Process Plant & Equipment UP-TIME for Plant Operators & Maintainers

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Regular features

Process Control Talk

Don't run centrifugal pumps on the end of the curve

ABSTRACT

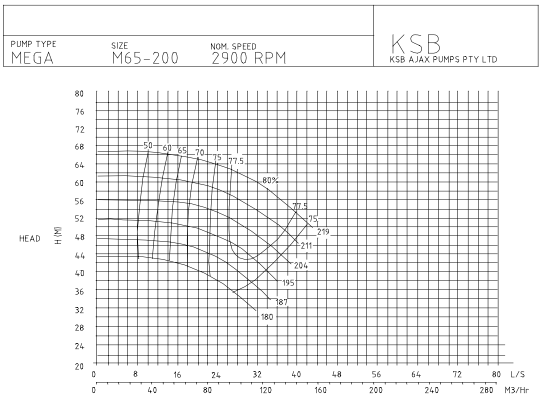
Don't run centrifugal pumps on the end of the curve. Pumps are designed and selected to operate near their highest efficiency point. If they operate at the right-hand end of the pump curve the likelihood of cavitation increases. Keywords: suction pressure, flow velocity, vapour pressure, duty point.

PUMP CURVES AND WHAT THEY MEAN

When the impellers in centrifugal pumps turn, they spin the liquid sitting in the cavities between the vanes outward. This liquid is forced up the discharge pipe and new liquid is sucked in to replace the liquid ejected by the spinning impeller. The amount of liquid pumped depends on:

i) the diameter of the impeller
ii) the size and shape of the cavity between the vanes
iii) the size of the pump and the size of its inlet and outlet openings
iv) the rotational speed (RPM) of the impeller
v) how much back pressure is at the pump discharge
vi) how much pressure is at the pump suction
vii) the density and viscosity (slipperiness) of the liquid

For a pump with a particular impeller running at a certain speed in a liquid, the only items on the list above that can change the amount flowing through the pump are the pressures at the pump inlet and outlet



The effect on the flow through a pump by changing the outlet pressures is graphed on a pump curve. A typical set of pump curves for a centrifugal pump is shown above.

The lines running to the right and downward are the performance curves for the pump. They apply only to this pump running at 2900 RPM with the impeller diameters shown at the right end of each curve. At different speeds or with different impellers different curves would result. As an example of how to use the curves, assume 120 cubic meters per hour of water had to be pumped up to a tank on a 50-meter high building. The impeller size to use in the pump is found from the curves by running a line up the page at 120M^3/H. Another line is run across the page at 55 meters (allowing about 10% extra back pressure due to friction loss in the piping and valves). The intersection point falls near the 211 mm size impeller.

The curves running up and down are the pump efficiency curves. They indicate the pump efficiency at different operating conditions. Pump efficiency is a measure of how much of the energy put into the pump actually goes into pumping the liquid. The duty point of 120M^3/H and 55 m back pressure for the 211 mm impeller determined above is well positioned at a high efficiency. This is a good pump selection for the duty.

The pump curves tell what flow to expect from a particular size impeller for a given amount of back-pressure on the pump. When a pump is selected for a duty, the designer selects a pump that operates at high efficiencies on the pump curve for the impeller size. Changing the impeller width, the impeller diameter or the angle of the vanes in the impeller alters the impeller curve characteristics. A wider impeller scoops more liquid and produces more flow, a larger diameter impeller flings liquid out at higher speed and so produces more pressure and changing the angle of the vanes alters the shape and steepness of the pump curve.

The pump curves suddenly stop at the right end of each curve. Beyond the end of the curve the pump manufacturer is advising that the pump cannot be safely operated. Trying to run a pump off the right end of the curve will result in pump cavitation and eventually destroy the pump.

PUMP CAVITATION

Pump cavitation occurs when pockets of vapour enter the pump because the liquid is boiling. As a pump tries to pull through more liquid, the pipe friction pressure loss on the suction line rises and the liquid entering the pump sees less pressure (because it was lost to friction). A vacuum starts to develop at the pump suction. If the vacuum gets deep enough the liquid will start to boil and vapourise and the liquid passing through the pump will contain bubbles of vapour. There is a roaring sound, as if the pump is pumping gravel. This noise is the vapour bubbles imploding when the pressure increases again after the low pressure point.

