2017 Annual Conference

March 28-31

WWW.PRWA.COM/CONFERENCE

Penn Stater Hotel & Conference Center | State College, PA

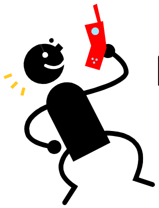
pa rural water Association

Schedule at http://mobile.prwa.com

Welcome!

Pumping Station Design for Operators

We're Glad You're Here!



Please, put your cell phones on vibrate during sessions and, take calls to the hallway

Pumping Station Design for Operators

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Class Goals and Objectives

- Class will be predominantly based on duplex pumping station design and layout (centrifugal)
- Highlight the basics with regard to how hydraulic systems are designed
- Give the end user a better basis of understanding in order to effectively communicate with their design and/or engineering professional (know the language)
- Allow the end user a better opportunity to participate in the design process

References and Sources

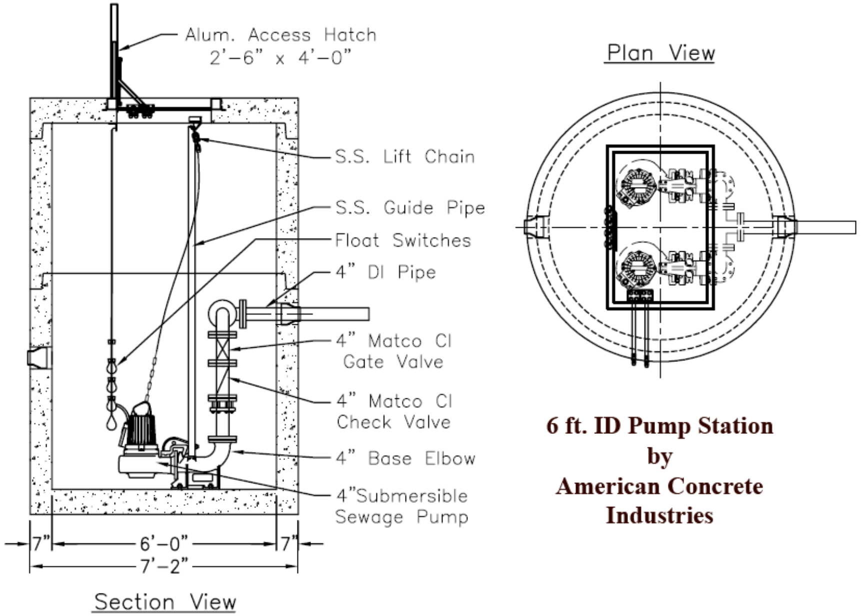
1. Pennsylvania Department of Environmental Protection (PA DEP) “Domestic Wastewater Facilities Manual; 10/97”

2. “Recommended Standards for Wastewater Facilities” (10 States Standards)

3. “Pumping Station Design; Third Edition” Garr M. Jones, et al.

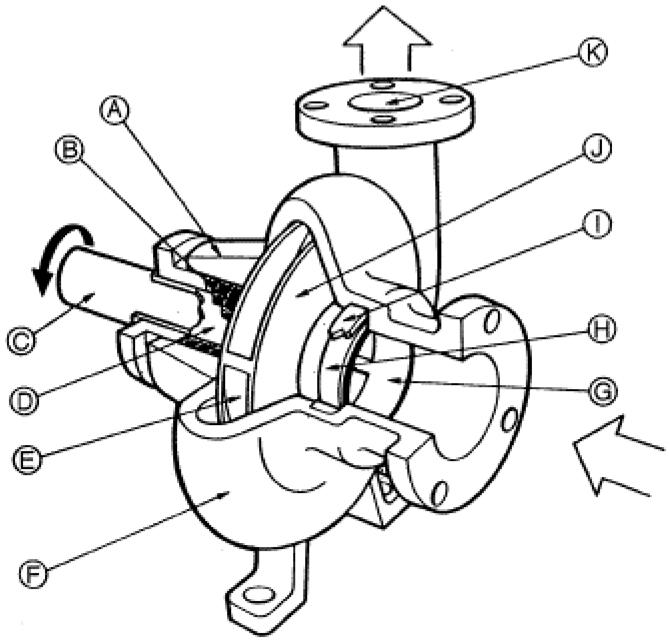
Basic Hydraulics – Terms and Definitions

- Pump - A machine that imparts kinetic and potential energy to a liquid to force a discharge from the machine.



6 ft. ID Pump Station
by
American Concrete
Industries

Basic Centrifugal Pump



A Stuffing Box

B Packing

C Shaft

D Shaft Sleeve

E Vane

F Casing

G eye of Impeller

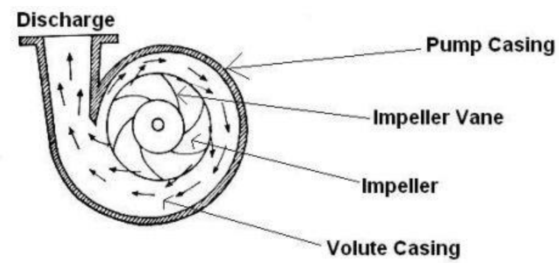
H Impeller

I Casing wear ring

J Impeller

K Discharge nozzle

source: www.pumpfundamentals.com

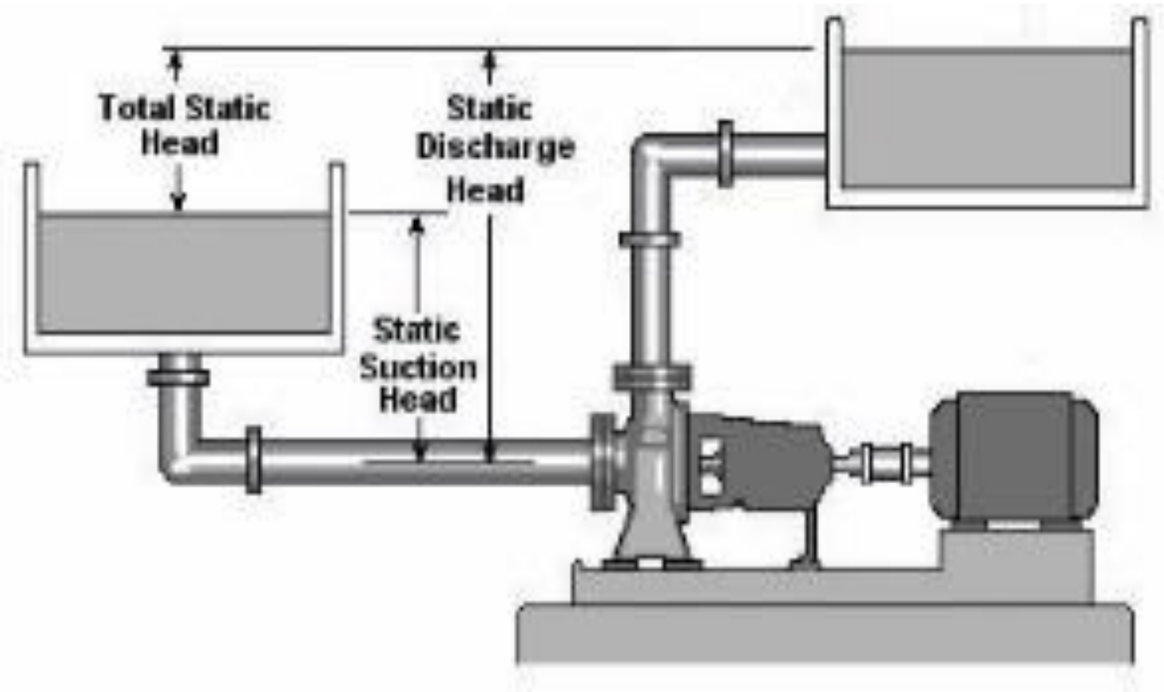


source: http://marineengineeringonline.com

Basic Hydraulics – Terms and Definitions

- Pressure - In most cases measured as pounds per square inch (psi). For wastewater hydraulics we convert this pressure to the term "head" and measure it in feet of water column.
- Static Head – The total distance that water has to be elevated to for discharge. This is typically measured in feet.

