AVOIDING PRESSURE SURGE DAMAGE IN PIPELINE SYSTEMS

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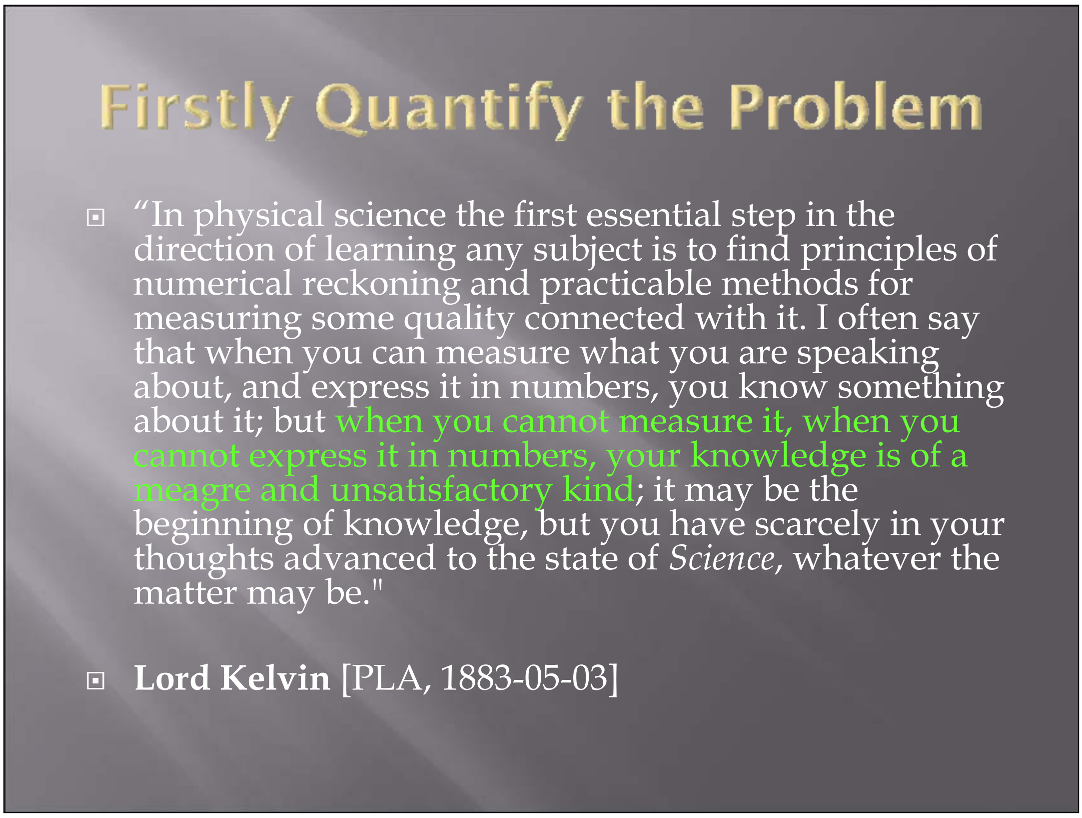


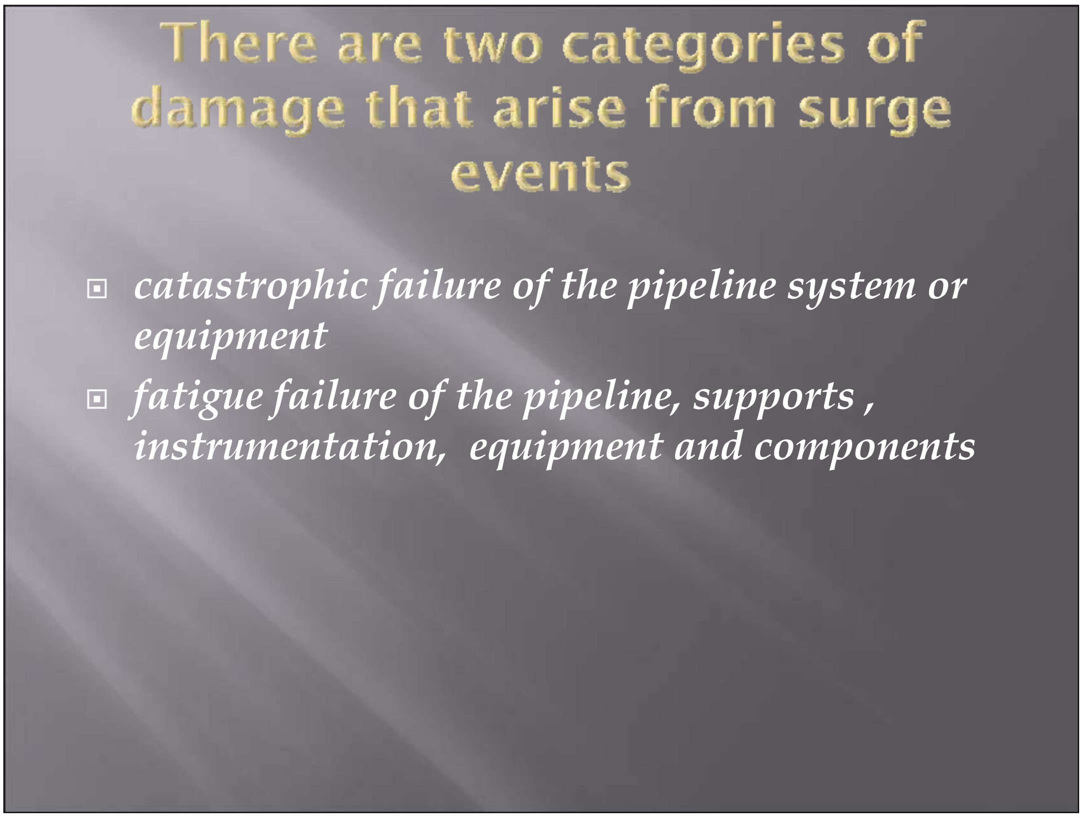
In order to avoid surge pressure damage to piping and pipelines there is one prime requirement. If there is one thing that you, the reader, should gain from this presentation it is this premise. This is that you actually need to know that there is likely to be surge in a pipeline system either by measurement or by engineering analysis.

If You Don't–
The Aftermath

76 People Died

Many National Codes and Standards have requirements to design piping systems to take account of the effects of occasional loads such as pressure transients in systems. This slide lists a number of Australian Codes and Standards where specific requirements to consider surge are provided. The list can be augmented by those documents that apply in your country or industry. This not only concerns positive pressures but also negative pressures. Full vacuum can occur when there is column separation in a pipeline. This commonly occurs when there is a loss of power or rapid closure of an upstream valve. Thin wall ferrous and low stiffness thermoplastic pipe may be subjected to the occurrence of buckling due to vacuum. Buckling may be more likely if the pipe has become oval because of the installation techniques.

Many international standards are employed in the petrochemical and mining industries in Australia. You may find any of these standards referred to in specifications. They all have requirements to consider surge in piping and pipeline design. Unless you quantify the surge pressure the design of the system will not comply with the standard.



Catastrophic Failure of a Pipeline

Pipelines have been known to fail catastrophically as a result of surge events. The failure may take the form of a pipe burst or a pipeline collapse from buckling. What are the consequences of a pipeline failure:-

•Delay to completion of the project

•Plant and equipment non availability to the process and thus loss of earnings

•Environmental damage

•Personal injury

•Loss of reputation and branding

•Loss of future work from the client

•Litigation with the necessary allocation of valuable resources away from their primary duties

•Increased insurance premiums

Fatigue Damage to Pipelines and Equipment

Pipelines From the requirements in the Codes and Standards listed it can be seen that the phenomenon of fatigue is recognised. The derating of pipeline materials occurs because of the fatigue that occurs. To overcome the potential of fatigue failure increased pipe wall thickness is required to reduce the stress level in the pipe wall. Historically SN Curves have been used to evaluate the fatigue resistance of pipe materials. Certainly for thermoplastic materials the newer science of fracture mechanics with FEA is being used to determine the design life of materials. Pipeline accessories may succumb to fatigue damage. These include leaking gaskets, valve body, seal or gasket failure, instrument failure or pipe support failure.

Consequences of Fatigue Damage The consequences of such damage in addition to those listed above are:-

