PUMP FUNDAMENTALS

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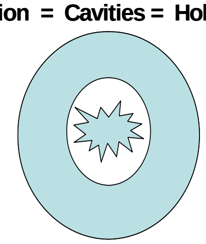
Vapor Pressure

The vapor pressure of a liquid is the pressure required on the surface of the medium to keep it in liquid form at a relative temperature. Every liquid has its own unique vapor pressure. At a given temperature every liquid must have a specific amount of pressure on its surface or it will flash or boil. If we look at water for example, at 212°F water has a vapor pressure of 14.7 psia absolute. When you live at sea level you can see this every day when you poach an egg if you use a thermometer. On the other hand if you live in Colorado Springs water boils at 200°F because of the lower atmospheric pressure 11.8Cavitation is the vaporizing of a fluid creating small vapor pockets, which violently implode (collapse) when they return to their fluid state. The degree of full-blown cavitation is determined by the difference between a fluids vapor pressure and the absolute pressure on its surface.

Cavitation

Cavitation is the formation and collapse of vapor bubbles within a piece of process equipment, I.E a valve, instrument, pump or pipe. This is caused by the localized boiling of a media due to its pressure falling below its own vapor pressure. As these vapor bubbles collapse in enough frequency, a noise is heard which sounds like marbles in your pipe, elbow, valve or pump. If these bubbles collapse with enough energy, metal can be removed in small pockets on the surface.

Cavitation = Cavities = Holes In Liquid



The implosion of cavitation bubbles is like artillery shells going off inside your process systems. A cavitation bubble only lasts 50 millionths of a second, and sends a water jet at a speed up to 560 miles per hour at the surrounding material. The bubbles are less than 100 microns in size, and create an imploding pressure approaching, 10000 psi and when the bubbles collapse the water is traveling at the speed of sound 4800 feet per second (in water). This tremendously violent effect will continue on and on and on until something is ruined.

Trim Material	Hardness Rcwell C	Impact Strength	Corrosion Resistance	Max.Temp Range F°	Erosion Resistance	Abrasion Resistance
316 SS	8	Excellent	Excellent	600°F	Fair	Fair
Stellite 6	44	Excellent	Excellent	1500°F	Good	Good
Stellite 12	46-52	Good	Excellent	1800°F	Good	Excellent
416 SS	40	Good	Fair	800°F	Good	Good
17-4 Ph SS	44	Good	Good-Exc	800°F	Good	Good
440C SS	55-60	Fair	Fair	800°F	Excellent	Excellent
K-Monel	32	Good	Good-Exc	600°F	Fair-Good	Good
Tungsten Carbide	72	Fair	Goodbases Poor-acids	1200°F	Excellent	Excellent
Colmonoy#5	40-50	Good	Fair	1200°F	Good	Good
Hastelloy C	23	Excellent	Excellent	1000°F	Fair	Fair
Nitrite	70-80	Good	Fair	Base Mtl	Excellent	Excellent
Chrome plt	60-70	Good	Excellent	800°F	Good	Good
Electroless Nickle	49-70	Good	Good	1200°	Good	Good

Velocity

Velocity is the rate of motion in a given direction in relation to time. The rate of increase in velocity or the average increase of velocity in a given unit of time is called acceleration. The flow rate of a liquid through a piece of pipe will dictate what the liquid velocity will be. For example lets look at a flow rate of 220 GPM and see what the velocity would be through 2 ½″ pipe and then 6″ pipe. As you can see we will be able to flow the required amount in both sizes but the velocity and friction loss will be different.

Velocity of the suction piping is very important as you try and provide a pump smooth laminar flow into the eye of your pumps impeller. As a rule of thumb you should limit suction velocity to 4 feet per second to assure this slow quiet liquid path.

	Suction Velocities			
General Service	50-150	PSIG	4	Feet Per Second
	Practical Water Velocities			
City Water	25-40	PSIG	2-5	Feet Per Second
General Service	50-150	PSIG	5-10	Feet Per Second
Boiler Feed	150	PSIG	10	Feet Per Second
Plastic Pipe	any	PSIG	5	Feet Per Second Max
Copper > 140′F	any	PSIG	2-3	Feet Per Second
Copper < 140′F	any	PSIG	4-5	Feet Per Second
Copper Cold Water	any	PSIG	5-8	Feet Per Second

Discharge velocities can be much greater and the things you need to consider are cost of material, and potential life of system.

Water Hammer

A conservative way to calculate the adverse effects of water hammer is to multiply the flowing velocity by 54 to determine the pressure rise. Therefore with the instantaneous closure of a check valve, a pressure of 540 psi above system pressure is realistic with a flowing velocity of 10 feet per second.