Static Head



source: http://www.pumpsandsystems.com

Basic Hydraulics – Terms and Definitions

Major or Friction Loss – The amount of energy expended, as measured in feet of water, needed to overcome the friction imparted between the liquid and the pipe. This is a function of velocity. The faster you want to pump the more it will cost you. This value is calculated by the engineer based on assumptions on the "roughness" of the interior of the pipe.

The value chosen for roughness is usually based on a pipe age of 20 years.

Basic Hydraulics – Terms and Definitions

Minor Loss – These are the losses associated with moving liquid through components such as elbows, valves and components. These too are dependent on velocity.

The design professional calculates the minor loss using an assumed value dependent on the type of fitting.

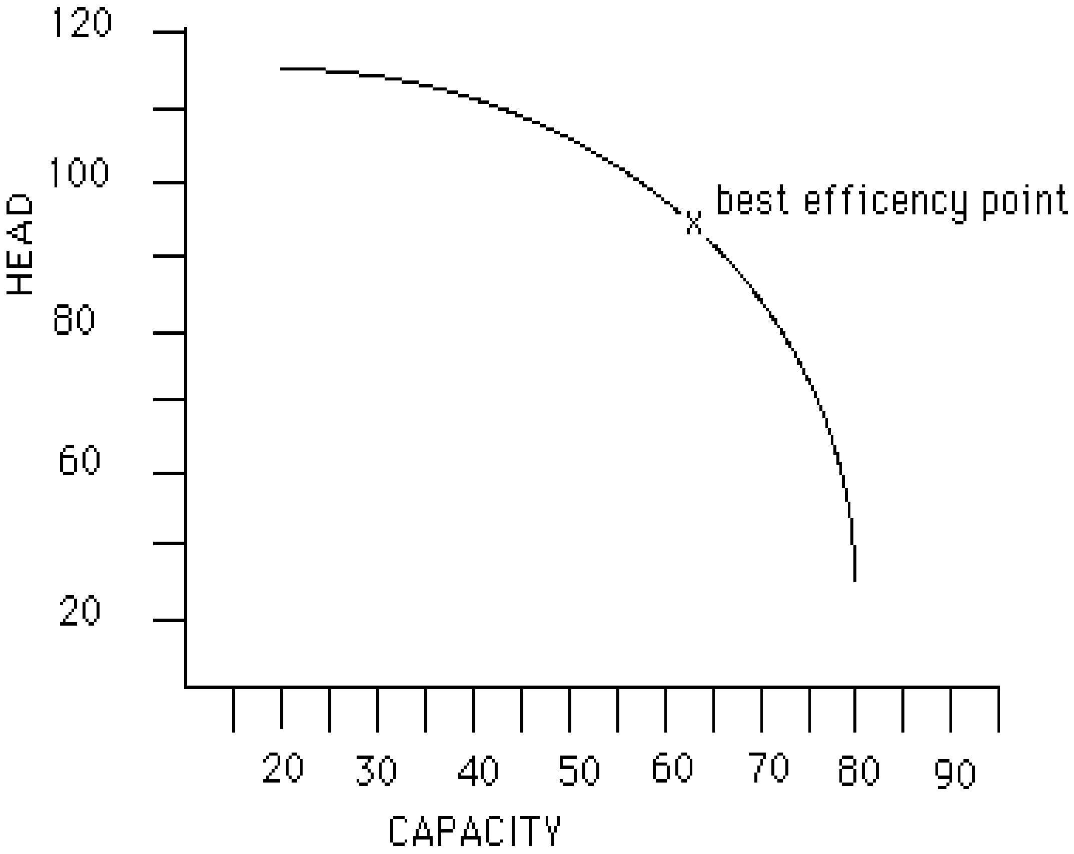
Basic Hydraulics – Terms and Definitions

Total Dynamic Head (TDH) – The combination of the static head plus the friction losses plus the minor losses. The total amount of energy required to move a given flow rate as measured in feet of water column.

Pump Curves

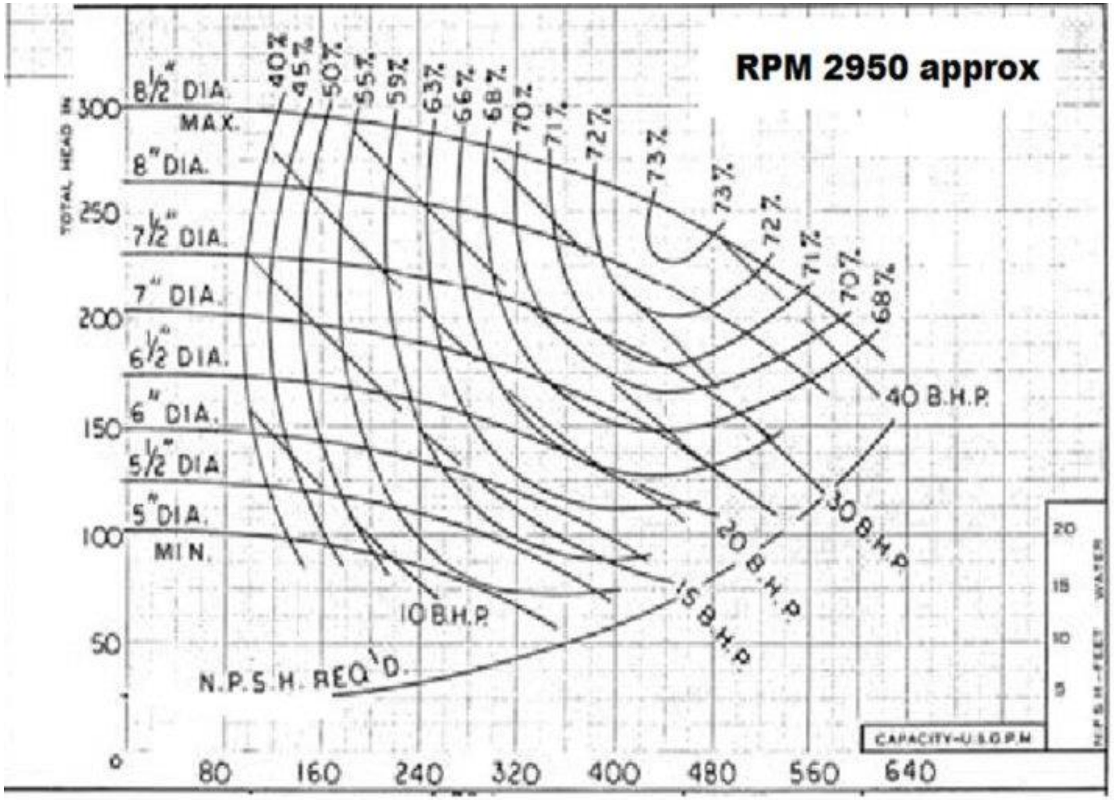
- Produced by the pump manufacturer to show the head available at a given flow rate
- Flow is along the x-axis (horizontal)
- Head is along the y-axis (vertical)
- As flow increases available energy decreases
- Note: Dead head condition and Best Efficiency Point