•Emergency call out resources

•Alternate supply lines

•Increased maintenance costs

•Increased investment in maintenance resources

•Complaints procedures

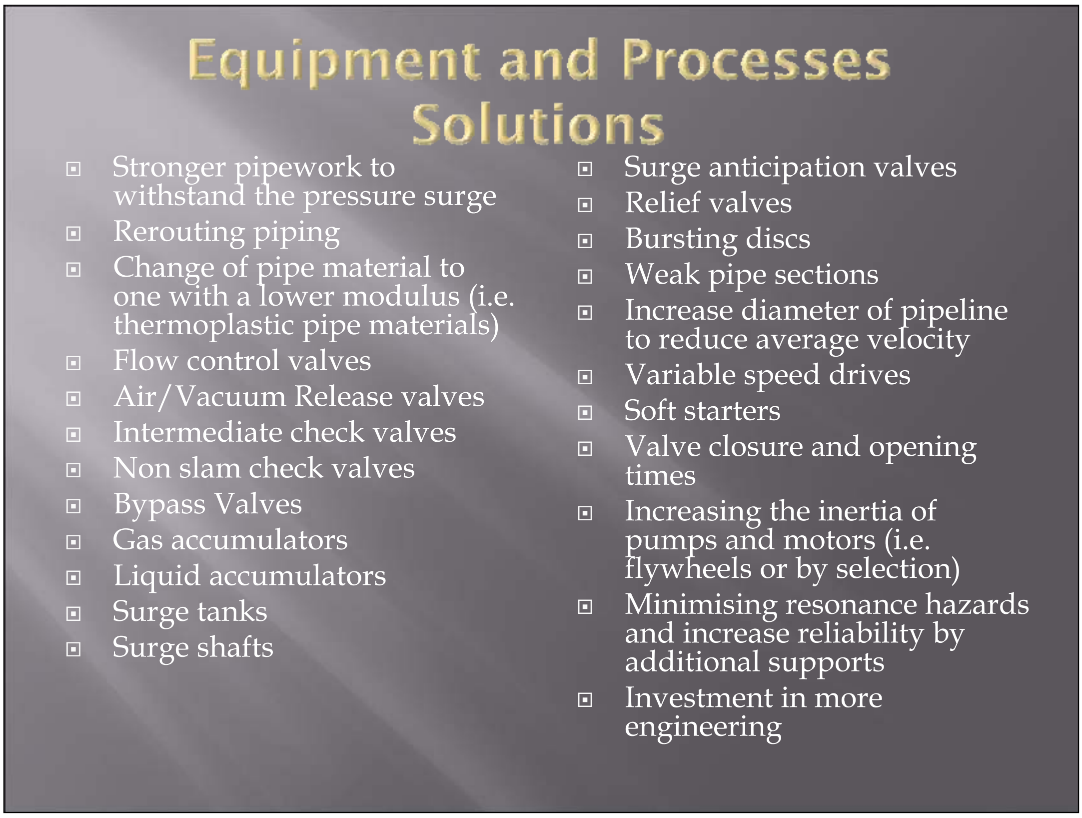
•Standby equipment

•Increased level of spares holding

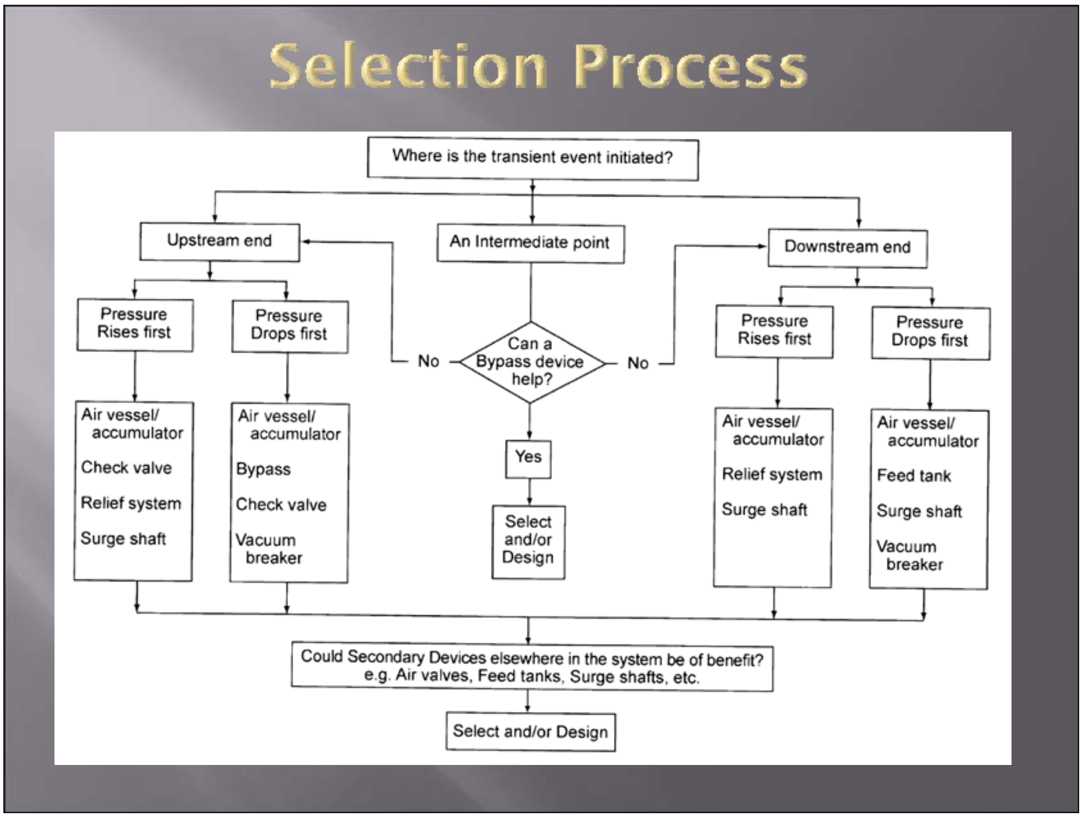
•Possible special freight arrangements for remote sites

•Increased insurance premiums

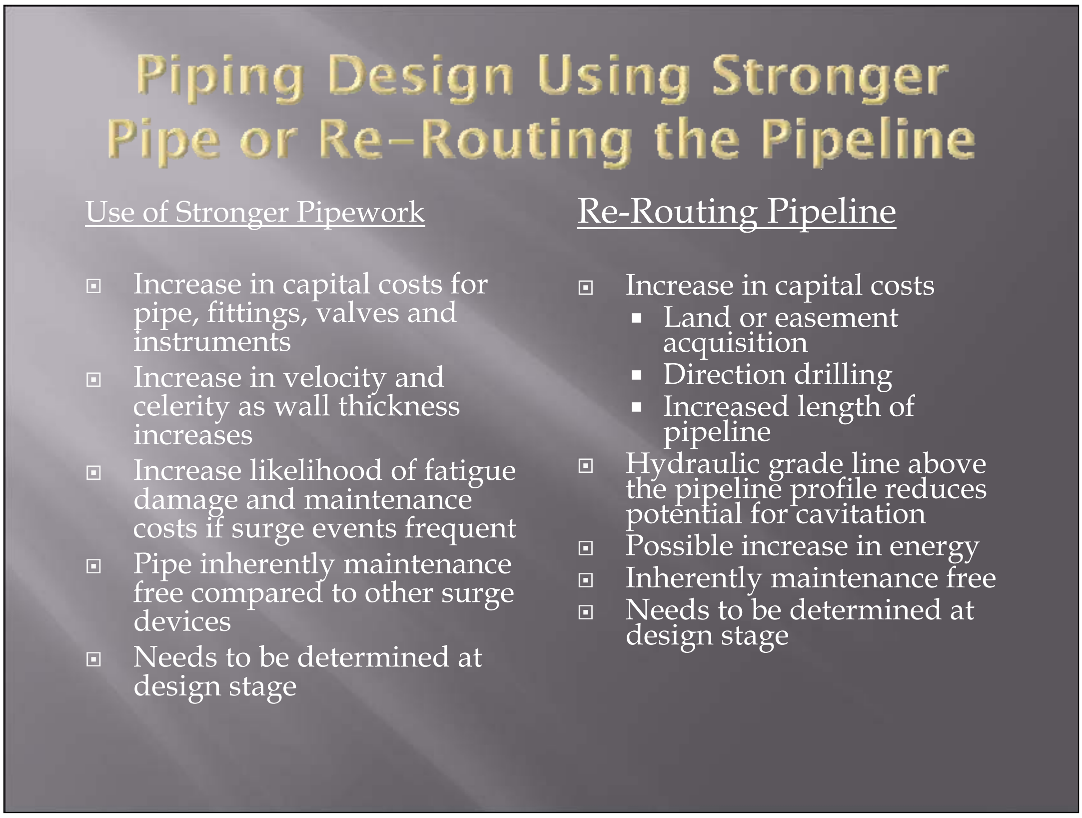
•OH&S and industrial relations problems



Each of these solutions of equipment and processes are discussed in subsequent slides. They may be used singly or in combination to effect a solution. In any event their effectiveness can only be determined by calculation or measurement.



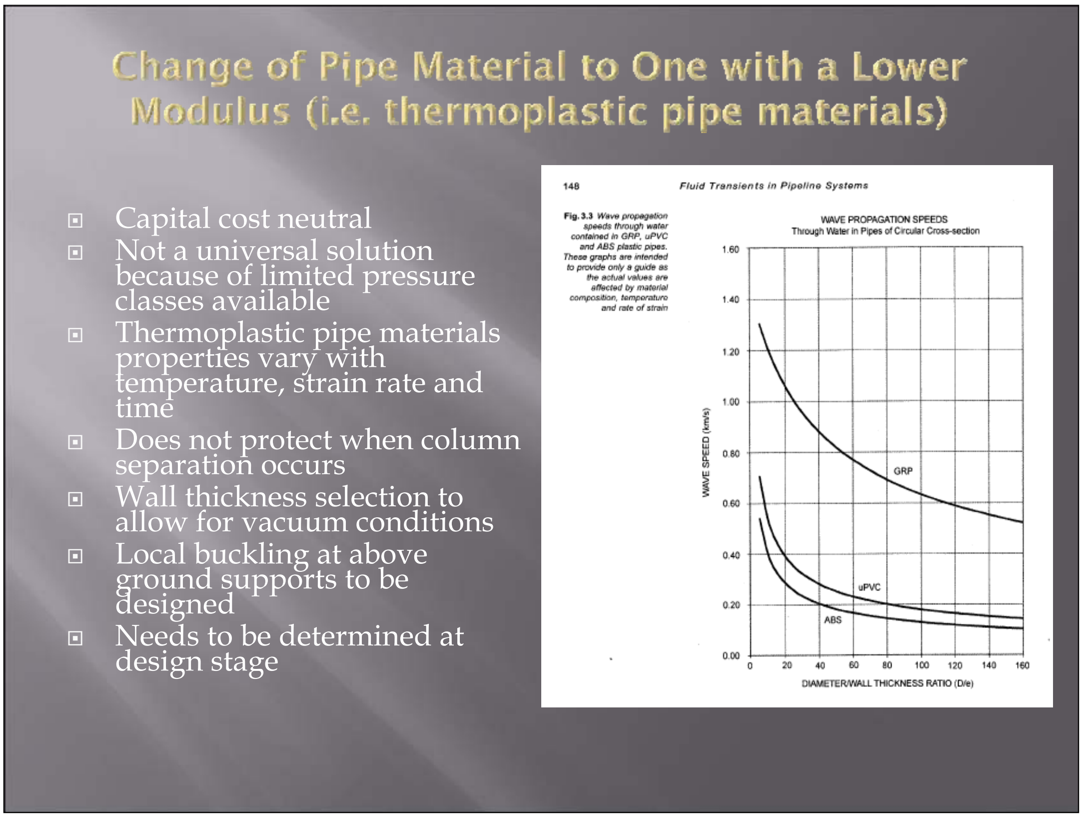
This selection process comes from Prof ARD Thorley's book Fluid Transients In Pipeline Systems. It serves to illustrate that some solutions are more effective depending on the piping system and where the transient event is initiated.



Pipework can be designed to withstand the damaging effects of pressure surges. This may be necessary where conventional means of mitigating surge pressures cannot be employed such as when handling radioactive, highly corrosive or lethal fluids, where no fluid is allowed to escape.

Increase in pipe wall thickness, flange rating and pipe supports can be designed to prevent catastrophic failure. In increasing the wall thickness of the pipe (if this reduces the internal diameter) or the pipe modulus the celerity will increase and create even higher surge pressures. To prevent an increase in fatigue damage devices such as variable speed drives for pumps and slow closing valves should be considered. Although a more costly method of mitigating transient pressures, once installed higher class pipework does not require further maintenance and testing as other mitigation devices require.

Rerouting of pipelines can avoid a profile that is conducive to column separation and resulting vacuum or high surge pressures. The profile of a pipeline described as *convex downwards* is more likely to be free from column separation. Changing the route can include going around or through an obstacle. The intent is that the hydraulic grade line is always above the pipeline profile. Although a more costly method of mitigating transient pressures, once installed a more desirably routed pipeline does not require further maintenance and testing as other mitigation devices require.



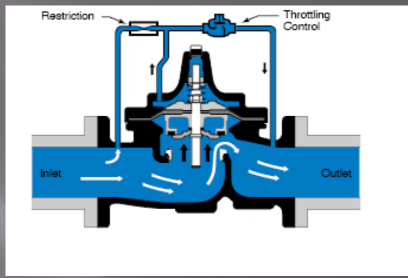
For a particular pipeline it may be possible to use a thermoplastic or GRP material rather than a ferrous pipe material. This applies to low head pipelines found in the mining, water and wastewater industry where high temperatures do not occur. The reduced modulus results in a reduced celerity (wave speed). The modulus is the prime variable in establishing the celerity[1].