When a pump shuts off, the column of water maintains its momentum until it is consumed by friction and gravity. In a check valve application for the check valve to operate without noise it must close before the reversal of flow. It is this sudden stoppage of the reversal of flow which causes water hammer, and the longer this reversed flow continues, the greater the hammer when stopped. Since water is relatively incompressible, it can be compared to a solid column and its effect on the disc of a check valve is the same as dropping the weight of a pile driver. The farther the weight falls, the greater the force exerted when stopped.

To prove this theory a series of tests were conducted with conventional horizontal swing checks and center-guided silent check valves. The tests were administered to prove the effects of water hammer and also the directional distribution of the pressure surge. They were trying to determine if the pressure surge is the same on the system side of a check valve as it is on the pump side when the check valve is closed?

The study shows in figure #1 the results of water hammer caused by check valves installed on the discharge or system side of a pump. The test conditions for figure #1 were a metal faced horizontal swing check. For figure #2 a metal faced silent check valve was used and both units were 6" size, flow = 500 GPM, velocity of outflow = 6' feet per second. Both units installed in horizontal lines. Recording instruments were placed on the discharge side of these valves . The metal faced swing check (fig#1)recorded a pressure surge of 380 psi which caused a loud water hammer noise and vibration of the pipe system. The metal faced silent check(fig#2) registered a pressure surge of 130 psi with no water hammer and associated vibration. On the pump side a metal faced swing check valve in figure #3 registered a pressure surge of 75 psi. Metal faced silent check valves figure #4 recorded a pressure of 10 psi. This study clearly shows how silent check valves can drastically reduce or eliminate the damaging effects of water hammer. For this reason it is good insurance to put silent checks on the discharge side of your pumps to protect not only the pumps but control valves, instruments and piping components.

2000 gpm flow in an 8" steel pipe would have a water hammer potential of

Flowing velocity of 12.8' ft/sec x 54 = 691 pressure prox. over system pressure

Water hammer can be minimized or eliminated by slowing process closing time with the following formula:

Time seconds = 0.14Q / S(P)

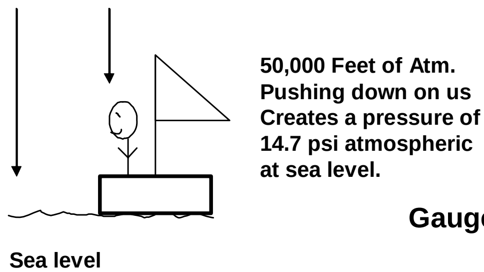
Where:

Q = flow in gpm
S = upstream pipe size in square feet
P = pressure rating of the valve in psi.

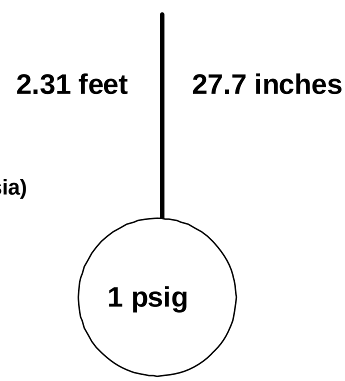
Normally a closing time of 6 – 8 seconds is sufficient to eliminate water hammer.

Head in Feet

Head is another word used to express pressure. Static head is the pressure at any point in a fluid caused by a vertical column. In a static liquid (a body of liquid at rest) the pressure difference between any two points is in direct proportion only to the vertical distance between the points. This pressure difference is due to the weight of the liquid and can be calculated simply. An advantage of using head in feet of liquid to denote pressure is that it is equal to the foot-pounds of pressure energy available from each pound of fluid.

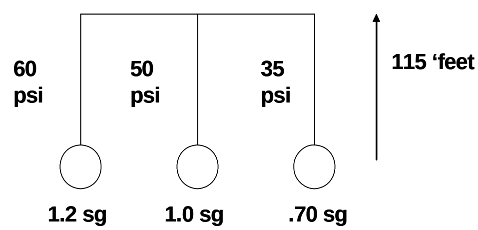


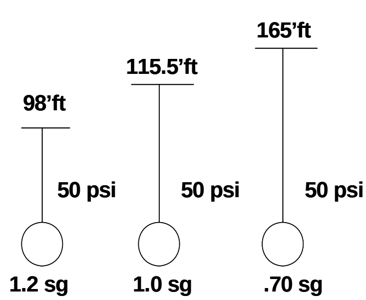
Gauge Psi + Atm Psi = Absolute Psi



Atmospheric Pressure (1 Standard atm) =

0	**psig (gauge pressure)**
14.7	**pounds per square inch (psia)**
760	**mm of mercury**
760	**torr**
760,000	**millitor or microns**
101,325	**pascal**
1.013	**bar**
1013	**millibar**
29.92	**Inch of Hg**