Pump Curves



source: http://www.mcnallyinstitute.com

Pump Curves



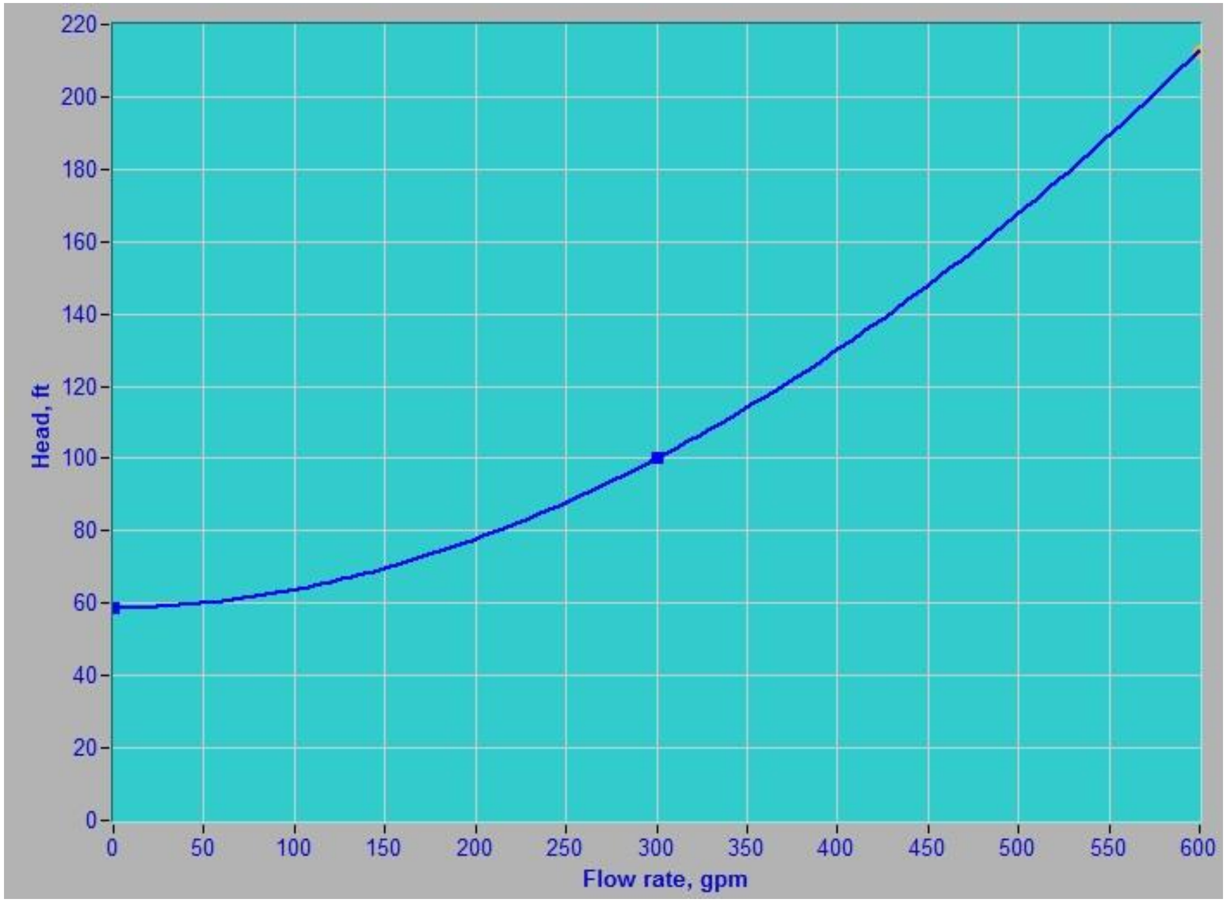
source: https://www.linkedin.com/pulse/drawing-system-resistance-curve-your-parallel-pumping-arindom-borah

System Curves

System Curves depict the status of the TDH at a given flow. They are calculated incrementally starting at zero flow to a design maximum flow.

