Common Valve Problems

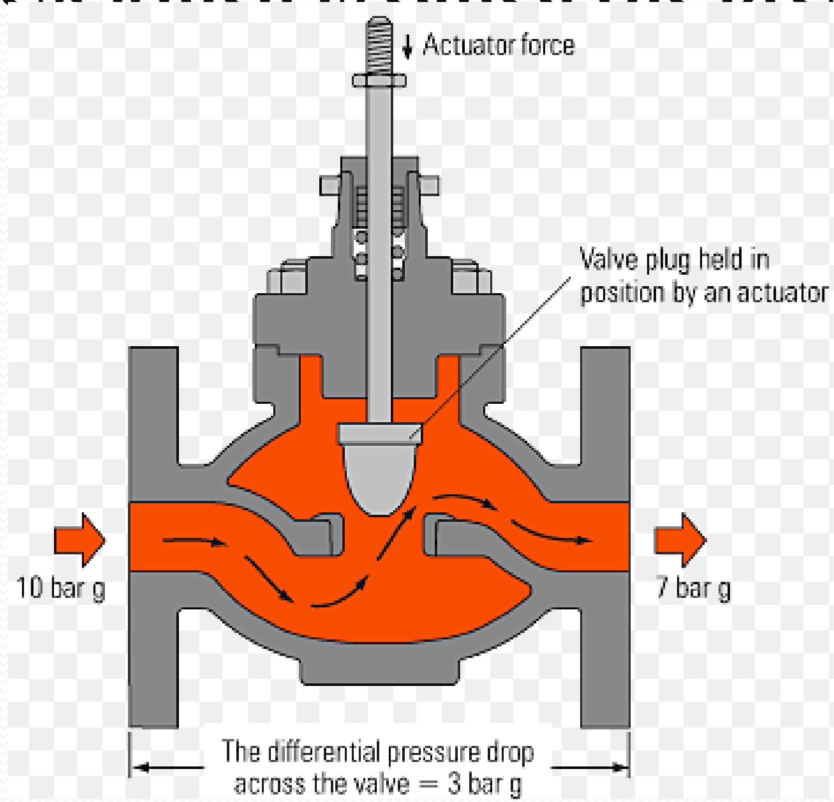
Eng Ibrahim mahmoud

Title and Content Layout with List

- High Pressure Drops
- Cavitations
- Flashing
- Choked Flow
- High Velocities
- Water-Hammer Effects
- High Noise Levels

1.High Pressure Drops

- **Flow moves through a valve due to a difference between the upstream**
- **and downstream pressures, which is called the pressure drop(P) or the**
- **pressure differential.**



1.High Pressure Drops

- valve's frictional losses can be attributed to:
- Friction between the fluid and the valve wall. However, this friction is minimal and is not sufficient to create enough pressure drop for an adequate flow.

- Through a restriction within the body A more effective way to create a significant frictional loss in the valve is Because many valves are
- designed to allow a portion of the valve to be more narrow than the
- piping