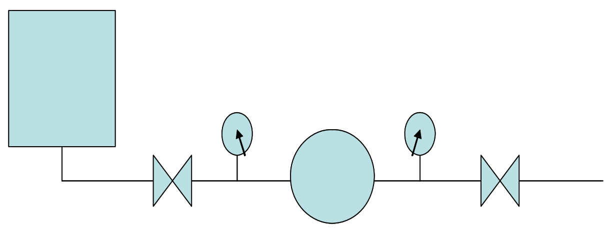


Troubleshooting Shooting with A Pressure Gauge

Too may pump installations are missing one simple item that, when needed, can provide a world of troubleshooting information. All too often, simple pressure gauges are not installed on the suction and discharge ports of a pump. Many times when they are installed, they are placed in poor locations that negate their troubleshooting value.

Gauge Placement

The discharge gauge should be placed before the discharge isolation valve and close to the pump. Install the suction gauge after the suction isolation valve and, again, close to the pump. You should have the following flow path: suction isolation valve, suction gauge, pump, discharge gauge, discharge isolation valve. Rule of thumb is for the discharge gauge to read 2x normal pump output. The suction gauge should read 1x normal suction pressure. Note that the gauges should have their own isolation valves. This will make replacement of the components easier.



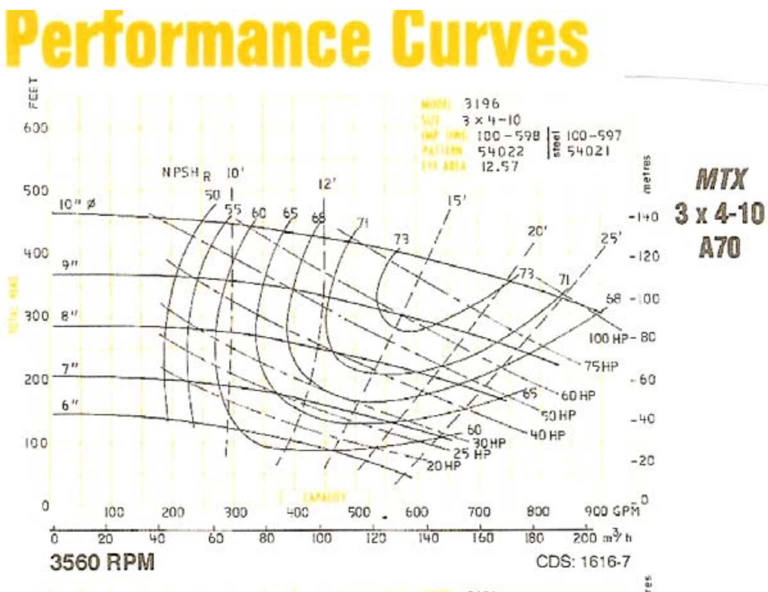
Troubleshooting with Gauges

What can these gauges do for you? Imagine this situation. An operator reports that the pump you installed four years ago is not pumping, an all too common occurrence in the pumping industry. What do you do? If you have operational gauges, your first step is to note the reading of the discharge gauge. Then quickly deadhead the pump using the pump discharge isolation valve. (you should always ask your operations people if you can do this safely.) While watching the discharge gauge, slowly reopen the discharge valve. The gauge might do any of the following: not move, move up a little, or move up a lot.

There are several possible causes for each of the three gauge reactions. If the gauge does not move, it could mean that the pump truly is not pumping, it is broken. No gauge movement can also mean that the system is plugged; the pump is operating correctly, but is being deadheaded. You might also have installed the wrong size impeller or a valve might have been closed by accident. Lastly, the gauge itself could be broken. If the gauge moves only slightly, the pump might be pumping but is not deadheaded. This kind of gauge movement would also tell you that little flow is moving through the system and that the pump or system might be partially plugged. A valve could be partially closed, a valve actuator could have malfunctioned, or the wrong size impeller could have been installed. If the gauge moves up a lot, the pump is pumping and there is a lot of flow moving through the system. A valve that is normally closed might have been opened by accident.

Interpreting the Signs

How do you know what the gauges are telling you? First, you need to convert the gauge readings to feet of head (TDH). You will need the pump curve handy. The TDH at zero flow on the curve will be the TDH obtained from the deadheaded gauge reading. The pump curve also tells you the pump impeller size installed for this TDH. Following the curve to the right, find the initial gauge reading. The point where it falls on the curve indicates the amount of flow moving through the systems. This can all be done in five minutes with no additional instrumentation, lockouts or work orders. Take this information to the operations people and find out what "normal" pressure & flow is.



You can see what a gauge pressure reading should be if you pick an impeller diameter and follow the curve from zero flow to run-out conditions. Lets say the impeller is 9 3/8" diameter. The shutoff zero flow gauge reading would be 173 psi in a water application. The same pump and impeller could have at gauge reading of 119 psi at run-out flow of 850 GPM.

