ASHRAE QATAR ORYX CHAPTER

Technical Seminar

Understanding Pumps - Sizing, Selection and Applications

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Topics of Coverage

Part 1 - Pump Terminology

1. Pump Flow Rate
2. Pump Total Head
3. Hydraulic HP and Break HP
4. System Efficiency/Power
5. Cavitation
6. NPSH

Topics of Coverage

Part 2- Introduction to Pumps

1. Pump Classification
2. Pump Types
3. Pump DNA
4. Pump Applications
5. Understanding Pump Curves
6. Pump Selections

Topics of Coverage

Part 3-Understanding Packaged Pump Stations

1. Traditional Site Built Pump Stations
2. Packaged Pump Stations
   - Brief Description
   - Applications
3. Benefits of Using Packaged Pump Stations
   - To the Owner
   - To the Engineer
   - To the Contractor
4. Constant Speed Pump Stations
   - Reality of System Demand
   - Typical System Components
   - System Limitations
   - Energy Conservation Methods

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Topics of Coverage

Part 3-Understanding Packaged Pump Stations

5. Variable Speed Systems
   - Typical System Components
   - Normal System Operation
   - True Power of Affinity Laws
   - How System Saves Energy
   - Power Consumption Comparison

Topics of Coverage

Part 4 - Pump Accessories

1. Motor Classifications
2. Motor Design
3. Motor Application
4. Couplings, guards, gauges

Part 1
Pump Terminology

Pump Terminology

Pump Flow Rate

Capacity – Because liquids are essentially incompressible, there is a direct relationship between the capacity in a pipe and the velocity of flow.

$$Q = A \times V \quad \text{OR} \quad V = \frac{Q}{A}$$

Where

Q = capacity in gpm

V = Velocity of flow in Ft/Sec

A = Area of pipe or conduit in Sq.Ft.

Pump Flow – The pump flow rate is typically a calculated figure of the total demand of a building taking into consideration all of the fixture units. It is expressed as a unit of volume per increment of time. The US units is GPM. Other units of flow include Lit/Sec, M3/Hr, IGPM.

Pump Terminology

Pump Total Head

Total Dynamic Suction Lift (Hl) – Is the static suction lift minus the velocity head at the pump suction flange plus the total friction head in the suction line.

Total Dynamic Suction Head (Hs) – **I**s the static suction head plus the velocity head at the pump suction minus the total friction head in the suction line.

Total Dynamic Discharge Head (Hd) – Is the static discharge head plus the velocity head at the pump discharge flange plus the total friction head in the discharge line.

Total Head or formerly TDH (H) – Is the total dynamic discharge head minus the total dynamic suction head or plus the total dynamic suction lift.

H or TDH = Hd + Hs (with a suction lift)

H or TDH = Hd – Hs (with a suction head)

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Pump Terminology

Pump Total Head

With Suction Lift

TDH = Hd + Hs

(Hst + Hf) + (Hl + Hf)

With Suction Head

TDH = Hd – Hs

(Hst + Hf) + (Hsu –Hf)

Note: Keep in mind that the friction head includes all friction losses in pipes and plus any equipment pressure drop (ΔP), such as valves, strainers, heat exchangers, etc…

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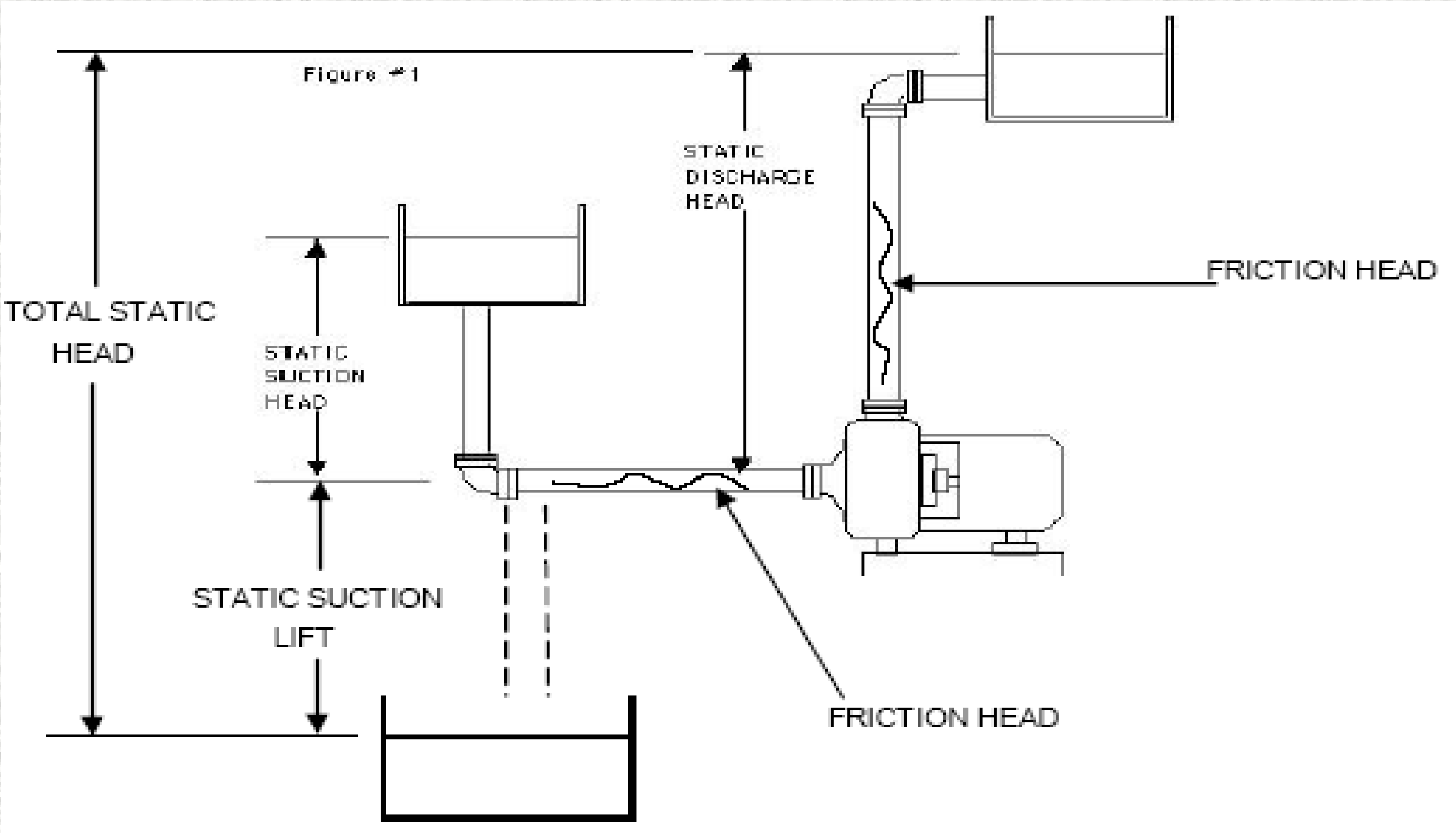
Pump Terminology

Pump Total Head



Pump Terminology

Pump Total Head

Keep in mind that friction losses through pipes and fittings can be obtained directly from tables in several publications, including HI standards.

4"									
	IRON / STEEL Schedule 40			PLASTIC Schedule 40			COPPER Type M		
US GPM	Vel. Ft./ Sec.	Vel. Hd. Ft.	Head Loss Ft./ 100'	Vel. Ft./ Sec.	Vel. Hd. Ft.	Head Loss Ft./ 100'	Vel. Ft./ Sec.	Vel. Hd. Ft.	Head Loss Ft./ 100'
100	2.5	0.1	0.6	2.5	0.1	0.6	2.6	0.1	0.8
110	2.8	0.1	0.7	2.8	0.1	0.7	2.9	0.1	1.0
120	3.0	0.1	0.9	3.0	0.1	0.8	3.2	0.1	1.2
130	3.3	0.2	1.0	3.3	0.2	0.9	3.4	0.2	1.3
140	3.5	0.2	1.2	3.5	0.2	1.1	3.7	0.2	1.5
150	3.8	0.2	1.3	3.8	0.2	1.2	4.0	0.3	1.7
160	4.0	0.3	1.5	4.0	0.3	1.4	4.2	0.3	1.9
170	4.3	0.3	1.7	4.3	0.3	1.5	4.5	0.3	2.2
180	4.5	0.3	1.9	4.5	0.3	1.7	4.7	0.4	2.4
190	4.8	0.4	2.1	4.8	0.4	1.9	5.0	0.4	2.7
200	5.0	0.4	2.3	5.0	0.4	2.1	5.3	0.4	2.9
220	5.5	0.5	2.7	5.5	0.5	2.4	5.8	0.5	3.5
240	6.1	0.6	3.2	6.1	0.6	2.9	6.3	0.6	4.1
260	6.6	0.7	3.7	6.6	0.7	3.3	6.9	0.7	4.8
280	7.1	0.8	4.3	7.1	0.8	3.9	7.4	0.9	5.5
300	7.6	0.9	4.9	7.6	0.9	4.4	7.9	1.0	6.2
320	8.1	1.0	5.5	8.1	1.0	4.9	8.4	1.1	7.0
340	8.6	1.1	6.2	8.6	1.1	5.5	9.0	1.3	7.8
360	9.1	1.3	6.9	9.1	1.3	6.2	9.5	1.4	8.7
380	9.6	1.4	7.7	9.6	1.4	6.6	10.0	1.6	9.7
400	10.1	1.6	8.5	10.1	1.6	7.5	10.5	1.7	10.6

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Pump Terminology

Hydraulic HP and Break HP

Horsepower = Work performed in pumping

The work performed in pumping a liquid depends on the weight of the liquid being handled in a given time against the total head (in feet of liquid) or differential pressure (in psi) being developed and its S.G..

Since one HP equals 33,000 ft lb per minute, the theoretical HP (usually called the hydraulic HP) will equal:

$$\text{Hyd HP} = \frac{\text{Lb of Liquid/min} \times \text{H (ft)}}{33{,}000}$$

However, the engineering community typically use pump capacity in GPM and the liquid S.G. rather than the actual weight of the liquid pumped. If we do this the hydraulic HP or pump output (Whp) is the liquid HP delivered by the pump. It is defined by the following formula:

$$\text{Whp} = \frac{\text{Q (gpm)} \times \text{H (ft)} \times \text{S.G.}}{3960}$$

Note: The constant 3960 is obtained by dividing the number of foot pounds for one HP (33,000) by the weight of one gallon of water (8.33 pounds).

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Pump Terminology

Hydraulic HP and Break HP

Break HP or pump input HP (Bhp) is the actual HP delivered to the pump shaft. It is expressed by the following formula:

$$Bhp = \frac{Q\ (gpm) \times H\ (ft) \times S.G.}{3960 \times Pump\ Eff.}$$

The break HP or input to a pump is greater than hydraulic HP or output due the mechanical and hydraulic losses developed inside the pump. Therefore, the pump efficiency is the ratio of these two values:

$$Pump\ Eff. = \frac{output}{input} = \frac{Whp}{Bhp}$$

Pump Terminology

System Efficiency

Input HP is the general term used to indicate the power required at the control panel. It is the pump Bhp divided by the motor efficiency. It is expressed in the following formula:

Electrical HP Input to Motor = $\frac{\text{Bhp}}{\text{Motor Eff.}}$ or **KW Input** = $\frac{\text{Bhp x 0.746}}{\text{Motor Eff.}}$

Field Efficiency or Overall Efficiency = $\frac{\text{Water HP}}{\text{BHP}}$ or Pump Eff. X Motor Eff.

Overall Plant Efficiency* = $\frac{\text{Whp}}{\text{Input HP}}$

* Overall plant efficiency is sometimes referred to as "wire to water" efficiency.

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Pump Terminology

Cavitation

Cavitation is a phenomenon of vapor bubbles collapsing as they go from low pressure to high pressure region inside the pump. These bubbles are formed when liquid enters the impeller eye and encounters a sudden decrease in pressure, which in turn causes an increase in the liquid temperature. If the vapor pressure falls below the corresponding liquid temperature, pockets of vapor will be created.

To prevent cavitation, do not select pumps:

1. On the left hand side of the curve (less than 20% of flow at BEP).
2. On the right hand side of the curve (no more than 85% of the maximum flow at the end of the curve).
3. NPSHa should always be larger than NPSHr.
4. Speeds higher than the manufacturer's recommendation.

Pump Terminology

NPSH

The Net Positive Suction Head is the total suction head in feet of liquid being pumped less the absolute vapor pressure (in feet) of the liquid being pumped, less the friction losses. NPSH has two values that must always be considered: NPSHr and NPSHa.

NPSHr = Net positive suction head required by the pump. It is a function of the pump design. It is a calculated figure by the pump manufacturer typically shown on the pump curve.

NPSHa = Net positive suction head available is a function of the system. In practical terms, it is the energy available at the impeller eye. It is a calculated figure for any system based on the following formula:

Pump Terminology

NPSH

NPSHa = Ha –Hvp – Hf -/+ Hst where

Ha = Absolute pressure (in feet) on the surface of the liquid supply level. In case of an open tank, this is usually barometric pressure at sea level. In a closed tank, it is the absolute pressure. At sea level, it is 14.5psi.

Hvp = The head in feet corresponding to the vapor pressure of the liquid at the pumped temperature. In an open tank, this value is always zero.

Hst = Static height in feet of the free liquid level from the supply source. The value is a plus if the liquid is above the pump and a minus if it is below the pump.

Hf = All suction line losses (in feet) including friction losses in pipes, fittings and equipment.

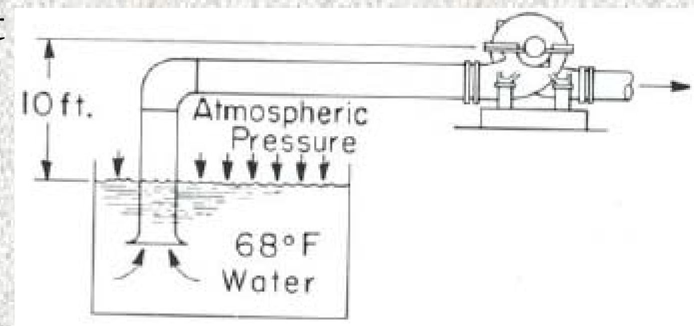
Note: NPSHa must always be greater than NPSHr by at least 1m.

Pump Terminology

NPSH Examples

Example 1: water at 68^0 F, Hst=10Ft, Ha=33.96, Hf=2.92Ft
Hvp=0.783Ft
Ha = 14.696psia x 2.31 = 33.96Ft abs.
Hf = friction through suction pipe = 2.92Ft
Hvp = vapor pressure of water at 68^{0}F = 0.339psia x 2.31 = 0.783 Ft abs.

NPSHa = 33.96 – 0.783 – 10 – 2.92 = 20.26Ft



Suction Lift = 10 + 2.92 = 12.92
This should be added to the discharge
Head to obtain total head.

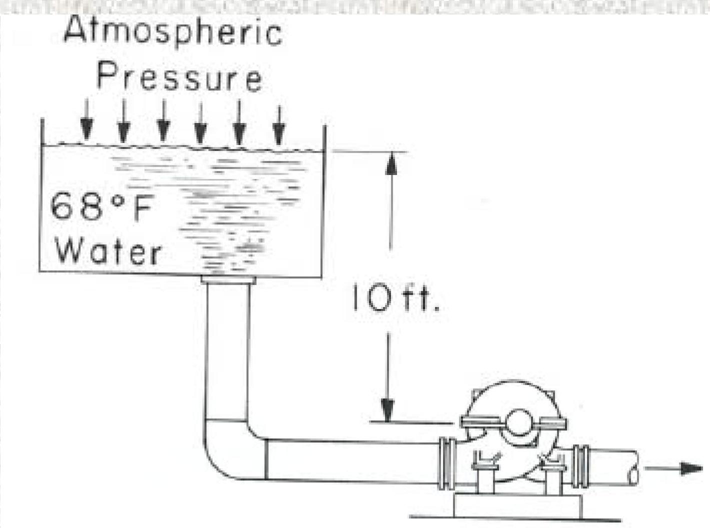
Pump Terminology

NPSH Examples

Example 2: water at 68⁰ F, Hst=10Ft, Ha=33.96, Hf=2.92Ft
Hvp = 0.783Ft
Ha = 14.696psia x 2.31 = 33.96Ft abs.
Hf = friction through suction pipe = 2.92Ft
Hvp = vapor pressure of water at 68⁰F = 0.339psia x 2.31 = 0.783 Ft abs.