TDH = Static + Minor + Friction

System Curves

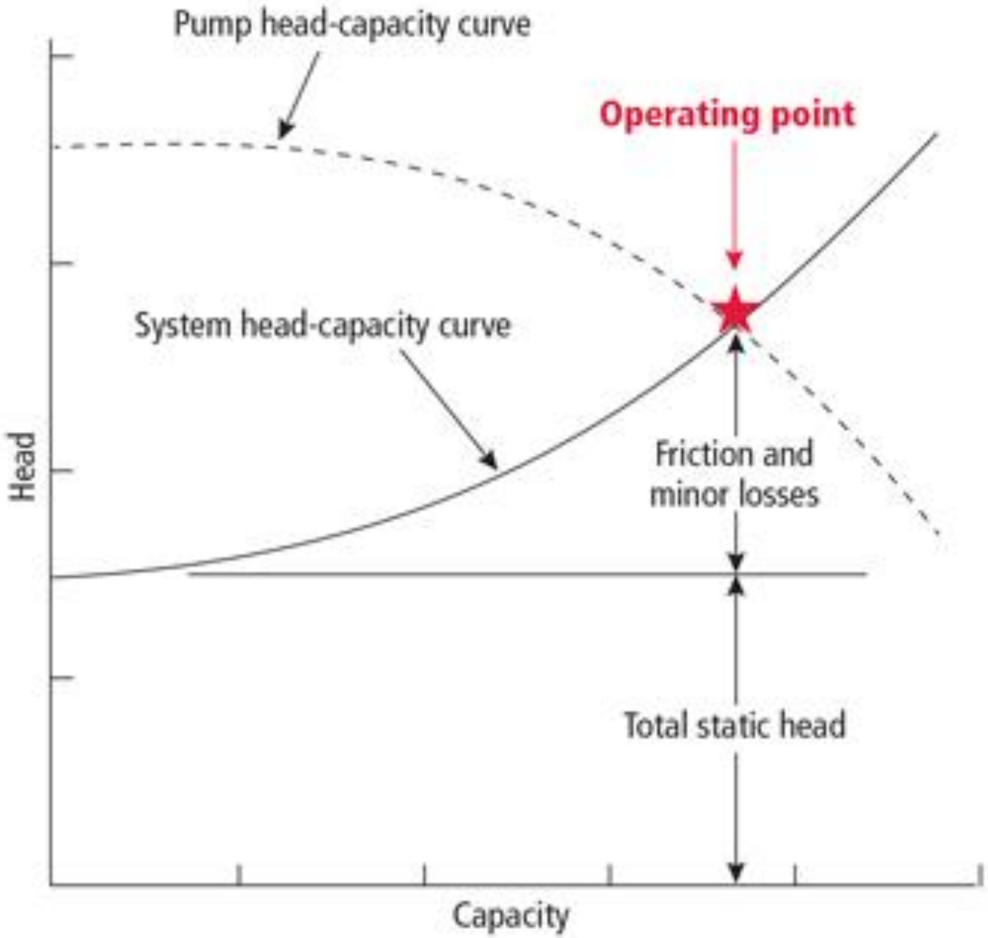


source: http://www.jensenengineeredsystems.com/

Finding the Pump Duty Point

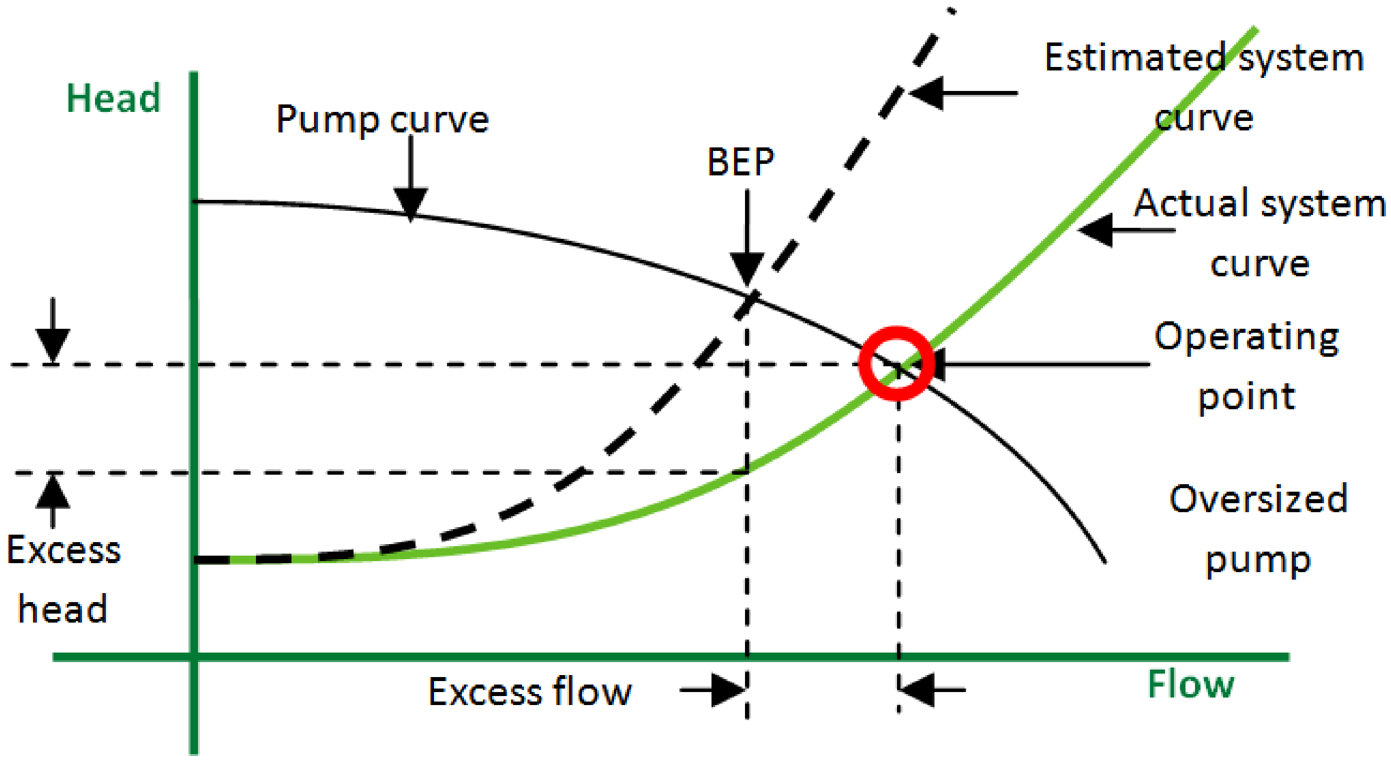
- Overlay the pump curve with the system curve
- The intersection of those two lines is the point that the pump is calculated to be operating
- This is a calculation and is based on many assumptions
- Actual conditions should be verified at startup by means of a “draw down test”

Combined Curves



source: https://www.isa.org/

Actual Operating Conditions



source: http://www.aginnovators.org.au

QUIZ NO. 1

Design Flows as per the PA DEP

Design Flow Parameter	General Definition	Typical Application
Annual Average Flow	The total flow received at the facility during any one calendar year divided by 365 (the number of days in that period).	The "nominal" design flow of a facility. Used for cost comparisons and annual estimates of O&M costs. Used for water quality modeling. Used for evaluating Act 537 plan updates. Used to determine allowable mass loadings in NPDES permits.
Monthly Average Flow	The total flow received at the facility during any one calendar month divided by the number of days in that month.	A flow reporting parameter used in discharge monitoring reports.
Maximum Monthly Average Flow	The highest monthly average flow during any one calendar year.	Determine the overall hydraulic design of the facility. Used for evaluating Act 537 plan updates and planning modules. Is the "hydraulic capacity" for Chapter 94 determinations. Establishes the monthly average flow limitation on NPDES permit.
Peak Hourly Flow	The maximum flow rate received at the facility averaged over a period of one hour.	Designing clarifers, chlorine contact tanks, and other hydraulically sensitive units.
Peak Instantaneous	The maximum instantaneous flow rate received at the facility at any given time.	Designing comminutors, pump stations, piping, and units subject to peak flow conditions.
Minimum Hourly Flow	The least flow rate received at the facility over a period of one hour.	Designing pump stations, and other units sensitive to excessive detention times.

Major Design Requirements from PA DEP

- Operational during the 25 year storm event and protected from the 100 year storm event
- Be able to pump peak instantaneous flow with single pump out of service (10 States only requires peak hourly)
- Pumps shall be capable of passing a 3” sphere
- Suction, discharge and piping shall 4” diameter
- Pumps shall be Class I, Division I (explosion proof)
- No check valves in the vertical

Major Design Requirements from PA DEP (cont.)

- Wet wells shall provide a holding period not to exceed 10 minutes at maximum monthly average flow (MMAF) and for small collection systems this should not exceed 30 minutes
- Force mains shall be sized to produce a fluid velocity of 2.0 fps at MMAF (but you are designing the pump to meet peak instantaneous)

Design Challenges

- Peak Instantaneous Flow - This design criteria is suspect for the following reasons:

  a. It is an arbitrary number that is “guessed” at by the engineer. There is very little data to support it.
  b. It forces engineers to oversize pumps.
  c. It is meant to insure that pumps can keep up with peak flow but there is no evidence to suggest that it works.
  d. Monitoring levels within a wet well is more logical, while tracking flow measurements.

