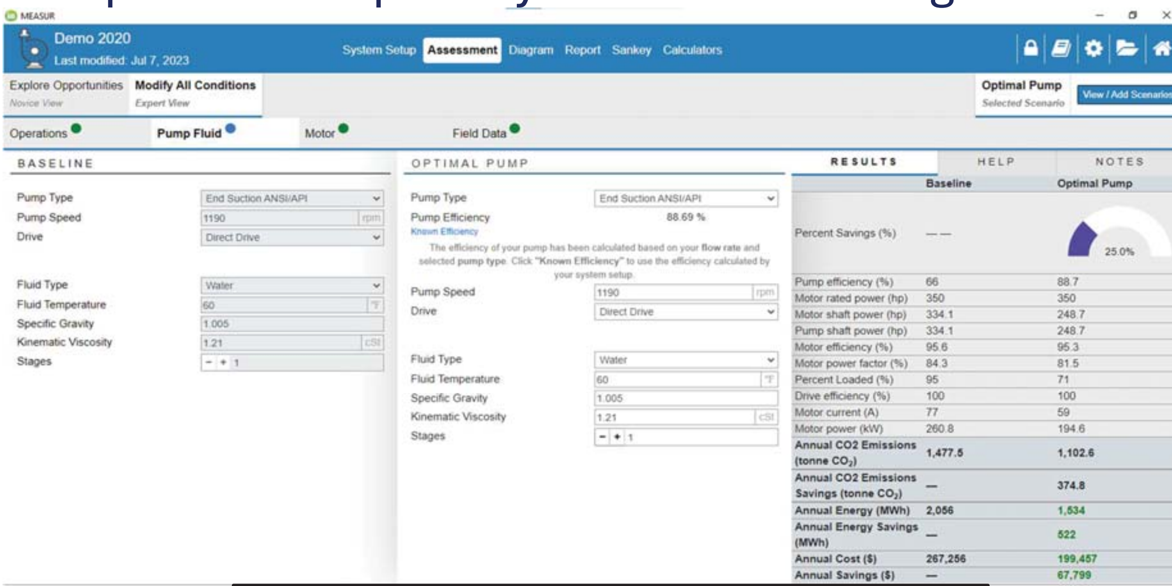
Pump head dropped to 160 feet

Compare Existing Pump to Optimal Pump



To evaluate an "optimized" pump based on Hydraulic Institute algorithms click here

Optimize Pump w/ Hydraulic Institute Algorithms

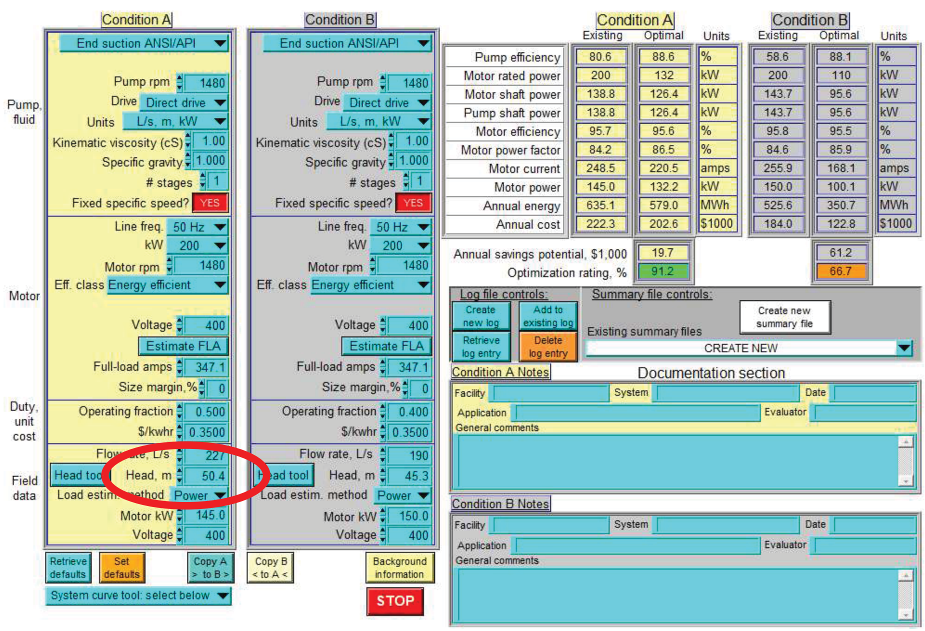


Same flow and same head –
Original Pump Efficiency is 66.0%
Optimal Pump is 88.7%