EFFECTS OF 'RUNNING ON THE RIGHT'

A pump operating off the right of the curve is cavitating. The suction and discharge pressures fluctuate wildly pulling and pushing the impeller about because of the out-of-balance forces. The shaft rattles; mechanical seals are damaged; packing is worn; bearings are destroyed by brinelling (hammering) and shafts are bent. Pumps will be noisy, vibrate and shake, get hot and the microjets of liquid ejected by imploding bubbles will hit and erode the impeller metal. Consequently the pump will fail often and need a lot of maintenance.

Some possible reasons why a pump may be running off the right side of the curve are shown in the table below:

Incorrect head pressure calculation	The pump duty was incorrectly determined or unknown. Grabbing any pump available without doing calculations and checking the pump curve can result in this problem.
Additional tankage was added and the suction line extended	A longer suction line has more pipe wall friction pressure loss so lowering the pressure available at the pump suction.
Blocked suction line.	Blocked strainers and closed valves are examples
Suction pipe line	Pressure loss occurs at every valve, every elbow

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friction losses not allowed for.	and tee, every projection into the flow and along every millimeter of pipe.
Broken discharge pipeline or discharge bypass valve opened.	Once the back pressure is lowered a higher flow occurs which forces the duty point to the right of the original operating point.
Removing valves, tanks and pipes from the pump delivery line.	Reducing the back-pressure on a pump causes the flow through the pump to rise. The duty point moves to the right of the original point.
An old pump is moved to a new duty.	To keep capital costs down old pumps are often reused. If the pump is oversized it will operate on the right side of its original design duty point.
Change in the process conditions.	Often a new product will be put through an existing pump. This product may have different properties and so will behave differently.

CORRECTING THE SITUATION

To solve the problems caused by pumps running off the right side of the curve it is necessary to insure the pump suction pressure is above the pressure at which the liquid vapourises (boils). The list below indicates ways to maintain suction pressure:

Use larger diameter suction pipelines	A larger diameter pipe has less pipe wall friction loss because the flow velocity is lower.
Pressurise the suction side.	The suction pressure can be increased by keeping a higher level in the tank, by moving the tank higher and by lowering the pump.
Put more back-pressure on the pump discharge.	Partially closing a valve on the pump discharge will increase the back-pressure and force the pump to operate further up on the left of the pump curve.
Install inducers to reduce suction loss.	These are long helical screws (like a feed screw on an auger) which fit up the suction pipe and spin with the impeller. They scavenge the liquid and draw it through by force.
Stop unnecessary pressure losses.	Maintain free flowing suction line conditions. Clear blockages, use smooth bore pipes and long radius elbows.
Change to a slower, larger pump impeller	Change the pump size to one that delivers the same flow and pressure but at a slower speed. This usually also requires suction piping changes.
Keep the process liquid cool	Keep the liquid as cool as possible to increase the temperature range to the boiling point temperature.
Slow the impeller speed.	Slowing the pump down reduces the flow rate of the liquid and lessens the pipe friction losses. Pumping takes longer and the head pressure falls.
Let the pump manufacturer know the range of duties required.	The manufacturer can make changes to the pump such as using harder impeller material, bigger bearings and changing the impeller shape to improve operation under cavitation conditions.

Mike Sondalini - Maintenance Engineer

When Spinning Equipment is Unbalanced

ABSTRACT

When spinning equipment is out of balance. Vibration from out-of -balance rotating equipment can be frightening. The ground shakes, machines jump about, hold down bolts come loose and parts break. An unbalanced rotating body will produce forces on its bearings and transmit them throughout its structure and into the foundations. Keywords: rotor, centrifugal forces, balance quality.