Design Challenges

Designing for year 20

- Year 1 flows may be significantly lower than designed for = long holding times (odor)
- Low flow and high pumping capacity can create an environment where pumps start and stop frequently
- See slide on actual versus calculated design conditions

Design Challenges

Inflow and Infiltration (I/I)

- Flows can go from a normal flow to 8, 9, 10 times higher
- Design for high flows versus remediate the I/I
- Oversized pumps for events that occur infrequently

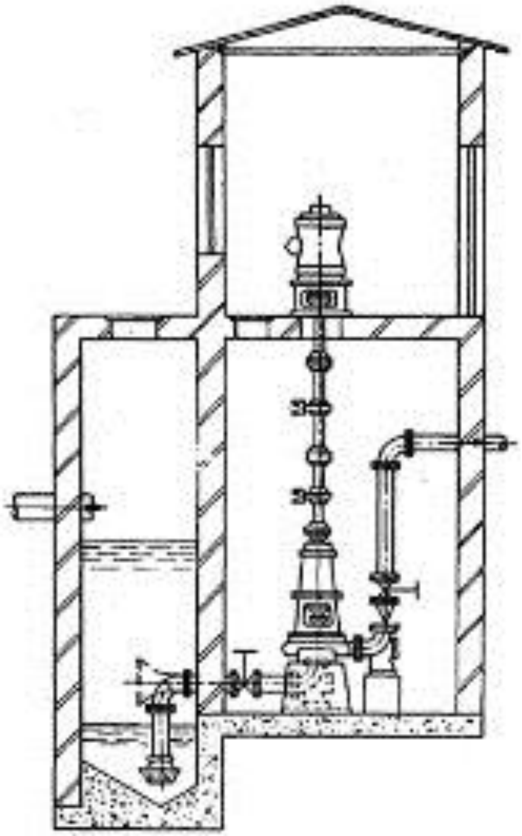
Wet Well Design

- Volume: Too big = odor, too small = overflow
- Geometry: 6, 8, 10 foot versus a rectangular wet well
- Depth: Free fall for the nearest connection
    - Deep = Expensive
- Lowest point in the collection system (flooding)
- Acces: Someone may have to get into the wet well

Dry Well Design

- Typically made for larger stations
- Allows for dry access to the pumps
- Allows for pumps to be in a flood area while motors are elevated out of the area (extended shafts)
- Expensive

Typical Dry Well Design



Area Classification

- Sumbersible pump stations deal with the potential of methane and therefore have to be considered for the potential of explosion.
- This potential classifies the area as hazardous.
- Class I, Division 1 classified locations

  An area where ignitable concentrations of flammable gases, vapors or liquids can exist all of the time or some of the time under normal operating conditions.

Area Classification (cont.)

Class I, Division 2 classified locations

An area where ignitable concentrations of flammable gases, vapors or liquids are not likely to exist under normal operating conditions. In this area the gas, vapor or liquids would only be present under abnormal conditions (most often leaks under abnormal conditions).

Type 7 Enclosures constructed for indoor use in hazardous (classified) locations classified as Class I, Division 1, Groups A, B, C, or D as defined in NFPA 70.

Accessory Equipment

- Grinders-Minimize clogging/protect pumps
- Screens –Solids removal/protect pumps
- Odor Control/protect public
    - Chemical
    - Forced Air/Bio-Filter/Carbon

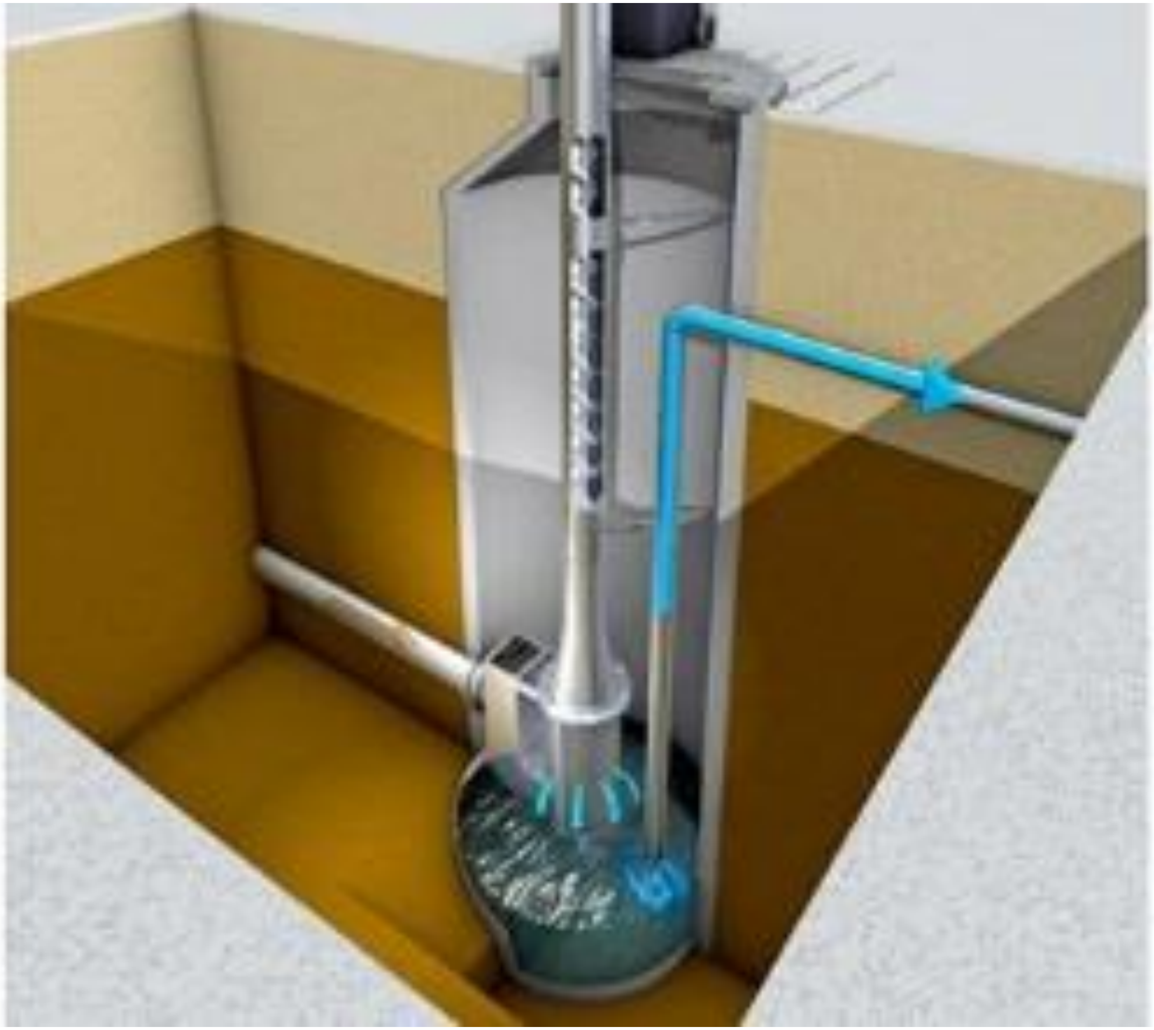
Grinders

source: http://www.septicmatters.com

Grinders

source: http://www.muffinmonster.com

Screens



source:
http://www.huber.com

Access

- Hoist
  - Power versus manual
- Monorail
  - Typically dry well installation over each pump
- Hatches
  - Design for pump extraction
  - Design for access

Hoist

source: www.thern.com

QUIZ NO. 2

Piping Requirements

- Required to meet 2.0 fps based upon MMAF
- Can increase velocity but this creates greater friction
- Greater friction means higher energy cost over the life of the pumping station