An important consideration: Demand and Supply - in the engineering domain

- There is often a difference between what the pump is providing the system and what the system really needs
- Try to think in terms of demand, not supply

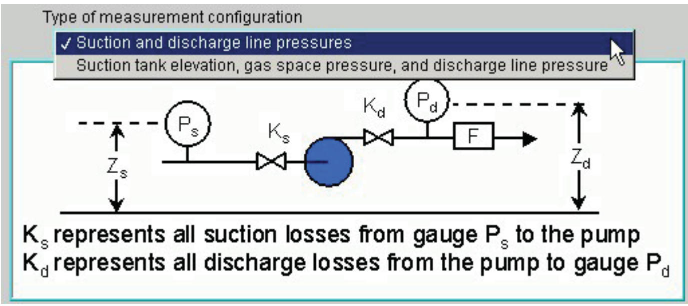
Head is a required input, where does it come from?



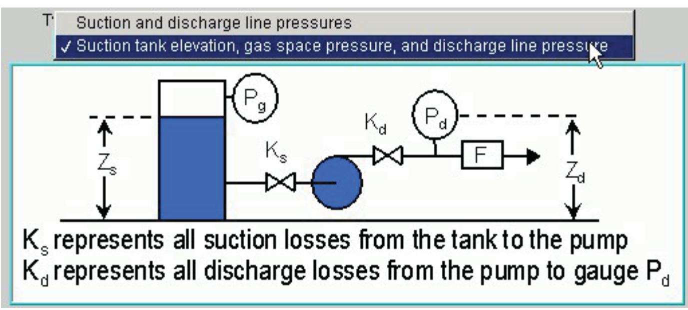
Where did the head values just shown in PSAT come from?

- From the head calculator included with PSAT
- Based on standard methods (i.e., Bernoulli), but also provides a method to adjust for non-ideal field conditions
- Information needed:
  - Suction pressure measurement
  - Discharge pressure measurement
  - Elevations of the pressure measurement locations
  - Line sizes at the same locations
  - Flow rate*
- Two basic layouts are supported