CAUSES OF OUT-OF-BALANCE

The table below lists some common causes for unbalance.

a)	Bent or bowed between support bearings
b)	Overhung weight bends shaft under gravity
c)	Unevenly distributed solid or liquid inside rotor
d)	Loose parts on the rotor
e)	Eccentrically manufactured diameters on the rotor
f)	Misalignment of the drive train to the rotor axis
g)	Loose drive couplings flop about
h)	Loose tolerances between assembled parts on rotor
i)	Shoulders on rotor manufactured out-of-square to axis
j)	Voids or cavities within the rotor
k)	Misalignment of bearings force shaft to bow

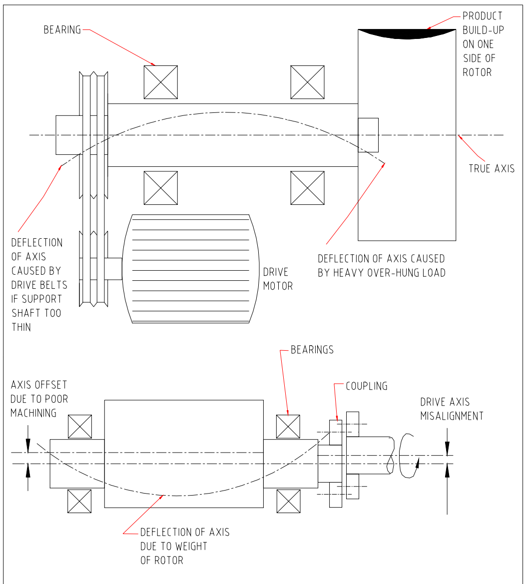
The drawings below provide examples of some of the problems listed in the table above.

REDUCING OUT-OF-BALANCE PROBLEMS

Minimising vibration involves minimising out-of-balance forces. The following table indicates simple actions to take to reduce the problems of out-of-balance.

)	Make the rotor with all diameters on the same axis
i)	Machine the rotor from one piece of material
ii)	Machine the rotor complete without altering the initial machining set-up
v)	Finish machine multiple part rotors when fully assembled on the shaft
)	Reduce lengths of unsupported sections and overhangs
i)	Keep tolerances tight on parts assembled on the rotor
ii)	Align the drive train to the axis of the rotor carefully
iii)	Insure the bearing supports are aligned

BALANCING ROTORS



TYPICAL OUT-OF-BALANCE CAUSES

An out-of -balance machine can be made to run smoothly by balancing the rotating parts to within acceptable limits. Balancing is the process of attempting to improve the distribution of mass in a body so that it rotates in its bearings without unbalanced centrifugal forces. It can only be attained to a certain degree.

When a part is to be balanced it is necessary to specify the quality of balance required. The more precise the balance required the higher the cost to attain it. Relevant standards have been set for various types of components. The list below is taken from BS 6861 and shows typical grades of balance for common components.

Balance Quality	**Rotor Types – General Examples**
G4000	Drive trains of slow marine diesel engines
G1600	Drive trains of rigidly mounted large two-cycle engines
G630	Drive trains of large four-cycle engines
G250	Drive trains of fast, rigidly mounted diesel engines
G100	Complete assembled engines of cars, trucks and locomotives
G40	Car wheels, wheel rims, wheel sets, drive shafts
G16	Propeller shafts, individual car engine components, crushing machine parts
G6.3	Fans, pump impellers, electric motors, general machinery parts
G2.5	Gas and steam turbines, computer disks, machine tool

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	drives
G1	Grinding machine drives, tape recorder drives
G0.4	Precision grinder spindles, gyroscopes

Attaching or removing weight at relevant points on the rotor permits balance corrections. For example specifically weighted tags can be welded to the rotor, or metal can be removed by drilling holes into the rotor at relevant positions.

To minimise the possibility of vibration problems, specify to the machine shop the degree of balance quality required of the part. To improve the accuracy of balancing send all the attached assemblies such as couplings, bolts, keys and pulleys with the rotor so the effect of the components can be allowed for in the balance corrections.

Mike Sondalini - Maintenance Engineer

From the Mechanical Workshop

Get Mechanical Seals Working Properly

ABSTRACT

Get mechanical seals working properly. Mechanical seals are used to keep the bulk contents of rotating equipment such as pumps and compressors from escaping. They do this by sealing the shaft that protrudes from the casing. They require quality installation and operation conditions for a long life. Keywords: precision assembly, barrier fluid, stationary seal, rotary seal, alignment.

The sketch below shows the basic construction of a simple single mechanical seal.