NPSHa = 33.96 – 0.783 + 10 – 2.92 = 40.26Ft

Suction Head = 10 - 2.92 = 7.08Ft
This should be subtracted from the Discharge Head to obtain Total Head.



Pump Terminology

NPSH Examples

Example 3: water at 212^0 F, Hst=10Ft, Ha=35.38, Hf=2.92Ft
In this case, we have a vapor pressure to consider. Vapor pressure of water in feet at 212^0 F is (14.96psi x 144 / 59.81 = 35.38
NPSHa = 35.38 – 35.38 +10 – 2.92 = 7.08 Ft

In this case atmospheric pressure does not add to NPSHa since It is required to keep the water in liquid phase.

Suction Head = 10 – 2.92 = 7.08Ft
This should be subtracted from the Discharge head to obtain Total Head.

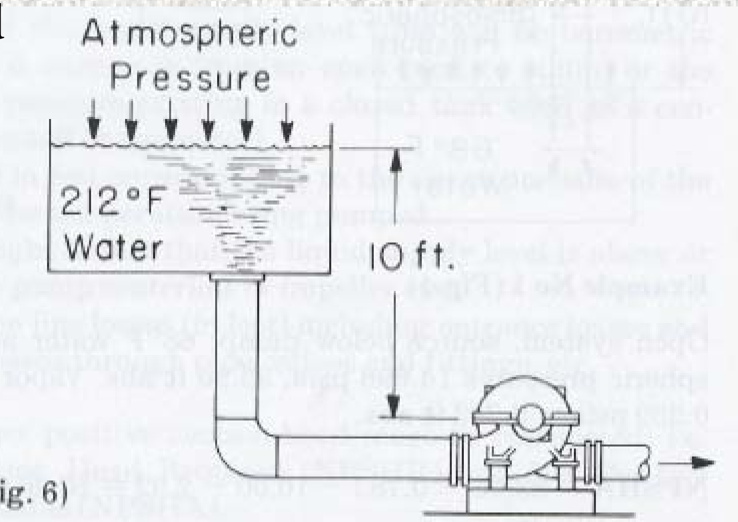


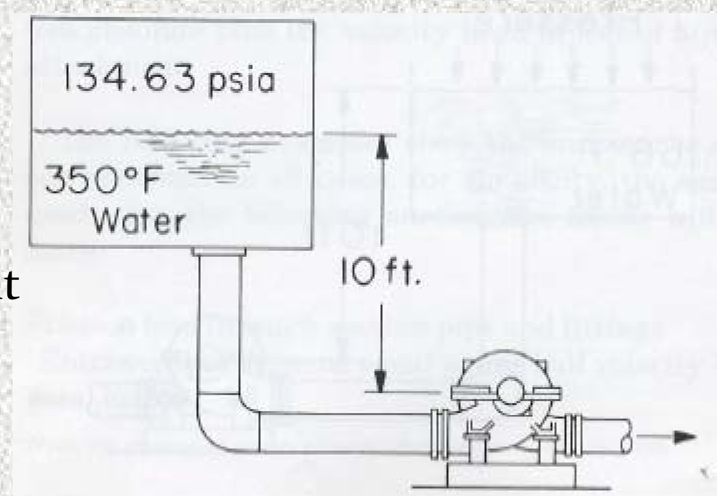
Fig. 6)

Pump Terminology

NPSH Examples

Example 4: water at 350^0 F, Hst=10Ft, Hvp=348.67Ft, Hf=2.92Ft
In this case, we have a vapor pressure to consider. Vapor pressure of water in feet at 350^0 F is (134.6psia x 2.31/0.89) = 348.67
NPSHa = 348.67 – 348.67 +10 – 2.92 = 7.08 Ft

Suction Head
Assume the gauge pressure reading is 119psig = (119 x 2.31 / 0.89) = 308.8Ft
Suction Head = 308.8+10–2.92 = 315.8Ft
This is to be subtracted from the disch. Head to obtain Total Head. It is important to note that while the Suction Head is 315.8Ft, the NPSHa is still only 7.08Ft



Part 2
Introduction to Pumps

Introduction to Pumps

Pump Classifications

Centrifugal Pumps

Centrifugal Pumps utilize centrifugal force to transfer liquid from point A to point B. The amount of head that a pump can deliver is limited to the impeller diameter. UOM = Head (feet, meters, Bar)

Positive Displacement

PD Pumps work against system resistance. They deliver a certain volume per revolution against variable system pressure. The discharge must always have a relief valve. UOM = Pressure (PSI, Bar)

Introduction to Pumps

Pump Classifications

Examples of Pump Types

- Centrifugal Pumps

  End suction, split case, VMS, Vertical turbine, Inline, Submersible sewage, self-priming, horizontal multi-stage, etc…

- Positive Displacement

  Gear, vane, piston, air operated diaphragm, rotary lobe, peristaltic, screw, progressing cavity, metering, etc…

Introduction to Pumps

Pump Types

End Suction Pumps

Also known as radially split case pumps. Two basic types:

- Close coupled
- Frame mounted

Close coupled pumps are so named because the pump parts are mounted directly on the motor shaft. Because of that, there is a limit on the size of these pumps. They are mainly used in areas where space comes at a premium. They are typically selected for small flow low head applications.

Introduction to Pumps

Pump Types

centrifugal pumps nomenclature

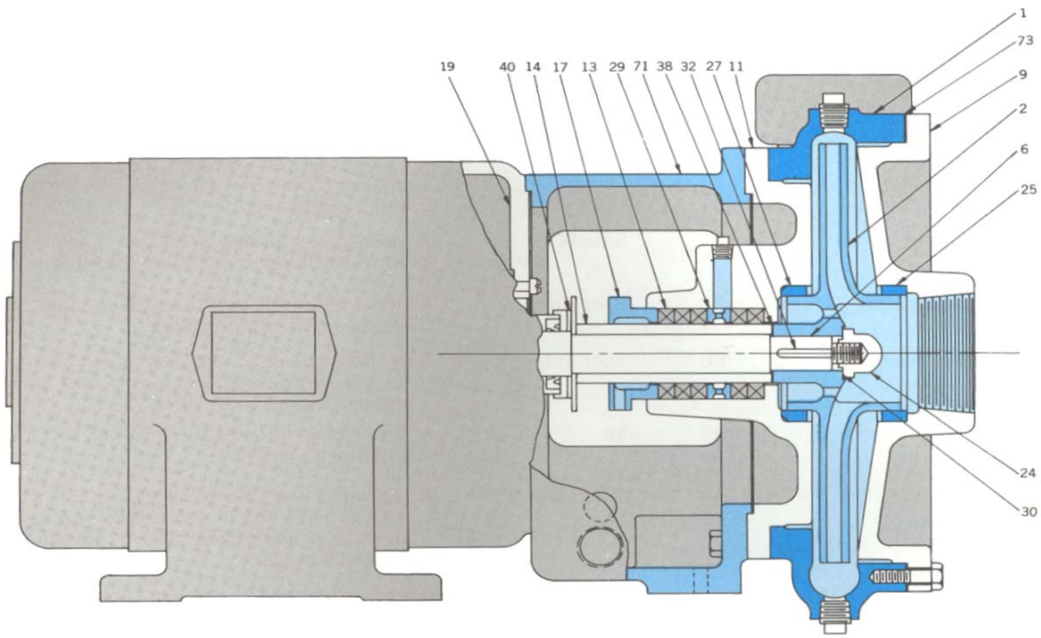


Fig. 6 OVERHUNG IMPELLER, CLOSE COUPLED, SINGLE STAGE, END SUCTION

1	Casing
2	Impeller
6	Shaft
9	Cover, Suction
11	Cover, Stuffing Box
13	Packing
14	Sleeve, Shaft
17	Gland
19	Frame
24	Nut, Impeller
25	Ring, Suction Cover
27	Ring, Stuffing Box Cover
29	Ring, Lantern
30	Gasket, Impeller Nut
32	Key, Impeller
38	Gasket, Shaft Sleeve
40	Deflector
71	Adapter
73	Gasket

The numbers shown on this drawing *do not* necessarily represent standard part numbers in use by any manufacturer.

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Introduction to Pumps

Pump Types

End Suction Pumps

Frame mounted pumps have the same liquid end as a close coupled pump with the addition of a bearing frame. They are available in larger sizes with higher flows and heads. Most manufacturer's offer pumps with back pull-out design to facilitate maintenance.

Introduction to Pumps

Pump Types

centrifugal pumps nomenclature

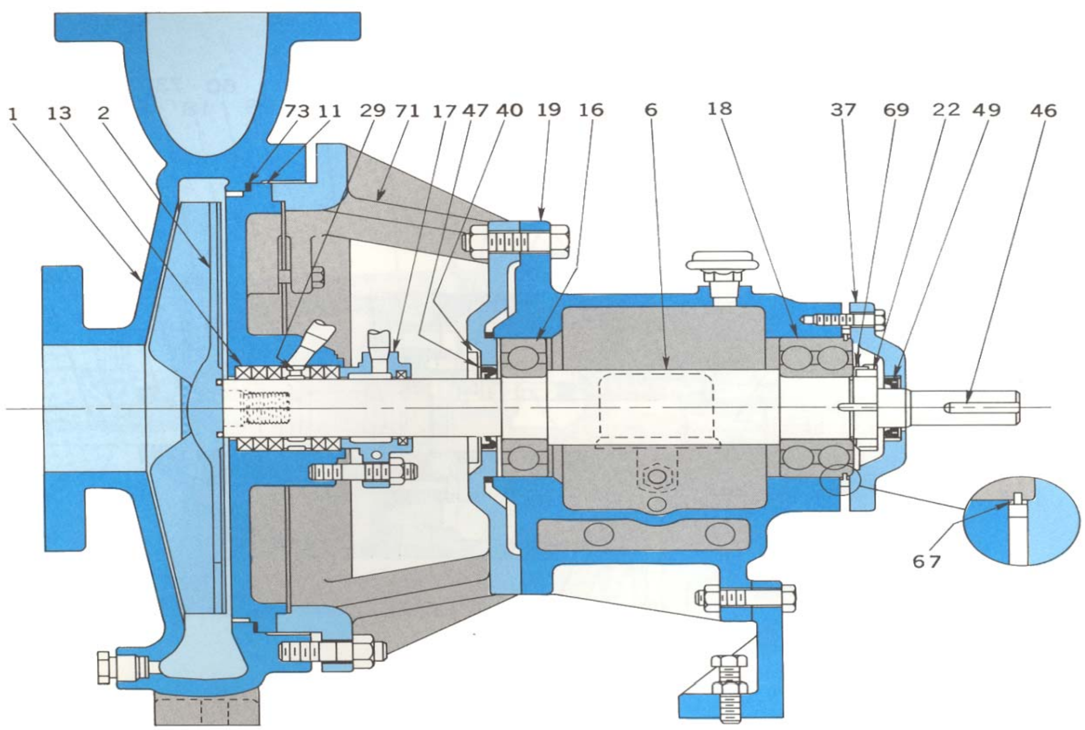

Fig. 14 OVERHUNG IMPELLER, SEPARATELY COUPLED, SINGLE STAGE, FRAME MOUNTED, ANSI B73.1

1	Casing
2	Impeller
6	Shaft, Pump
11	Cover, Stuffing Box
13	Packing
16	Bearing, Inboard
17	Gland
18	Bearing, Outboard
19	Frame
22	Locknut, Bearing
29	Ring, Lantern
37	Cover, Bearing, Outboard
40	Deflector
46	Key, Coupling
47	Seal, Bearing Cover, Inboard
49	Seal, Bearing, Cover, Outboard
67	Shim, Frame Liner
69	Lockwasher
71	Adapter
73	Gasket

The numbers shown on this drawing *do not* necessarily represent standard part numbers in use by any manufacturer.

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Introduction to Pumps

Pump Types

Horizontal Split Case Pumps

These pumps are also known as axially split case pumps. They are commonly referred to as "in between bearing design". They are mainly used for large flow and relatively large head applications. These pumps are the best horizontal pumps available in the market offering long trouble free life. They are also very easy to maintain.

Introduction to Pumps

Pump Types

centrifugal pumps
nomenclature

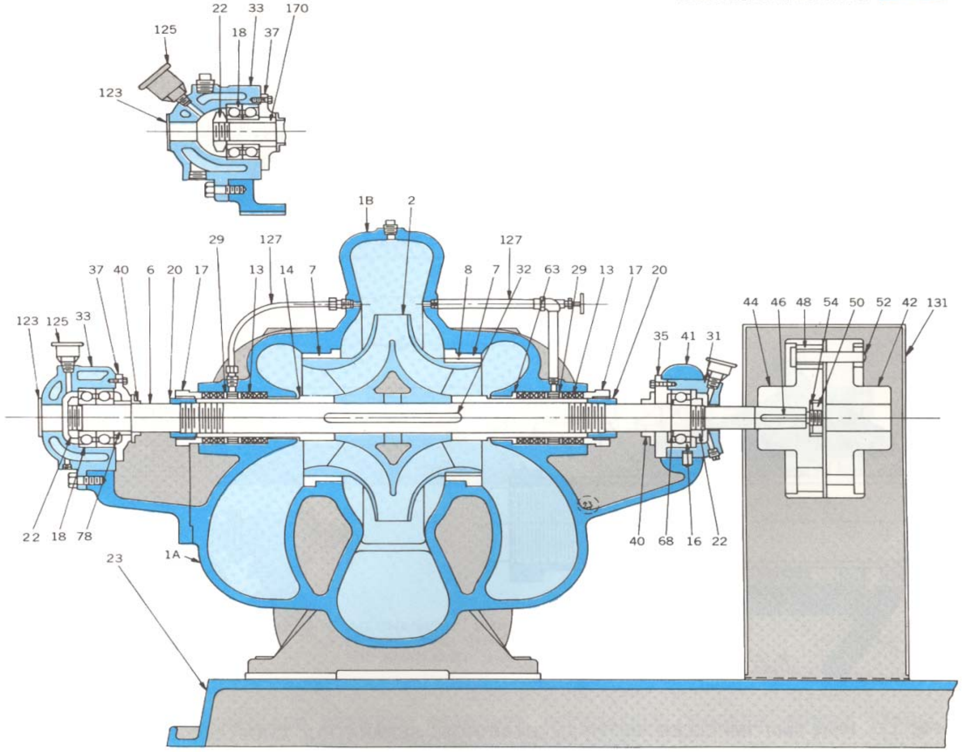

Fig. 17 (Part One) IMPELLER BETWEEN BEARINGS, SEPARATELY COUPLED, SINGLE STAGE AXIAL (HORIZONTAL) SPLIT CASE

1A	Casing, Lower Half
1B	Casing, Upper Half
2	Impeller
6	Shaft, Pump
7	Ring, Casing
8	Ring, Impeller
13	Packing
14	Sleeve, Shaft
16	Bearing, Inboard
17	Gland
18	Bearing, Outboard
20	Nut, Shaft Sleeve
22	Locknut
23	Base Plate
29	Ring, Lantern
31	Housing, Bearing, Inboard
32	Key, Impeller
33	Housing, Bearing, Outboard
35	Cover, Bearing, Inboard
37	Cover, Bearing, Outboard
40	Deflector
41	Cap, Bearing, Inboard
42	Coupling Half, Driver
44	Coupling Half, Pump
46	Key, Coupling
48	Bushing, Coupling
50	Locknut, Coupling
52	Pin, Coupling
54	Washer, Coupling
63	Bushing, Stuffing Box
68	Collar, Shaft
78	Spacer, Bearing
123	Cover, Bearing End
125	Cup, Grease
127	Piping, Seal
131	Guard, Coupling
170	Adapter, Bearing

The numbers shown on this drawing *do not* necessarily represent standard part numbers in use by any manufacturer.