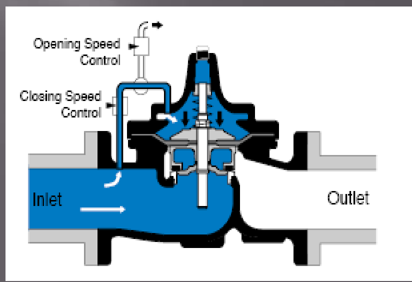
The reduced friction in a plastic material reduces the damping effect of a surge wave and the number of oscillations may actually increase. The reduced celerity means that the time for a pressure wave to travel to the end of the pipeline and return is increased proportionally. Thus the critical time for closing of valves has to be increased so that they don't act as rapid close valves and create surge phenomenon on themselves.

[1] Introduction to Fluid Mechanics Prof Nakayama & RF Boucher

Flow Control Valves

- Moderate capital cost
- Increased maintenance to ensure they remain effective
- Can be used for multiple duties and scenarios
- Power or instrumentation not necessarily required
- Can be retrofitted





Flow control valves can provide a means of changing the hydraulic grade line to reduce the potential for column separation. In a pipeline with varying slopes that may include ascending and descending gradients there is a great potential for column separation. This is particularly so if the HGL is below any of the peaks in the pipeline profile during one or more of the operating scenarios. It is a common solution to provide a flow control valve at the end of the pipeline to ensure that the HGL remains above the profile.

This is also advantageous in water transmission lines as it avoids the potential of negative pressures that may result in contamination of the water. Valves used in this industry are self contained pilot operated piston diaphragm valves. There are a number of manufacturers in Cla-val, Singer, Dorot, Senior Mack, Tyco etc. These valves have the advantage of flexibility in design in that a number of pilot valves can be mounted to enable them to function in a number of modes. The flow control valve can be linked with a float operated pilot to operate as an altitude valve for the receiving reservoir.

Air/Vacuum Release Valves

- Increased capital costs
- Increased maintenance to ensure effective operation
- Use requires extensive modelling to ensure operation in all scenarios
- Not suitable for hazardous liquids
- Primary duty is for line filling and draining and hence location may not be optimal for surge mitigation
- Not all air valves are suitable for this purpose due to their original design
- Valve pit may be in road causing problems during construction or maintenance
- Can be retro fitted easily if reducing tees in pipeline already installed otherwise tee type couplings required to be fitted

The air/vacuum release valves used on pipelines come in many forms of complexity. Many manufacturers have developed the form of valve from the basic *kinetic* air valve developed many years ago. Many of the valves are manufactured to an outdated design that can actually contribute more to a surge event than they relieve.

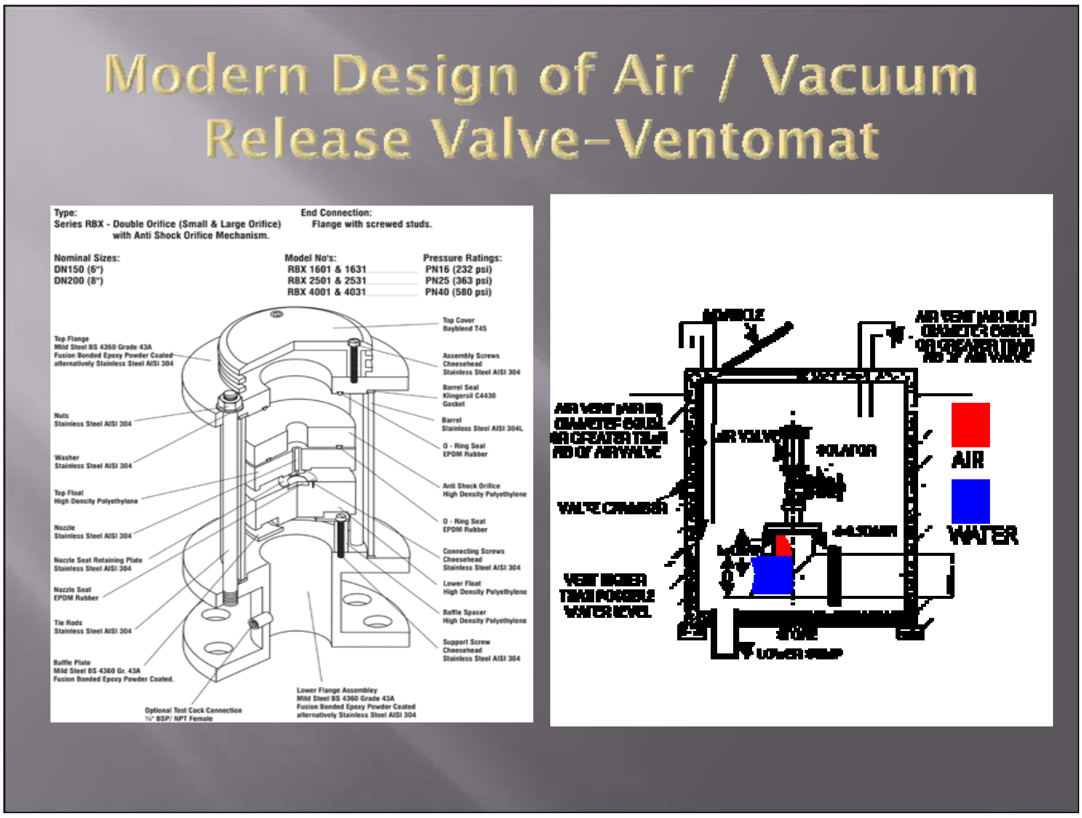
Although in practice the admission of air is not without problems, most of the problems are found during the release of air, sometimes resulting in pressures even higher than if air valves were not installed. ***[1]***

Many air valves are described as being of a nominal diameter. This generally only describes the connection size and not the orifice size for the air ingress or air release. These latter criteria have significant bearing on the air valve performance. It should be remembered that the maximum pressure differential for air ingress is atmospheric pressure to full vacuum whereas the similar parameter for air egress is pipeline pressure to atmospheric pressure. The latter can be significantly higher than the former. In addition, the condition of the air may be above sonic velocity in either situation. This gives rise to four equations that may cover the situation occurring at the air valve. Any software needs to be able to determine the condition and apply the correct equation of state.

In sewage or other solids bearing service there is a reluctance to use air valves. There are designs for air valves for these services. There is no escaping that maintenance level will be increased if this device is used to mitigate transient pressures in contaminated service.

This type of device cannot be used on liquid hydrocarbon service as the ingress of air may create greater problems than it solves.

[1] Dynamic performance of Air Valves BHRA Group 2004 International conference on Pressure Surges



Ventomat have developed the design of air valve to provide a simple multiple orifice unit. It doesn't have complex linkages or easily deformed ball floats requiring high maintenance. It has proven to be effective in mitigating surge pressures as well as meeting the primary criteria of air elimination and vacuum relief when scouring a pipeline. The Ventomat valve is taller than legacy units. The decision to use these valves needs to be determined early in the design process if it is desired to keep them below ground in a chamber. This may be necessary if the pipeline is in a road reserve or an urban area. Further information on the behaviour of air valves may be found at www.ventomat.com. There are other manufacturers of multiple orifice valves. The design of the air valve should be carefully considered by the designer.

Intermediate Check Valves

- Increase in capital costs for check valve but reduction in rating of other pipeline components
- Effective in splitting the surge pressure rise in two
- Degree of increase in maintenance minimal
- Protects pumps from highest peak pressure
- Non slam check valves preferred
- Valve pit may be in road way causing traffic problems during construction or maintenance
- Check valves are not considered an adequate form of isolation and hence should be installed with isolation valves
- Needs to be determined at design stage otherwise pipeline needs to be out of service for retrofitting check valve

An intermediate check valve, in a long pipeline, has the ability of preventing damaging reverse velocity from reaching a pump station. It effectively halves the pressure surge. The difficulty is that such a valve may end up being located in a remote location or in a road reserve. If the need for such a valve is established early in the design process then the pipeline route can be re arranged to suit.

Any intermediate check valve is preferred to be of the non slam variety described below.

Non Slam Check Valve

- Capital cost increase
- Fast closing valve reduces surge pressure at pump
- Reduces fatigue damage
- Increase in maintenance low
- Inherently trouble free
- Available as short or long pattern
- Used extensively in Europe
- Can be retrofitted as valves standard lengths

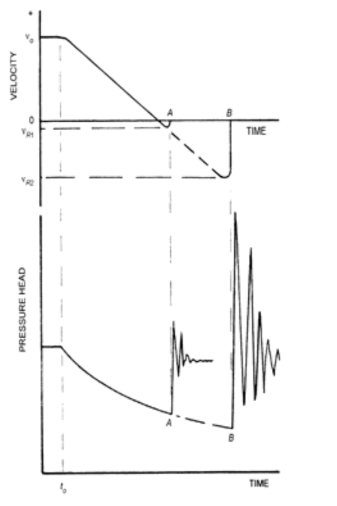


Fig. 2.28 *Plots of flow velocity and pressure head against time immediately downstream of the check valve next to the pump that has been tripped. If the check valve is able to respond quickly to changing flow conditions, the maximum reverse velocity, v_{R1}, when it closes is quite small. If the valve response is slow, a much higher reverse velocity, v_{R2}, will develop and the associated pressure rise will also be very large*

The type of check valve used has a great bearing on the pressure transients that can occur in a system. European designers have long recognised this and the use of nozzle type check valves is more common place. In the scheme of things the use of this type of valve is but a small investment in reducing risk and fatigue damage.

Swing check valves are considered by many as unsuitable in high head systems.

*Simple clapper valves tend to have a very poor response, spring assisted split disc valves, especially with stronger springs, are a little better, whereas nozzle type valves generally have a an excellent response.***[1]**

Many facilities exposed to check valve slam with conventional swing check valves have been made silent by the use of the nozzle type check valve. For more details refer www.noreva.de or www.mokveld.com . The nozzle check comes in two types. The single spindle single spring or annulus multiple spring type. Like all items of equipment the designer should take note of the specific design requirements of the equipment. The valve should be installed in a pipeline in accordance with the manufacturer's instructions and the knowledge available from recognised piping and valve design texts.

There have been some instances of horizontal orientated single spring nozzle type valves jamming and users should check with the particular manufacturer as to their experiences. A rare problem with the multiple spring design is that is may jam when a flow is unevenly distributed, for example after a bend. Some models are better than others and the engineer needs to determine this in the technical evaluation.

Jamming of a valve has to do with internal friction of a valve and the applied spring strength, not whether they are multiple spring of not. Mokveld & Noreva check valves are optimised to allow the highest spring strength possible, providing an improved dynamic behaviour but also this will prevent jamming of the valve. Further more the Mokveld & Noreva designs have less friction of moving parts than other designs again eliminating the chance of jamming. The Mokveld & Noreva designs are less prone to failure than other designs on the market. They have replaced many of their competitor's valves, especially in critical applications. Mokveld & Noreva are considered by many, including their competitors, as technology leaders. These manufacturers provide technical information based on flow testing at Delft laboratories. They have characteristics of low pressure loss and non slam action.