The harder stationary ring is held in place and the softer rotary ring rotates with the shaft. Springs or a convoluted bellows (rubber or metal) pushes the rotary ring against the stationary. With the faces sealed together as they turn, no path exists for the bulk contents to escape.

Between the seal faces an extremely thin layer of product or seal flush fluid develops and acts to lubricate and cool. This thin layer prevents rubbing contact of the surfaces, without which frictional heat would rapidly destroy the seal faces.

WHAT CAUSES A MECHANICAL SEAL TO LEAK?

Mechanical seals leak when the faces are forced apart. If there is evidence of product leaking from a mechanical seal then the faces have had cause to separate. The challenge to maintainers is to find the cause and rectify it. Below are some of the common causes of face separation.

1 Pressure hammer within the equipment caused by such occurrences as rapid closure of valves somewhere in the process.
2 Solids/dirt pinned between the seal faces during assembly or during a pressure surge.
3 Crystal build-up on the seal faces as crystallising products seep past the running faces.
4 Seal faces run dry and build-up heat and crack due to nil or poor lubrication.
5 Under-loaded springs/bellows pushing on the rotary seal when the seal was set-up on the shaft.
6 Unequal spring force on the rotary seal due to damaged or jammed springs/bellows.
7 Movement of the rotary seal housing along the shaft if the locking screw loosens.
8 The seal was damaged during installation and not corrected.

The mechanical seal configuration can promote loss of liquid from the mechanical seal. The seal faces on an external seal are outside of the pump. The internal pump pressure or the barrier liquid pressure, if a barrier liquid is used, combines with the centrifugal action of the spinning seal to drive liquid past the seal faces and drip from the seal. If the liquid is harmless then the few drops will be acceptable. But for harmful chemicals no leakage is permitted. If no leakage of product is allowed it is best to get mechanical seals with the seal faces internal to the pump where any the weep past the faces goes into the product and where the centrifugal action flings the product away from the seals.

REQUIREMENTS FOR LONG MECHANICAL SEAL LIFE

To get a long life, mechanical seal faces must be kept clean, cool, lubricated, square to the shaft and flat together.

a) ACHIEVE A HEALTHY LOCAL ENVIRONMENT

Use a barrier fluid to clean, cool and lubricate. These first three requirements are best achieved by pressurising the spring/bellows chamber with a suitable clean, cool barrier fluid at a pressure higher than on the process side (stuffing box) of the stationary seal. The barrier fluid can be a liquid or gas depending on the service required of the seal. Usually a pressure difference of 100kPa is sufficient to guarantee slight weeping across the seal faces from the barrier fluid into the process. As a rough rule of thumb the stuffing box pressure is about two-thirds the discharge pressure.

An exception to use of a barrier fluid is when the fluid being pumped is itself clean and non-threatening to safety and the environment. Products such as clean water do not need a barrier fluid because the centrifugal action of the spinning seal will draw in minute amounts of water that will cool and lubricate the faces. This water escapes as vapor to atmosphere.

b) ACHIEVE PRECISION ASSEMBLY

Quality seal manufacture and installation achieve the last two requirements. Mechanical seal faces are manufactured to a flatness that is measured using wavelengths of light. Such fine tolerances imply high precision equipment. This is why seals reconstructed in maintenance workshop conditions never last. Precision manufacture requires a precision environment.

High precision is normally only possible at the time of manufacture. Mechanical seals installed by the pump manufacturer tend to last longer than seals installed in the same pump when on-site. The growth in the use of cartridge seals reflects a growing awareness of the importance of precision in the construction and installation of mechanical seals.

c) ACHIEVE PRECISION RUNNING

The alignment between the centre lines of motor and pump, for 4 pole motor speeds and less, must be perfect to within 0.050 mm (0.002”) from the end of the motor shaft to the end of the pump shaft when at operating temperature. There must be no vibration of the mechanical seal due to poor balance, poor tolerances, poor operation, wrong usage practices or poor installation.

