Well Pump Selection To Match System Hydraulics

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GROUNDWATER USE

- Well pumps used in over 10,000 public supply groundwater wells in CA
- Pumping groundwater accounts for 25 to 40% of CA's water supply
- Nearly 15 billion gallons of groundwater per day in CA

GOAL OF PRESENTATION

- To educate participants using real world examples that inform them of the importance of efficiently well pump selection
- Provide the participants with the tools needed to select a well pump should they be involved with equipping one of the 10,000 CA public supply groundwater well projects

IMPORTANCE OF UNDERSTANDING WELL PUMPING HYDRAULICS

- Pumping Groundwater is a Major Cost For Many Cities and Water Districts

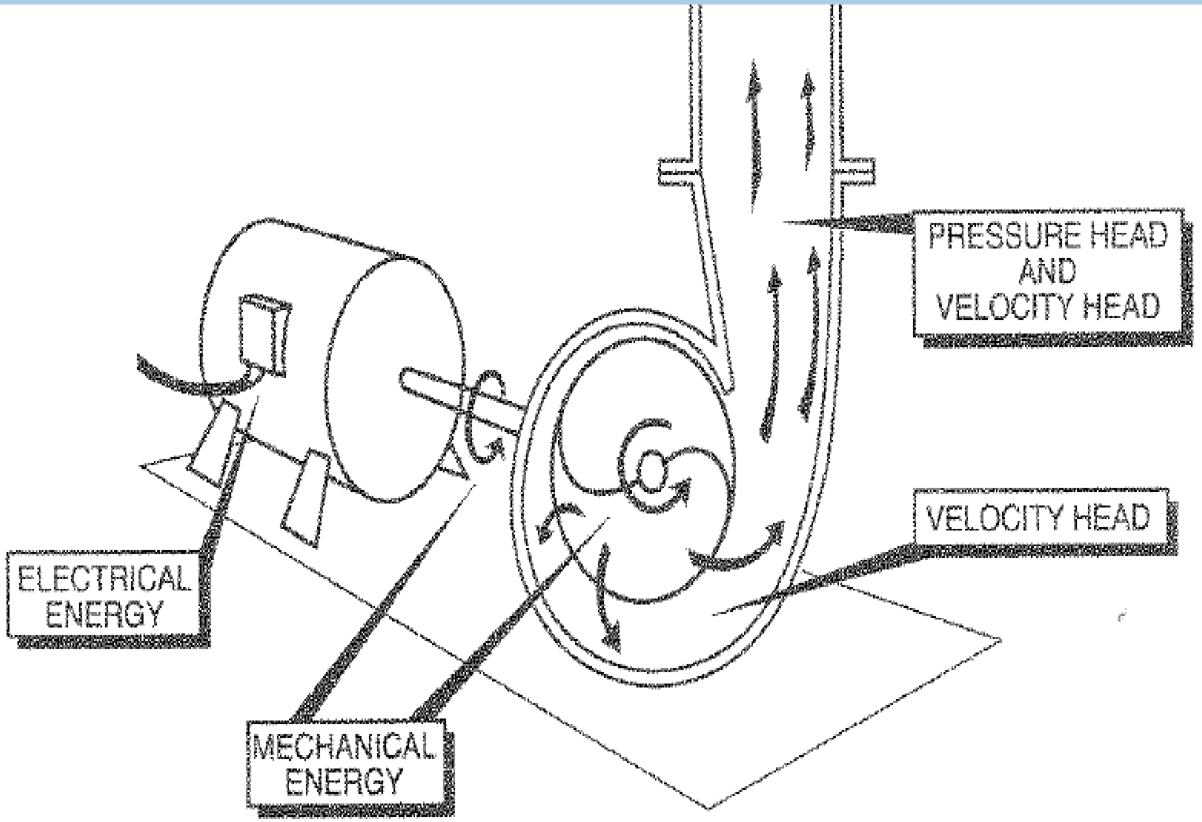
- Head losses account for one third of all energy

- Good Hydraulic Design = Less Energy = Less Greenhouse Emissions

Presentation Content

- Well & Well Pump Hydraulics
- Well Pump Selection
- VFD & Well Pump Performance
- Examples

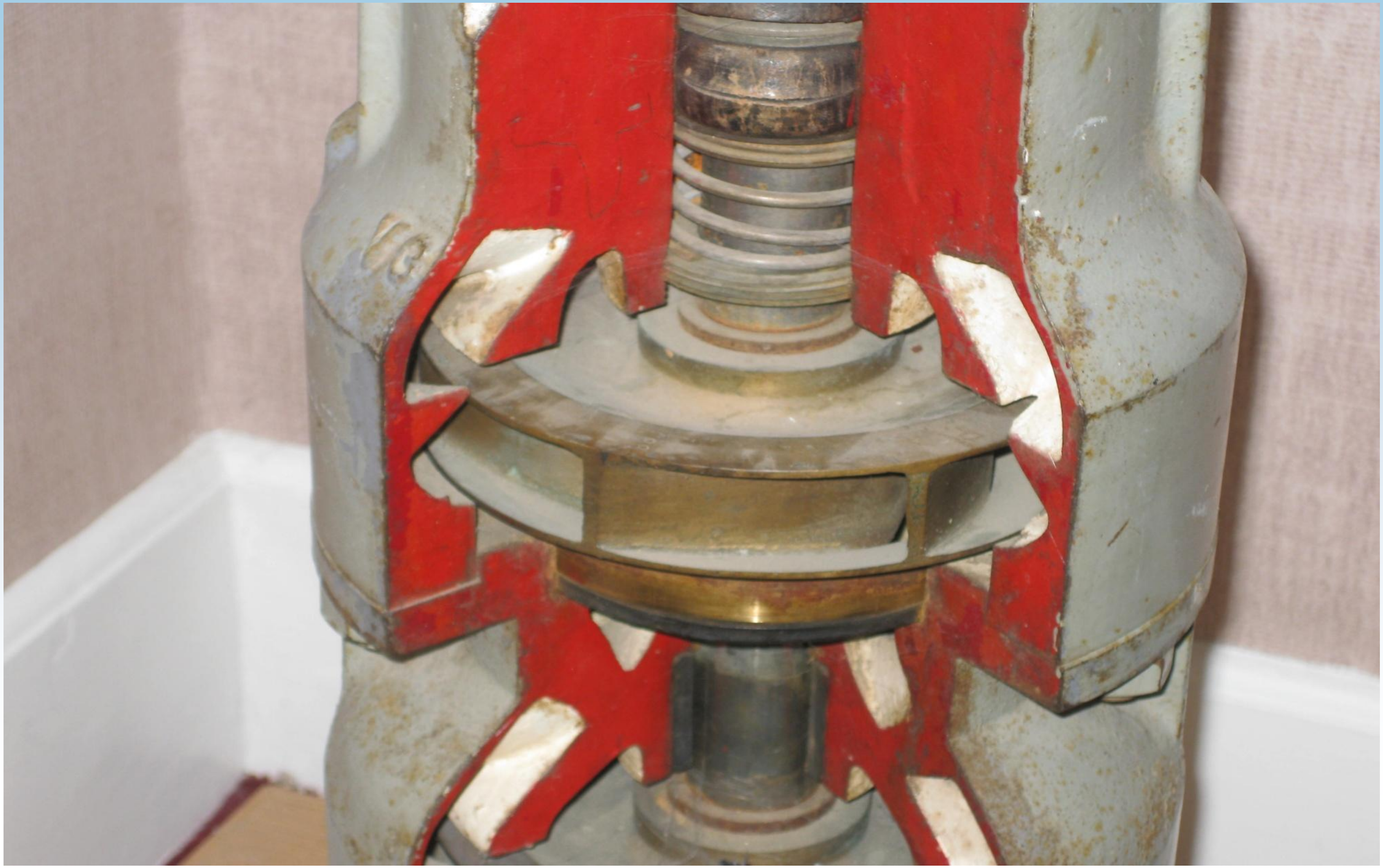
Imparting Energy To The Fluid



Eye Of An Enclosed Impeller

Sectional View Of A Pump Bowl

Impeller With Shaft



Submersible Pumps

General Uses:

- Water well duty

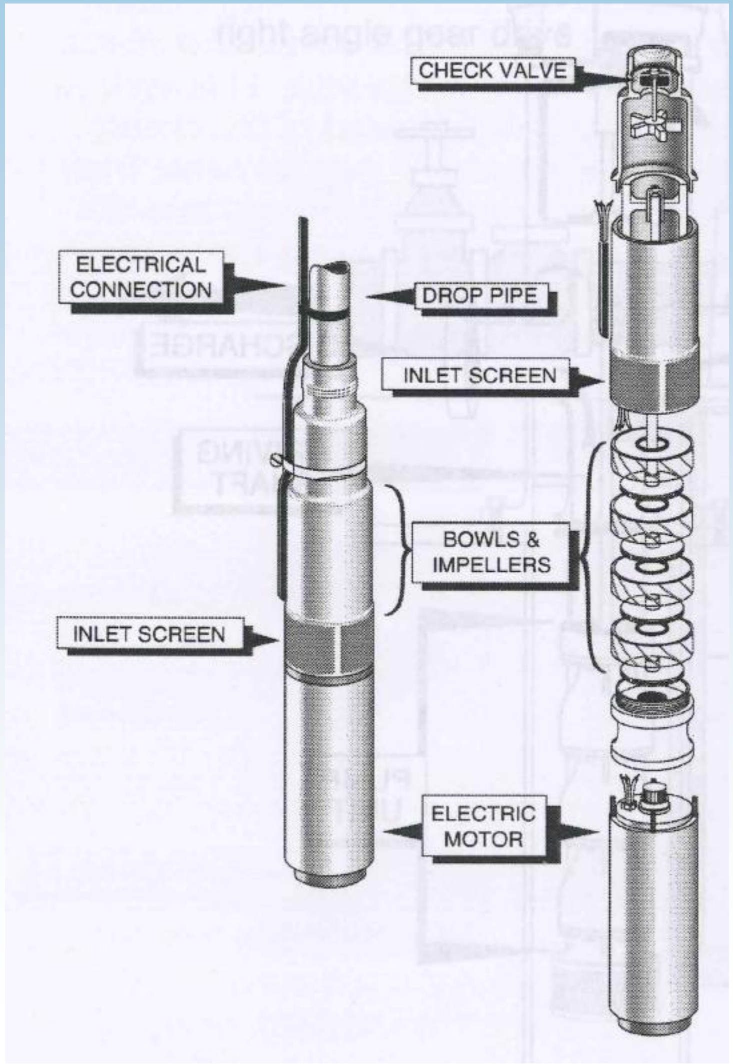
Advantages:

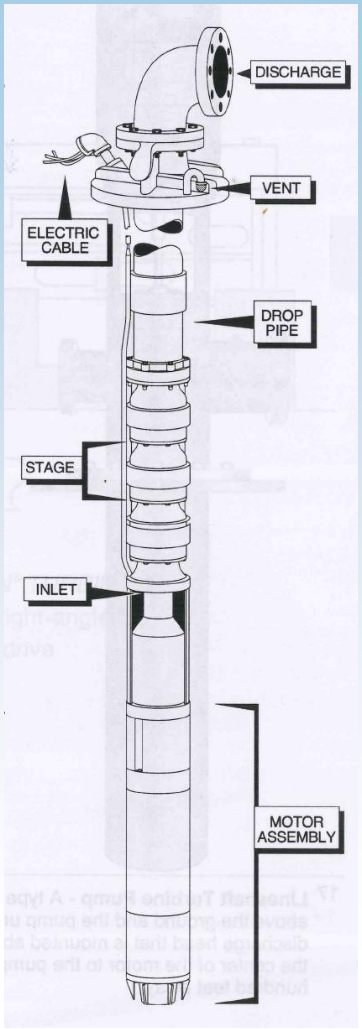
- Wide range of capacities

Disadvantages:

- Minimum flow required for cooling motor
- Power cable vulnerability

Example Of A Submersible Pump





Discharge Head For Submersible Pumps

Submersible Pump and Motor

Vertical Lineshaft Pumps

General Uses:

- Water well duty
- Booster duty

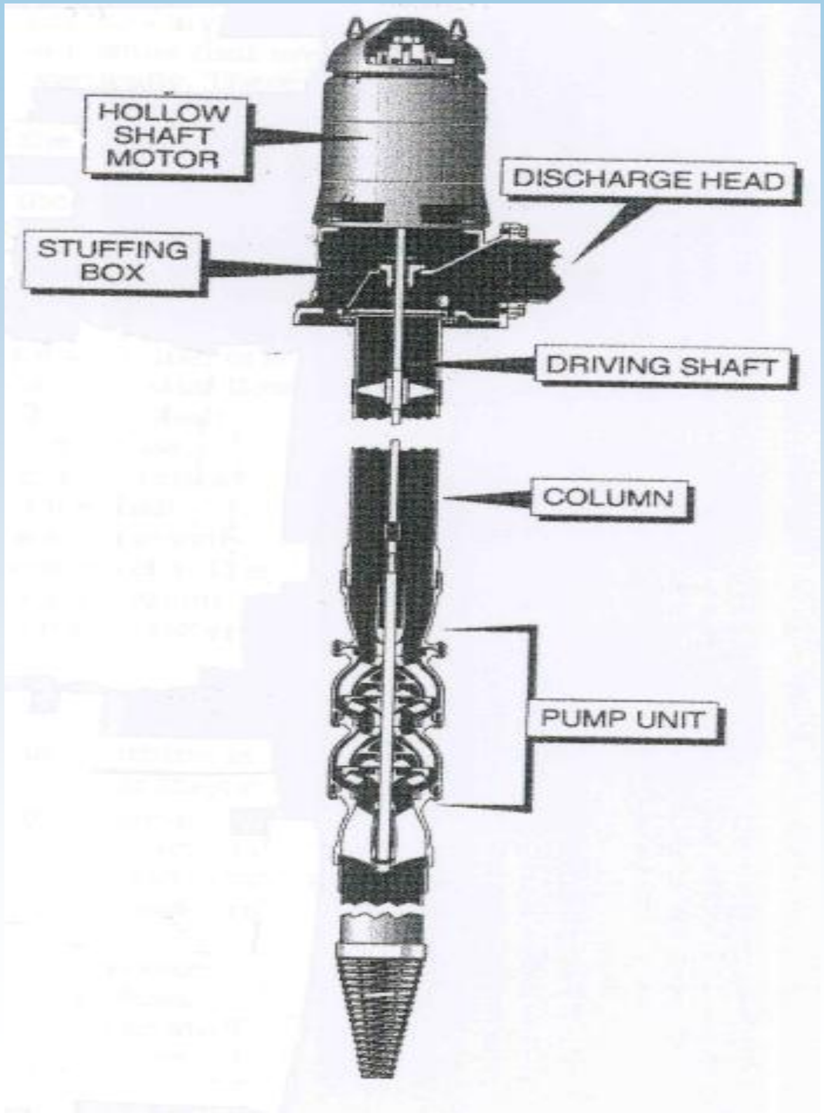
Advantages:

- Wide range of capacities and heads
- High operating efficiency

Disadvantages:

- Minimum operational speed required to cool motor and bowl assembly
- Well alignment concerns

Example Of A Lineshaft Pump



Deep Well Product Lubricated Lineshaft Pump

Water Lube Lineshaft Pump

Submersible and Lineshaft Pumps Advantages and Disadvantages

Variable	Submersible	Turbine
1. Noise	X	
2. Motor Serviceability		X
3. Initial Capital Cost		X
4. Operating Cost (Electrical)		X
5. Service Life		X
6. Flexibility (Use of Different Primer Movers)		X
7. Well Alignment Problem	X	

X Denotes Advantage

Why is Proper Well Pump Selection Important?

- Well Pump Stations Have a High Capital Cost
- Reliability
- Operational Flexibility
- Efficiency/Operational Cost

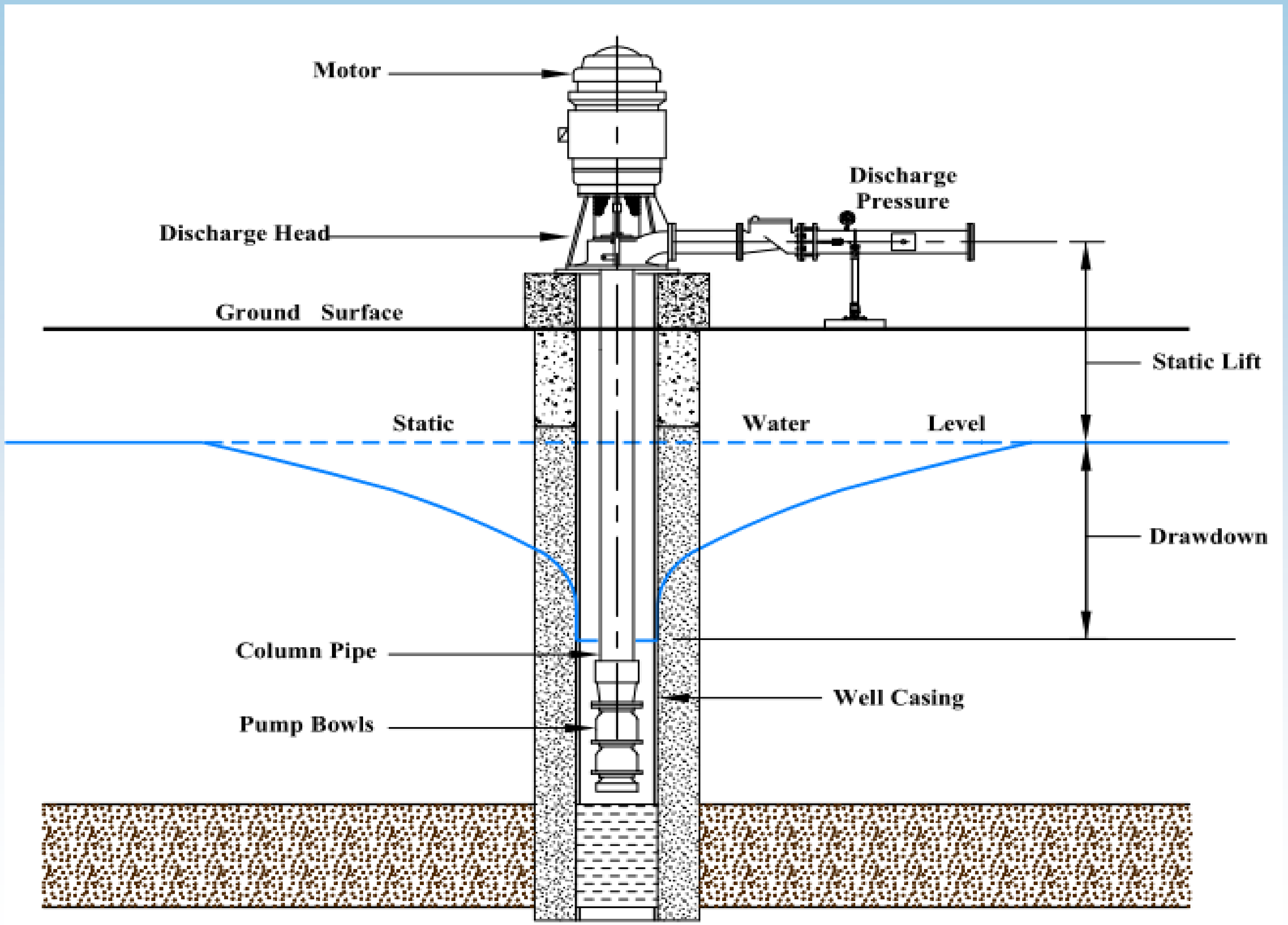
Quick Examples That illustrate Cost of Poor Pump Selection

- Inefficient Pump Example
  Cost of Mistake: $3,500/year
- Not Needed VFD Example
  Cost of Mistake: $23,000 + Ongoing $
- Saved Money on Column Pipe Example
  Cost of Mistake: $2,000 over pump life

Well/Aquifer Data Link To Pump Selection

- Water Level
- Well Design Capacity
- Well Tests/Specific Capacity
- Mutual Pumping Interference
- Well Physical Characteristics
- Well Plumbness and Alignment Tests