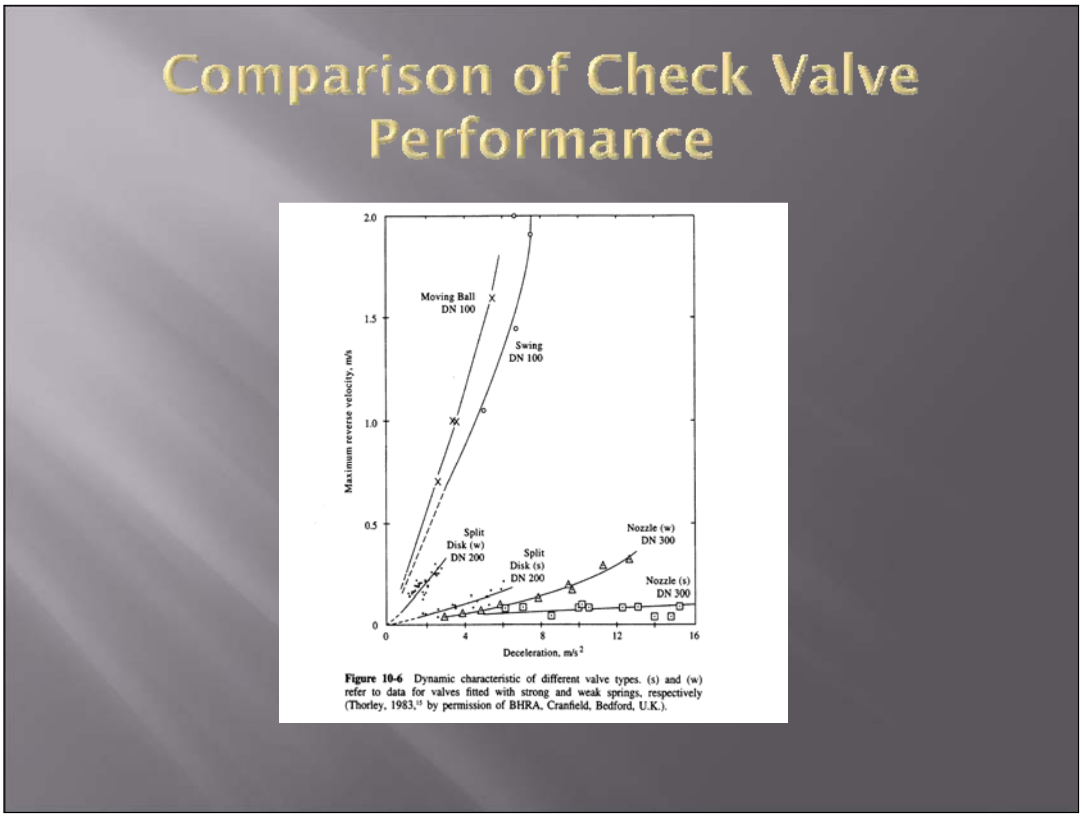
The surge analysis needs information such as the *pressure to re open* a closed valve, the *reverse velocity* to close. The latter can be obtained only if the manufacturer has tested the valve. Facilities exist at the Delft Laboratories or Utah State University to test independently. Many manufacturers have not had their valves tested, they rely upon a design copied or licensed from decades previously and the current resources just do not understand the fundamental design of the devices and how they interact with the piping system. Technically professional valve suppliers, such as Noreva & Mokveld, can provide *deceleration versus maximum reverse velocity* data.

There may be other valve suppliers with similarly competent valves and technology and the designer should investigate these fully before deploying there valves. Readers are referred to the work by Prof ARD Thorley[2] for a more complete understanding of the behaviour of check valves and their relationship to transient events.

Difficult applications such as sewage and slurries require specific designs of valves and sometimes compromises in their design and application. In fact automated isolation valves may replace a check valve in severe applications such as these. The characterised Cv versus % open combined with opening/closing time of these valves then needs to be considered in the analysis.

[1] Fluid Transients in Pipeline Systems Prof ARD Thorley ref 1.3.2.4

[2] 1 Fluid transients in Pipeline Systems Ch3.8 ISBN 86058 405 5



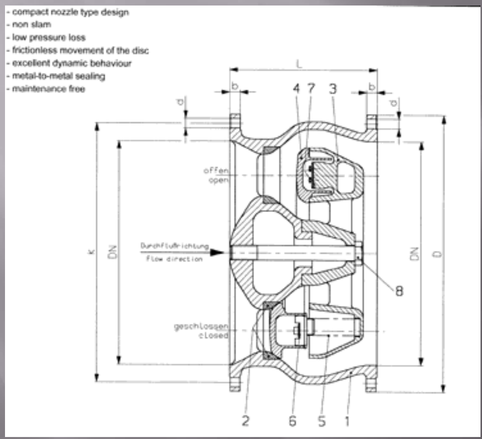
The ideal check valve is one that closes the instant the flow velocity at the valve reaches zero. This is likely to control valve slam but may not yield pressures at acceptable levels. The decision as to the best type of valve in a particular installation depends on the characteristics of the pipeline system.

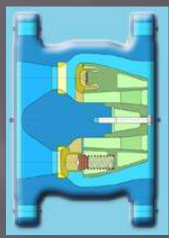
If the check valve dynamic characteristic is available the pressure transients ina particular system may be determined. The deceleration flow rate is the most important parameter and it can be determined by analysing the system without the check valve. When the fluid deceleration rate has been determined the maximum backflow velocity Vr can be determined from the dynamic characteristic of the check valve.***1]***

From the graph above it can be seen that a nozzle check valve with strong springs allows the lowest maximum reverse velocity to deveop. Hence this type of valve is closest to the ideal check valve as described in this reference.

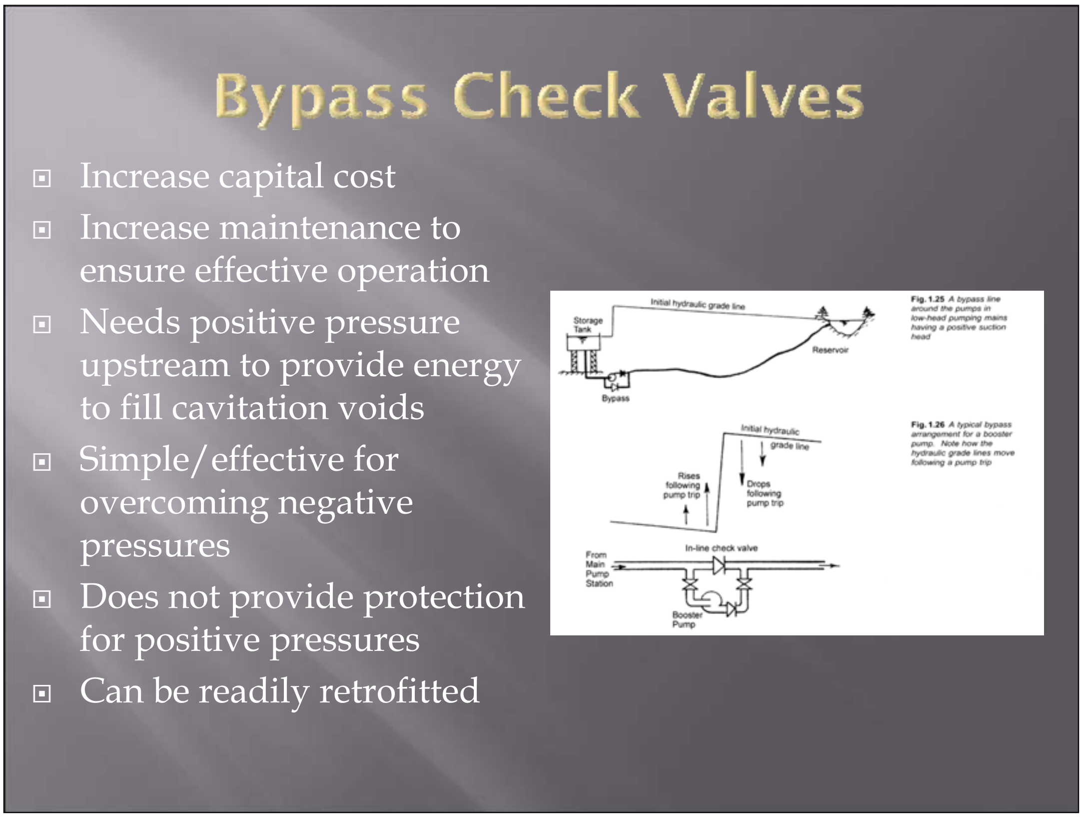
[1] Fluid Transients in Systems Streeter, Wylie & Sou Ch 10-4

Noreva Annulus Type Non Slam Check Valves





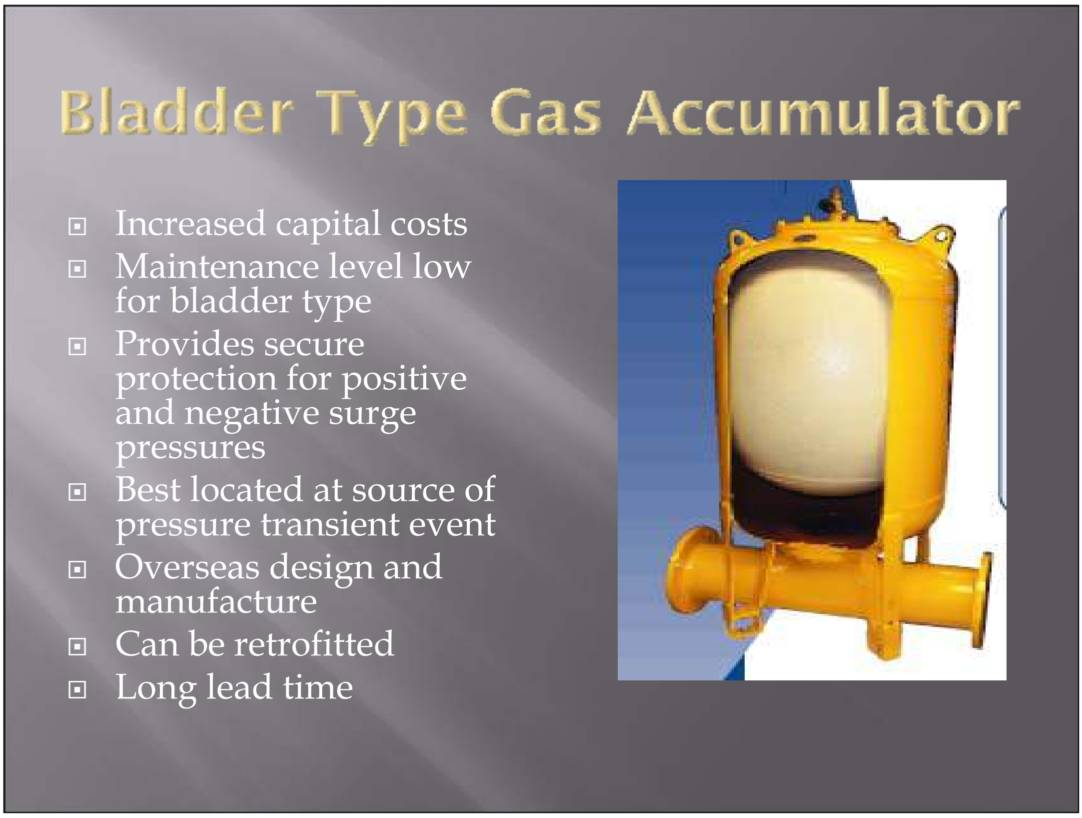
This is an illustration of a Noreva non slam check valve of the annulus type. It has a rapid closing time of less than 0.4s. When flow reverses the valve is already closed and thus the pump is protected from any high pressures. These valves are commonly used in Europe in water transmission lines. Their simplicity of design has many benefits over traditional valves augmented with counterweights, pilot valves and other devices requiring a high level of maintenance.