Everything must be done to keep the mechanical seal faces together. The seal faces must be square to the shaft. The shaft can only deflect a maximum of 0.025-mm (0.001”) at the mechanical seal face. The shaft and seal centerlines must be concentric to 0.025-mm (0.001”). If the entire shaft rocks and sways the seal must move with the shaft. If necessary mount steady bearings close to the seal to insure the shaft and seal remain concentric. Shaft overhang must be kept small and if that is not possible a thicker shaft or one made of stiffer materials or design is required.

Use C frames (imperial pumps) and D frames (metric pumps) between the pump and motor to provide stiffness, support and constant alignment of the assembly.

ALTERNATIVES TO MECHANICAL SEALS

Other options are now available to use in place of a mechanical sealed pump. For example, if pumping clean liquids, magnetic drive pumps are now available that totally encloses the process. In these pumps a rotating magnet drives the shaft attached to the pump impeller. Similarly ‘canned motor’ pumps operate without mechanical seals. In these pumps the motor is encased within the pump body and cooled by the process contents.

On-going seal failures lead to high life cycle costs. The cost justification to use seal-less pumps on clean liquids is easily achieved once the $2,000 plus cost of the first mechanical seal replacement is added to the purchase price of the mechanically sealed pump. If a pump continues to suffer numerous seal failures then a seal-less pump may totally remove the problem.

WHAT TO DO TO EXTEND SEAL LIFE.

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The working life of a mechanical seal should be at least three to five years. Lives of ten years have been achieved in clean, carefully controlled and monitored applications. People involved in the operation of equipment with mechanical seals need to be aware of the following:

OPERATORS
Pressure hammer problems need to be found and fixed.
Keep the barrier fluid pressure slightly higher than the stuffing box pressure.
Run the pump at design flow and pressure. Never deadhead it.
MAINTAINERS
Insure a clean flushing product or barrier fluid is provided to the seal faces. Make use of valves and pressure gauges to regulate the flow.
Align shafts to near perfection at the operating temperature.
Have mechanical seals repaired by authorised repairers.
Follow the manufacturer's instructions during installation.

Mike Sondalini - Maintenance Engineer

Asset Management

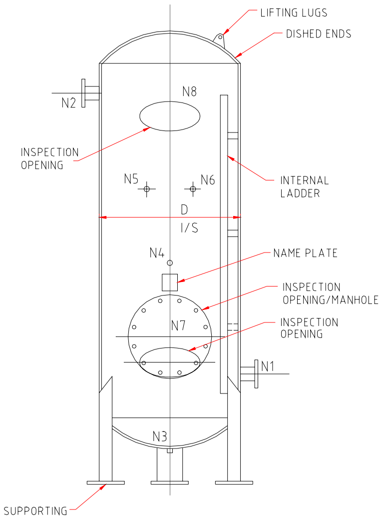
Unfired Pressure Vessel Inspections

ABSTRACT

Unfired pressure vessel inspections. Pressure vessels must be regularly inspected and be maintained in a safe operating condition. New Australian laws stipulate that all pressure vessels must have a Hazard Level rating ('A' highest to 'E' lowest) which reflects the vessel's safety risk (see AS3920.1). The higher the risk the more stringent the requirements for operating and inspecting the vessel.

Keywords: receiver, non-destructive testing, internal inspection.

The definition of a pressure vessel in Australian Standard AS 3873 is " a vessel subject to internal or external pressure. It includes interconnecting parts and components, valves, gauges and other fittings up to the first point of connection to connecting piping." Pressure vessels are such things as compressed air receivers (see the drawing below), barbecue gas bottles, steam boilers, aerosol cans, vertical leaf filters, beer bottles, cigarette lighters and fire extinguishers. This article discusses the general requirements for inspection of unfired pressure vessels such as compressed air and liquefied gas receivers and process reactors. The other types of vessels are inspected to different criteria.



ELEVATION
AIR RECEIVER

WHY INSPECT PRESSURE VESSELS?

It is necessary to inspect the integrity of pressure vessels.

(a) Gases and liquids stored under pressure inside a container are in an energised and compressed state. Rupture of the vessel would result in catastrophic release of pressure.

(b) The chemicals within the pressure vessel may be toxic (e.g. chlorine and ammonia gases).

(c) The contents may attack, erode, corrode, induce stress, change the metal characteristics or weaken the containment vessel over a period of time.