Typical Well Pump



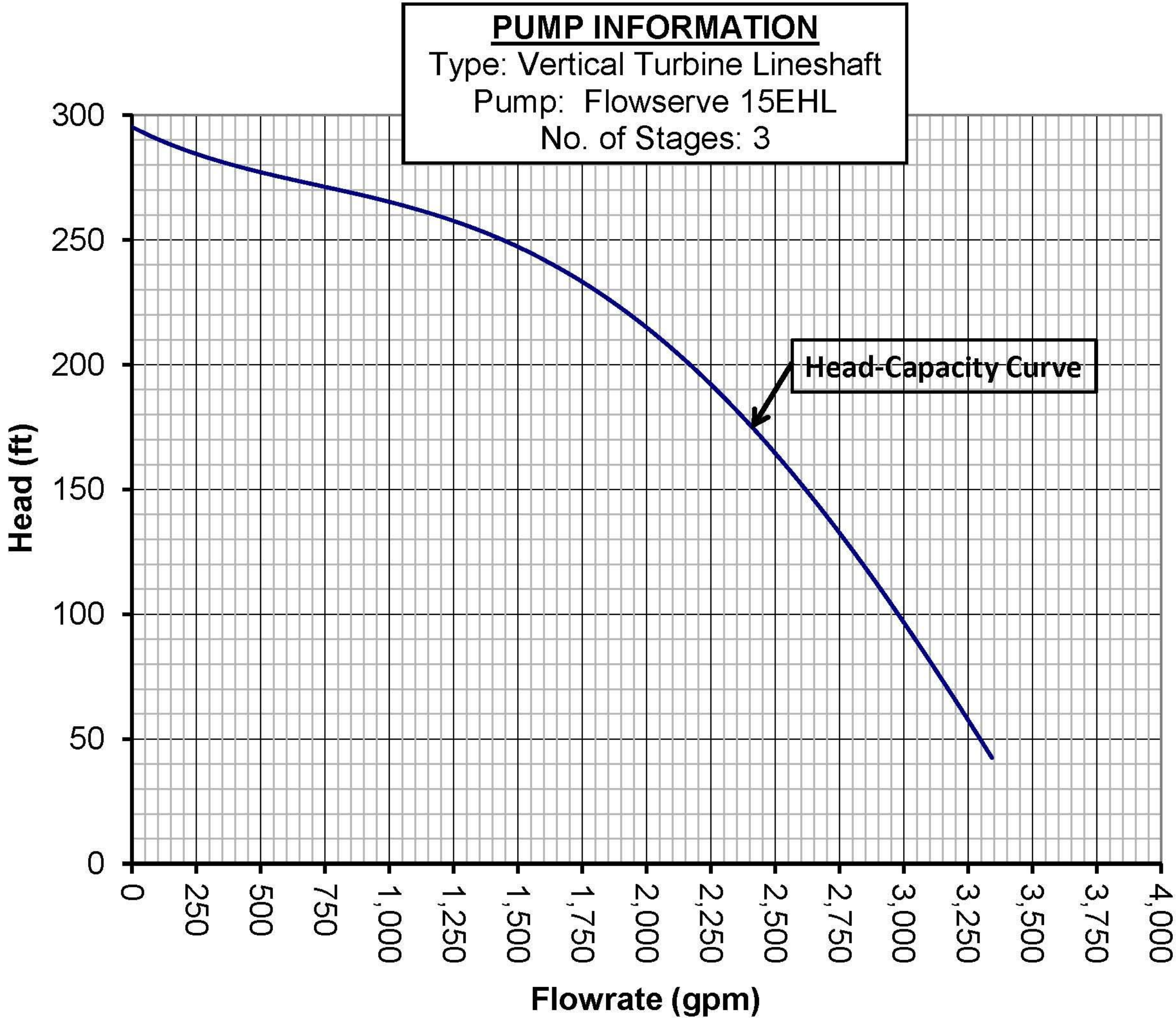
Pump Characteristics Curve

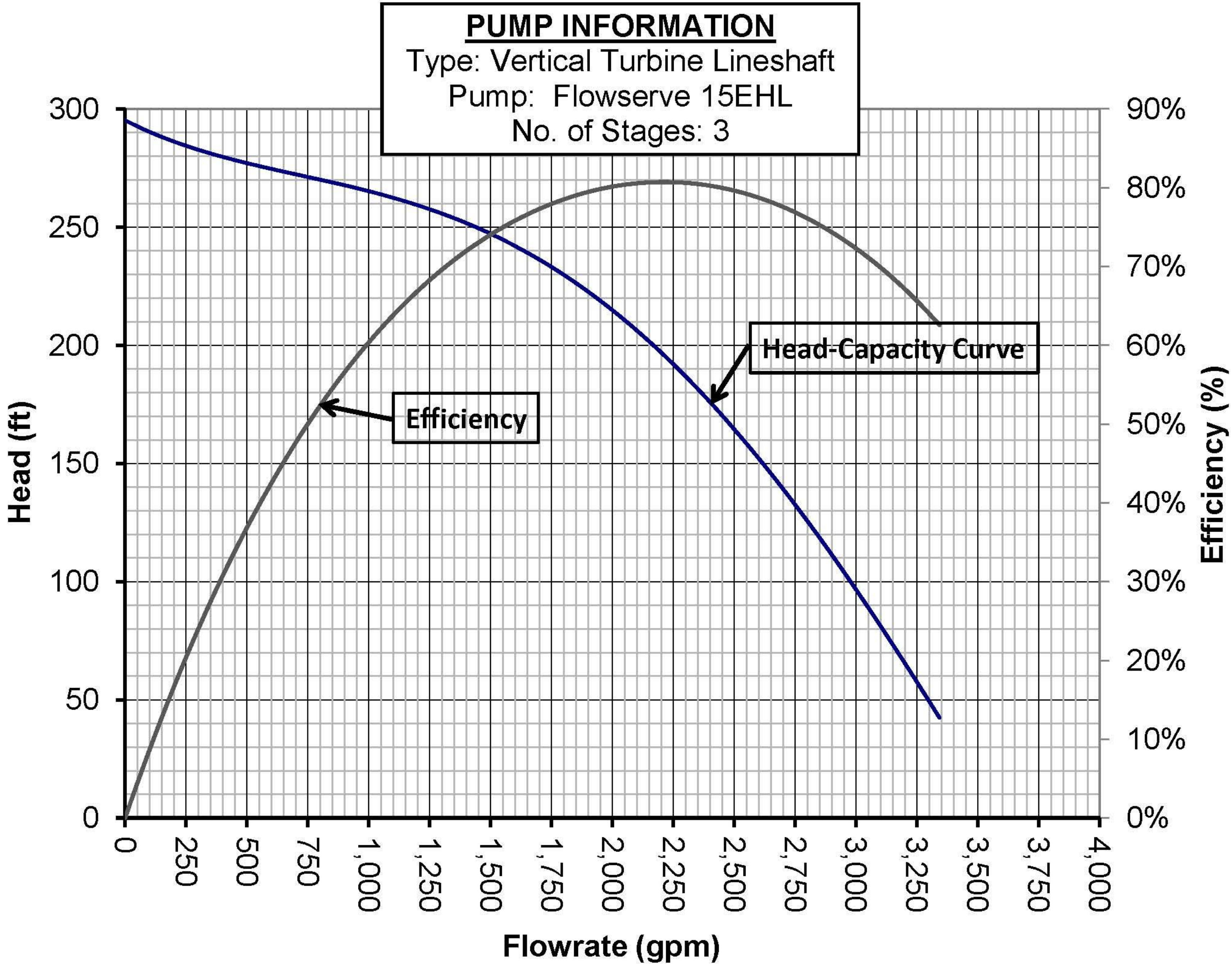
- Head-Capacity Curve
  Head developed by pump and flow passing through it