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Introduction to Pumps

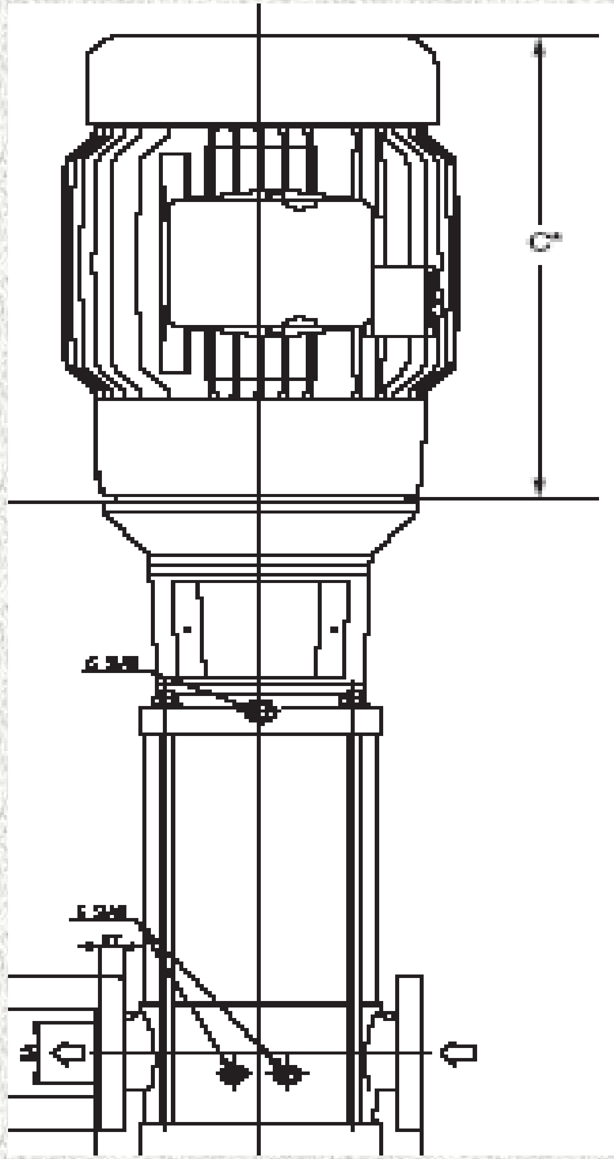
Pump Types

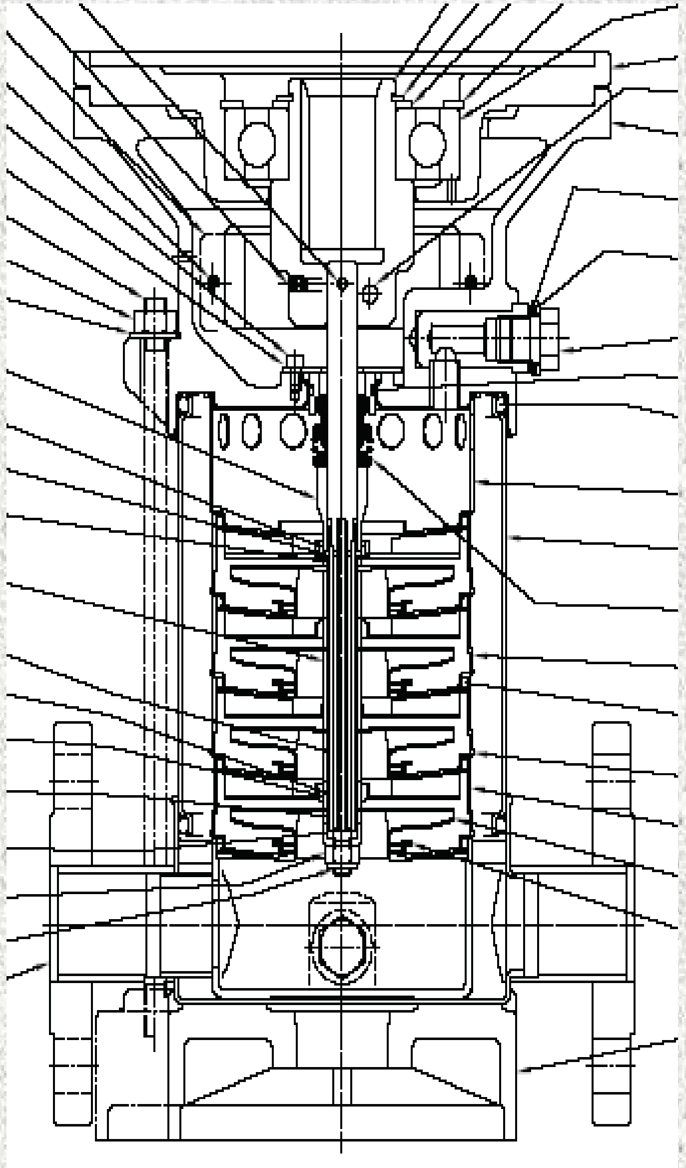
Vertical Multi-stage Pumps

These pumps are mainly used for low flow high head applications or where space saving is a priority. The stamped SS pumps are the most common type of pump sold in the market place. However, this design is not very rugged as these pumps tend to be throw-away pumps. Cast pumps are preferred as they have a longer life and can be easily repaired.

Introduction to Pumps

Pump Types





Introduction to Pumps

Pump Types

Vertical Turbine Pumps

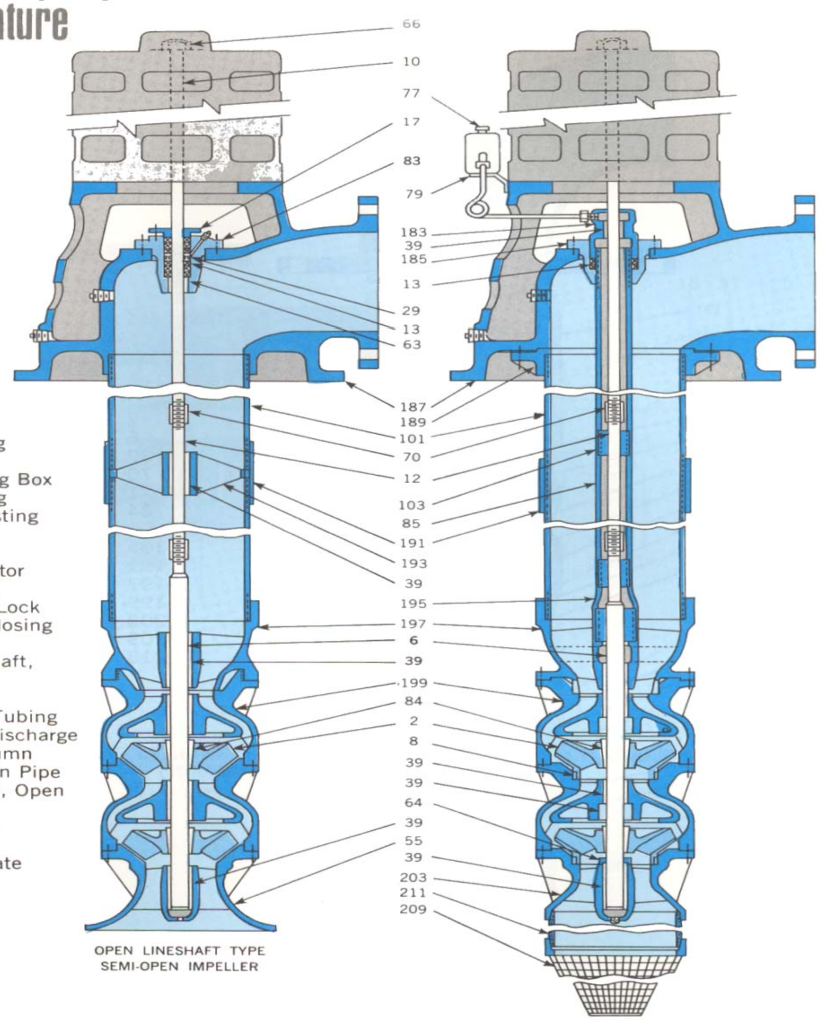
These pumps are mainly used for medium and high flow at high head applications. They are the best designed most flexible vertical pump available in the market. They are made from variety of materials and configurations to suit almost any application.

A variation of this pump is the submersible well pump. This pump has the same bowl assembly as a line shaft pump, but uses a submersible motor as the driver.

Introduction to Pumps

Pump Types

centrifugal pumps nomenclature



OPEN LINESHAFT TYPE
SEMI-OPEN IMPELLER

ENCLOSED LINESHAFT TYPE
ENCLOSED IMPELLER

2	Impeller
6	Shaft, Pump
8	Ring, Impeller
10	Shaft, Head
12	Shaft, Drive
13	Packing
17	Gland
29	Ring, Lantern
39	Bushing, Bearing
55	Bell, Suction
63	Bushing, Stuffing Box
64	Collar, Protecting
66	Nut, Shaft Adjusting
70	Coupling, Shaft
77	Lubricator
79	Bracket, Lubricator
83	Stuffing Box
84	Collet, Impeller Lock
85	Tube, Shaft Enclosing
101	Pipe, Column
103	Bearing, Line Shaft, Enclosed
183	Nut, Tubing
185	Plate, Tension, Tubing
187	Head, Surface Discharge
189	Flange, Top Column
191	Coupling, Column Pipe
193	Retainer Bearing, Open Lineshaft
195	Adapter, Tubing
197	Case, Discharge
199	Bowl, Intermediate
203	Case, Suction
209	Strainer
211	Pipe, Suction

Fig. 22 TURBINE TYPE, VERTICAL, MULTI-STAGE, DEEP WELL

The cross sectional drawings illustrate the largest possible number of parts in their proper relationship and a few construction modifications but *do not* necessarily represent recommended design.

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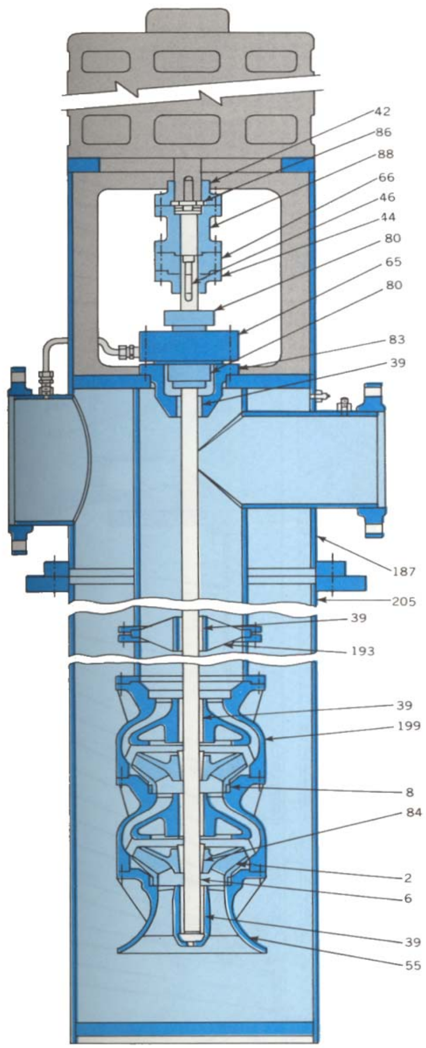
Introduction to Pumps

Pump Types

centrifugal pumps
nomenclature



2 Impeller
6 Shaft, Pump
8 Ring, Impeller
39 Bushing, Bearing
42 Coupling Half, Driver
44 Coupling Half, Pump
46 Key, Coupling
55 Bell, Suction
65 Seal, Mechanical, Stationary Element
66 Nut, Shaft Adjusting
80 Seal, Mechanical, Rotating Element
83 Stuffing Box
84 Collet, Impeller Lock
86 Ring, Thrust, Split
88 Spacer, Coupling
187 Head, Surface Discharge
193 Retainer, Bearing, Open Lineshaft
199 Bowl, Intermediate
205 Barrel or Can Suction

Fig. 23 TURBINE TYPE, VERTICAL, MULTI-STAGE, BARREL OR CAN PUMP

The cross sectional drawings illustrate the largest possible number of parts in their proper relationship and a few construction modifications but *do not* necessarily represent recommended design.

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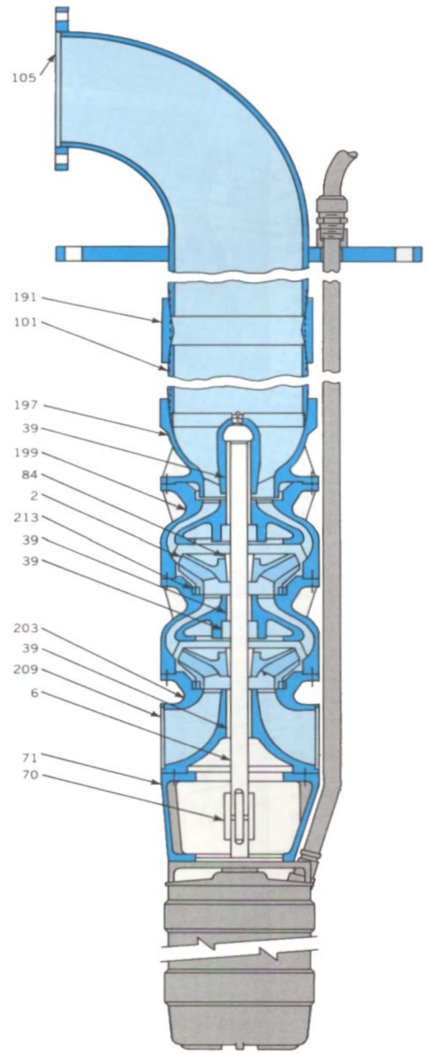
Introduction to Pumps

Pump Types

centrifugal pumps
nomenclature



2 Impeller
6 Shaft, Pump
39 Bushing, Bearing
70 Coupling, Shaft
71 Adapter
84 Collet, Impeller Lock
101 Pipe, Column
105 Elbow, Discharge
191 Coupling, Column Pipe
197 Case, Discharge
199 Bowl, Intermediate
203 Case, Suction
209 Strainer
213 Ring, Bowl

Fig. 21 TURBINE TYPE, VERTICAL, MULTI-STAGE, DEEP WELL, SUBMERSIBLE

The cross sectional drawings illustrate the largest possible number of parts in their proper relationship and a few construction modifications but *do not* necessarily represent recommended design.

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Introduction to Pumps

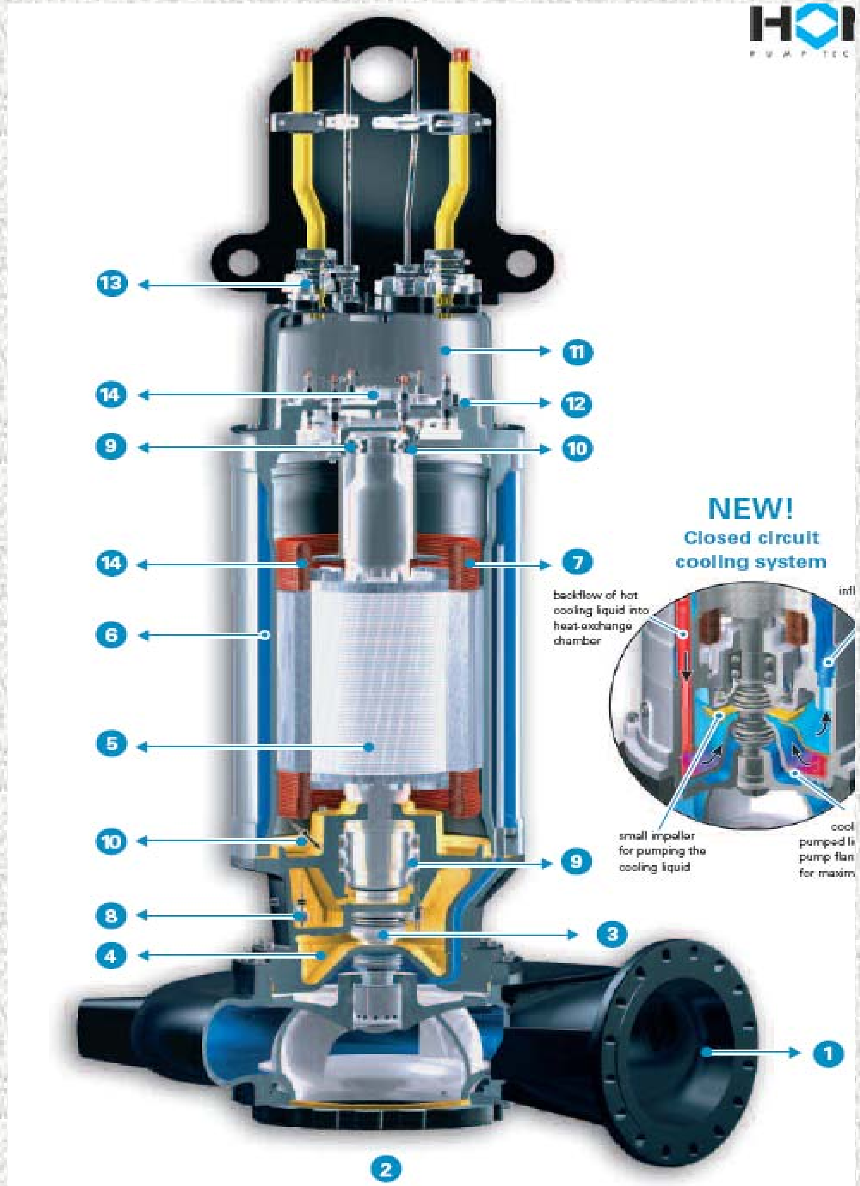
Pump Types

Submersible Sewage Pumps

These pumps are mainly used to pump wastewater where they have to pass solids. They are available in a variety of designs to suit many applications. They are usually installed with a quick disconnect coupling to facilitate maintenance. They are available in different materials of construction to suit various applications.