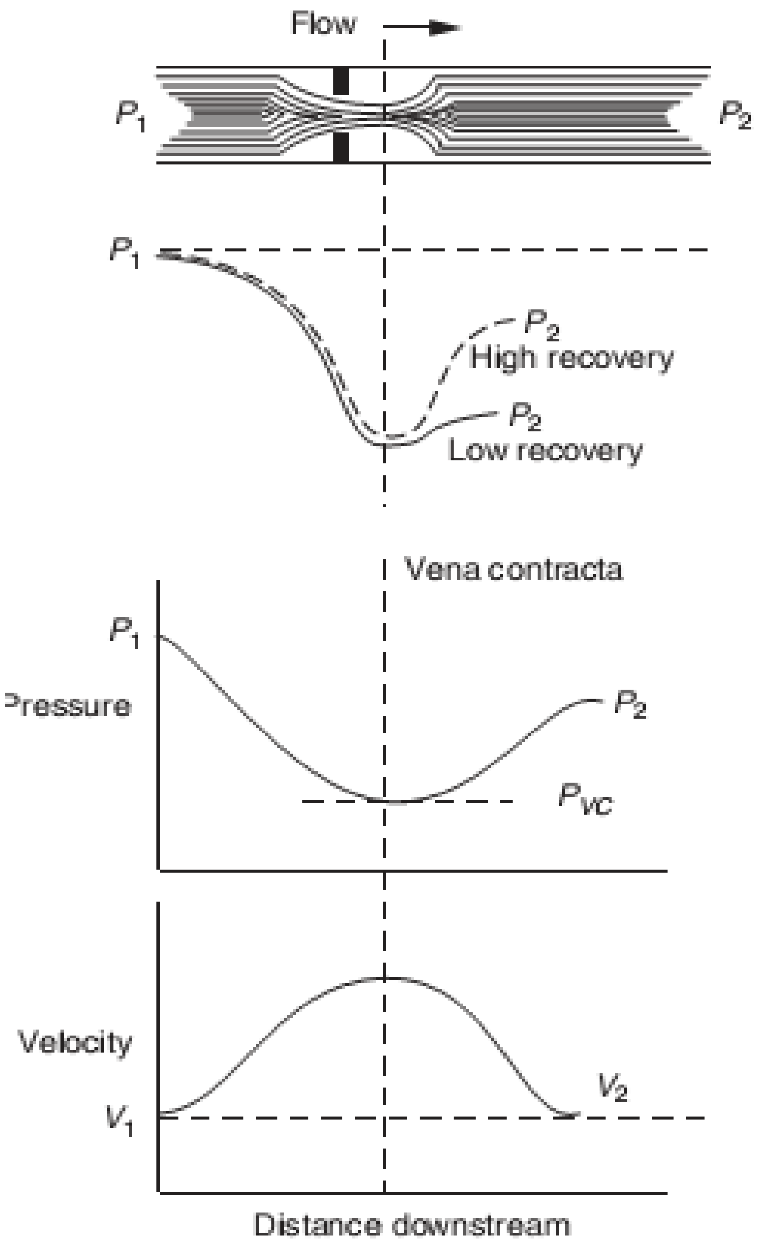
1.High Pressure Drops

- **laws of conservation**

$$\frac{\rho V_1^2}{2g_C} + P_1 = \frac{\rho V_{VC}^2}{2g_C} + P_{VC}$$

as the fluid approaches the valve, its velocity increases in order for the full flow to pass through the valve, inversely producing a corresponding decrease in pressure

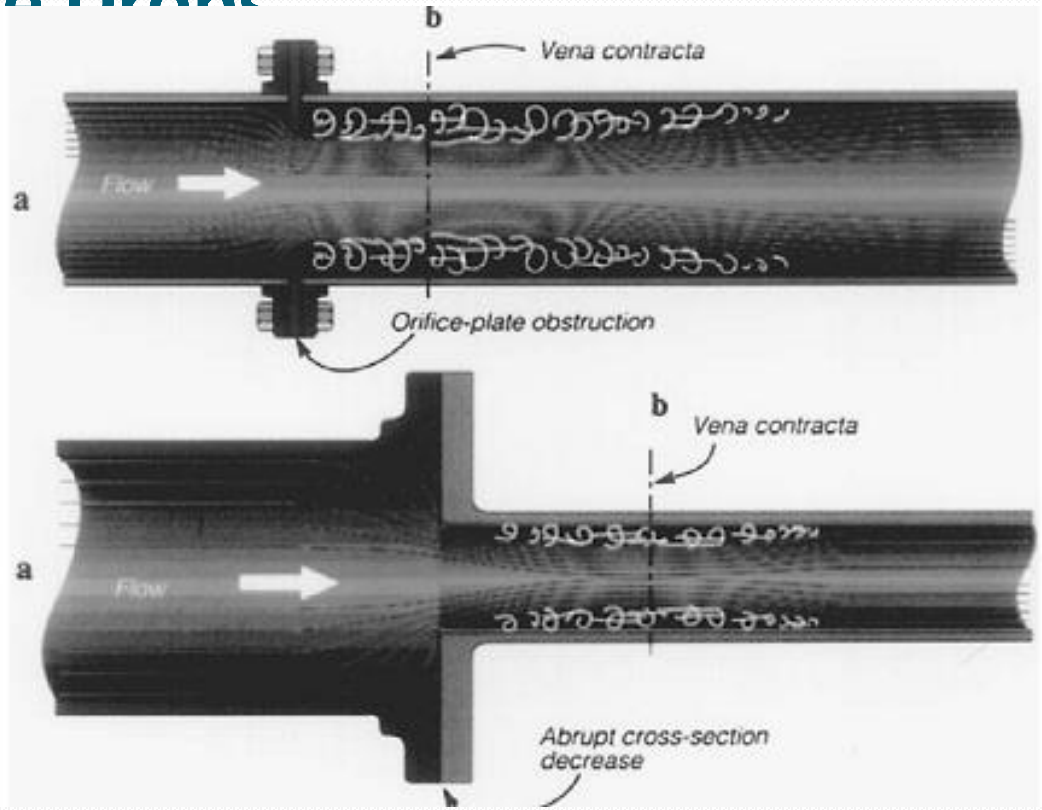
1.High Pressure Drops



where ρ = density units
V_1 = upstream velocity
g_c = gravitational units conversion
V_{VC} = velocity at vena contracta
P_{VC} = pressure at vena contracta
P_1 = upstream pressure

The highest velocity and lowest pressure occur immediately down-stream from the narrowest constriction, which is called the vena contracta.