Bypass valves take the form of a valve in parallel to the pumps. The concept is that on loss of power there is still a reduced flow into the pipeline via this valve. This prevents the column separation occurring immediately downstream of the pump discharge check valve. This type of device is used where the tank being pumped from is above ground and has enough head to drive liquid into the pipeline with a low static head. The second application is where there is a booster pump in the pipeline. The bypass valve opens and thus protects the pipeline when the booster pump fails.

The bypass valve is commonly a reduced size check valve. A fail open actuated valve may also be used. This may be of the pilot actuated cylinder or diaphragm type valves.

The selection of valve size, characteristics and location cannot be guessed. A number of sensitivity analyses are recommended to fully evaluate the effectiveness of these devices. This should include varying flow, heads and pipeline roughness.



There are two types of gas accumulator used for the mitigation of surge pressures. Firstly there is a pressure vessel with a back up compressor that maintains the volume of gas in the unit to cater for pressure changes. This is shown on the following slide. The second is a pressure vessels fitted with an elastomeric bladder with gas one side and the process fluid the other.

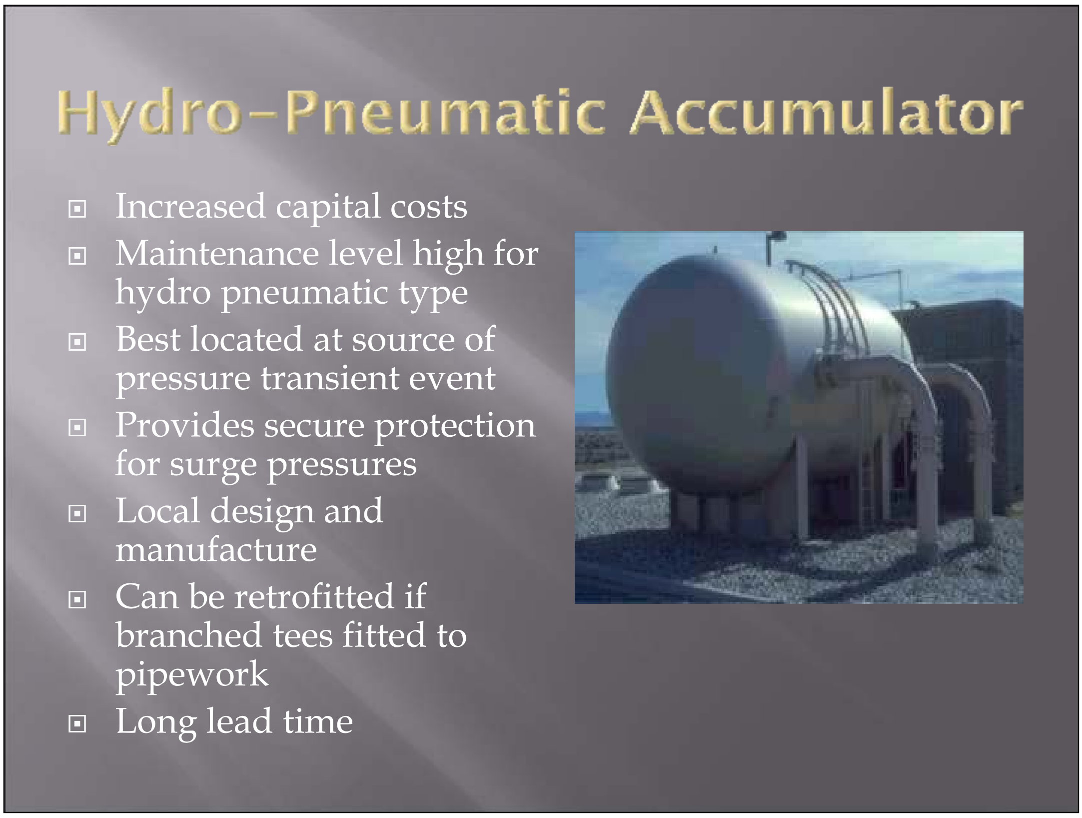
The gas accumulator is particularly effective when there is a loss of power situation and a negative pressure wave develops immediately downstream of the pump check valve. The residual pressure in the gas accumulator reduces the deceleration of the liquid column and prevents column separation. The gas accumulator needs to be located close to the boundary element that causes the transient event.

One consideration to be borne in mind with the use of gas accumulators is when pumps are operated in parallel. Should one pump fail then the check valve on that pump is liable to slam closed quickly as the pressure is maintained by the gas accumulator. Consideration should be given to a non slam type check valve that closes very quickly and would thus avoid such phenomenon.

Sizing of gas accumulators can be done manually however this involves some rigorous analysis. Surge analysis software enables the sizing to be undertaken for a system.

One manufacturer dominates the proprietary manufacture of these units. Information can be found at www.olaer.com.au. Other types are available from www.pulsco.com

Gas accumulators are commonly used on the discharge of positive displacement reciprocating pumps. The volume and gas pressure need to be designed and then tested during commissioning.



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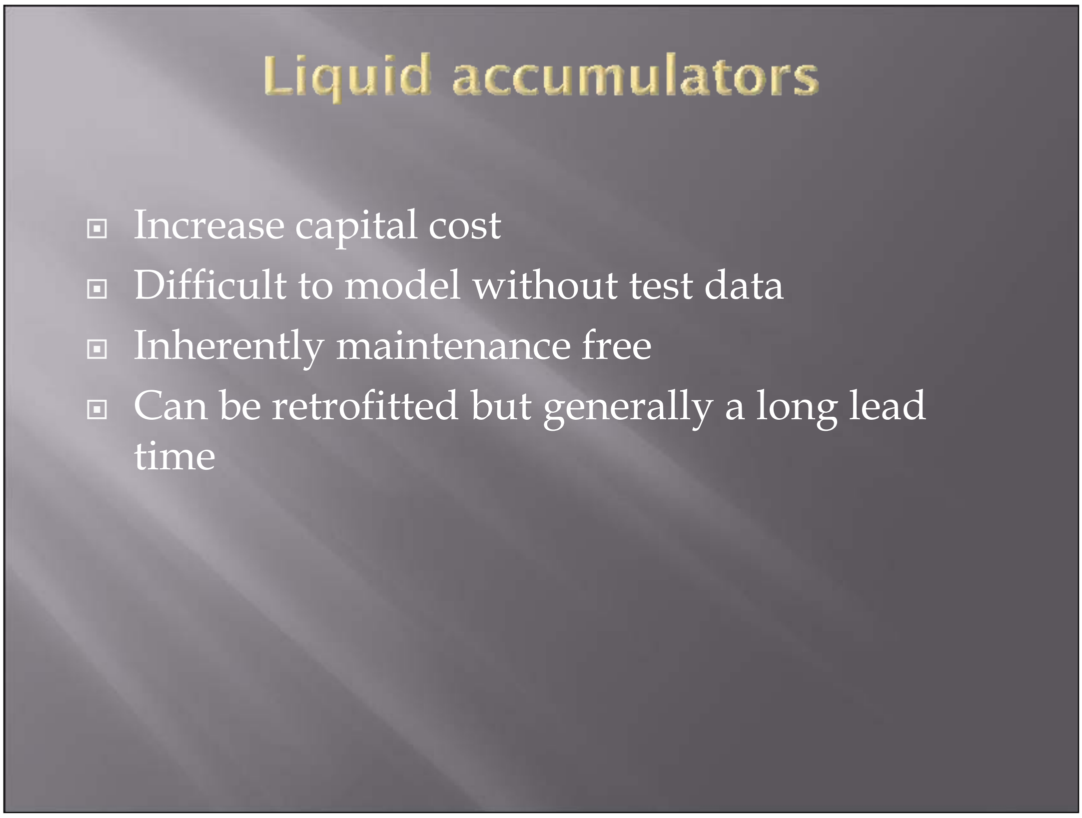
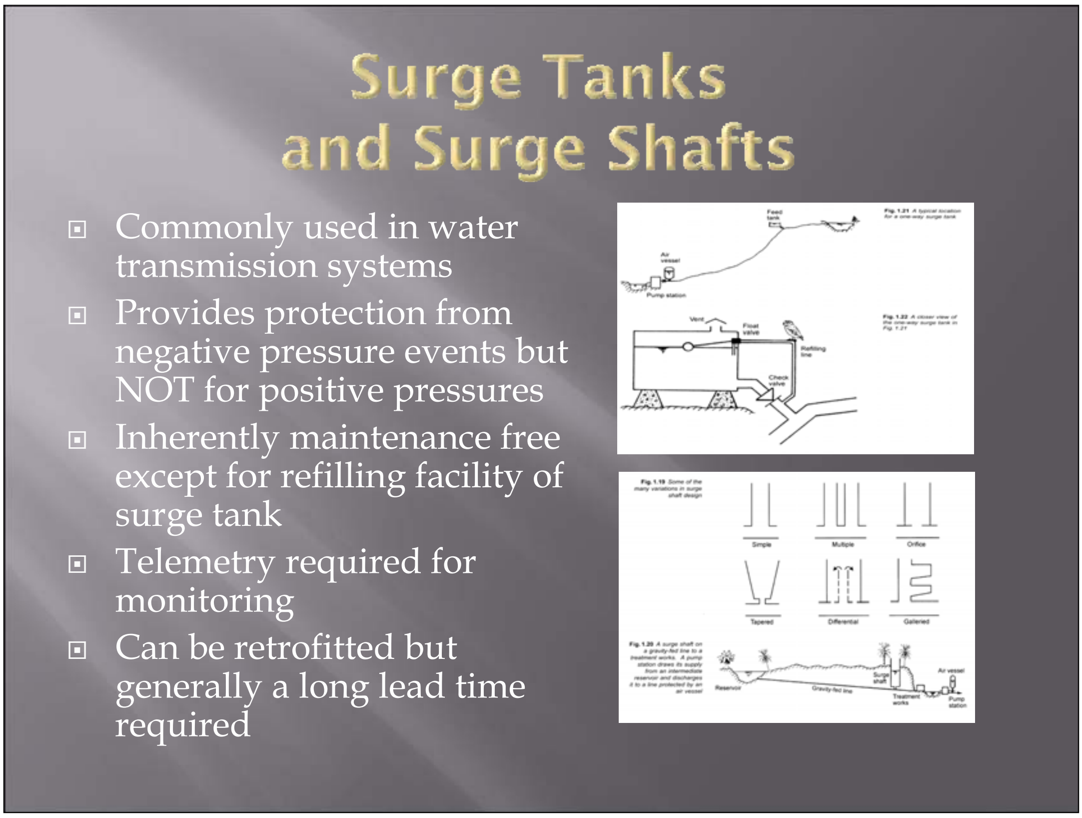


A liquid accumulator is a vessel that has lower elasticity than the pipe itself. The concept is that the vessel will exhibit strain to a higher degree than the pipe and thus mitigate pressure transient. These units are not as effective as a gas accumulator. In general it may be a piece of equipment in the process for another purpose that when modelled does mitigate a surge. One example is a plate type heat exchanger where the plates may deform on the process fluid side. The pressure surge is then transferred to the heat transfer fluid side of the exchanger. If the HT fluid system is an open system with an air release tank then the surge pressures may be mitigated via this secondary system.