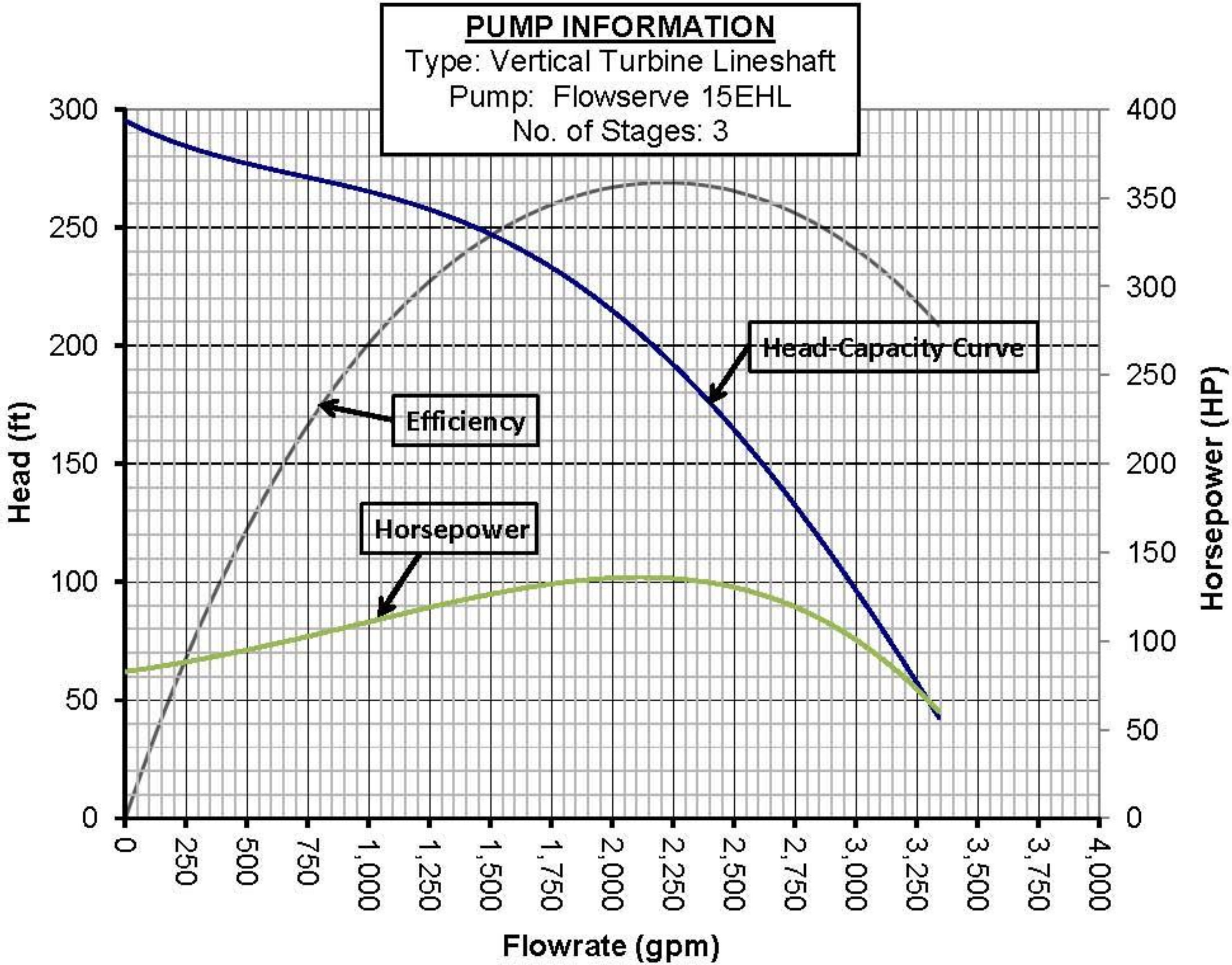
- Efficiency Curve
  A pump operates most efficiently at only one point

- Horsepower Curve
  Brake horsepower (called bowl/impeller horsepower)

- Combined Curve
  Head-Capacity, efficiency and power on the same curve


PUMP INFORMATION
Type: Vertical Turbine Lineshaft
Pump: Flowserve 15EHL
No. of Stages: 3
Head-Capacity Curve
Head (ft)
Flowrate (gpm)
300
250
200
150
100
50
0
0
250
500
750
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000


PUMP INFORMATION
Type: Vertical Turbine Lineshaft
Pump: Flowserve 15EHL
No. of Stages: 3
Head-Capacity Curve
Efficiency
Head (ft)
Efficiency (%)
Flowrate (gpm)
300
250
200
150
100
50
0
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
250
500
750
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000


PUMP INFORMATION
Type: Vertical Turbine Lineshaft
Pump: Flowserve 15EHL
No. of Stages: 3
Head (ft)
Horsepower (HP)
Flowrate (gpm)
Head-Capacity Curve
Efficiency
Horsepower
0
50
100
150
200
250
300
350
400
250
500
750
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000

Total Dynamic Head (TDH)

TDH is the total energy a pump imparts to the water for a specific flow rate

TDH of a Well Pump = Static Lift
+ Drawdown
+ Surface Discharge Head
+ Column and Discharge Head Losses

System Curves

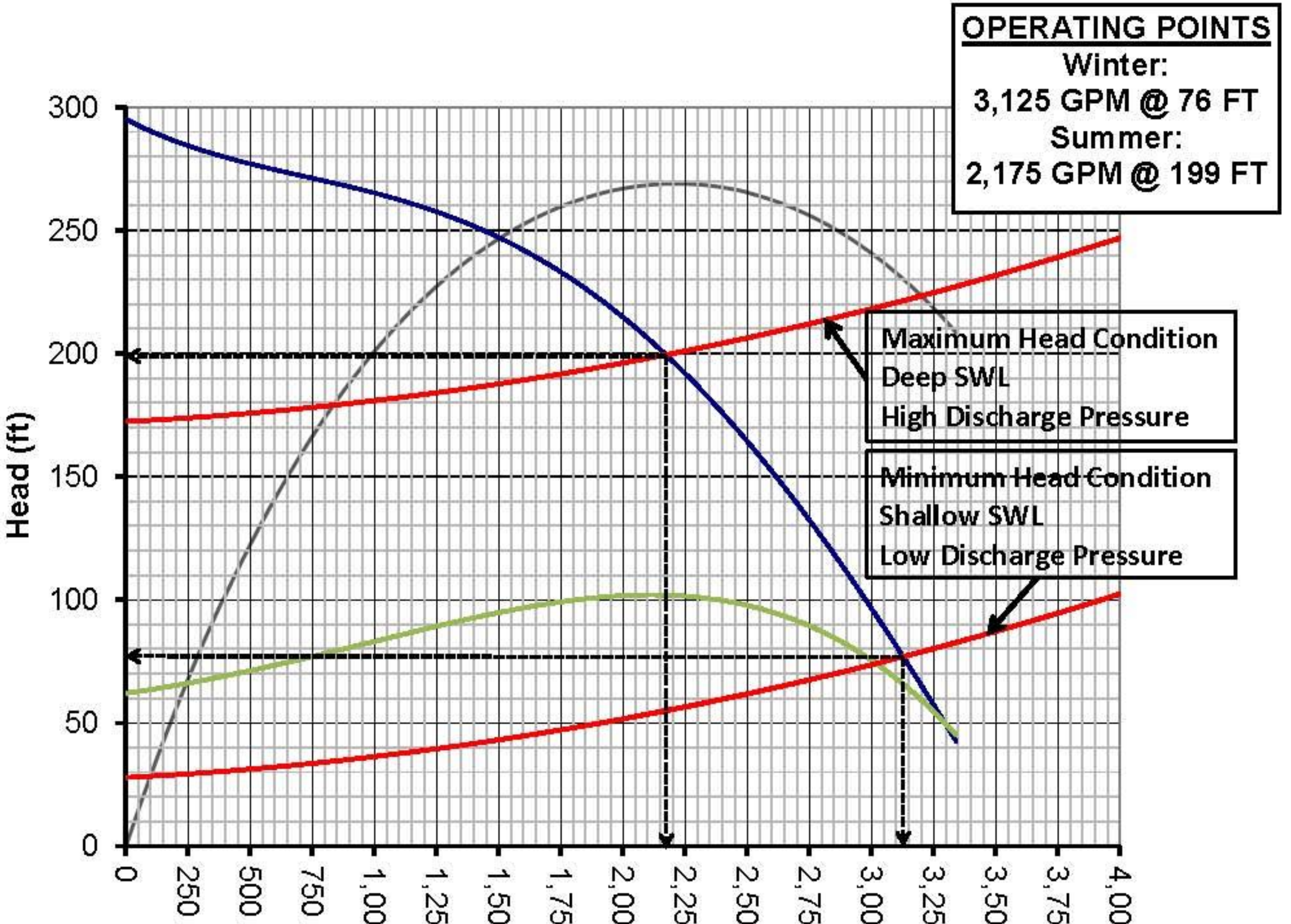
Definition: Graphical plot of the **TDH** required by the system for a change in flow rate