Introduction to Pumps

Pump Types



Introduction to Pumps

Pump DNA

Pumps are made up of several components with each of these components having a specific function:

- Casing
- Casing wear ring
- Impeller
- Shaft
- Shaft sleeve
- Mechanical seal or packing
- Bearings
- Bearing housing

Introduction to Pumps

Pump Applications

Pumps are used whenever you need to transfer any liquid from point A to a higher point B. Pumps are the second most commonly used rotating equipment after motors. They are used on thousands of applications. Below is a list of common applications:

Centrifugal Pumps

HVAC – condenser water, chilled water, cooling tower make-up

Plumbing – Hot water, drainage, condensate return, boiler feed, fuel feed

General Service – Cooling tower, booster, raw water intake, plant service water, fire fighting, filter feed

Industrial – hundreds of process applications inside the plant

Wastewater – grinder, lift stations, sewage transfer

Turf Irrigation – golf courses, parks, crop irrigation

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Introduction to Pumps

Pump Application

Positive Displacement Pumps

PD Pumps are used to pump viscous fluids. Therefore most of their applications are in industrial and food sectors.

Food Industry

Pharmaceutical Plants

Wastewater Treatment Plants

Pulp & Paper

Petrochemical Plants

Introduction to Pumps

Understanding Pump Curves

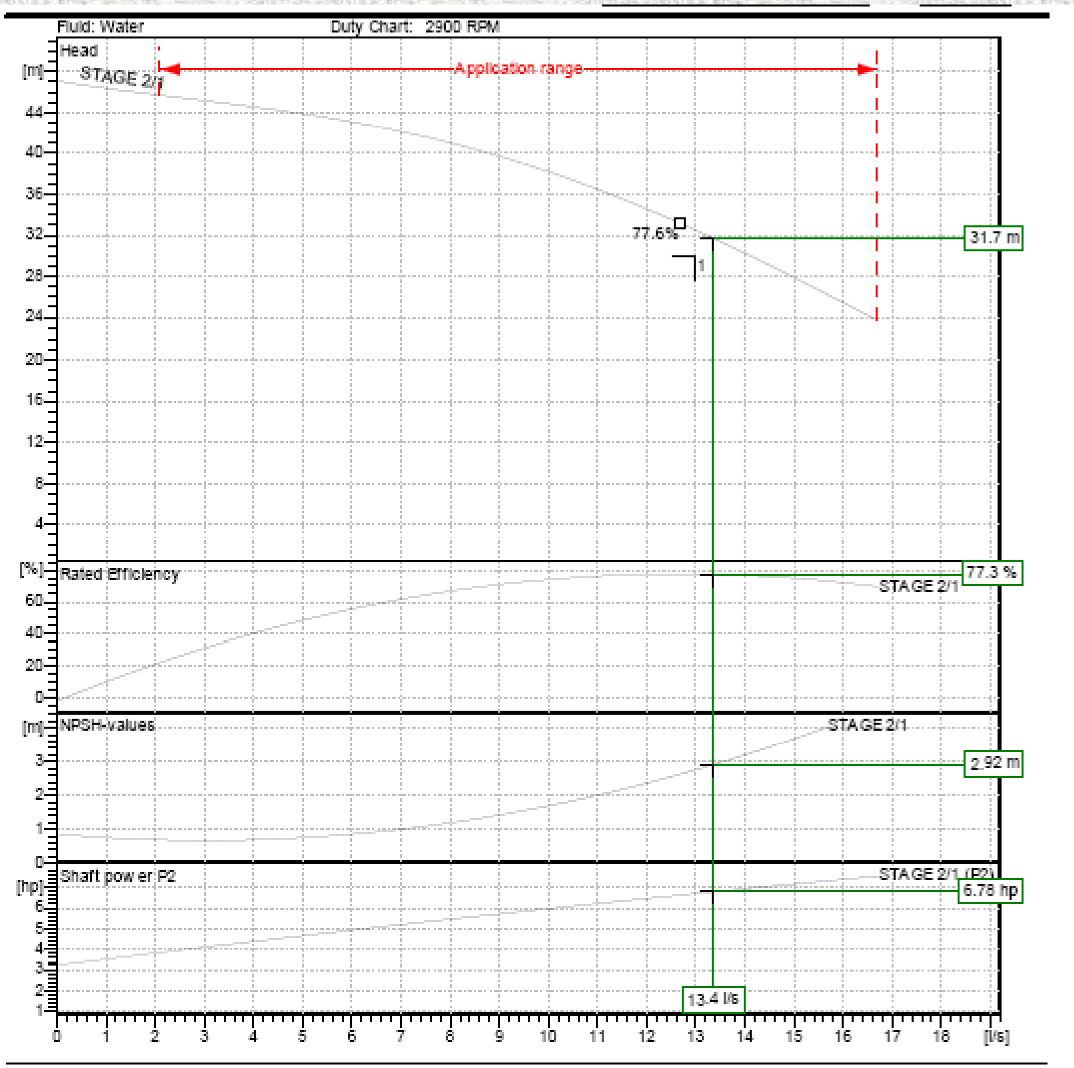
What information is typically found on a pump curve:

- Flow and head
- Efficiency
- NPSHr
- BHP

Are there other things that we can learn from a pump curve?

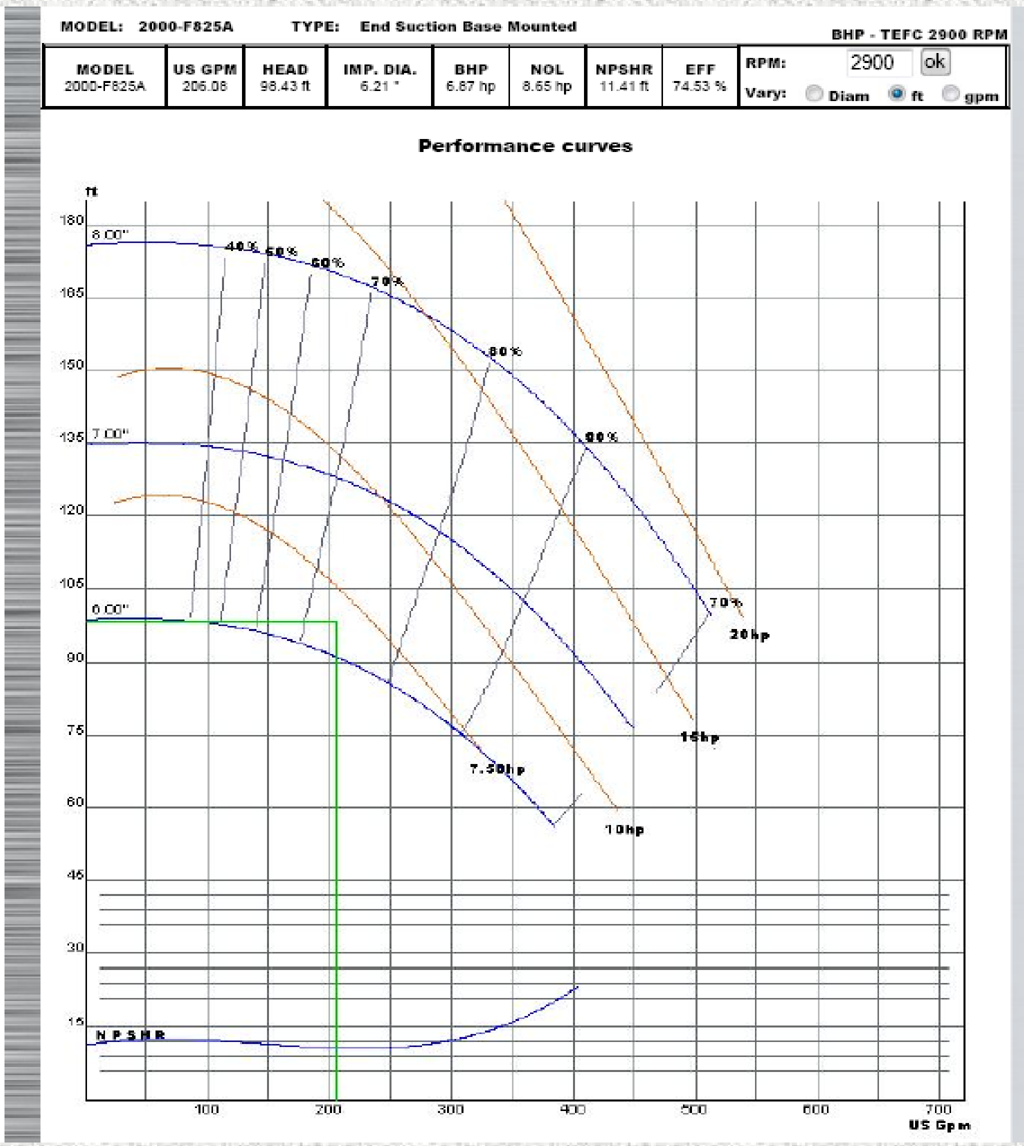
Introduction to Pumps

Understanding Pump Curves



Introduction to Pumps

Understanding Pump Curves



Introduction to Pumps

System Curve

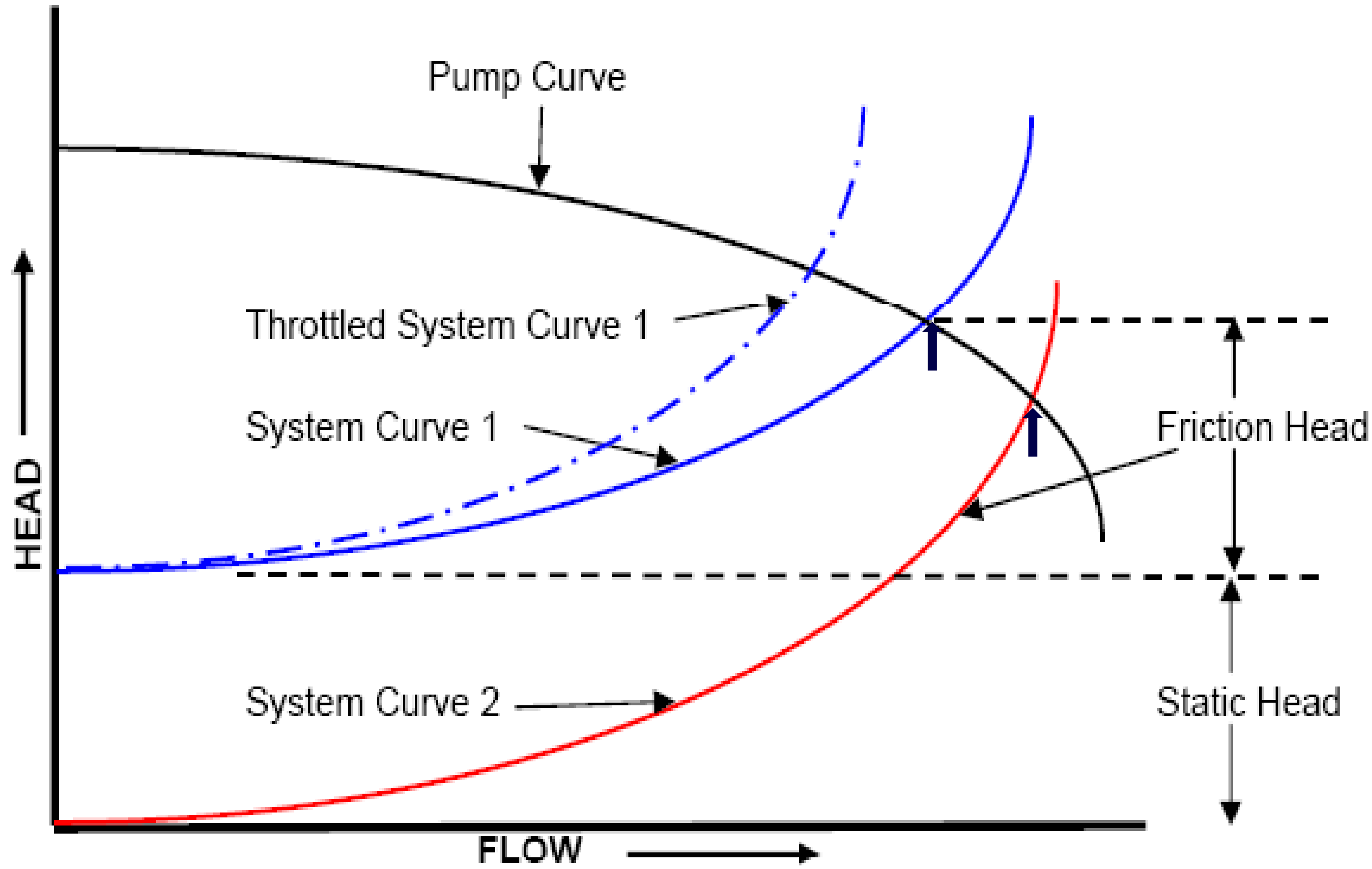
A system curve represents the head required to move fluid through the system at various flow rates.