Without physical test data of the bulk modulus of a liquid accumulator it is difficult to model accurately in an analysis.



One way surge tanks are principally used on water transmission lines to overcome sub atmospheric pressures. They only function when the local hydraulic grade line falls below the water level in the tank. Under transient conditions the places in the pipeline where this is most likely to occur will be at significant reductions in upward slope and in the vicinity of peaks in the pipeline profile.

They prevent a pipeline collapsing due to buckling from external pressure. The surge tank is suitable sized to fill a cavity formed by vapour column separation. The discharge pipe has to be sized to enable the fluid to enter the pipeline. A check valve is normally fitted to the discharge pipe to prevent positive pressures overflowing the surge tank. To fill the surge tank a pipe from the main transmission line via a float valve feeds the tank.

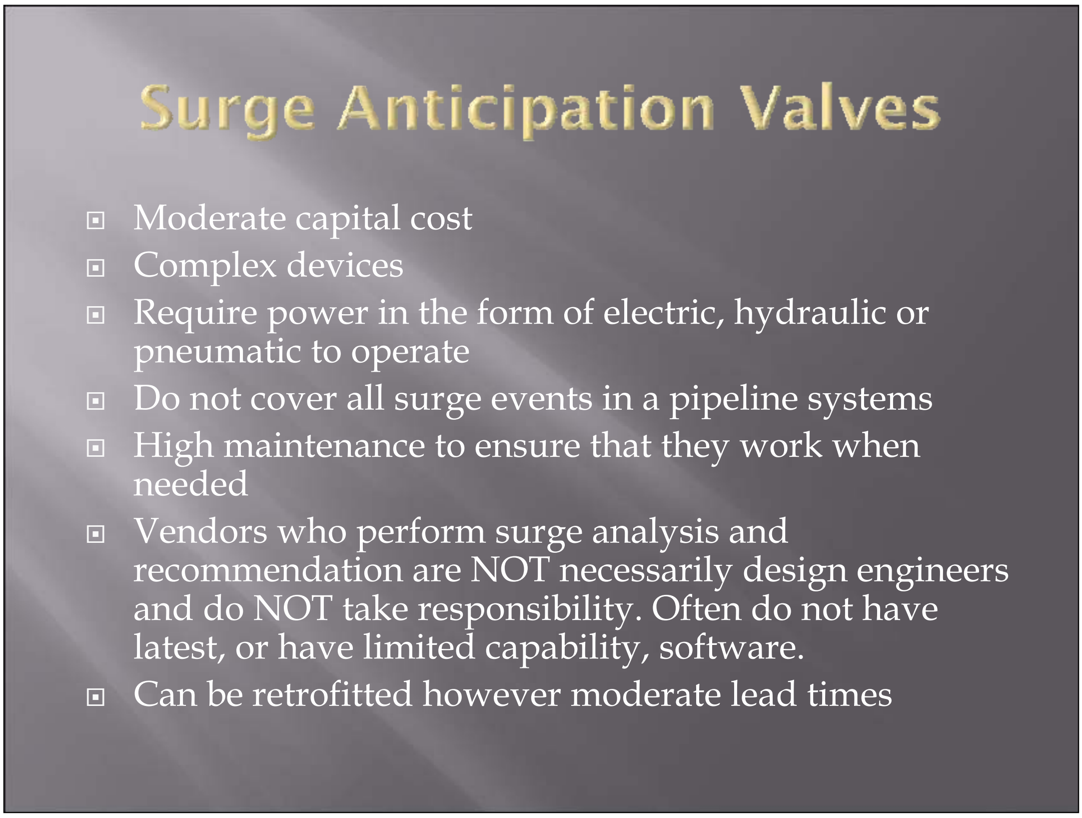
Surge tanks do not provide protection against positive pressures.

Sufficient time must be allowed in the pipeline for the surge tanks to be filled again after an event. This can be done by slow starting of the pumps under VSD control or by one pump in a pair of pumps running to refill the tank. Ideally the level in the tank should be made available to the operator starting he pumps by telemetry or satellite link.

Surge shafts have been used on low pressure applications. The design of surge shafts is a specialised subject traditional used in the hydroelectric industry. References are given to this design process[1]. A surge shaft is effective in providing protection where a valve or penstock at the end of a pipeline is closed rapidly.

Not all software can adequately model gravity lines feeding a turbine generator. Designers should consider carefully the ability of software to handle this type of application.

[1] Pressure Surges in Pipeline Systems Prof. ARD Thorley 1.3.3.3



A surge anticipation valve is designed to provide a diversionary flow of fluid in the event of a transient pressure occurring. These valves are low cost and have had some measure of success. They do need a higher degree of engineering and commissioning at site to ensure that they work efficiently. The concept is designed to release energy in a system before damaging pressures can occur.

The device needs to be deployed as close to the point where the transient event is initiated. It may be designed to allow fluid in or out of the system. In the oil pipeline industry very high pressure nitrogen gas operated valves have been used to rapidly open such valves to dissipate energy.

These devices are complex and rely upon a high degree of maintenance to ensure that they work effectively. Control systems need to be backed up by a uninterruptible power supply to ensure that on loss of power they work. Generally remote pumping stations don’t have a UPS.

Some manufacturers offer to undertake the surge analysis and to size the valves. A designer needs to ensure that the software is capable of analysis the whole system for a range of scenarios to ensure that the predicted performance is valid. Designers should not see the vendor as a means of reducing their design commitment. Rarely do vendors have any professional indemnity insurance to rely upon.

Relief Valves and Bursting Discs

- Increase in capital cost
- Conventional devices do not react quickly enough to prevent damage from surge pressure
- Do not protect against vacuum conditions
- High level of maintenance
- Bursting discs require replacement after operation
- Need for registration and routine testing per Code
- Suitable for lethal and flammable liquids as part of an overall protection strategy
- Can be retrofitted however may be moderate lead times

Relief valves come in a variety of designs. A simple conventional spring loaded relief valve is most unlikely to operate sufficiently fast to relieve a pressure wave as it passes the relief valve nozzle.

To be effective against shock waves a pressure relief valve must be placed as close as practicable to the main pipe which is being protected. If a valve is located on a branch pipe the shock wave will have passed the branch by a distance of about twice the branch \length before the reflected wave from the relief valve gets back to the pipe junction as a reduced pressure wave.[1].

Specialised relief valves have been designed for use in the water industry. They are termed a Neyrpic valve. They are direct acting valve designed to operate in milliseconds. It is a simple spring loaded disc with no guides that require maintenance to ensure that the valve operates.

The use of pressure relief valves comes under the codes and standards listed in the previous slides.

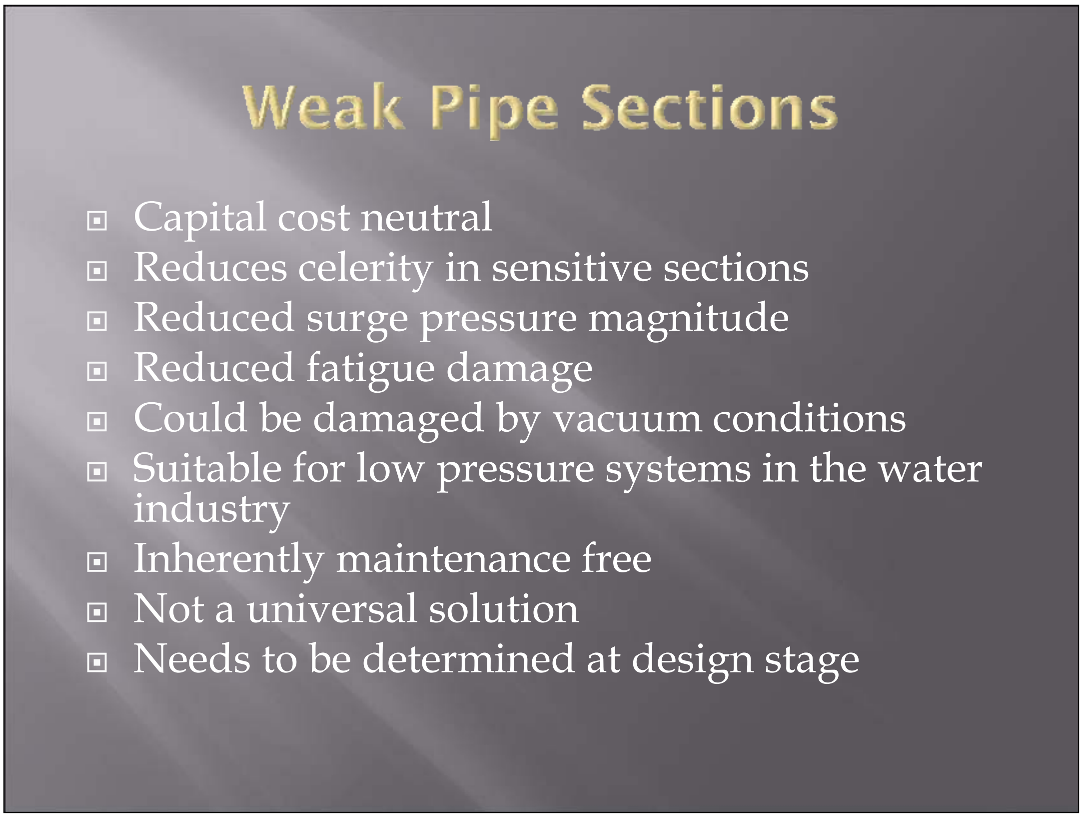
[1] Waterhammer T. Webb & BW Gould Waterhammer Mitigation

The bursting disc is another form of relief device. The drawbacks from the use of a bursting disc are similar to the relief valve. If deployed when they have served their purpose they have to be replaced before the process can be restarted.

The designer should bear in mind that a bursting disc pressure rating is provided by manufacturing a quantity and testing some of them. By statistical means then assign a burst pressure to the balance that are to be used to protect a pipeline. Some design factor has to be employed to ensure that protection at the design pressure will occur.