1.High Pressure Drops



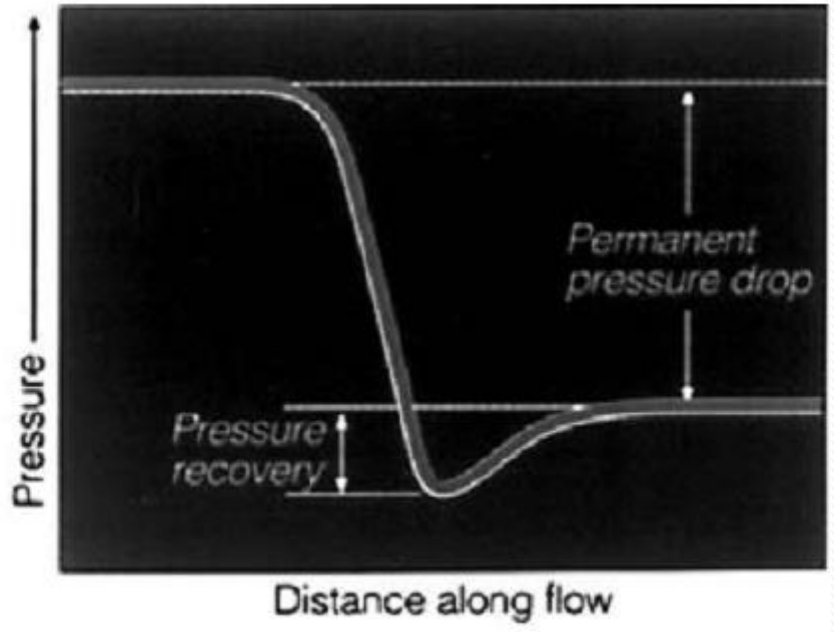
1.At the vena contracta the flow velocity is at a maximum speed, while the flow area of the fluid stream is at its minimum value.

2.Following the vena contracta, the fluid slows and pressure builds once again, although not to the original upstream pressure.

1.High Pressure Drops

- permanent pressure drop- This differ-ence between the upstream and downstream pressures.

- the pressure recovery- The difference in pressure from the pressure at the vena contracta and the downstream pressure



1.High Pressure Drops

The flow rate for a valve can be increased by decreasing the down stream pressure.

However, **in liquid** applications the flow can be limited by the pressure drop falling below the vapor pressure of the fluid,

and can no longer be increased by lowering the downstream pressure.

In other words, the formation of gas in a liquid crowds the vena contracta, which limits the amount of flow that can pass through the valve.

With gases, as the velocity approaches sonic speeds, choked

flow also occurs and the valve will not be able to increase flow despite a reduction in downstream pressure.

1.High Pressure Drops

- the flow function of the valve is dependent on the existence of a pressure drop, which allows flow movement from the upstream vessel to the downstream vessel or to atmosphere.

- The ideal pressure drop allows the full flow to pass through the body without excessive velocity, absorbing less energy.

1.High Pressure Drops

A high pressure drop through a valve creates a number of problems,such as :

1. Cavitation
2. Flashing
3. choked flow
4. high noise levels
5. and vibration
6. erosion or cavitation damage to the body and trim,
7. malfunction or poor performance of the valve itself
8. wandering calibration of attached instrumentation
9. piping fatigue

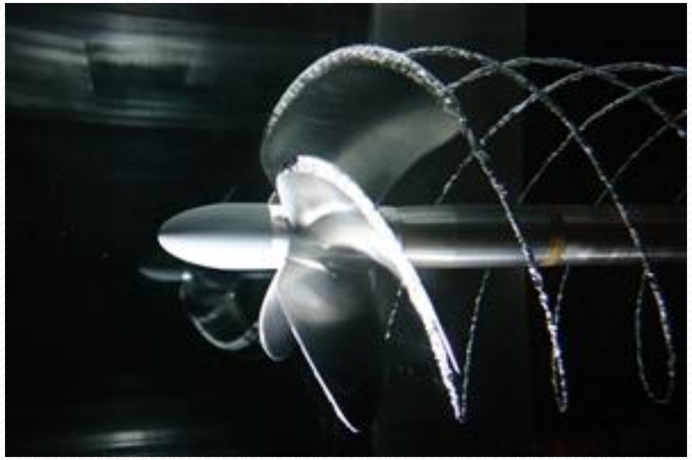
1.High Pressure Drops

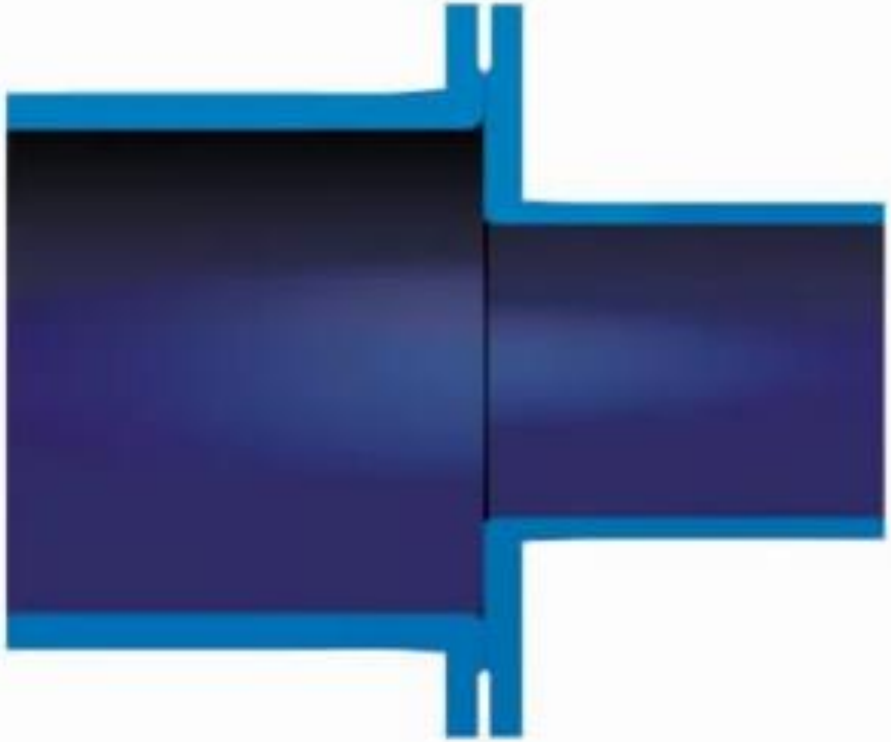
valves in high-pressure-drop applications require:

1. expensive trims
2. more frequent maintenance
3. large spare-part inventories
4. and piping supports. Such measures drive up maintenance .
5. engineering costs.

2. Cavitation

Cavitation is a phenomenon that occurs only in liquid services. It was first discovered as a problem in the early 1900s, when naval engineers noticed that high-speed boat propellers generated vapor bubbles. These bubbles seemed to lessen the speed of the ship, as well as cause physical deterioration to the propeller.

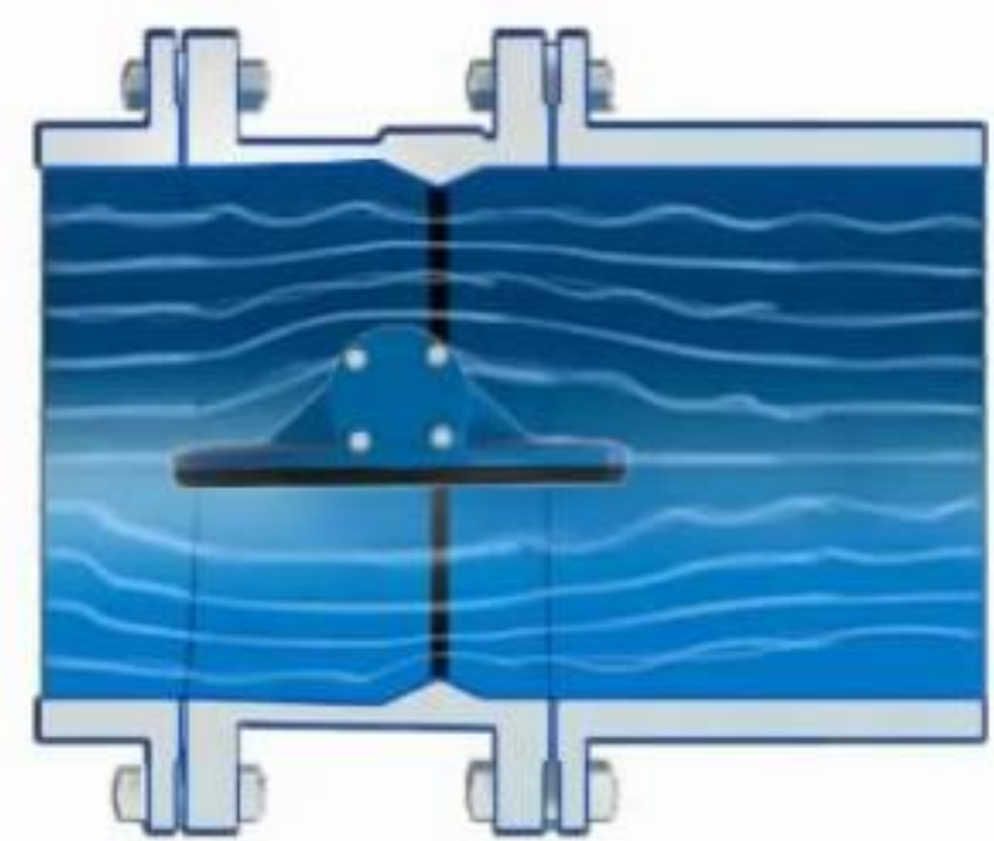