Used Two Ways:

- **One-point Method – Conditions Not Changing** Pump not expected to change over time (e.g., pumping from tank to reservoir)

- **Two-point Method – Pump Conditions Changing**
  (e.g., seasonal lowering of water level in well)

System Head Curve



Well Pump Acquisition

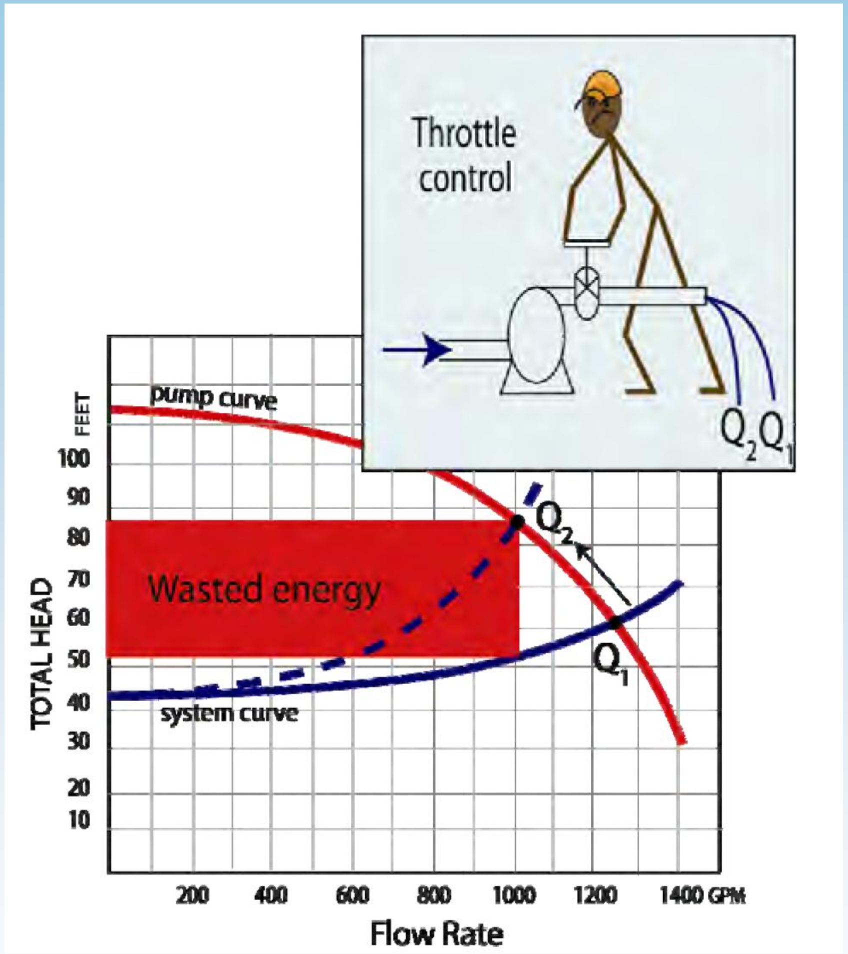
- Specify Well Pump Operation Points Using Two-point Method
- Specify Pump Supplier Provide All Pump System Appurtenances
- Require Certified Factory Curve
- Specify OPE & Vibration Testing by Independent Contractor

Variable Frequency Drive (VFD)

VFD Advantages

- Potential Power Savings
- Enhances Operational Flexibility
- Soft/Start Lowers In-rush Current & Reduces Mechanical Stress
- Reduces Chance of Water Hammer

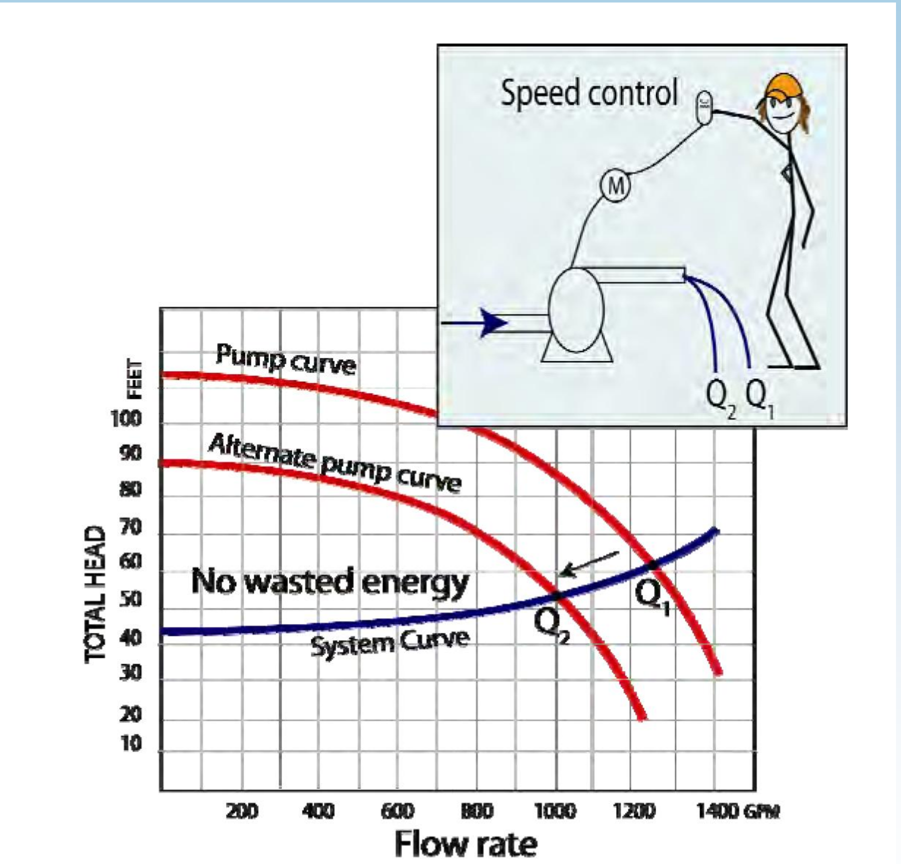
Throttle Control Is Not Efficient



Shutting Valves To Control Flow Wastes Energy

Reference: USDA ,MT-14 , January 2010

Speed Control Using VFD



Operator Controls Flow Using VFD as Opposed to Turning Valve

Reference: USDA ,MT-14 , January 2010

Affinity Laws and VFDs

Laws of affinity express mathematical relationship between flow, pump speed, head and power consumption for well pumps