In the absence of control features, the system will always operate at the intersection of the system curve and the pump curve. The head in a typical system is made up of two components:

- Static
- Friction

Introduction to Pumps

System Curve



Introduction to Pumps

Required Pump Data

The first step in selecting a pump for a particular application is to decide what type of pump to use. The following selection criteria need to be considered:

1. Application
2. Space requirements
3. Power source
4. Life Expectancy
5. Budget

After deciding on what type of pump to use, we can begin the selection process. For any application, the following information must be known to properly select a pump:

1. Flow (GPM or L/S, M^3/Hr)
2. TDH (FT, M, KPa)
3. Fluid name and temperature
4. Pump speed
5. S.G. and viscosity
6. Horizontal or vertical installation
7. Materials of construction
8. Motor data

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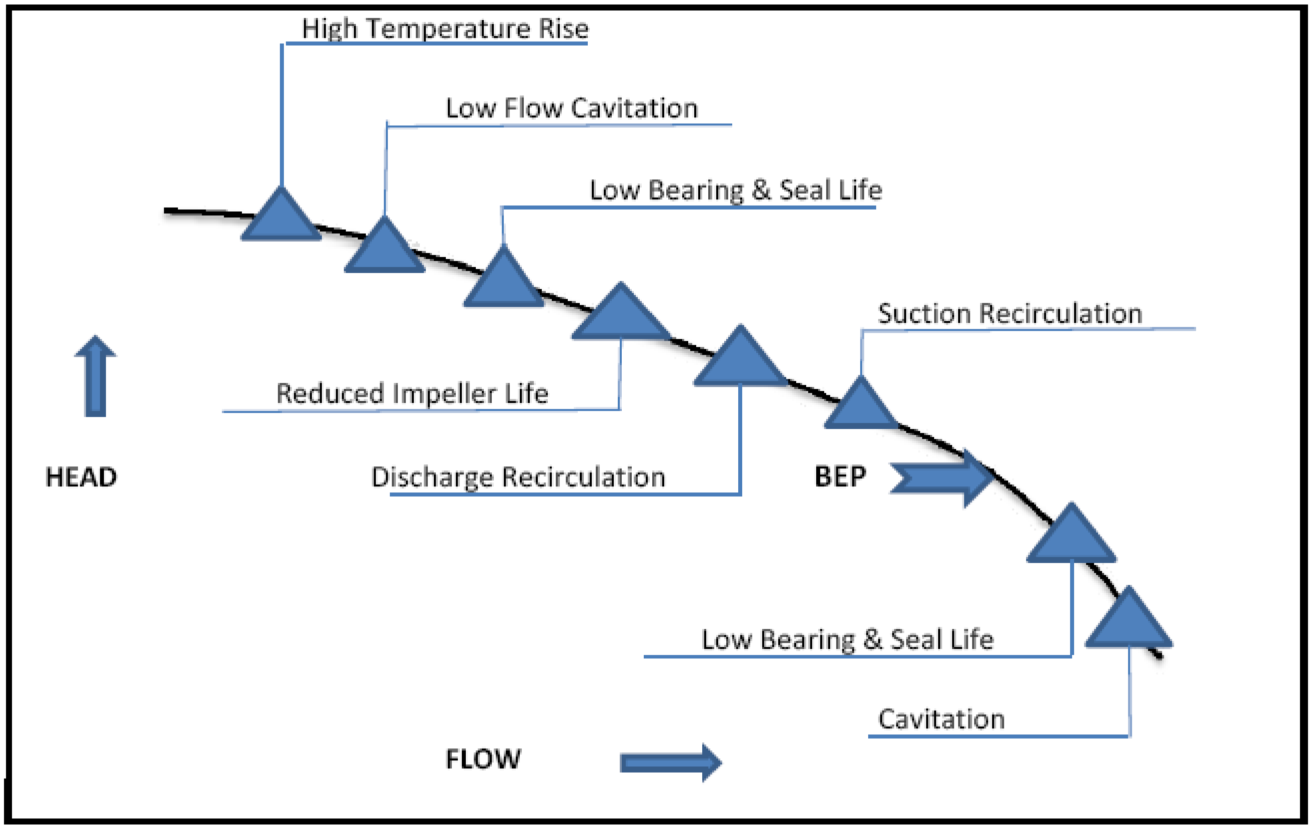
Introduction to Pumps

Improper Pump Selection - WARNING



Introduction to Pumps

Proper Pump Selection

Example 1: Water Transfer application

Select an end suction frame mounted pump to deliver 56M3/Hr of clean water at 42M TDH. Maximum allowable speed is 3000RPM. NPSHa=6M. Water temperature 150 F. Suction source: above ground tank

Look at the curves on the next slide. Which pump would you select? Why?

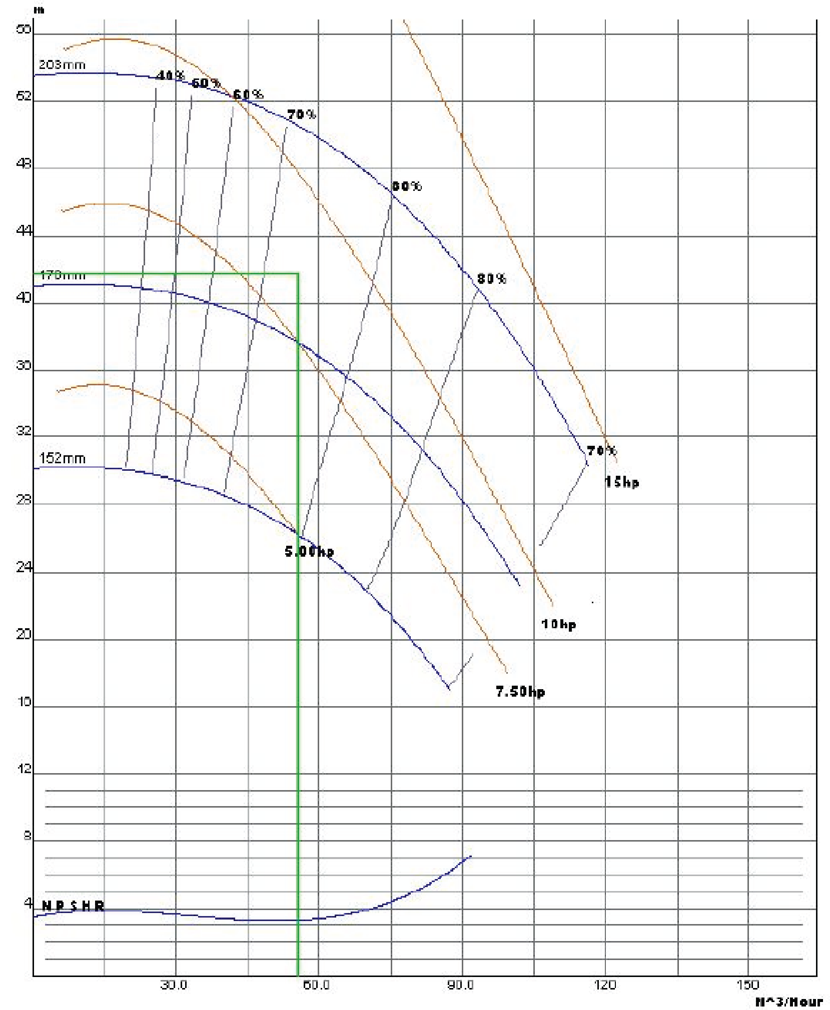
Introduction to Pumps

MODEL: 2000-F825A TYPE: End Suction Base Mounted

NOL - TEFC 2900 RPM

MODEL	Metre³/H	HEAD	IMP. DIA.	BHP	NOL	NPSHR	EFF	RPM: 2900
2000-F825A	55.87	41.76 M	187 mm	8.49 Kw	10.65 Kw	3.46 M	74.76 %	Vary: Diam M M³/H

Performance curves

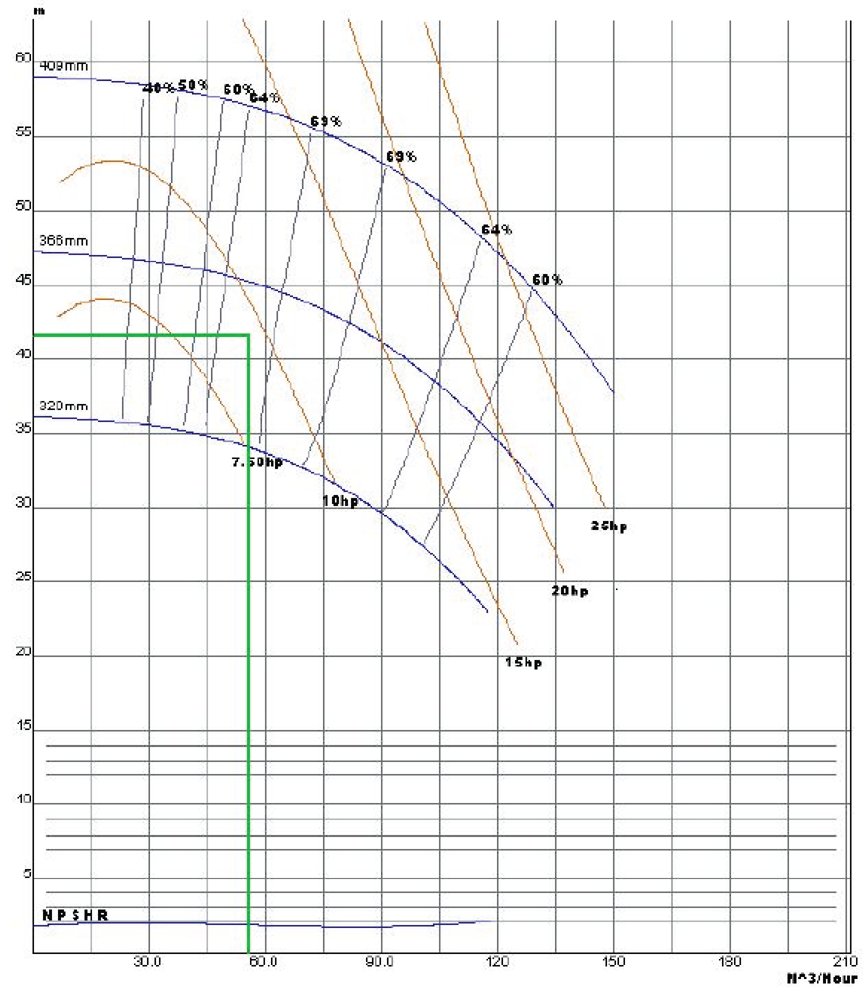


MODEL: 2600P-4X3-16 TYPE: End Suction Base Mounted

NOL - TEFC 1450 RPM

MODEL	Metre³/H	HEAD	IMP. DIA.	BHP	NOL	NPSHR	EFF	RPM: 1450
2600P-4X3-16	55.87	41.76 M	352 mm	9.41 Kw	18.93 Kw	1.84 M	67.50 %	Vary: Diam M M³/H

Performance curves



Introduction to Pumps

Proper Pump Selection

Select Pump Model F825A, because it is higher in efficiency, is closer to BEP and will require a smaller size motor.

$$BHP = \frac{56\ (4.4)\ X\ 42\ (3.28)\ X\ 1.0}{3960\ X\ 0.747} = 11.47 \quad \text{or } 8.56\text{kw}$$

Max. non-overloading power = 14.23hp or 10.62 kw
Motor size = 15hp (11.2kw), 2900RPM
NPSHr = 3.46 M less than NPSHa = 6M

Proper Pump Selection

Example 2: Water Booster Application

Select a horizontal split case pump to deliver 2000GPM of clean water at 350FT Head. Maximum allowable speed is 1500RPM. NPSHa=24Ft. Water temperature 150 F. Suction pressure is 20psi

First thing we need to do is determine the pump TDH. We have 20psi of positive suction pressure aiding the pump. 20psi x 2.31 = 46.2Ft

So, pump head = 350 – 46 = 304Ft

Select pump to deliver 2000GPM at 304Ft

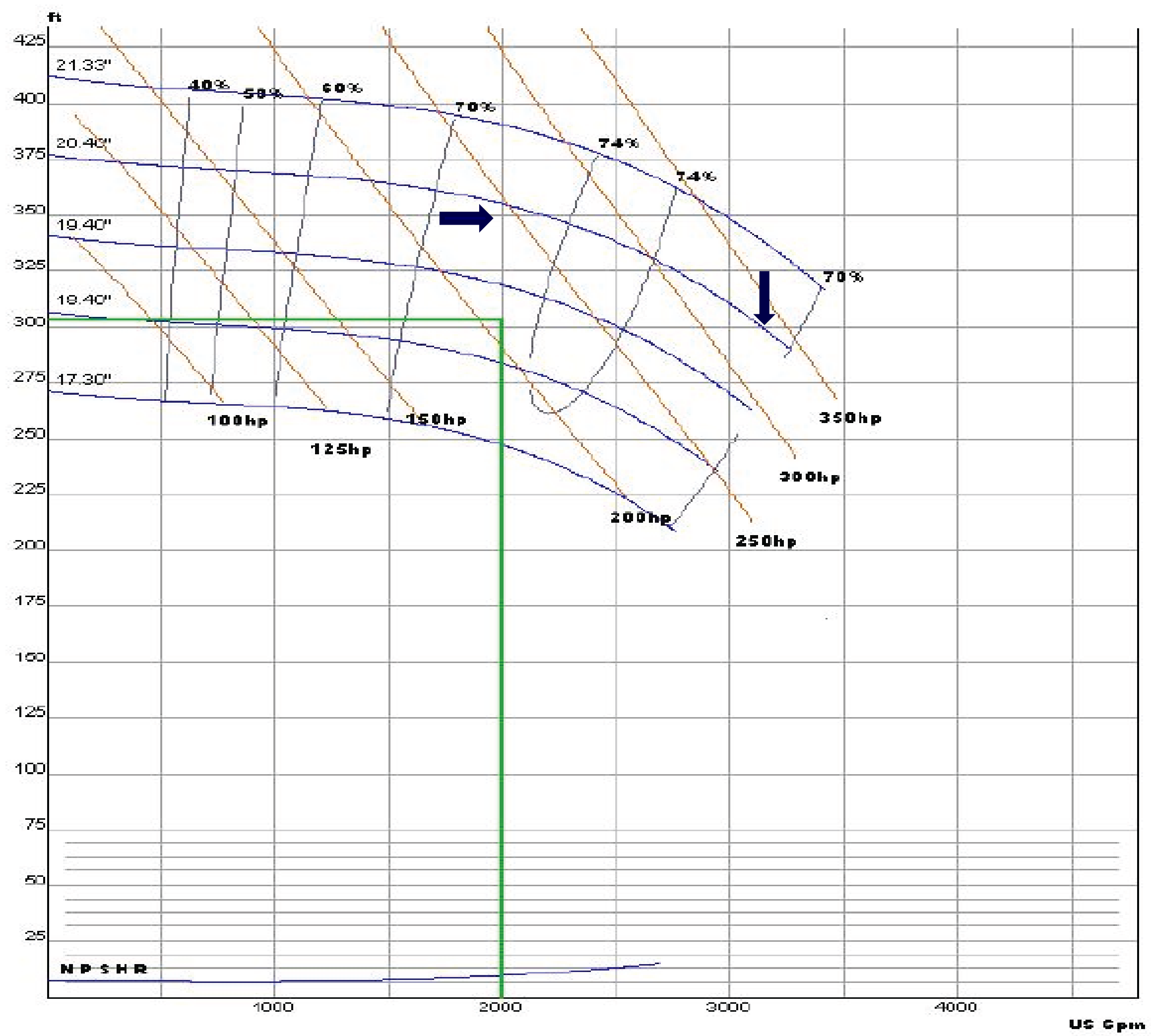
Introduction to Pumps

MODEL: 4800-8X6-21.33 (605i) **TYPE:** Split Case

BHP - TEFC 1450 RPM

MODEL	US GPM	HEAD	IMP. DIA.	BHP	NOL	NPSHR	EFF	RPM: 1450
4800-8X6-21.33 (605i)	2000.00	304.00 ft	18.97 "	209.00 hp	275.35 hp	11.98 ft	73.46 %	Vary: Diam / ft / gpm

Performance curves



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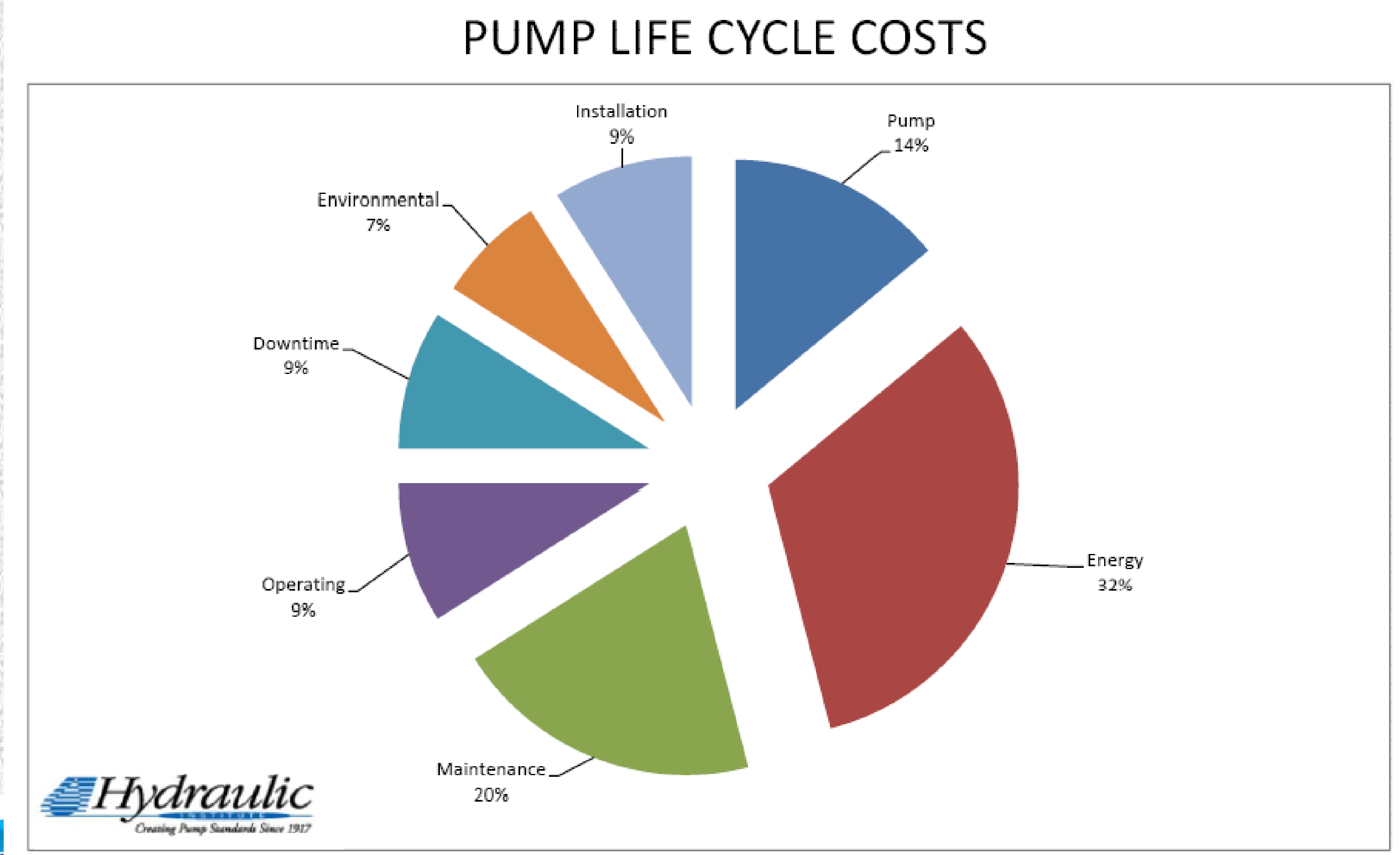
Topics of Coverage

What other things can we learn from reading pump curves?????