Stationary parts

- Cross-section of pipes is suddenly constricted

Stationary parts



- Flow restricted by a valve

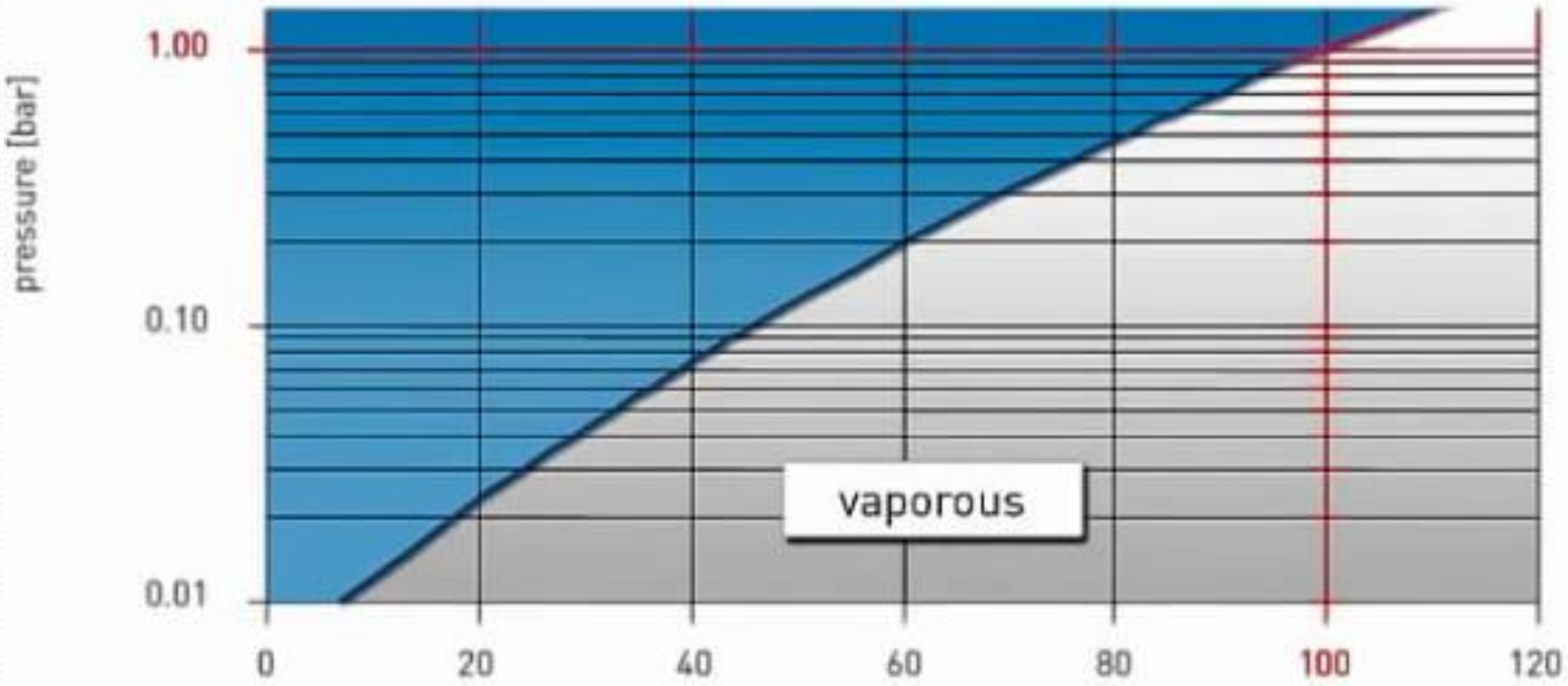
2. Cavitation

Cases:

Whenever the atmospheric pressure is equal to the vapor pressure of a liquid, vapor bubbles are created by heating.

This same phenomenon can also occur by decreasing the atmospheric pressure to equal the vapor pressure of the liquid.

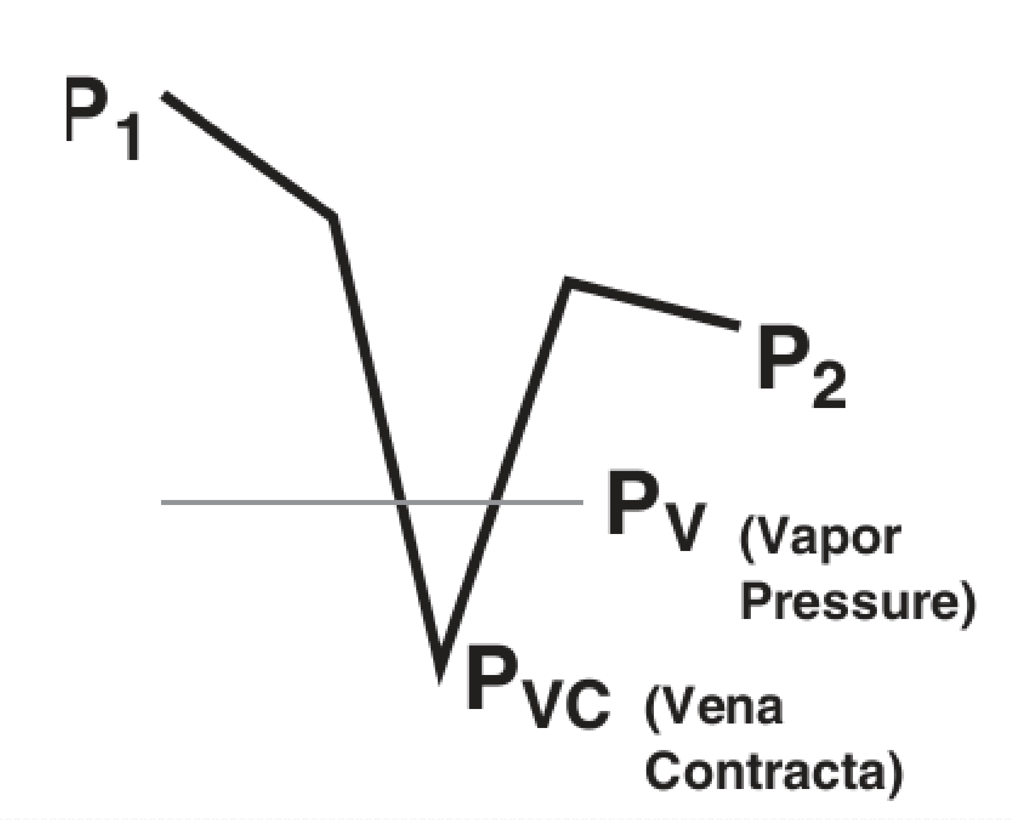
100°C
1 bar atmospheric pressure



Temp.