(d) External impact or corrosion may weaken the pressure vessel. (A real problem with externally insulated vessels where the insulation gets wet from rain or from the process.)

EXTENT OF INSPECTIONS

Inspections can be in-service inspections where the inspector does an external inspection, tests the pressure relief device operation and does documentation review so he can certify the vessel for continued use for a short period of time. Or the inspection can be a full inspection requiring inspection of the vessel internal walls and attachments, the external surfaces and attachments, pressure gauges, pressure relief devices, the immediate surrounds of the vessel and documentation. It maybe necessary to remove sections of insulation to expose the outer shell wall

If full visual inspections are impossible or costly it may be possible to substitute nondestructive testing (NDT) methods to confirm the vessel integrity. Such NDT methods as ultrasonic thickness testing, eddy current thickness testing, acoustic crack detection, magnetic particle crack detection and hydrostatic pressure tests are all viable means of proving vessel integrity.

WHAT THE INSPECTOR LOOKS FOR

Only persons experienced and trained in the techniques of pressure vessel inspections are allowed to conduct the inspection. Normally a competent, independent third party is used. The inspector may require improvements to insure compliance with relevant codes of practice. He provides a written report on his findings and certifies the vessel for continued use for a specific period of time. The inspector also advises the relevant government department of the condition of the vessel and the due date for the next inspection. When the certificate is received it is normally displayed in a prominent place near the vessel as proof the vessel complies with the law.

The inspector looks for the following evidence of performance and compliance depending on the Hazard Level of the vessel.

He looks for signs of shell wall thinning.
He inspects for cracks at welds and at connections to the vessel walls caused by stresses.
He checks for damage to the shell by impact.
He looks for leaking gaskets and seals and other evidence of poor maintenance practices.
He inspects protective coatings and linings to insure they are in good condition.
He inspects the soundness of foundations and supports.
He will want to see the pressure relief device work properly and insure it relieves pressure build-up.
He will check the pressure gauge calibration.
He inspects the immediate vicinity of the vessel for potential risks to the vessel.
He will look at the relief piping to insure it vents to a safe place safely.
He will ask to see evidence of vessel registration with the governing authority.
He will want to see where the registration is displayed.
He will look on the vessel for the registration number.
He will want proof that the design of the vessel is registered with the governing authority.
He may want to see verified design drawings and calculations.
He may want to see the manufacturer's fabrication and materials report.
He may want to see as-built installation drawings.
He may want to see the vessel designer's hazard identification and risk assessment.
He may want to see proof of the hydrostatic test and other testing performed by the manufacturer.
He may want to see the installation, commissioning and maintenance instructions from the manufacturer.
He may want to see the commissioning compliance statement especially on new installations.
He may want to see records of inspections, servicing and maintenance.
He may want to see the operating log showing records of operating conditions for plant of Hazard Level 'A'.
He may want to see records of any in-service inspections or special tests such as proof of instrumentation calibration.

Mike Sondalini – Maintenance Engineer

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Net Positive Suction Head Losses
(or why you can suck through a straw)

ABSTRACT
Net positive suction head losses (or why you can suck through a straw). Pumps cavitate and run dry when the pressure leading into them falls below the vapour pressure of what they are pumping. At vapour pressure the liquid boils into a vapour and fills the pipe. In order to know that the pressure to a pump is always above the vapour pressure it is necessary to calculate that the pressure losses from pipe friction and suction lift will not cause the pressure to drop under the vapour pressure. The presence of dissolved gas in the liquid complicates the problem.
Keywords: cavitation, NPSH, net positive suction head required, net positive suction head available, vapour lock

Why you can suck through a straw

When you understand how you suck liquid up a straw you will then have a good understanding of suction lift and its effect on net positive suction head (NPSH).

At the moment all around you is air. The air has weight because Earth's gravity is pulling it down. This weight is acting on the outside surfaces of everything. When you put a straw into a glass of water and suck, you draw the air out of the straw into your mouth. The air that was in the straw has gone and you have created a vacuum inside the straw.

The vacuum you created in the straw is at a lower pressure than the air around you. But the end of the straw is under the water in the glass. A difference in pressure will cause flow from the area of high pressure to the area of low pressure. The inside of the straw is at a lower pressure than the air around you and so the air around you will try to flow to the inside of the straw. But in doing so the air first pushes the water up the straw and into your mouth.