Electrical Cost

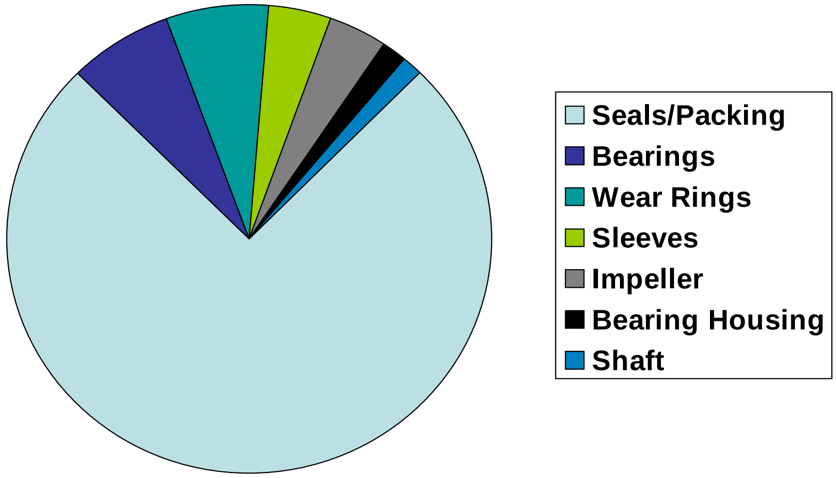
If you take a simple formula for cost of pumping and put the numbers in for a PR = .05 cents K/Wh.

Cost per yr = 8760 hrs per year x Ihp x .746 x .05 cents/kWh
30 HP pump = $9802.00
40HP pump = $13069.00

Cost/hr. = kWI x PR	Cost/hr. = IHp x .746 x PR	Cost/hr. = $\frac{Q \times TH \times .746 \times PR}{3960 \times PE \times Em}$
Cost/hr. = $\frac{.000189 \times Q \times TH \times PR}{OPE}$		

Where: **kWI** = kW Input, **PR** = power rate($/kWh)
IHp = Input Hp, **PE** = Pump Efficiency,
Em = Motor Efficiency, **TH** = Total head (ft),
Q = flow (gpm), **Cost** = $(dollars)

Pump Failure Analysis



Payback Analysis

A - Condensate Load to be Returned	5,000 lb/hr
B - Annual Operation Hours	4,000 hr/yr
C - Total Water Cost (C1+C2+C3)	$ .005 /gal.
C1-Untreated Makeup Water	$ .002 per gal.
C2-Sewage	$ .001 per gal.
C3-Chemical Treatment	$ .002 per gal.
D - Makeup Water Preheating Required	130 BTU/lb
E - Steam Cost (per 1,000 lb)	$5.00

F - Savings of Total Water Costs

$$\frac{A \times B \times C}{8.34 \text{ lb/gal}}$$

$$\frac{5{,}000 \times 4{,}000 \times .005}{8.34 \text{ lb/gal}} = \$\ 11{,}990.00/\text{yr}$$

G - Savings of Steam for Preheating Makeup Water

$$\frac{A \times B \times D}{*1{,}000} \qquad \frac{E}{1{,}000}$$

$$\frac{5{,}000 \times 4{,}000 \times 130}{*1{,}000} \times \frac{5.00}{1{,}000}$$

or $ 13,000.00/yr

* (BTU/lb from Direct Injection)

H - Cost of Steam to Pump Condensate - PPP

Steam consumption is approximately 3 lb per 1,000 lb pumped in a vented atmospheric system. In a closed system, steam cost is negligible.

$$\frac{A \times B}{1{,}000} \qquad \frac{E}{1{,}000}$$

$$\frac{5{,}000 \times 4{,}000}{1{,}000} \times \frac{5.00}{1{,}000}$$

or $300.00/yr

I - Total Annual Savings

F + G - H

$11,990.00 + $13,000.00 - $300.00

or $24, 690.00/yr

F - Savings of Total Water Costs
G - Savings of Steam for Preheating Makeup Water
H - Cost of Steam to Pump Condensate

J - Payback Period

Cost of PPP/Total Annual Savings = Payback in Years

$4,500* / $ 24, 690.00   * is an approximate price for the PPP

= .18 years

or 65 ½ days

What To Ask When Selecting a Pump

Electric Pump:

- What type of pump? (Condensate or Boiler Feed)
- Simplex or Duplex? (1 pump/motor or 2 pumps/motors)
- What capacity? (In GPM, lb/hr or E.D.R.)
- What discharge pressure? (In psig or ft of head)
- What voltage and phase are the motors?
- What size receiver and of what material? (Cast Iron or Steel)
- Any Options?
- Does customer require a control panel?
- If so, what should it contain?