$$\frac{Q1}{Q2} = \frac{N1}{N2}$$

$$\frac{H1}{H2} = \left(\frac{N1}{N2}\right)^2$$

$$\frac{BHP1}{BHP2} = \left(\frac{N1}{N2}\right)^3$$

<u>Where</u>

Q = Capacity, GPM

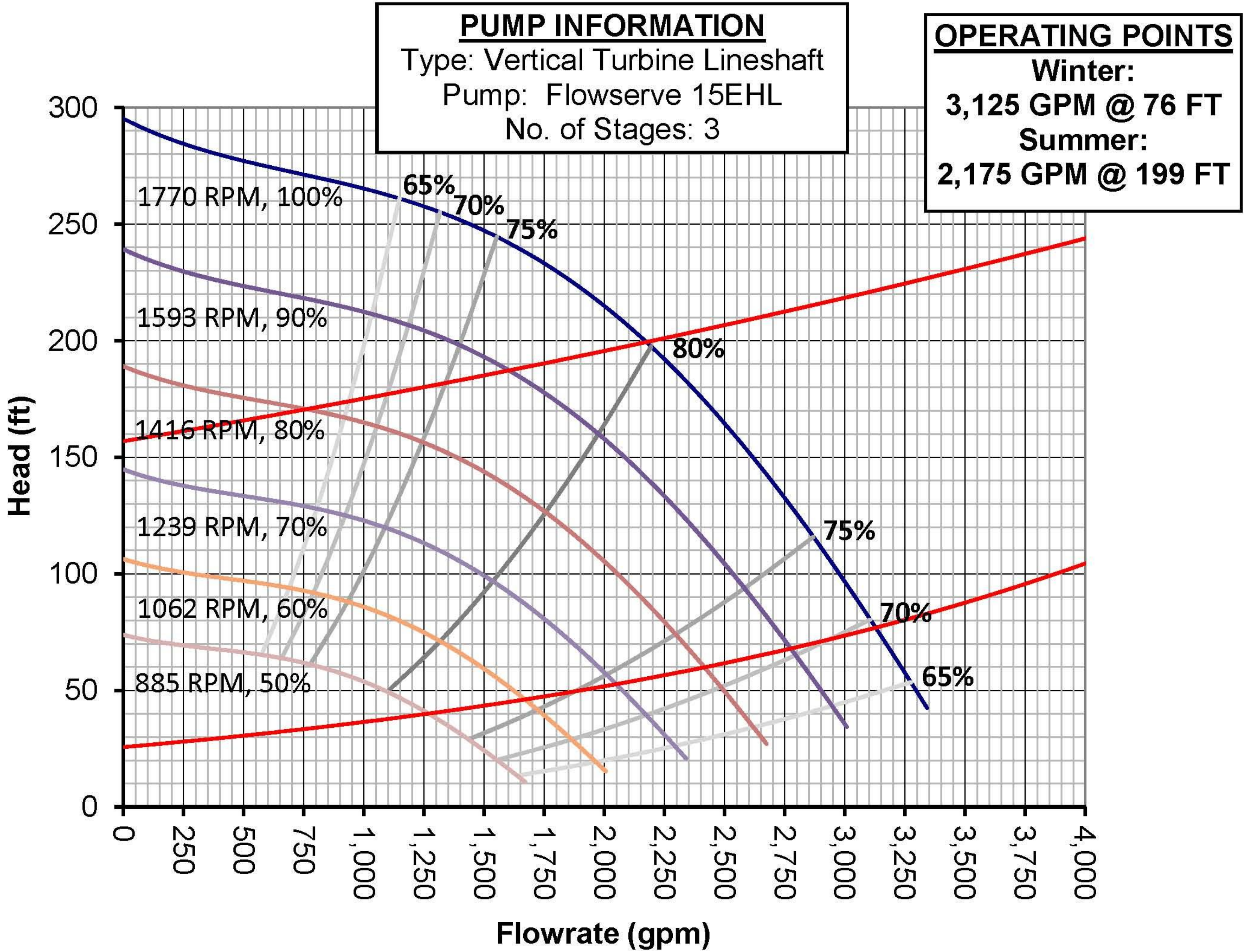
H = Total Head, Feet

BHP = Brake Horsepower

N = Pump Speed, RPM

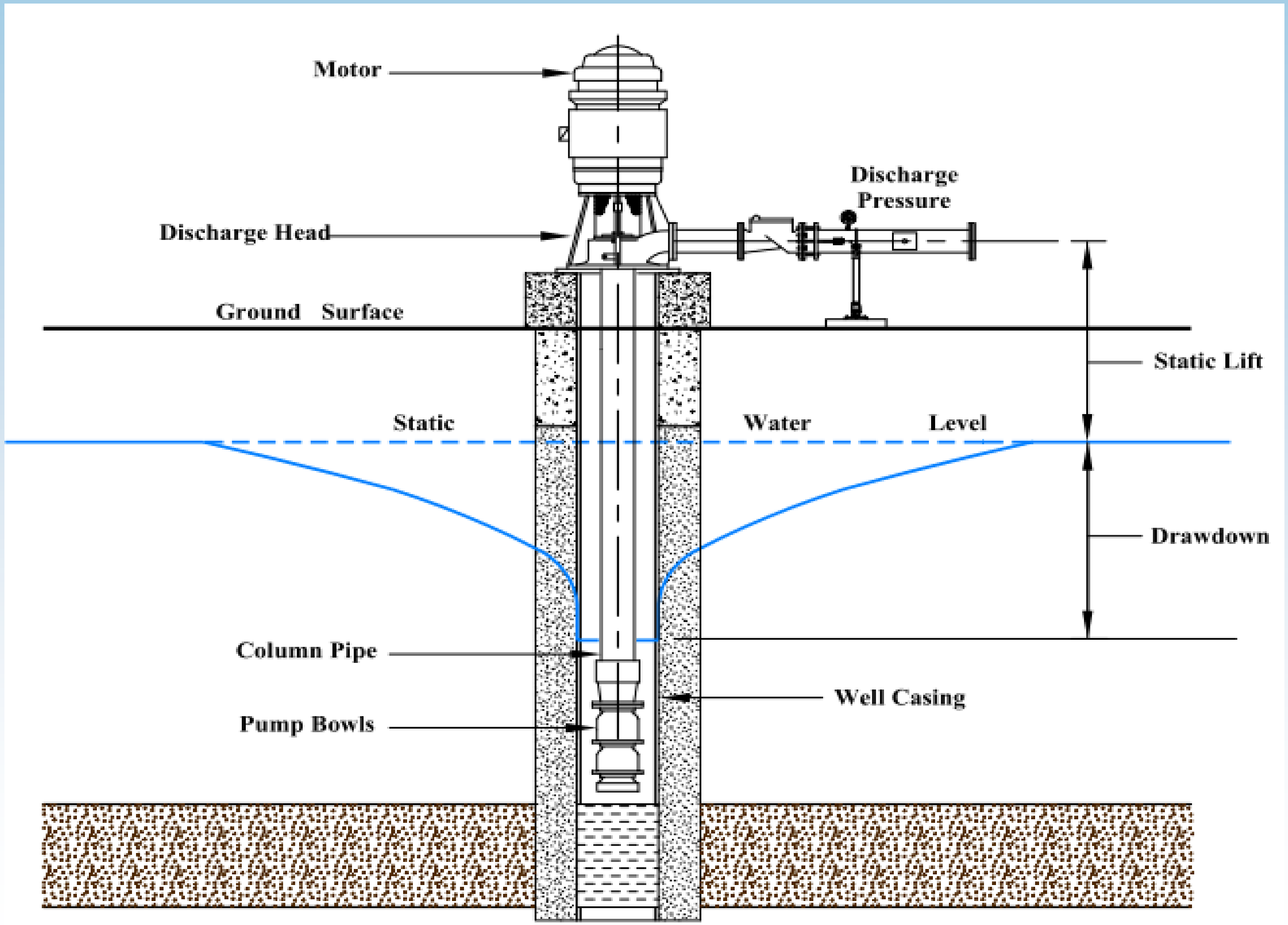
Affinity Laws and VFDs

- VFD Changes Pump Speed
- Reduce pump speed by 50%, flow reduced to 50%, head will be reduced to 25%, and power consumption will be reduced to 12.5%
- Small flow reduction can result in power reductions and hence energy consumption savings


PUMP INFORMATION
Type: Vertical Turbine Lineshaft
Pump: Flowserve 15EHL
No. of Stages: 3
OPERATING POINTS
Winter:
3,125 GPM @ 76 FT
Summer:
2,175 GPM @ 199 FT
1770 RPM, 100%
1593 RPM, 90%
1416 RPM, 80%
1239 RPM, 70%
1062 RPM, 60%
885 RPM, 50%
65%
70%
75%
80%
75%
70%
65%
Head (ft)
Flowrate (gpm)
0
50
100
150
200
250
300
0
250
500
750
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000

Working Examples

Typical Well Pump



Example TDH Calculations

Static Water Level (no pumping)	= 100 feet
Drawdown	= 30 feet
Discharge pressure	= 60 PSI
Pump bowl settling below ground	= 200 feet

800 GPM, 8” column pipe, 1.5” shaft with a type A discharge head

Find: Pump Total Dynamic Head required, TDH

Formula: TDH = Static Lift + Drawdown + Friction + Discharge Pressure

TDH Solution

Solution:

Determine the column and discharge head friction loss for a deep well turbine are determined.

Column H_f = (2.6 feet/100′) x 200 feet = 5.2 feet

Discharge head H_f for 8” Type A = 0.3 feet

TDH = Static Lift + Drawdown + Friction + Discharge Pressure

= 100′ + 30′ + (60 PSI x 2.31’/PSI) + 5.2 ft + 0.3 ft

= <u>274 feet</u>

NOTE: For a submersible well pump, the friction loss in the discharge pipe obtained using the same length of straight pipe made of the same material (no shaft or oil tube in the column pipe to cause extra friction)

Power Delivered In Three Places

Think of Power delivered in Three Places

1. The energy imparted to the water (WHP)

2. The impellers (BHP)
   (some consider BHP to include shaft also)

3. The Driver (electrical motor or engine) (IHP)

Example Water Horsepower (WHP)

$$WHP = \frac{(\text{GPM})\text{x } (\text{TDH in FEET})}{3960}$$

Where the flow rate is measured in Gallons Per Minute (GPM) and the Total Dynamic Head (TDH) is measured in feet:

Find: Water Horsepower (WHP)

Formula: WHP $= \frac{(GPM)x\ (TDH\ in\ FEET)}{3960}$

Solution: WHP $= \frac{(800\ GPM)\, x\ (274')}{3960}$

$=$ 55.4 HP

Brake Horsepower (BHP)

- Actual Power Delivered to Pump Impellers
- BHP is the Horsepower Value Printed on Pump Catalog Curves