- The shape of the pump curve (flat or steep) is important for certain applications
- We can visually see how the pump curve interacts with the system curve
- Diagnose pump problems in the field
- See how flow/head changes on VFD applications
- Determine the shut-off pressure which is important for component selection and system diagnosis

Part 3
Understanding Packaged Pump Stations

Topics of Coverage



Understanding Packaged Pump Stations

1. Traditional Site Built Pump Stations
2. Packaged Pump Stations
   - Brief Description
   - Applications
3. Benefits of Using Packaged Pump Stations
   - To the Owner
   - To the Engineer
   - To the Contractor
4. Constant Speed Pump Stations
   - Reality of System Demand
   - Typical System Components
   - System Limitations
   - Energy Conservation Methods

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Understanding Packaged Pump Stations

5. Variable Speed Systems
   - Typical System Components
   - Normal System Operation
   - True Power of Affinity Laws
   - How System Saves Energy
   - Power Consumption Comparison

Understanding Packaged Pump Stations

1. Traditional Site Built Pump Stations

- The challenge of project management.
- Must issue purchase orders for all equipment.
- Contractor responsible for integration of all equipment.
- Any delay to any component will affect the project timeline.
- Last minute failure of equipment.
- Finger pointing when equipment fails.
- Different warranty for different equipment.

2. Packaged Pump Stations

Brief Description

A packaged pump station includes all the components of a traditional site built station. This includes pumps, valves, pipes, controls and instrumentation all mounted on one skid and tested as a complete station before it leaves the factory.

2. Packaged Pump Stations

Applications

Packaged pump stations are used on a lot of applications.

- Plumbing
- HVAC
- Fire fighting
- Industrial
- Irrigation
- Municipal

Understanding Packaged Pump Stations

Understanding Packaged Pump Stations

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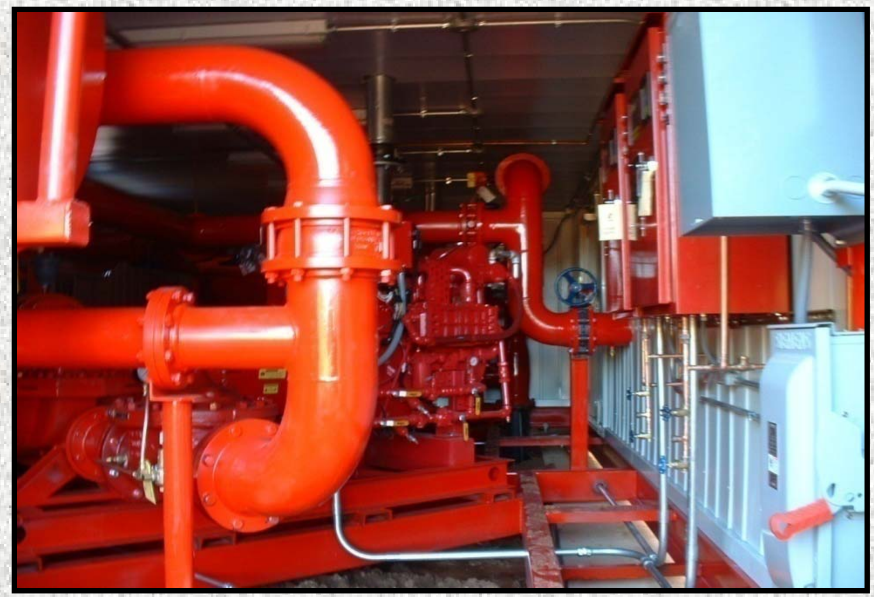
Understanding Packaged Pump Stations



Understanding Packaged Pump Stations

Understanding Packaged Pump Stations

3. Benefits of Using Packaged Pump Stations

<u>To Engineer</u>

- Assistance with system design, spec review
- Design optimization between mechanical and electrical components
- 2-D or 3-D layout drawings
- Highest possible system efficiency
- Complete system testing to design criteria
- Single source responsibility
- Complete support from design to start-up
- Integration of other equipment on pump skid

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Understanding Packaged Pump Stations

3. Benefits of Using Packaged Pump Stations

To Contractor

- Complete unit responsibility by system manufacturer
- Complete pre-tested system – no surprises at site
- Minimal installation time – minimizes field labor costs
- One P/O for entire system
- One warranty for entire system
- Timely project completion

Understanding Packaged Pump Stations

3. Benefits of Using Packaged Pump Stations

To Owner

- Complete unit responsibility by system manufacturer
- Complete pre-tested system – no surprises at site
- One warranty for entire system
- Timely project completion
- Highest possible system efficiency – lowest operating cost
- Minimize floor space in mechanical room

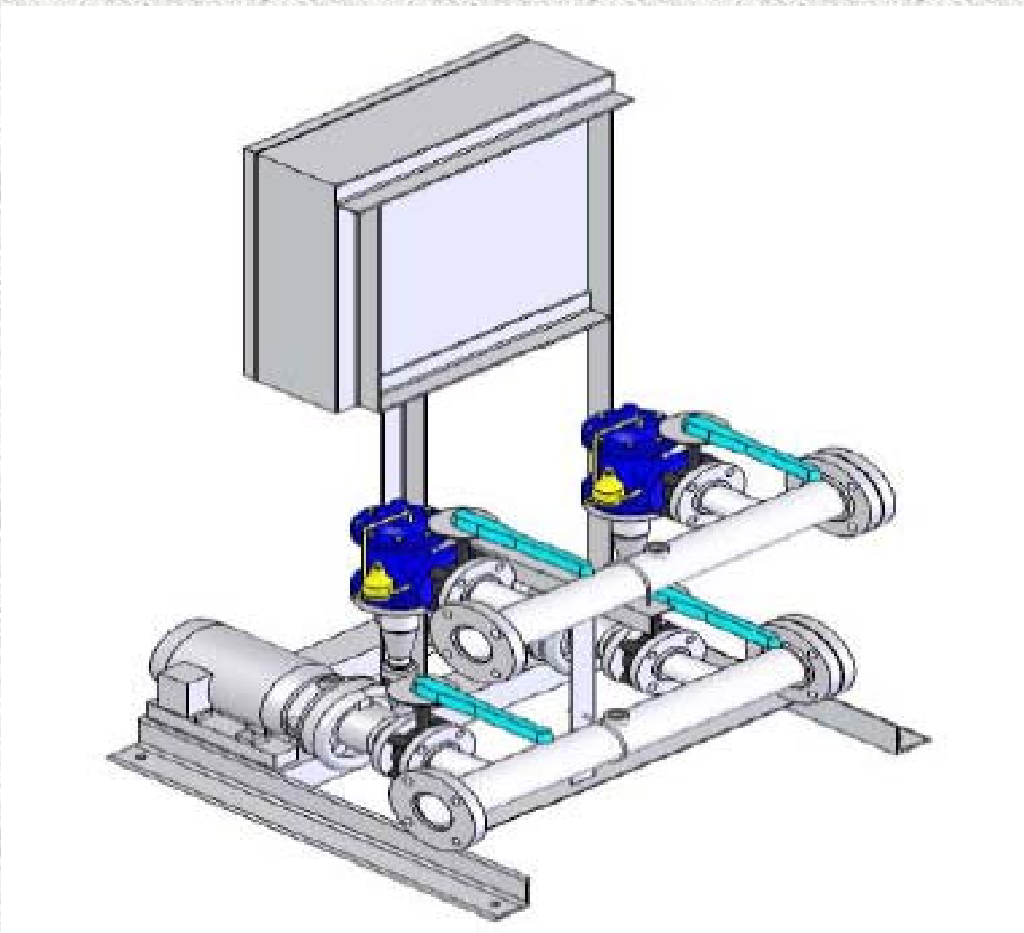
4. Constant Speed Packaged Pump Stations

<u>Typical System Components</u>

- Pumps – end suction, VMS, Inline, split case, VTP
- Motors – ODP or TEFC
- Isolating Valves – Butterfly, Ball, Gate
- PRV with built-in check valve
- Instrumentation – Pressure gauge, pressure switch, pressure transmitter, flow meter, etc…
- Control Panel – Houses all electrical components
- Piping – branch piping and headers
- Skid

Understanding Packaged Pump Stations

Constant Speed Packaged Pump Stations



4. Constant Speed Packaged Pump Stations

Reality of System Demand – 80/20% Rule

Generally speaking, 80% of the time the system demand flow is at 20% or less of the design flow capacity.

4. Constant Speed Packaged Pump Stations

System Operation

The system uses a “mechanical means” to reduce the discharge pressure. In these systems, the pump operates at 100% of the design motor speed all the time. Since the pump impeller diameter and speed are constant, the system requires hydraulically controlled mechanical forces to “hold-back” pump pressure regardless of where it is operating along its performance curve to maintain a constant downstream pressure.

4. Constant Speed Packaged Pump Stations

System Operation

The PRV is the mechanical device that regulates the pressure. The job of the PRV is to adjust its pressure drop to match the "over-pumped" pressure of the constant speed pump at a given point on its demand curve. The PRV would be throttled nearly closed 80% of the time forcing the valve to add significant friction head, which is dissipated as heat loss.

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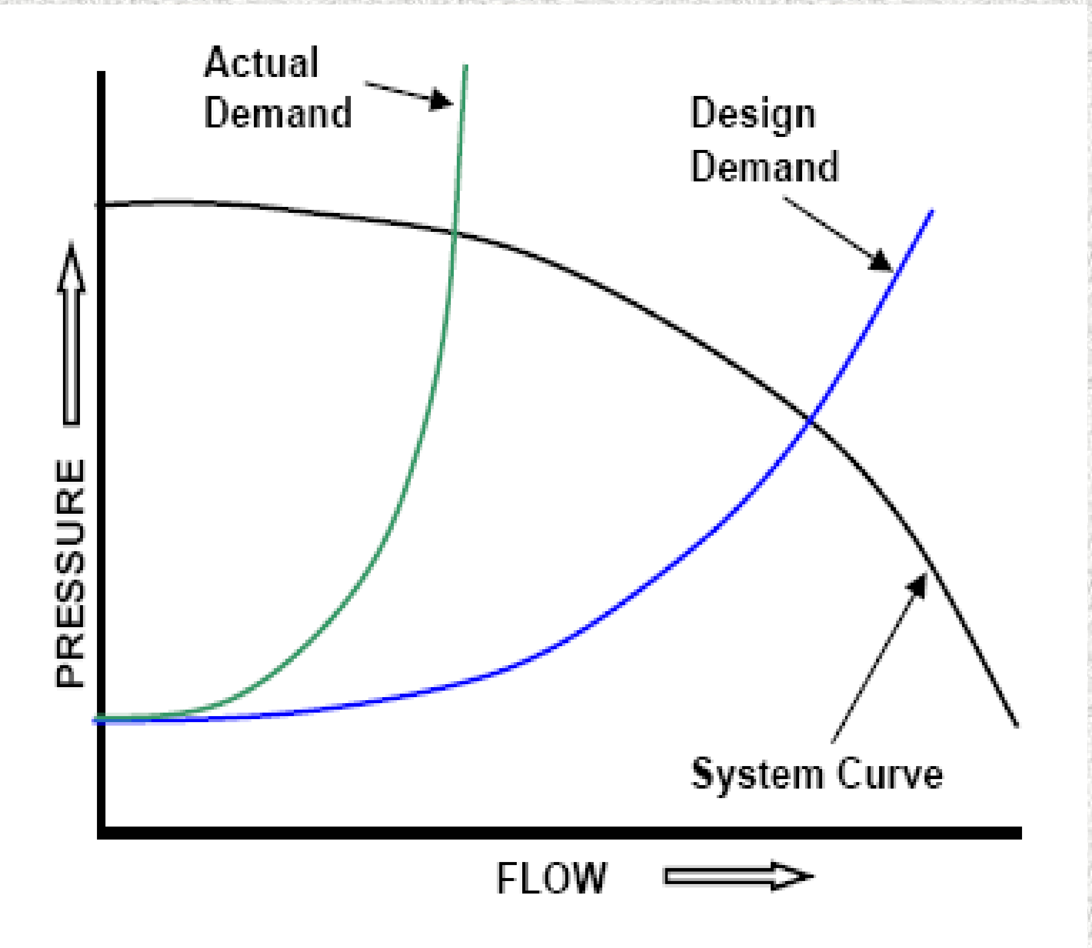
Understanding Packaged Pump Stations

4. Constant Speed Packaged Pump Stations



4. Constant Speed Packaged Pump Stations

Energy Conservation Methods

1. Use a Jockey Pump – for small loads
2. Pressure Switch Sequencing – 20/40/40% or 33/66/100%
3. Bladder Tank – Leak loads and pump short cycling

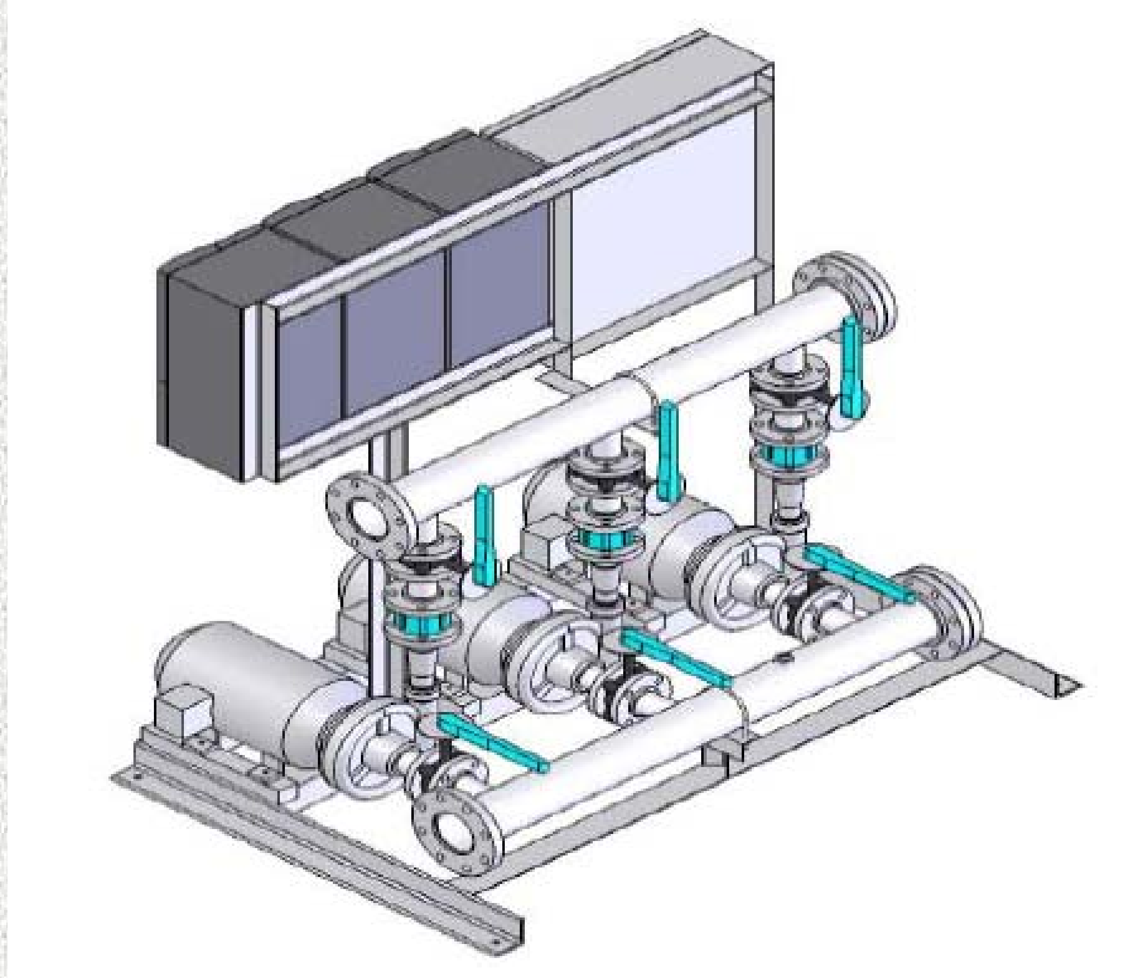
5. Variable Speed Packaged Pump Stations

Typical System Components

- Pumps – end suction, VMS, Inline, split case, VTP
- Motors – ODP or TEFC
- Isolating Valves – Butterfly, Ball, Gate
- Silent check valve
- Instrumentation – Pressure gauge, pressure switch, pressure transmitter, flow meter, etc…
- Variable frequency drives
- Control Panel – Houses all electrical components
- Piping – branch piping and headers
- Skid

Understanding Packaged Pump Stations

Variable Speed Packaged Pump Stations



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5. Variable Speed Packaged Pump Stations

System Operation

This system typically uses a variable frequency drive to vary the speed of the motor which will in turn vary the pump speed, thereby changing the flow and pressure of the pump. Taking the signal from a pressure or flow transmitter, the VFD ramps the speed of the motor up or down to constantly meet the building demand.