Two situations for calculating pump head are most commonly encountered

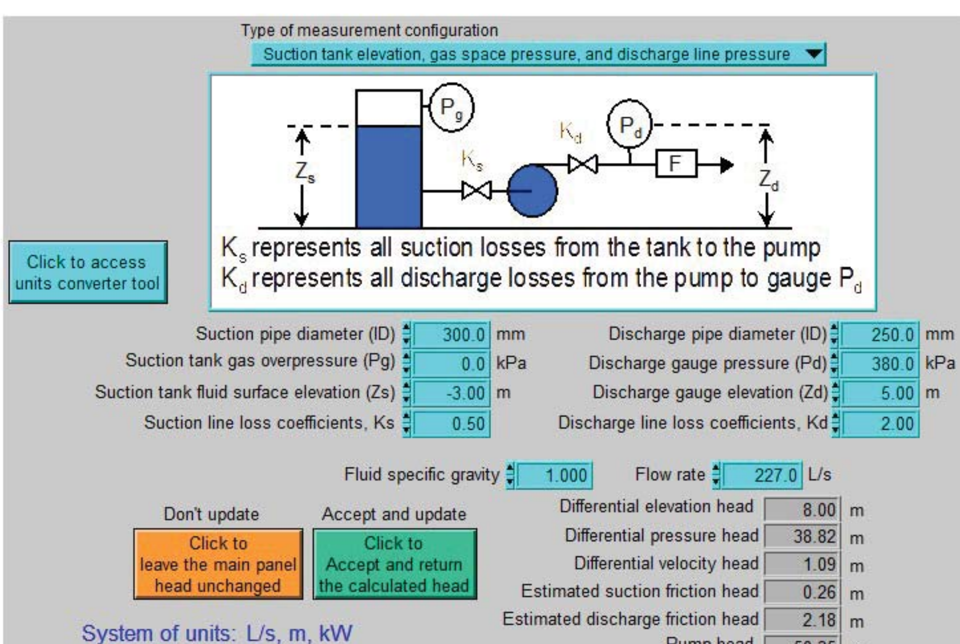


Method 1: pressure measured in pump suction and discharge lines

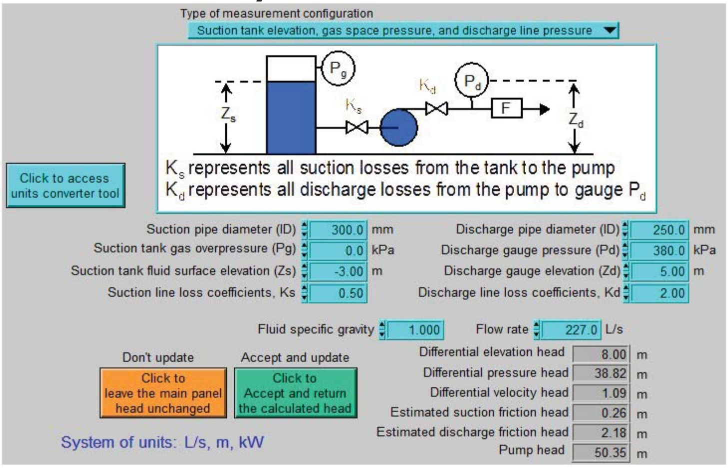


Method 2: pump draws suction from a tank (or well), with or without gas overpressure

Method 1 example (hypothetical)



Method 2 example (situation just covered)

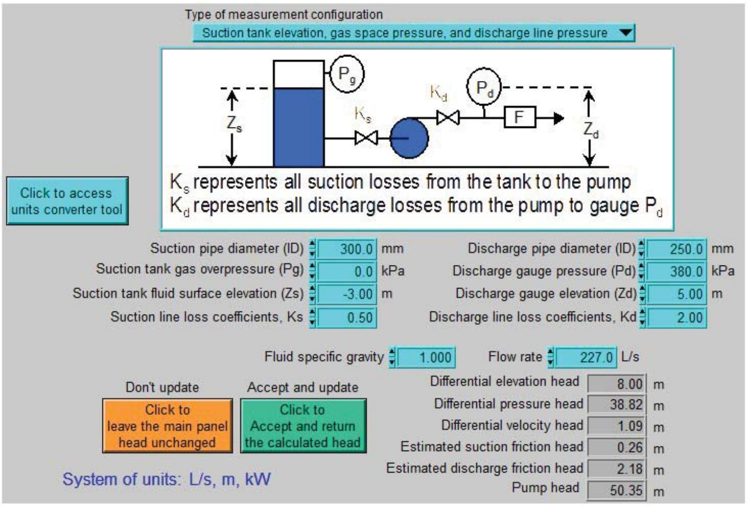


The 380 kPa listed as the discharge pressure corresponds to the average pressure in the pump discharge column head.

For cases involving long columns, it would be appropriate to address the column friction losses in the Discharge line loss coefficients entry.

Note that the suction tank fluid surface elevation is listed as -3.00 m. That is because the level in clear-well from which the pump drew suction was about 3m below floor level, which was used as a reference. The discharge pressure gauge was on the pump base, about 5m above the floor level.