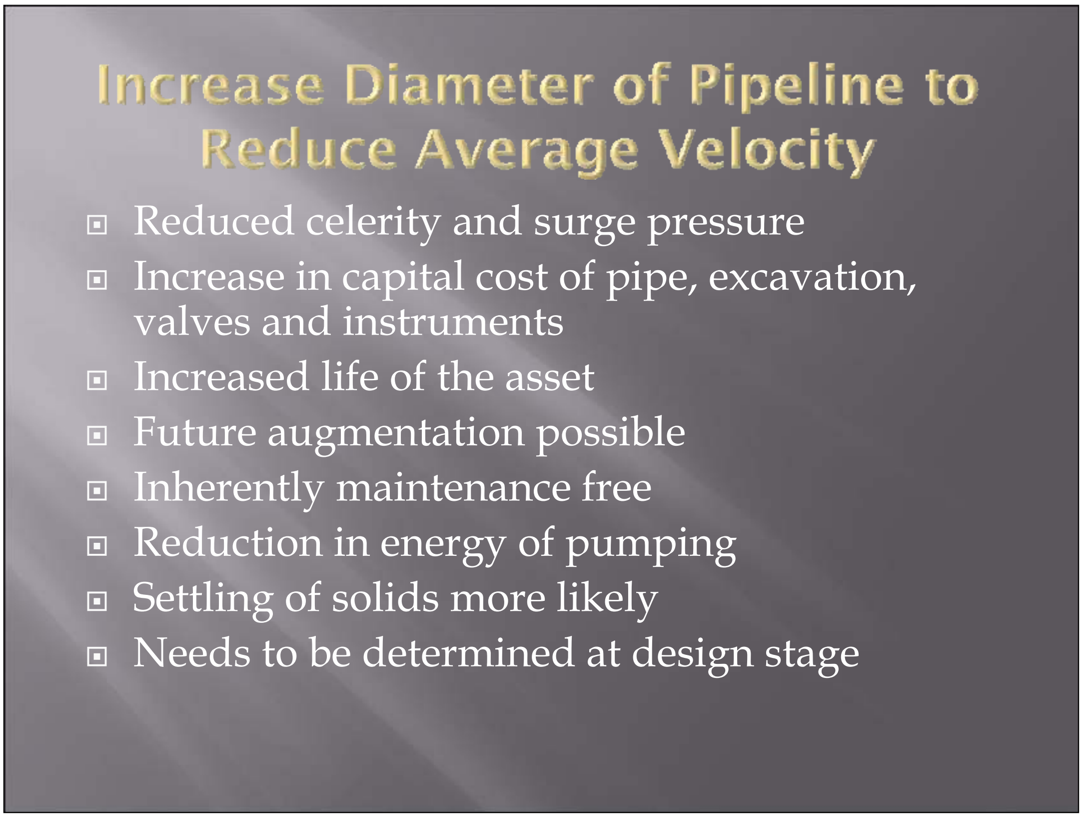
Metal bursting discs have been known to suffer from fatigue and fail prematurely reducing the availability of an asset.

The use of bursting discs comes under the codes and standards listed in previous slides.



It has been suggested that using a combination of ferrous pipeline materials with a lower modulus thermoplastic material provides a weak section that will mitigate a pressure surge. With the correct engineering analysis of all the scenarios this has merit. A high pressure section of the pipeline may by designed in ductile iron with a PE or ABS pipe used for the low pressure section. This has been successfully employed.

In chemical dosing lines some sections of plasticised PVC hose have been used to remove the pulsations from a positive displacement dosing pump.



If it is possible to increase the diameter of the pipeline the immediate effect is to reduce the surge pressures. This occurs as the velocity is reduced. When the fluid is brought to rest the change in momentum is reduced in direct proportion to the maximum velocity.

The downside is that the increased pipeline size reduces the friction so the damping of any pressure fluctuations is reduced and the transient may also considerably longer. This adds to the fatigue loading of components in the system.

The other consideration is the increased cost of the pipe versus the reduced energy costs over the life of the asset. It must be remembered that the pump will no doubt have a smaller motor; making the VSD and motor starters smaller so there will be some capital expenditure saving there.

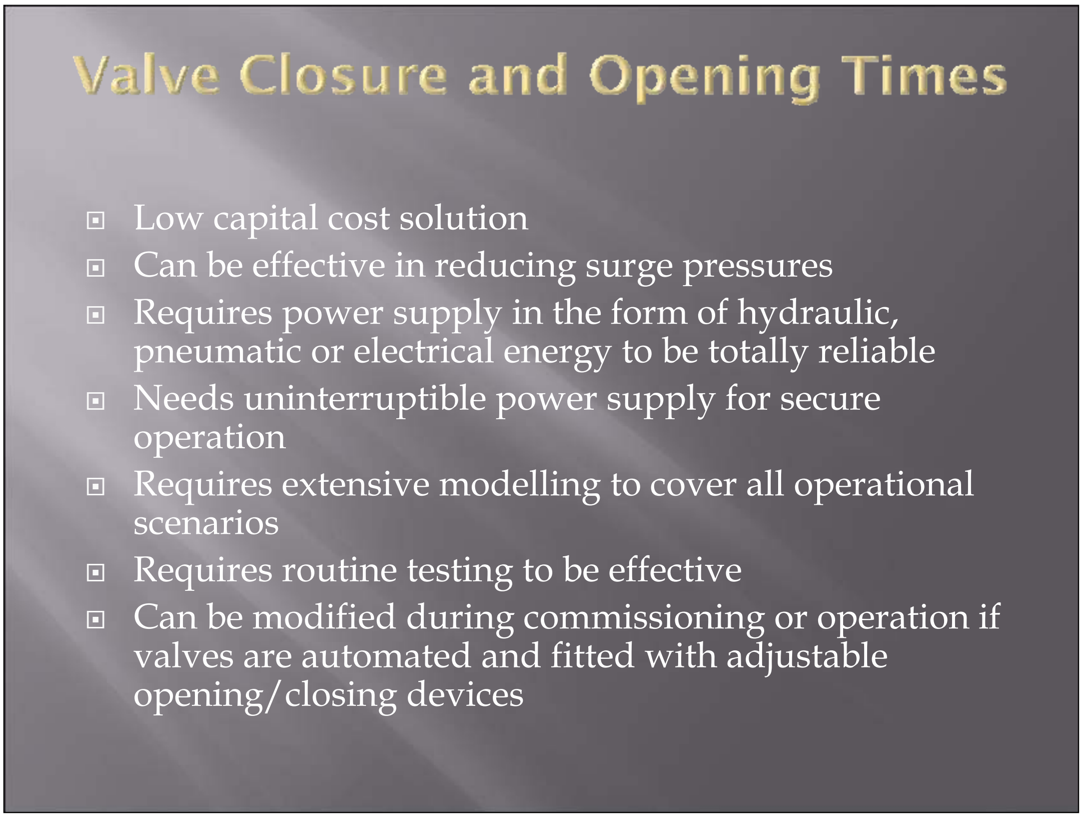
Variable speed drives provide a reliable means of prevention of damage from surge events. They only provide this when there is power so for a *loss of power* event they are of no use. A *loss of power* event can result in the highest positive and negative pressures in a system. In most applications this event is rare.

The VSD provides the best method of reducing fatigue damage to pipeline components. Check valve slam is avoided as the liquid column decelerates slowly. The VSD allows the pump speed to increase slowly to achieve slow line filling and thus the air can be removed without damaging the pipeline. They also provides flexibility of operation for a process where flows can be increased for future needs without changing the equipment.

The use of VSDs may require a more extensive air conditioning system in a switch room to remove the heat generated by the device. The efficiency of a VSD may be 95-98% depending upon its design. The 2-5% inefficiency is transmitted as heat energy into the switchroom.

Soft starters' primary purpose is to reduce the electrical load on the power supply to a facility. They are widely deployed in many pumping stations for this purpose particularly where the pump station is at the end of a long power transmission line.

Soft starters are described as a poor *mans VSD*. They have some but not all of the features of a VSD. They are able to control ramp speed up and down to some extent. Therefore they do provide benefits in reducing surge in some applications. This is not a universal panacea. There have been instances where a system still sees surge pressures and the soft starters have had to be replaced with VSD s or other mitigation measures employed.



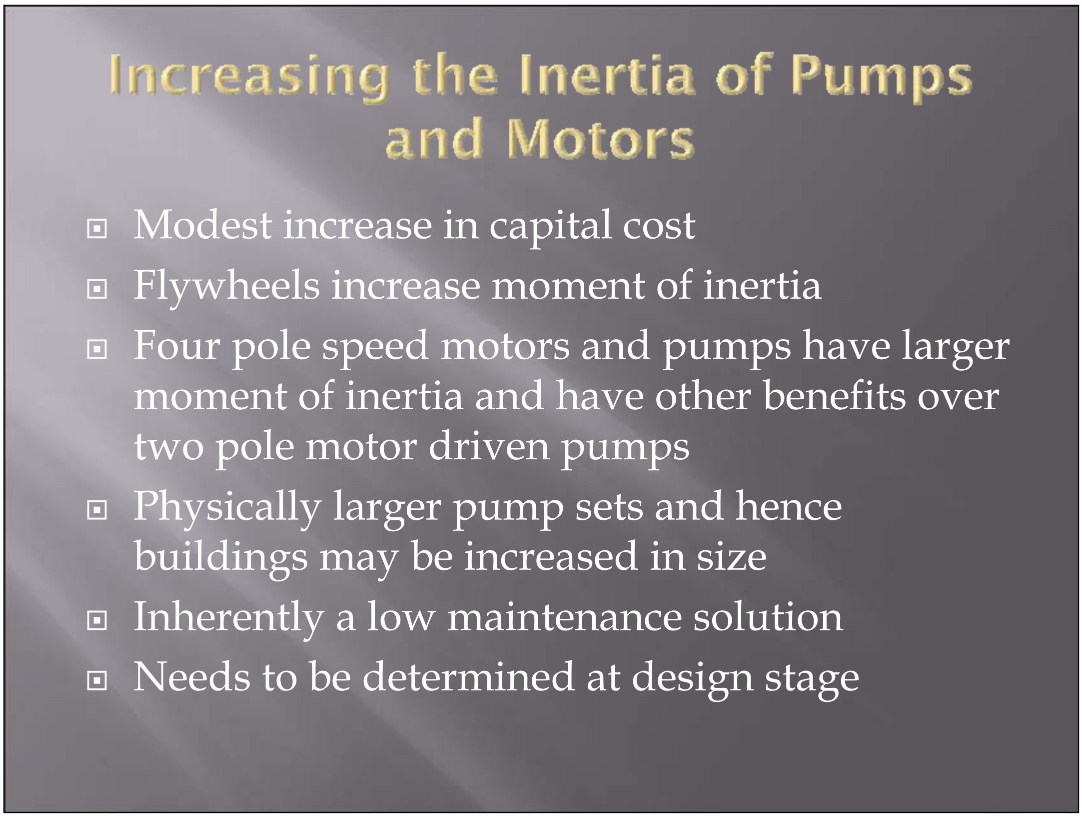
The worst valves for this event are the pneumatically operated butterfly, gate, globe, knife gate or sluice valve. The worst valves include manually operated quarter turn valve butterfly, ball and plug valves without a gearbox for these can be rapidly closed or opened. If the time of closure of a valve is less than the time a pressure wave to travel from its point of initiation to the end of a pipeline and return then the valve is described as having a *rapid closure.* This results in the maximum head predicted by the Joukowsky equation or column separation.