5. Variable Speed Packaged Pump Stations

The Affinity Laws

With impeller diameter held constant:

Law#1: $\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$

Law#2: $\frac{H_1}{H_2} = \frac{(N_1)^2}{(N_2)^2}$

Law #3: $\frac{Bhp_1}{Bhp_2} = \frac{(N_1)^3}{(N_2)^3}$

Where Q = capacity, H = head, N = speed

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5. Variable Speed Packaged Pump Stations

True Power of Affinity Laws

Law#1: Doubling the pump speed will basically double the flow.

Law#2: The pump pressure changes to the square of the speed. (i.e. When the speed is doubled, the head increases by 4 times)

Law #3: The pump power consumption changes to the cube of the speed. (i.e. When the speed is doubled, the power consumption increases by 8 times)

Example: Assume a 10% reduction in speed, this equates to $0.9^3 = 0.73$*. This means that with only 10% speed reduction, you can achieve 27% reduction in power consumption. Similarly, with 20% speed reduction, you can achieve almost 50% reduction in power consumption.*

5. Variable Speed Packaged Pump Stations

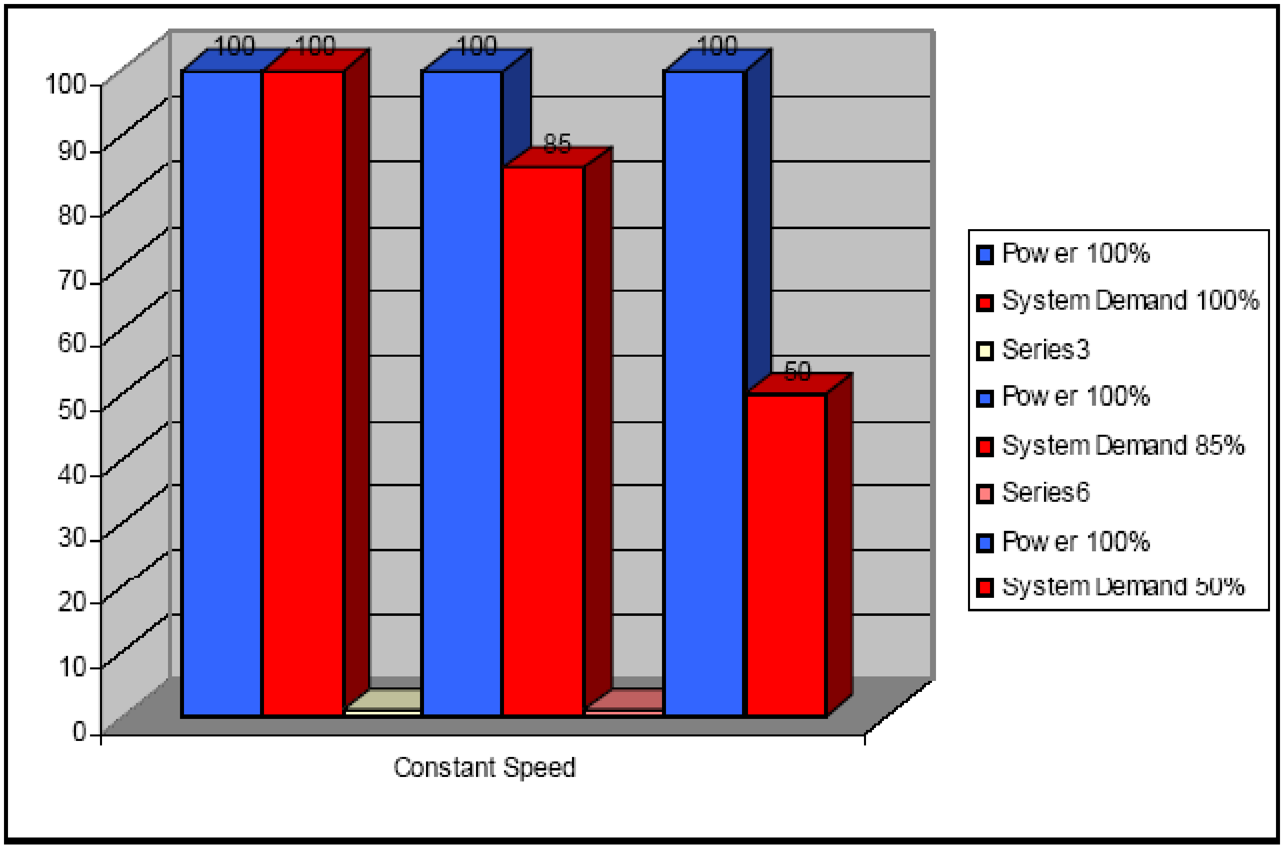
How VFD System Saves Energy

1. **Pressure Variation #1**: When calculating plumbing system loads, FRICTION LOSSES are calculated at the FULL system flow demand.
2. **Pressure Variation #2**: When calculating system pressure demand, WORST CASE CONDITION is taken for suction pressure.
3. **Pressure Variation #3**: As the pump rises toward shutoff and away from system design point, the pump pressure generally increases.

Understanding Packaged Pump Stations

5. Variable Speed Packaged Pump Stations

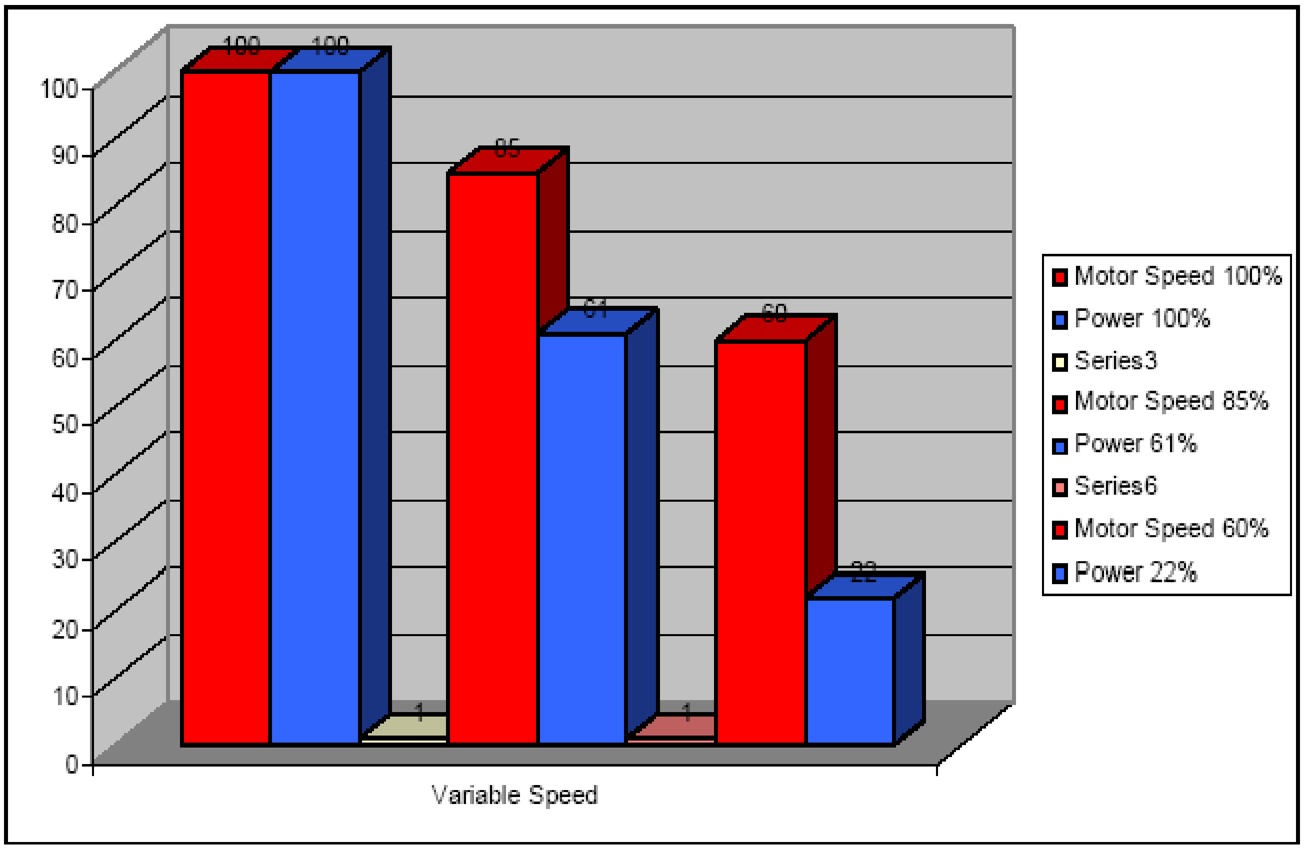
Power Consumption – Constant Speed



Understanding Packaged Pump Stations

5. Variable Speed Packaged Pump Stations

Power Consumption – Variable Speed



Understanding Packaged Pump Stations

5. Variable Speed Packaged Pump Stations

Reasons to Use VFD Systems

1. Electronic reduction of pressure reduces valve noise due to velocity across a nearly closed PRV seat.
2. Bearing radial loads are significantly reduced since pump reduces its speed as it approaches shut-off. These hydraulic loads contribute significantly to pre-mature bearing failure due to heat, stress and vibration.
3. A variable speed system can more closely follow the building load profile, applying only as much energy as required for any given duty condition.

5. Variable Speed Packaged Pump Stations

Reasons to Use VFD Systems

4. High maintenance bladder tanks and PRV's can be eliminated.
5. PID firmware control in each drive allows a more accurate means of pressure control which is not subject to tampering in the field.
6. VFD's offer soft starting capabilities. This reduces thermal and mechanical stresses on windings and couplings.

Understanding Packaged Pump Stations

5. Variable Speed Packaged Pump Stations

Where Should we Use VFD Systems

1. When we have variable system demand (either flow or pressure)
2. When we have variable suction pressure
3. When energy savings is at a premium
4. When there will be future demand changes

Proper System Selection

System Design Requirements

1. Calculate flow and boost pressure
2. Understand what are the overall selection criteria for the system/equipment
3. Select the type of pump that best meets the hydraulics as well as design criteria
4. Decide on number of pumps to use and pump split
5. Decide on how the system will interface with other equipment

Understanding Packaged Pump Stations

Proper System Selection

What is system Boost Pressure?

It is the difference between the desired system pressure and suction pressure.

The attached data sheet will help illustrate this.

Certifications

ISO 9001

Part 4
Pump Accessories

Introduction to Pumps

Pump Accessories

<u>Couplings</u>

Couplings are used to connect the driver shaft to the pump shaft. The coupling will allow for some slight misalignment. There are various types of couplings. The most common being the flexible or elastomeric coupling.

Other coupling types include:

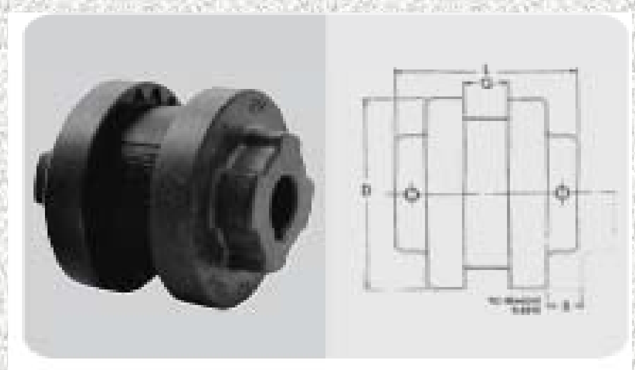
- Gear
- Disc
- Fluid

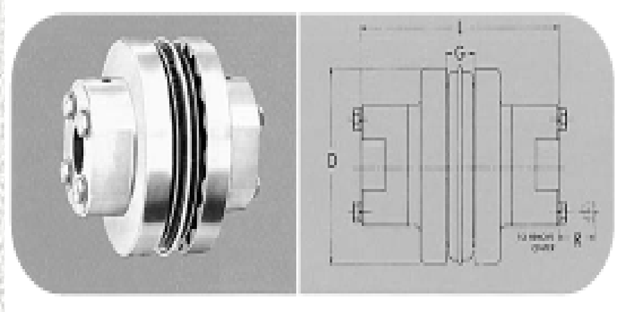
Introduction to Pumps

Pump Accessories

Flexible Couplings

Flexible or elastomeric couplings are used on most pump applications. There are two general categories; spacer and non-spacer couplings. Spacer couplings allow easier disassembly of pumps and motors when maintenance is required. The coupling is made up of 2 components; the flanges and elsatomeric insert.





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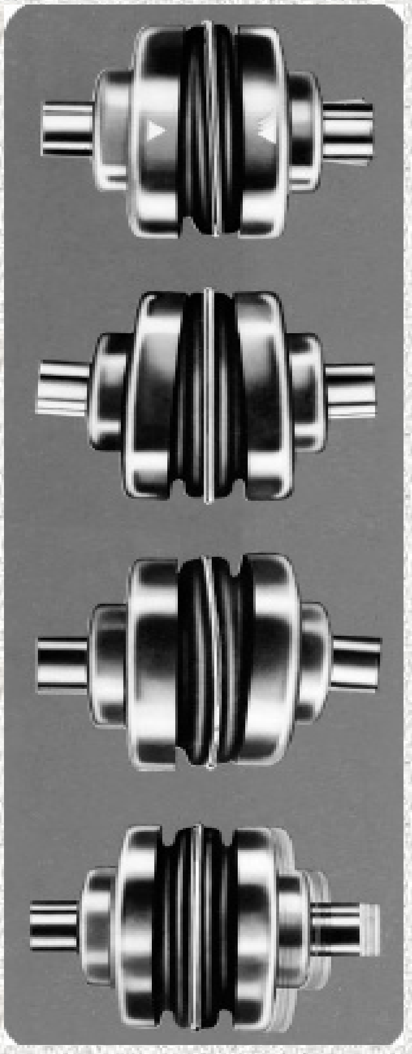
Examples of Shaft Misalignment

Torsional misalignment

Angular misalignment

Parallel misalignment

Axial misalignment



Introduction to Pumps

Pump Accessories

Pressure Gauges

Pressure gauges come in two general categories:

Compound gauges – read vacuum as well as positive pressure. They are typically used on the suction side of pumps.