Piping Requirements

Materials of Construction

- PVC
- Ductile Iron Pipe (DIP)
- HDPE

Ductile Iron Pipe

Special "Thickness Classes" of Ductile Iron Pipe†

NOMINAL PIPE SIZE (inches)	OUTSIDE DIAMETER (inches)	THICKNESS CLASS						
		50	51	52	53	54	55	56
		NOMINAL THICKNESS (inches)						
3"	3.96	—	0.25	0.28	0.31	0.34	0.37	0.40
4"	4.80	—	0.26	0.29	0.32	0.35	0.38	0.41
6"	6.90	0.25	0.28	0.31	0.34	0.37	0.40	0.43
8"	9.05	0.27	0.30	0.33	0.36	0.39	0.42	0.45
10"	11.10	0.29	0.32	0.35	0.38	0.41	0.44	0.47
12"	13.20	0.31	0.34	0.37	0.40	0.43	0.46	0.49
14"	15.30	0.33	0.36	0.39	0.42	0.45	0.48	0.51
16"	17.40	0.34	0.37	0.40	0.43	0.46	0.49	0.52
18"	19.50	0.35	0.38	0.41	0.44	0.47	0.50	0.53
20"	21.60	0.36	0.39	0.42	0.45	0.48	.051	0.54
24"	25.80	0.38	0.41	0.44	0.47	0.50	0.53	0.56
30"	32.00	0.39	0.43	0.48	0.51	0.55	0.59	0.63
36"	38.30	0.43	0.47	0.53	0.58	0.63	0.68	0.73
42"	44.50	0.47	0.53	0.59	0.65	0.71	0.77	0.83
48"	50.80	0.51	0.58	0.65	0.72	0.79	0.86	0.93
54"	57.56	0.57	0.65	0.73	0.81	0.89	0.97	1.05

†These special thickness classes were designated standard thickness classes by AWWA/ANSI Standard C150/A21.50-81.

source: https://constructionmentor.net/

Ductile Iron Piping

- Typically used for force mains
- Class 53 is the thinnest class that can be threaded or flanged
- Class 53 used above grade
- Class 52 used below grade
- Cement lined

PVC Pipe

- Conforms to AWWA C900 &905 (DIP fittings)
- SDR-21 for thickness
- Typically use DIP fitting and restrained joint
- Less friction loss
- Easier to install = Less costly
- Recently gaining more acceptance

HDPE

- Advent of boring has become more popular
- Field welded
- Similar friction characteristics to PVC
- Can accept DIP fittings

Coupling

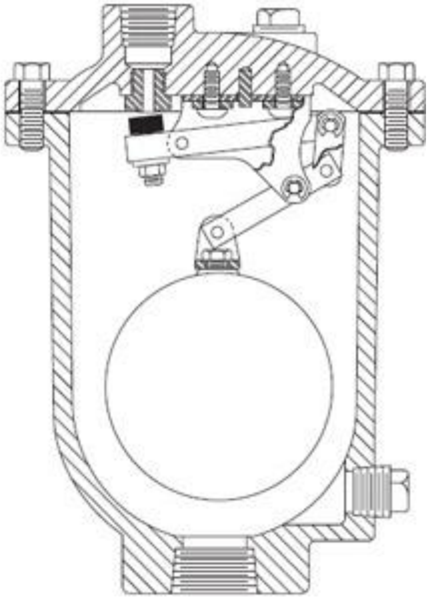
- Flanged (above grade)
- Mechanical joint below grade
- Push-on joint below grade
- Restrained joint
- HDPE field weld

Force Main Layout

- Eliminate the high spots (air release valve)
- ARV versus scouring velocity
- High static head = Water hammer
- Long lines at low pumping rate = septic conditions
- Short lines are susceptible to artificial peak flows