Method 2 - Using common header pressure

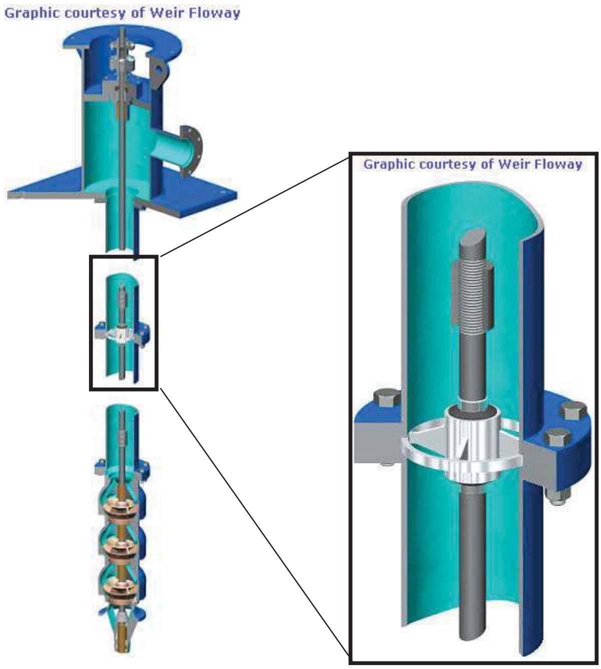


The discharge pressure used here is that measured in the common header, where the line is 400mm (nominal).

Note that a value of 2 is specified for discharge line loss coefficient.

Next: Some what, when, why, and how questions and answers regarding the loss coefficient terms

Pipe losses may be a pump head calculation factor



- The most common situation where this is true is in well applications with long columns
- It is rare otherwise
- For well columns, see if the pump supplier can provide specific loss data (should be able to)

- Line shaft bearings and the shaft for product-lubricated vertical turbine pumps cause losses to be somewhat higher than if the column was just plain pipe.

When, why, and how questions related to the loss coefficient

- When should it be used: Any time there are fittings between the pressure measurement reference points and the pump that may introduce friction losses
- Why use it: Failure to account for those losses will understate the actual pump head
- How:
  - Use component-specific loss coefficients *(excellent)*
  - Use generic loss coefficients *(poor)*
  - WAG at it *(all over the ballpark)*
  - A very helpful how to: use the PSAT head calculator to get a handle on whether it is important or not

The PSAT pump head calculator can be used to get a sense of uncertainty importance

Case 1A

Discharge pipe diameter (ID)	500.0	
Discharge gauge pressure (Pd)	860.0	
Discharge gauge elevation (Zd)	5.00	
Discharge line loss coefficients, Kd	5.00	
1.000 Flow rate	215.0	L/s
Differential elevation head	8.00	m
Differential pressure head	87.85	m
Differential velocity head	0.06	m
stimated suction friction head	0.24	m
imated discharge friction head	0.31	m
Pump head	96.46	m

Case 1B

Discharge pipe diameter (ID)	500.0	
Discharge gauge pressure (Pd)	860.0	
Discharge gauge elevation (Zd)	5.00	
Discharge line loss coefficients, Kd	20.00	
1.000 Flow rate	215.0	L/s
Differential elevation head	8.00	m
Differential pressure head	87.85	m
Differential velocity head	0.06	m
stimated suction friction head	0.24	m
mated discharge friction head	1.22	m
Pump head	97.37	m

4 x loss K =>
1% change in head

Case 2A

Discharge pipe diameter (ID)	400.0	
Discharge gauge pressure (Pd)	900.0	
Discharge gauge elevation (Zd)	5.00	
Discharge line loss coefficients, Kd	5.00	
1.000 Flow rate	870.0	L/s
Differential elevation head	8.00	m
Differential pressure head	91.94	m
Differential velocity head	2.44	m
stimated suction friction head	3.86	m
imated discharge friction head	12.22	m
Pump head	118.46	m

Case 2B

Discharge pipe diameter (ID)	400.0	
Discharge gauge pressure (Pd)	900.0	
Discharge gauge elevation (Zd)	5.00	
Discharge line loss coefficients, Kd	10.00	
1.000 Flow rate	870.0	L/s
Differential elevation head	8.00	m
Differential pressure head	91.94	m
Differential velocity head	2.44	m
stimated suction friction head	3.86	m
imated discharge friction head	24.44	m
Pump head	130.68	m

2 x loss K =>
10% change in head

DISCLAIMER

This document was developed within the framework of the project “Accelerating energy efficiency in large industries through energy management systems, system optimization and the promotion and adoption of energy efficiency in small and medium-sized enterprises (IEEP)”, funded by the European Union (EU), managed by the Ministry of Industry and Trade (MOIT), and implemented by the United Nations Industrial Development Organization (UNIDO). The content of this document is the sole responsibility of the Project and does not necessarily reflect the views of any individual or organization.