Standard gauges – come in standard increments anywhere from 30psi to 5000psi and higher. The face display can read any pressure unit (psi, bar, Kpa, etc…)

There are two common sizes of gauges, 2.5" and 4.5". The case is usually air filled or glycerin filled. Glycerin filled gauges are more robust. They are typically used in applications where there is a lot of vibration and stress.

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Introduction to Pumps

Pump Accessories

Pressure Gauge Examples

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INTRODUCTION TO MOTORS

Introduction to Motors

Motor Classifications

There are many different ways to classify motors. The most common ones are by:

- Installation - horizontal or vertical.
- Design – synchronous, induction, capacitor…
- Enclosure – ODP, TEFC, X-proof…
- Standards – NEMA, IEC…

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Introduction to Motors

Motor Design

Installation - Horizontal

The most common motors are horizontal foot mounted design. There are several types offered distinguished by their shaft extension. This is the means by which the motor shaft is coupled to the driven machinery. Examples include T frame, JM/JP, C-face.

These motors can be installed vertically with little modification.

Installation - Vertical

The two most common vertical motors are vertical solid shaft (VSS) and vertical hollow shaft (VHS). VSS motors have a shaft extension similar to a horizontal motor. VHS have a hollow tube along the centerline of the motor. The pump head shaft will go through the hollow center and is secured at the top of the motor by a special coupling. These motors are specially designed to absorb the high thrust generated by vertical pumps.

Introduction to Motors

Motor Design

Enclosure

Enclosure defines the motor construction according to environmental protection and method of cooling. The most common types are:

ODP (Open Drip Proof) – IP44

The construction of the ventilation openings allow successful operation even when drops of liquid and solid particles strike or enter the enclosure at any angle from 0 to 15 degrees downward from vertical. Most common for indoor use.

WP1 (Weather-Protected Type 1) - Vertical

This classification is typically used on vertical motors. Ventilation passages are so constructed to minimize the entrance of rain, snow or air-borne particles to the electric parts.

Motor Design

Enclosure

WPII (Weather-Protected Type II)

In addition to the enclosure in WPI, the ventilating passages at both intake and discharge are so arranged that high velocity air and air-borne particles blown into the motor by high winds can be discharged without entering the internal ventilation passages leading directly to the electrical parts.

TEFC (Totally Enclosed Fan Cooled) – IP54

An enclosed motor that prevents the free exchange of air between the inside and outside of the motor, but not considered airtight. Cooling occurs via a fan integral with the motor but external to the enclosing parts. Used mostly for outdoor applications and in locations which are dirty, damp and oily.

Motor Design

Enclosure

Explosion Proof - ATEX

A totally enclosed motor designed to withstand an internal explosion of specified gases or vapors and not allow the internal flame or explosion to escape. The motor degree of protection is selected based on the environment where the motor will operate.

Severe Duty

A totally enclosed motor with extra protection to resist entry of contaminants. This motor is typically used in extra dry, damp or other non-hazardous environments.

Motor Design

Insulation

Insulation is usually classified by maximum allowable operating temperatures as defined per U.L. It is the combination of ambient temperature plus temperature rise.

Class A – 105 C (221 F)
Class B – 130 C (266 F)
Class F – 155 C (311 F)
Class H – 180 C (356 F)

Note: Standard motor design in USA uses class F insulation with 40ºC Ambient temperature.

Introduction to Motors

Motor Design

Speed

It is important to distinguish between synchronous speed, nominal speed and actual full load speed.

Synchronous speed is the theoretical maximum speed at which an induction-type motor can operate. It is calculated by the following formula.

$$\text{Syn. RPM} = \frac{\text{Power supply Hz} \times 120}{\text{No. of Poles}}$$

Nominal speed is the speed achieved by the motor when operating under rated HP conditions. This will always be less than the synchronous speed and will vary depending on the rating and characteristics of the particular motor. The nominal speed is what is usually shown on the motor nameplate.

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Introduction to Motors

Motor Design

Speed

The actual motor speed will be close to the nominal speed. It is unique to that motor design.

Example: a 4-pole fractional horsepower motor will have a synchronous speed of 1800RPM, a nominal speed shown on the nameplate of 1725RPM and an actual full load speed ranging from 1715 to 1745RPM.

Typical synchronous speeds:

	50HZ	60HZ
2-pole	3000rpm	3600rpm
4-pole	1500rpm	1800rpm
6-pole	1000rpm	1200rpm

Motor Design

Service Factor

A measure of the reserve margin built into a motor. For example, motors rated at 1.15 S.F. have a safety margin of 15%. They are used where unusual conditions are likely to occur, like high or low voltage, momentary overloads, etc…

Note: Motors are designed to operate successfully where the voltage variation does not exceed -/+10% nominal voltage, or where frequency does not fluctuate more than -/+5%. The sum of voltage and frequency variation should not exceed 10%.

Introduction to Motors

Motor Design

Motor Efficiency

Motor efficiency is the ratio between the shaft output power and the electrical input power.

If power output is measured in *Watt (W)*, efficiency can be expressed as:

ηm = Pout / Pin?   *where*

ηm = motor efficiency

Pout = shaft power out (Watt, W)

Pin = electric power in to the motor (Watt, W)

If power output is measured in *horsepower (hp)*, efficiency can be expressed as:

ηm = Pout 746 / Pin   *where*

Pout = shaft power out (horsepower, hp)

Pin = electric power in to the motor (Watt, W)

Note: as of 1/1/2011, all motors used in USA must be premium efficiency.

Introduction to Motors

Motor Design

Torque

Torque is the turning effect caused by a force acting normal to a radius at a set distance from the axis of rotation. It can be expressed in Lb-Ft (Lb at a radius of 1 FT). The full-load torque of a motor is:

$$\text{Full-Load Torque} = \frac{5250 \times HP}{RPM}$$

The torque developed by a synchronous induction motors varies with the speed as the motor accelerates from zero to full speed.

Locked Rotor or Starting Torque – is the torque the motor develops when it starts from zero speed.

Pull-up Torque – is the minimum torque developed by a motor when it runs from zero to full load speed , before it reaches the break-down torque.

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Introduction to Motors

Motor Design

Torque

Break-down Torque – is the highest torque available before the torque decreases when the machine continues to accelerate to the working condition.

Full-load Torque – is the torque required to produce the rated power of the electrical motor at full speed

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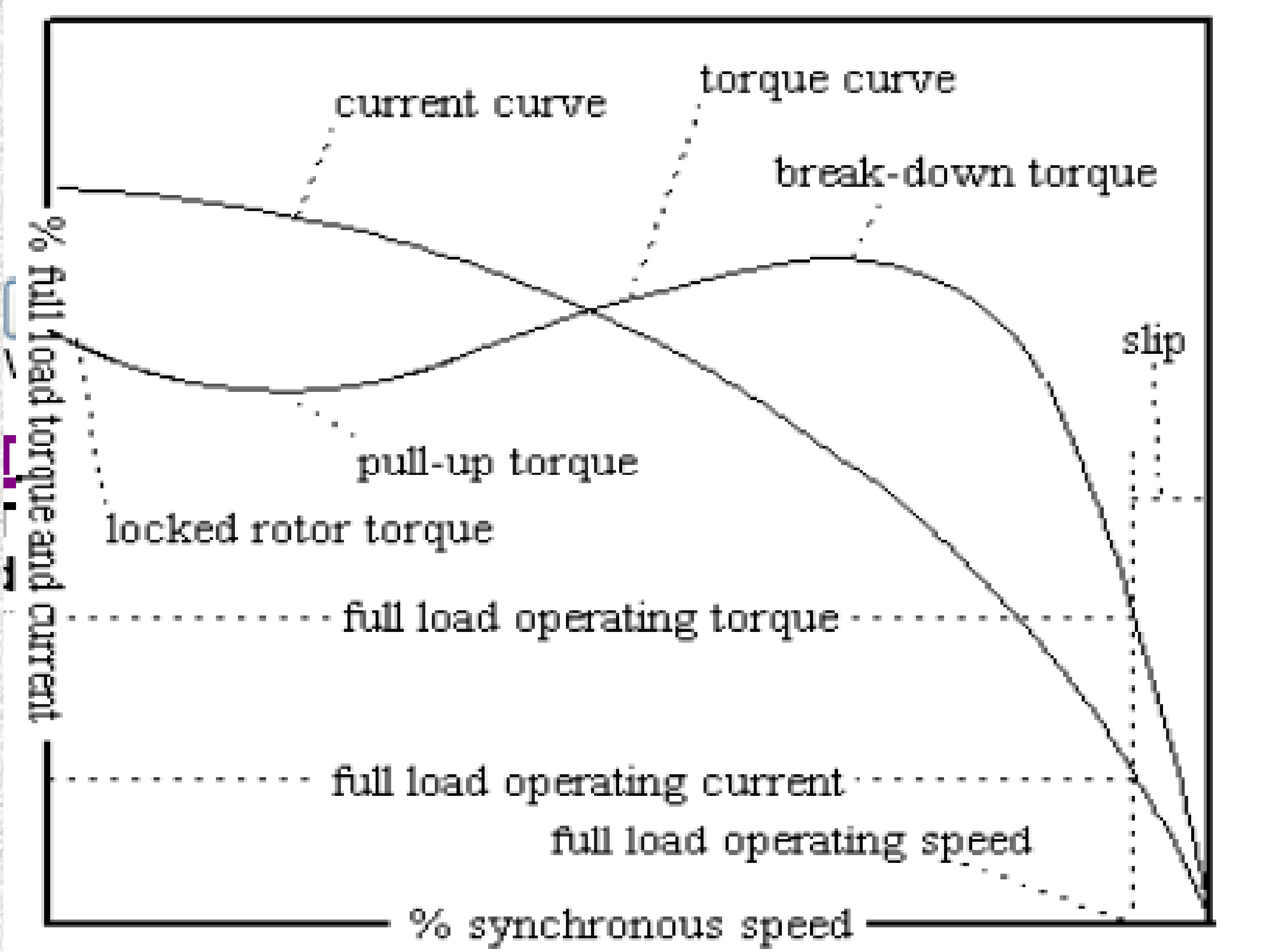
Introduction to Motors

Motor Design



Introduction to Motors

Motor Design

Three-phase—60 Hertz (NEMA design B)							
		Amperes—460 volt			Approx torque lb-ft		
Horse-power	Approx full load speed	Typical full load	NEMA locked rotor max	NEMA code letter	Full load	(Starting) Locked rotor (min)	Breakdown full-load (min)
5	3500 1745 1155	6.7 7.1 8.1	46.0	J	7.5 15.0 22.7	11.3 27.5 34.1	16.1 33.8 48.8
7½	3510 1740 1165	10.3 10.4 11.2	63.5	H	11.1 22.6 33.7	15.5 39.6 50.6	22.2 48.6 69.1
10	3515 1740 1160	13.2 13.6 15.3	81.0	H	14.9 30.1 45.3	20.1 49.7 68.0	29.8 60.2 90.6
15	3505 1750 1170	20.1 21.1 21.3	116	G	22.4 45.0 67.1	29.1 72.0 93.9	44.8 90.0 134
20	3540 1755 1170	25.7 26.2 26.5	145	F G G	24.7 59.8 89.5	32.1 89.7 120.8	49.4 119.6 179.0
25	3540 1760 1175	31.3 31.6 33.9	182.5	F G F	37.1 74.4 111.8	48.2 111.6 150.9	74.2 148.8 223.6
30	3545 1760 1175	32.0 37.5 39.8	217.5	F G G	44.4 89.3 134.0	57.7 134.0 181.0	88.8 178.6 268
40	3550 1770 1175	47.8 54.4 52.5	290	G F G	59.2 118.5 179.5	80.0 166.0 242.0	118.4 237.0 359.0

Motor Design

Motor Accessories

A <u>thermostat, thermistor or thermocouple</u> are temperature sensing devices with external leads that are connected to the control circuit of the motor controller to limit the frame or winding temperature of the motor.

<u>RTD's</u> are temperature sensing devices that are typically installed on bearings to limit the temperature of the motor.

<u>Space Heaters</u> are used in areas where there is high humidity to prevent condensation inside the motor windings.

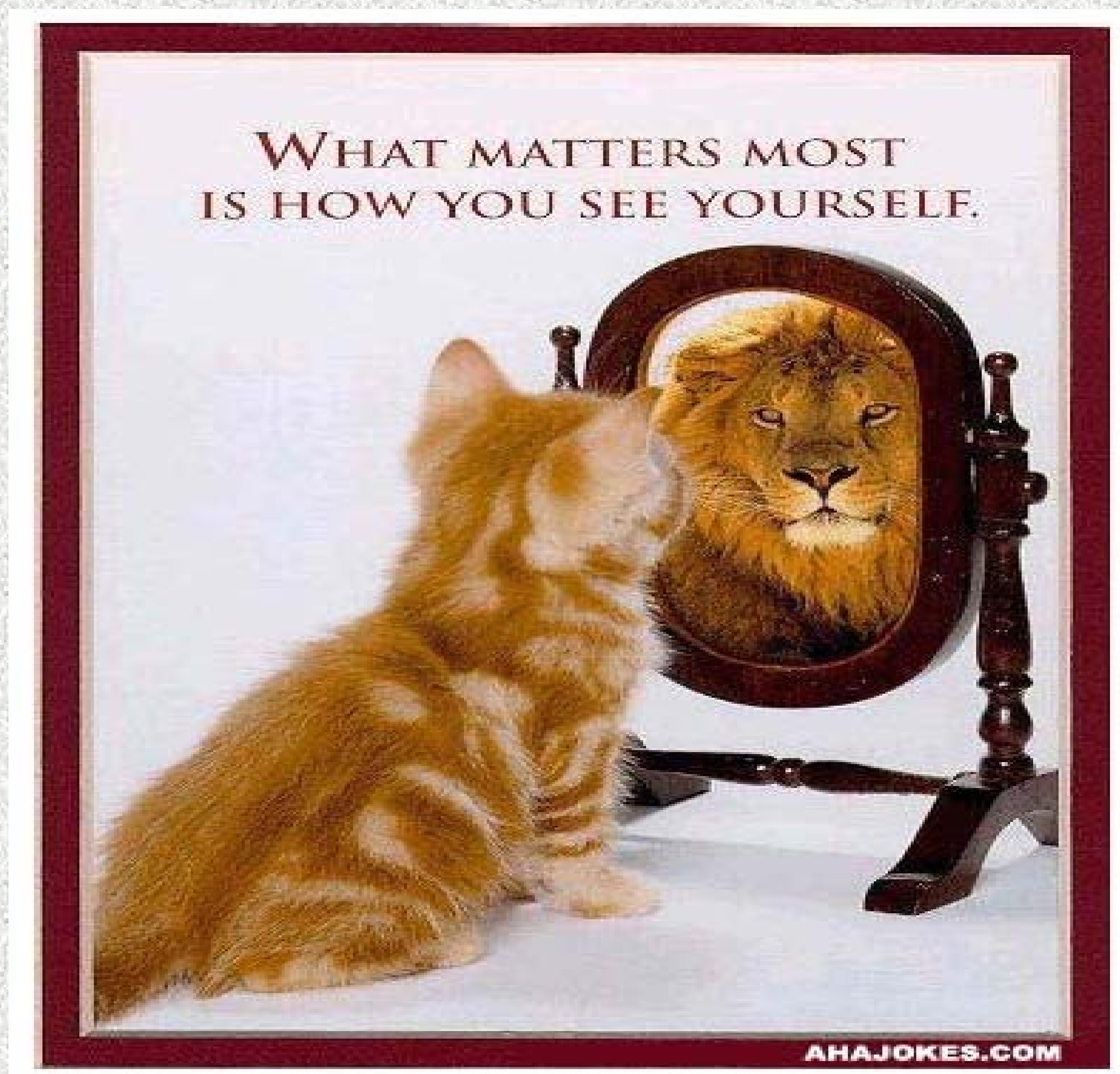
Introduction to Motors

Motor Application

To properly select a motor, the following must be either calculated or given by the design engineer:

- Type of motor
- Application
- HP and RPM
- Enclosure
- Class of insulation
- Voltage, phase and frequency
- Starting method
- Ambient temperature
- Altitude (site location)
- Any special accessories for special conditions, like heat, moisture, etc…

EFS Engineering Fluid Solutions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