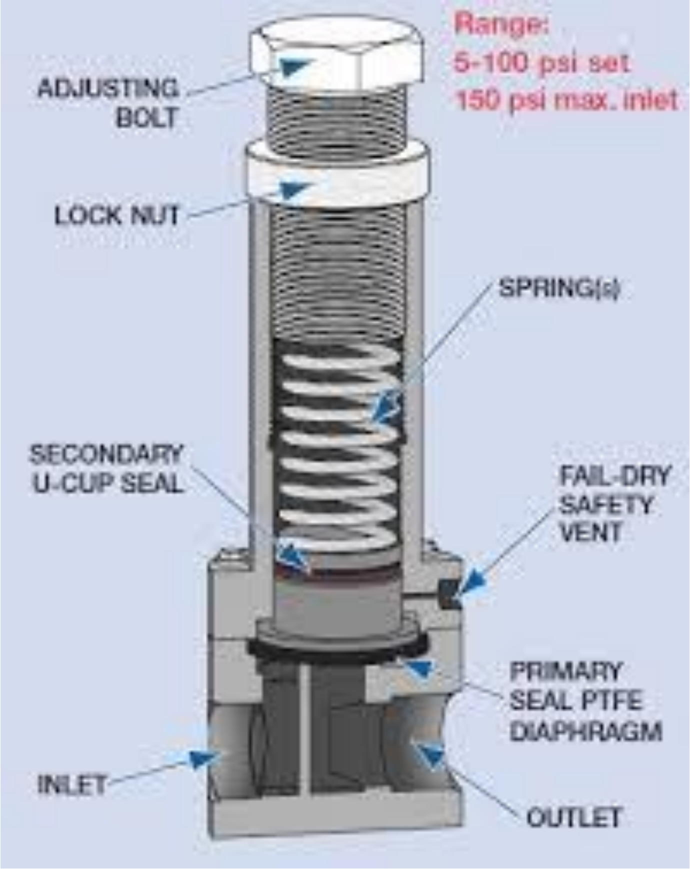
Air Release Valve

source:
http://www.bermad.com.au



source:
http://www.pumpsandsystems.com

Pressure Relief Valve



source: http://plastomatic.com

Minimize Water Hammer

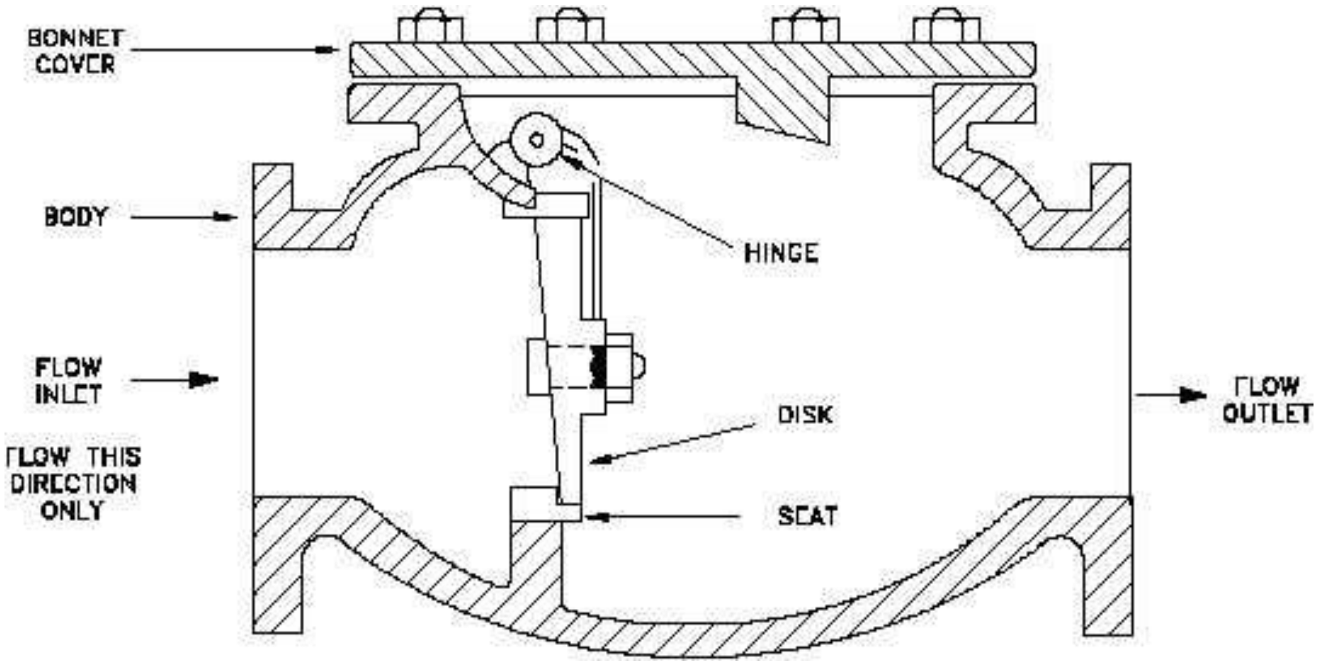
- Pressure Relief Valve
- VFD

Valving

MOST COMMON VALVES ON A PUMPING SYSTEM

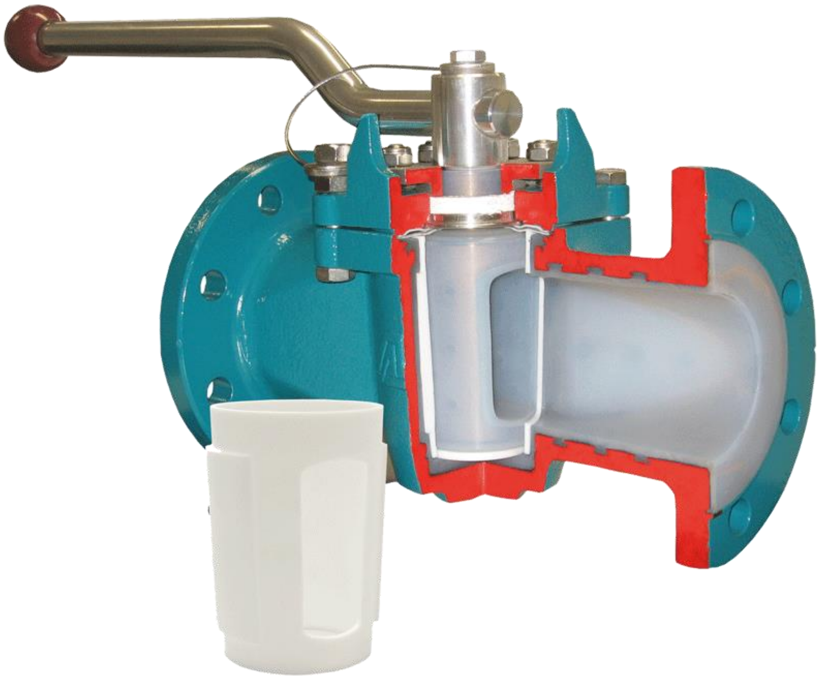
- Check Valve- Used to isolate flow
- Plug Valve-1/4 turn, can stand heavy solids
- Gate Valve –Resilient seat, Rising stem acts as an indicator

Check Valve



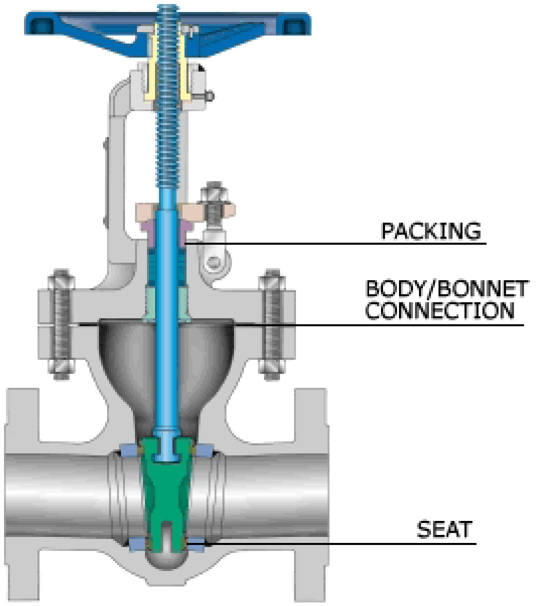
source: http://nuclearpowertraining.tpub.com