- For Close-Coupled Pumps (i.e. submersible & booster pumps output HP = BHP)
- For Line-Shaft Well Pumps HP Includes:
  - Thrust Bearing losses or HP loss driver thrust bearing (About 1% of BHP, or 0.8% of IHP)
  - Shaft losses or HP loss from friction in line shaft bearings (About 1 BHP/100ʹ of line shaft)

Input Horsepower (IHP)

- Power Delivered to Pump Driver
- Power Actually Billed For
- Energy Consumed Units Kilowatt-Hours
- Utility Company Bills of a Meter That Allows You to Read or Calculate IHP
- Engine Driver Input Measured by Noting Volume of Fuel Consumed Over Time

Efficiencies

- Impellers Don’t Convert All Mechanical to Hydraulic Energy
  Typical: 70% (+)

- Vertical Turbine Motors Don’t Convert All Electrical to Mechanical Energy:

  - Standard Efficient: 88 – 92%
  - Premium Efficient: 93 – 96%
  - Submersibles: 83 – 87%

- Engine Drivers Don’t Convert All Input Energy (Fuel) Into Mechanical Energy

  Typical: Internal Combustion Engine = 33%

Determine Motor Size Example

Given: A well pump

Floway 10LKM at 1770 RPM, impeller trim “A”

Flow rate (Q)	=	500 GPM
Total Dynamic Head (TDH)	=	150 feet
Shaft HP Loss	=	2 HP
Thrust	=	0.5 HP

Find:

a) WHP

b) BHP

c) Required Motor Size

d) Estimated Input HP to the Pumping Plant (IHP)

e) Overall Pumping Plant Efficiency (OPE)

Find WHP

Formula: WHP = $\frac{(8Q\ in\ GPM)x\ (TDH\ in\ ft)}{3960}$

Solution: WHP = $\frac{500\ GPM\ x\ 150\ ft}{3960}$

= 18.9 HP

Find BHP

Formula: BHP = $\dfrac{WHP}{\left(\frac{Ei}{100}\right)}$

p VI-38, TDH, E_i = 78%

Solution: BHP = $\dfrac{18.9\ HP}{.78}$

= 24.3 HP

BHP From Pump Curve

One can determine the BHP directly from the pump performance curve itself.

BHP	=	8.1 per stage (impeller)
	=	8.1/stage x 3 stages
	=	**24.3 HP**

HP Output From Motor

= BHP + shaft losses + bearing losses

= 24.3 + 2.0 + 0.5

= **26.8 HP**

Service Factor: Don't Overload Motor

1. A motor should not be overloaded by more than the service factor stamped on its nameplate
2. 25 HP motor having a service factor of 1.1 should not be loaded to greater than 25 HP x 1.1 = 27.5 HP
3. If there is no service factor on the motor nameplate, then do not overload motor
4. Conclusion: In this case choosing a 25 HP motor is OK, but LSCE does not usually recommend exceeding nameplate HP

Input HP to the Motor

$$= \frac{\text{BHP} + (\text{Shaft \& Bearing Loss})}{\left(\frac{\text{Em}}{100}\right)}$$

$$= \frac{24.3 \text{ HP} + 2.5 \text{ HP}}{\left(\frac{89}{100}\right)}$$

$$= \frac{226.8 \text{ HP}}{0.89}$$

$$= \boxed{\textbf{30.1 HP}}$$

Overall Pumping Plant Efficiency

$$= \frac{WHP}{IHP} \times 100$$

$$= \frac{18.9\ HP}{30.1\ HP} \times 100$$

OPE = **63 %**

Questions