2. Cavitation

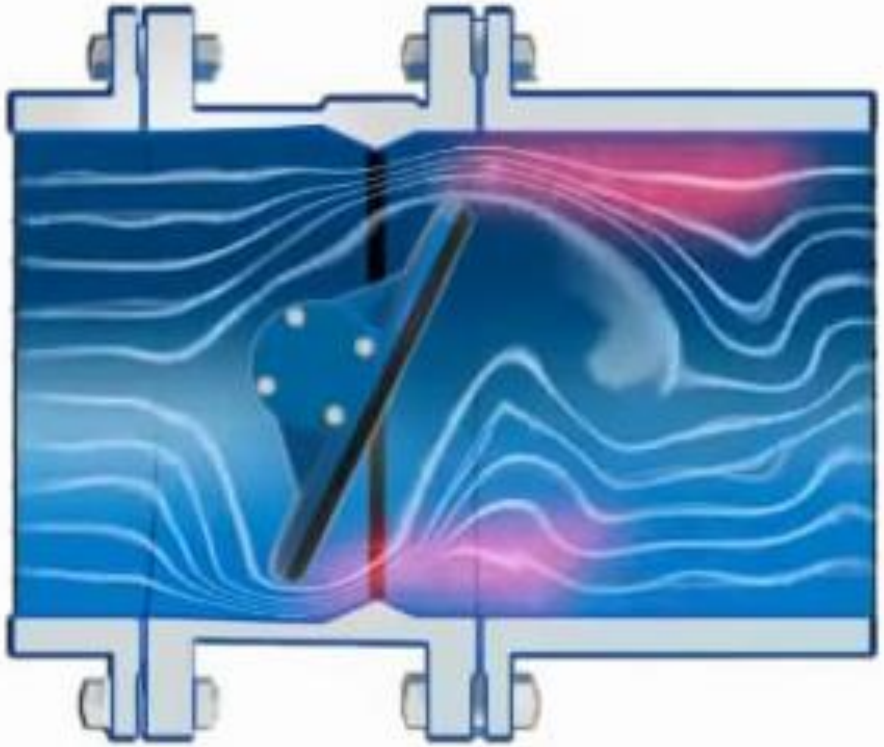
Cases:

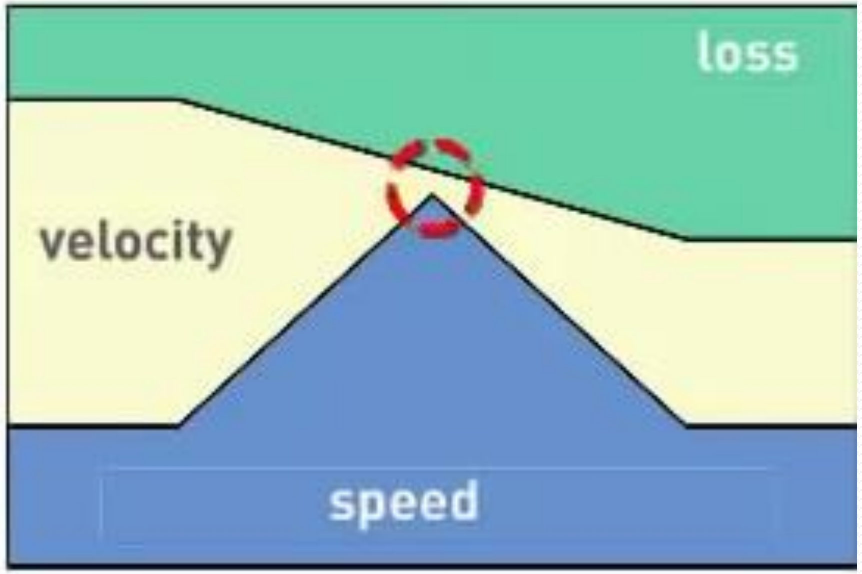


This two-step process—the formation of the bubble in the vena contracta and its subsequent implosion downstream is called cavitation.