Plug Valve

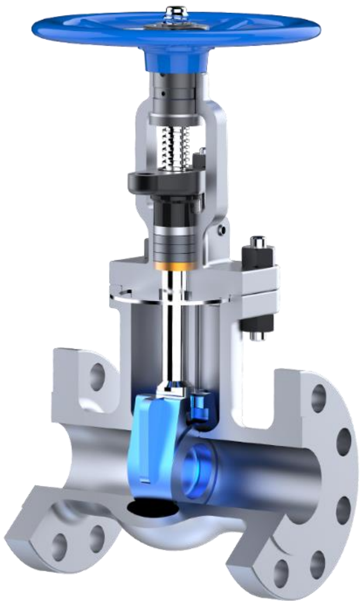


source: http://az-armaturen.de

Gate Valve



source: www.globalspec.com

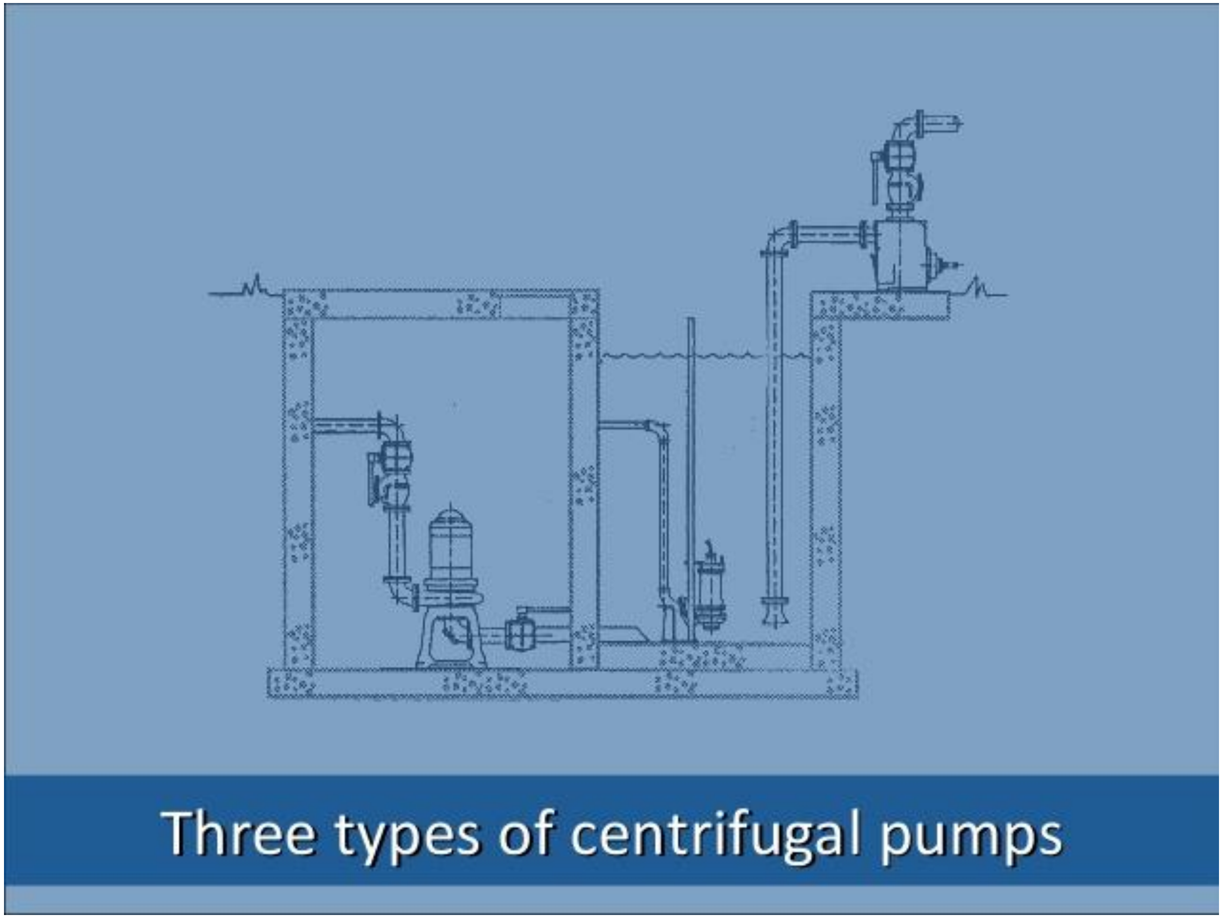


source: www.coppervalves.com

Centrifugal Pumps

- Submersible Pumps- Most commonly used.
- Dry Pit Submersible-Used in areas that are prone or could be flooded. Usually needed source of cooling.
- Self Priming-Allows for the pump to be outside areas of concern.

Three types of centrifugal pumps



source: https://www.slideshare.net/briangongol/a-brief-introduction-to-selfpriming-pumps

Submersible Pumps

source: www.flow-tech.com

Dry Pit Submersible

source: www.flygt.com

Self Priming Pumps

source: https://www.grpumps.com

Self Priming Pumps

source: https://www.thepumpco.co.uk

Motors and Starters

- Rule of thumb: Anything above 5 hp is typically relegated to three-phase 480 volt power
- Modern design is looking more to inverter duty, premium efficiency motors (VFD capable)

Motors

- Thermal protection/alarm
- Seal failure alarm
- Housing classification

Full Voltage Non Reversing (FVNR)

- Previously the most common starter
- ON/OFF
- Digital flow response versus analog
- Most wear on pump motor
- Requires higher emergency power requirement

Variable Frequency Drives

- Analog control of the pump speed
- Analog control of the pump output
- Increases efficiency – Start it once and forget
- Typically controlled by an analog element
- Can contribute to a large savings in electrical costs

Soft Starters

- Dumb version of a VFD
- Slow start over time (can be programmed)
- Can also be incorporated with a slow stop
- Can save in in-rush and emergency power requirements

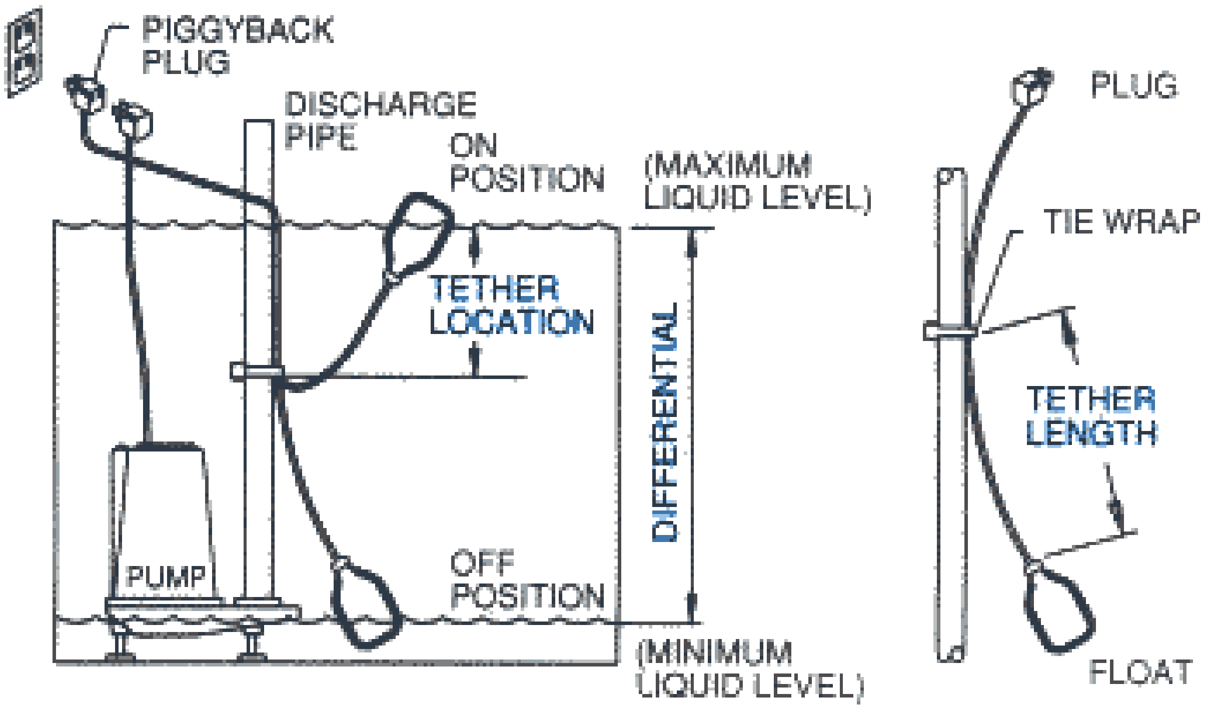
Starts per Hour

- Part of the design is to estimate the number of starts per hour
- Goal is to minimize
- Manufacturers should be consulted on the allowable

Pumping Station Controls

- Float Switches-Digital on/off (standard), can get hung up on rags, easily adjustable
- Pressure Transducer – Analog response to depth, usually debris does not interfere
- Ultrasonic-Measures depth from the surface, scum and piping can interfere
- Flow Meter – Mag meter on discharge, can be incorporated into an analog feed back
- SCADA

Float Switch



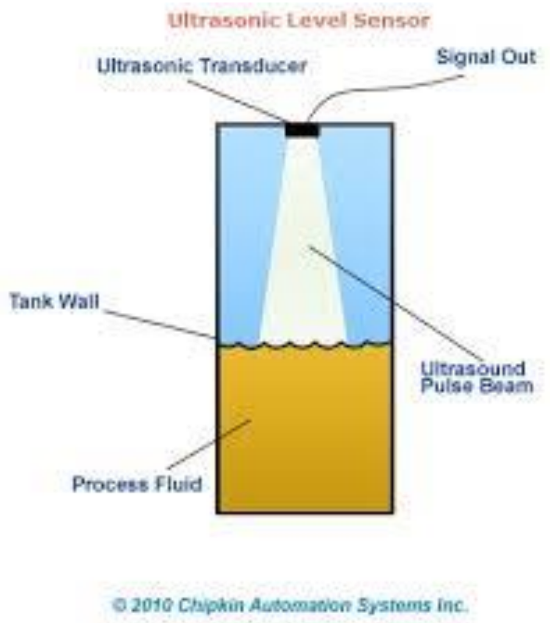
source: https://www.amazon.com/Float-Switch-Septic-System-Sump/dp/B0064BHEVM

Float Switch

Pressure Transducer

source: https://www.viatran.com

Ultrasonic



source: http://www.maxbotix.com

Mag Meter

source: http://www.flomotionsystems.com

Questions

Time for questions and answers.

QUIZ NO. 3

Thank You!

Pumping Station Design for Operators

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Schedule at http://mobile.prwa.com

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