The closure time may however be dictated by some other process requirement such as an Emergency Shutdown Valve (ESD).

Extending the closure times is often restricted to short pipelines. Some facilities employ the two stage closing process whereby the valve is closed to a 15-20% open position rapidly and then the last closure is over an extended period. Similarly the valve opening is a two stage process. In high pressure systems dual valves in parallel of different sizes are used with the smallest opening first, it closes whilst the bigger valve closes and then reopens to obtain maximum flow rates.

Butterfly valves are a valve to avoid this type of control. Their performance is not suited to a wide range. If butterfly valves are to be used then multiple varying sizes are suggested.

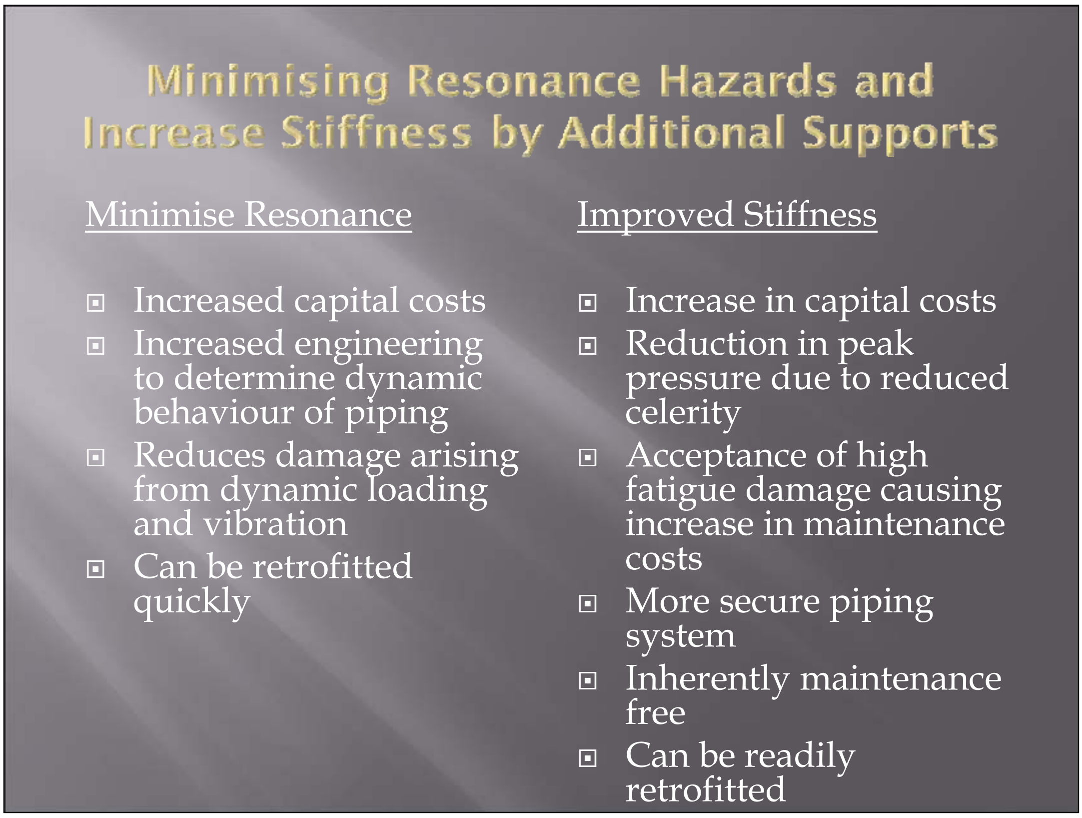
Where a process is complex and a number of valves are required to be opened and closed at different times this leads to a great number of computer runs to determine the sensitivity of a system.



A parameter used in the surge analysis of a pump system is the moment of inertia (MOI) of the combined pump, fluid and motor rotating elements. Four pole motor driven pumps generally have a higher MOI than an equivalent two pole motor driven pump.. But two pole speed pumps are more economic as far as a contractor building a facility is concerned. There are also added benefits with 2 pole motor driven pumps to the end user in that the cost of replacement components is lower than for 4 pole pumps as they are generally smaller. Sometimes the pump is more efficient than its larger slow running counterpart. The downside is that the faster running pump is unlikely to last as long as it's slower running counterpart.Four pole speed pumps are preferred for infrastructure assets but even so modern designs have reduced the MOI of units as manufacturers have optimised pump and motor designs with the use of FEA and other design tools.

One method of mitigating pressure transients caused by pumps is to use flywheels to increase the MOI. This appears to be contrary to saving money by using a smaller frame pump then spending more adding *metal* in a flywheel to meet a surge pressure mitigation need. Flywheels in pumping applications are rare. Flywheel will increase the starting current of a pump and thus there will be an increase in cost of motor starters, soft starters or VSDs.

Positive displacement pumps are a special case. This type of pump has a tendency to stop almost instantaneously on loss of power. There is little that can be done to improve this fact and thus other devices need to be employed. These include design and installation of the other devices and processes described in this paper.



Additional pipe supports allow the movement of pipes arising from pressure transients to be controlled so that an individual support has less likelihood of failing. In addition the natural frequency of the pipework is increased and thus there are fewer tendencies for excessive displacement due to resonance to occur[1].

Additional pipe supports can be provided at concentrated masses as it is at such locations that the most damaging displacements can occur resulting in high local stresses and buckling.

The method of fixing a pipeline changes the celerity of the fluid in the pipework. Most software packages include the selection of the type of fixation.

When dynamic loads are applied to piping systems the system may vibrate. If the forcing frequency resonates with the natural frequency of the pipework then the deflections may cause damage to the system. As fluids oscillate as a result of pressure surges this may occur. The designer needs to establish the natural frequency of the piping and that resulting from surge events. Software allows the input of forcing functions along with modal analysis to determine the interaction of these phenomena. The use of additional pipe supports can change the natural frequency of a piping system to overcome the problem of resonant vibrations.

[1] Design of Piping Systems MW Kellogg Company Ch. 9 Vibration, Prevention & Control

The designer should consider that many pipelines are designed for a fifty year life. The surface roughness of the pipeline defined in may codes takes into account the build up of slimes, corrosion and other deleterious effects. The worst case scenarios are used for pump and motor sizing. When it comes to commissioning the pipeline is new and friction is much reduced. So the system curve falls on a different point of the pump HQ curve. Add to that the conservatism built into the heat exchanger (clean not dirty), pump & valve performance prediction and the flow rate could be 20-25% greater than design.

The pipe materials used have tolerances that are quite wide. In particular thermoplastic pipe and cement lining allow a degree of latitude to the designer. If an analysis was made using nominal wall and lining thicknesses alone then the predictions could be in error. That said to undertake an analysis of a system with all manner of variables individually taken into account would result in a phenomenal engineering cost. The only efficient way of looking at the worst cases is to use modern software.

The designer may mitigate the risks involved in having to provide post commissioning surge mitigation devices. This is done by allowing for the following low cost items in the initial design, fabrication and construction:-

•a pair of flanges for an intermediate check valve

•a flange tee for an air valve(s)

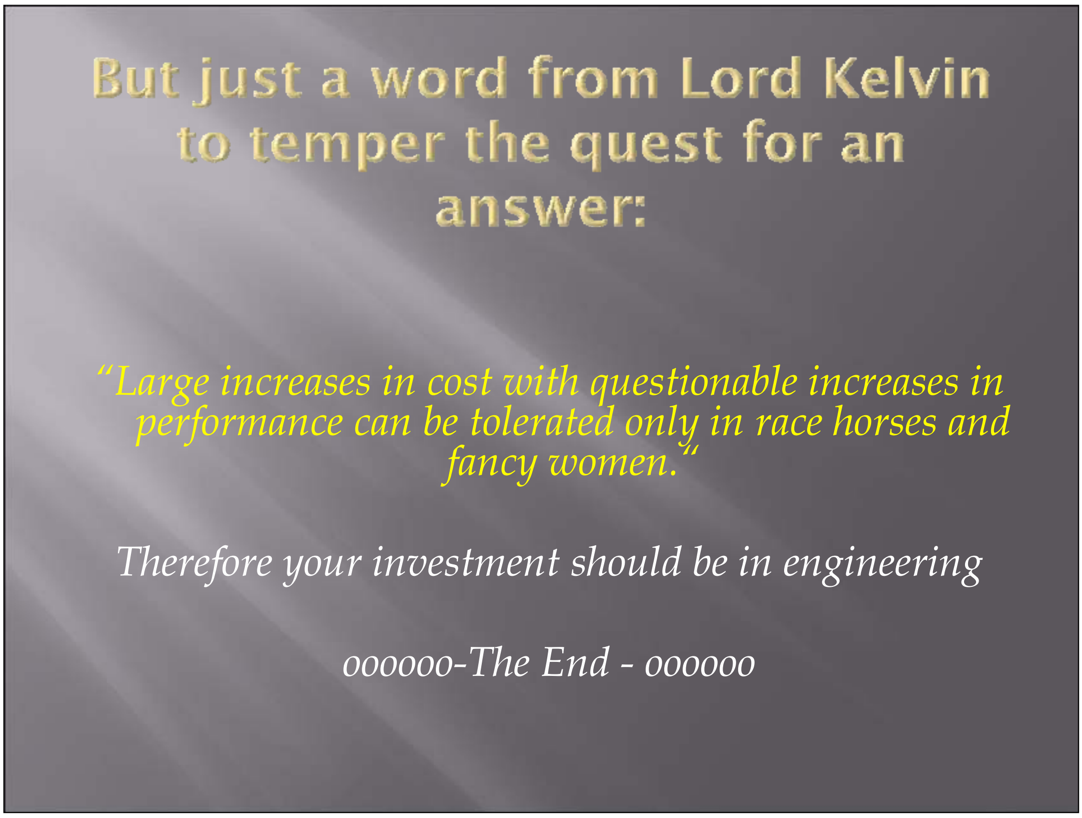
•valved nozzles to fit a bypass check valve around a pump

•a nozzle for surge tower or gas accumulator

• nozzles for a bursting disc, relief or surge anticipation valve

•a switchroom sized to house VSDs and increased air conditioning system

The other benefit is that if the pipeline is upgraded in the future and surge protection is needed for the increased flows it becomes easier to modify the systems.



This paper has been kindly peer reviewed by Trey Walters CEO of Applied Flow Technology www.aft.com and Graeme Ashford Principal of Accutech Pty Ltd www.accutech2000.com.au .

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Questions

- Do I have to do a surge analysis?
- How do I choose the right software/consultant?
- How do surge in complex piping systems differ from simple systems?
- What are the adverse consequences of pressure surges when a valve close rapidly, when a pump trips or starts and the influence of check valves
- Why are surge analyses needed for cooling water & fire water systems?