So really you don't suck water up the straw, but instead the water is pushed up the straw by the air pressure around you. All you do is make the vacuum in your mouth and then natural physics principles do the rest.

If instead of a straw we replace it with a pipe, and the vacuum made by your mouth is instead made by a pump. We now have a situation where the pipe friction losses may be so much, or the end of the pipe is so far below the pump (the suction lift), that the vacuum made by the pump can fall low enough to boil-off the liquid before it gets to the pump.

What is NPSH?

The NPSH is the difference between the pressure at the pump suction and the vapour pressure for the liquid. Provided the NPSH pressure difference is well above the vapour pressure, the liquid will flow to the pump without boiling-off and vapourising (cavitating).

NPSH requires that we know two conditions at the pump suction. The first is the real pressure at the pump inlet and the second is the liquid's vapour pressure at the temperature it is when entering the pump. The pressure difference between the liquid's vapour pressure and the real pressure at the pump is called the 'available NPSH'. The pressure lost along the pipe from the suction point into the pipe, through to the inlet to the pump is known as the 'required NPSH'. Provided the 'available NPSH' is greater than the 'required NPSH' the pump will draw the liquid to it and pump it out.

The pressure loss in the suction pipe consists of both friction losses and suction lift losses. If the pump is located lower than the tank nozzle it is sucking from, and the pressure in the tank is not a vacuum (i.e. below atmosphere pressure), then suction lift is not present and only pipe friction losses need to be calculated. If the vessel pressure is a vacuum then the amount of vacuum must be considered as an equivalent suction lift.

However if the pump is located higher than the tank outlet nozzle, then at some point when emptying the tank, the liquid level will go below the top of the pump suction flange and suction lift develops. The situation of having both pipe pressure friction loss and suction lift is shown in Figure No. 1. The height of the suction lift needs to be added to the pressure losses along the suction pipe.

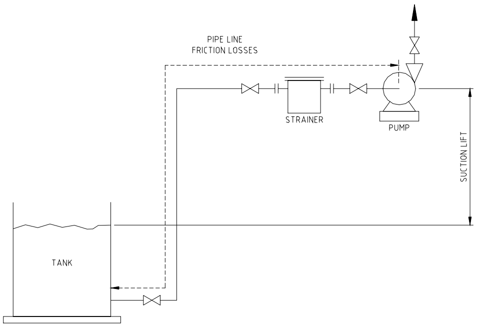

Figure No 1. Suction lift and pipe friction losses.

The effect of gas entrainment on NPSH.

Where gas is dissolved into the liquid, such as carbon dioxide in beer, or the liquid carries bubbles, such as air bubbles caught in water from cooling towers, the gas will separate from the liquid at pressures much higher than the vapour pressure of the liquid.

When making beer the pressure in the piping system after carbon dioxide injection is intentionally kept above the vapourising pressure for carbon dioxide to insure it stays dissolved in the beer and does not vent off.

In the case of the cooling tower pump, the air will come out of the water. This air needs to be vented off. The pump can be positioned so that the air can either go back out the suction pipe. This means that the suction pipe is only partly filled and a larger diameter pipe maybe needed to take both the water and air volumes. Or the air can flow upward to the pump and go out the discharge pipe. This will cause a suction lift situation. Or a venting tank or standpipe may be needed before the pump to let the air escape.

How to overcome NPSH problems

True NPSH problems only occur when the pressure in the liquid at the pump suction is near or below the vapour pressure at the temperature of the liquid. You have two options to solve the problem. You can play with either, or both, the pressure and the temperature of the liquid at the pump inlet.

On the pressure side either increase the supply pressure or decrease the pressure losses along the suction pipe. On the temperature side you must increase the liquid's temperature at the pump suction.

Some liquids have extremely high vapour pressures and are difficult to handle but these principles still apply.

One more viable option remains. It is to change the style of pump. If the pump were also able to safely pump the vapour as well as the liquid, then whenever the pressure fell low enough to create vapour the pump would still move the product. The flow rates would be greatly reduced but no vapour locking would occur.

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