2. Cavitation

Cases:





2. Cavitation

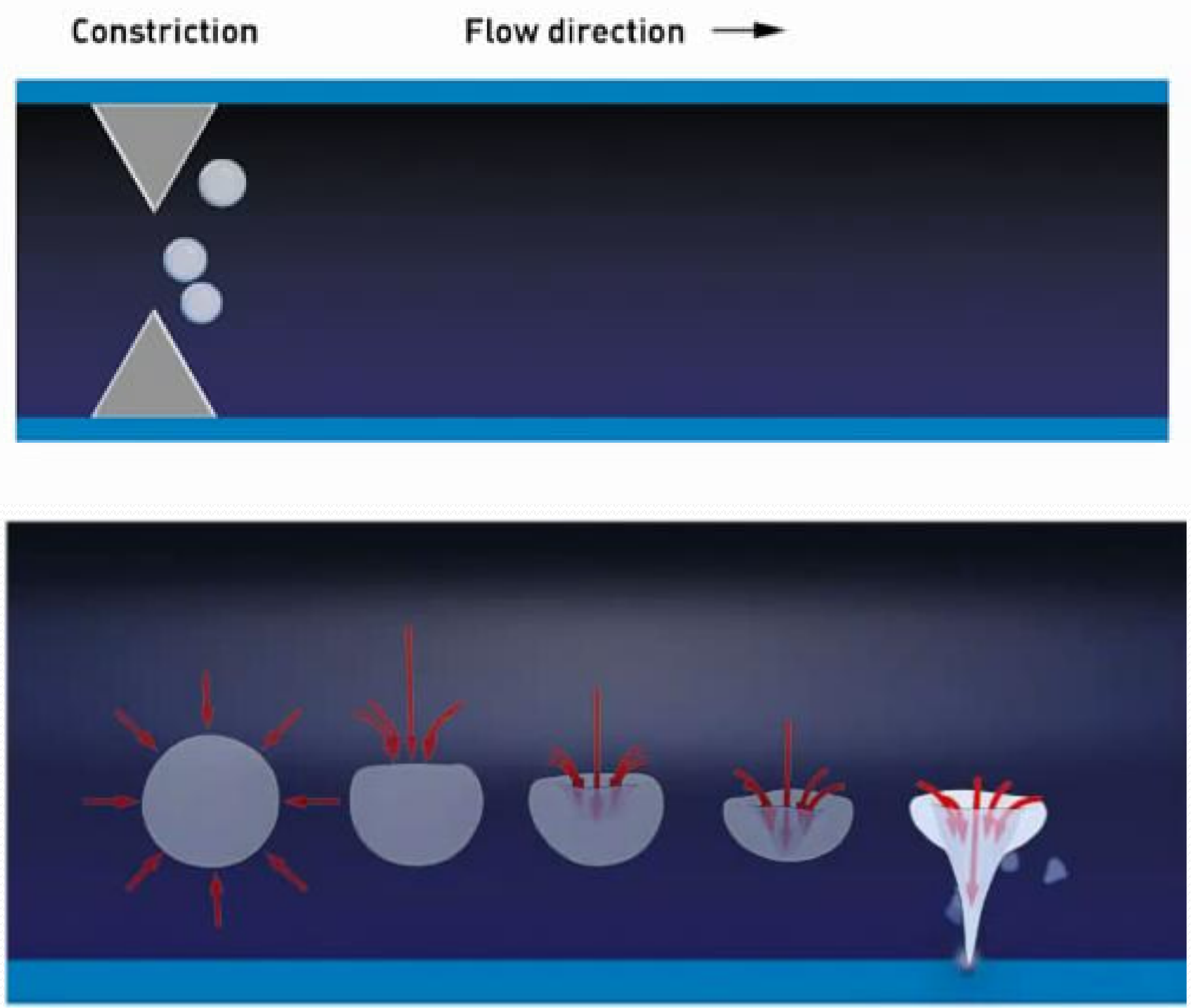
four conditions must be present to produce cavitation:

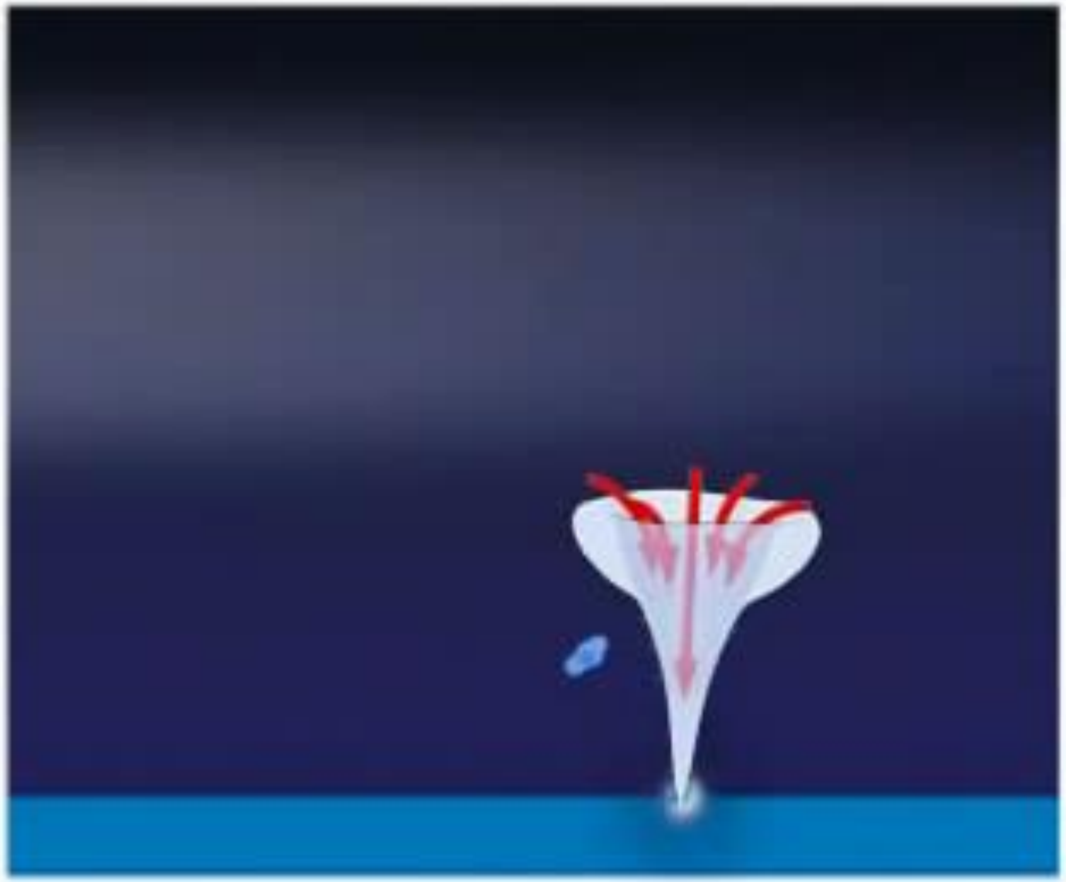
1. the fluid must remain a liquid both upstream and downstream from the valve.
2. the pressure drop at the vena contracta must drop below the vapor pressure of the process fluid.
3. the outlet pressure must recover at a level above the vapor pressure of the liquid.
4. the liquid must contain some entrained gases or impurities

2. Cavitation

The creation and implosion of the cavitation bubble involve five stages:

1. the liquid's pressure drops below the vapor pressure as velocity increases through the valve's restriction.
2. the liquid expands into vapor around a nuclei host, which is either a particulateor an entrained gas.
3. the bubble grows until the flow moves away from the vena contracta and the increasing pressure recovery inhibits the growth of the bubble.
4. as the flow moves away from the vena contracta, the area expands—slowing velocity and increasing pressure. This increased pressure collapses or implodes the bubble vapor back to a liquid.
5. if the bubble is near a valve surface, the force of the implosion is directed toward the surface wall, causing material fatigue.


Constriction
Flow direction



Microjet

- Pressure peak up to 10,000 bar
- Material loss

2. Cavitation

Cavitations problem:

1. limit the life expectancy of the valve.
2. It can also create excessive seat leakage,
3. distort flow characteristics,
4. cause the eventual failure of the pressure vessels (valve body, piping, etc.).
5. In some severe high-pressure-drop applications, valve parts can be destroyed within minutes bycavitation.

Cavitation damages - Shut-off Valve

Operating conditions

- Opening degree max. 5°
- Very high flow velocity in the remaining opening
- Operating time: 1 year

Cavitation damages - Gate Valve

Operating conditions

- Never completely closed
- Very high flow velocity in the remaining opening
- Operating time: **3 months!**

Cavitation damages - Needle Valve

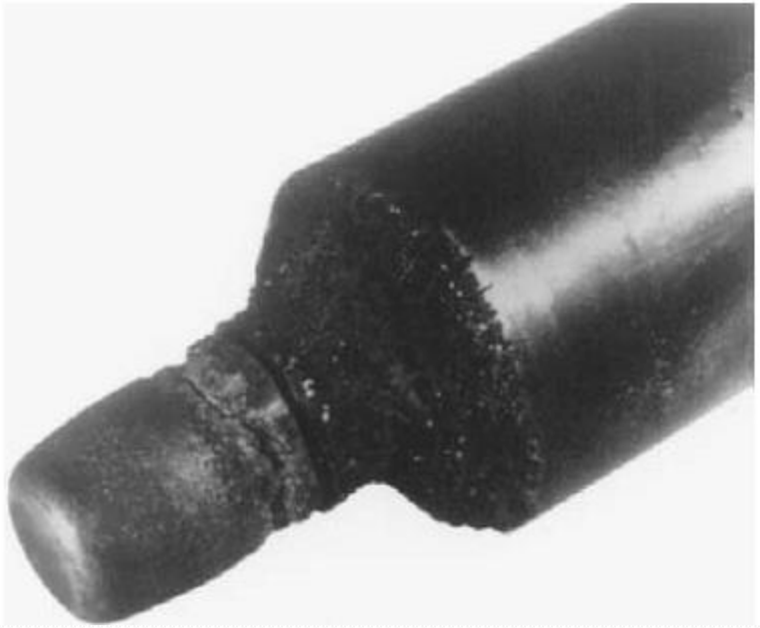
Operating conditions

- Operated desenting from the given values
- Too low downstream pressure
- Operating time: 2 years

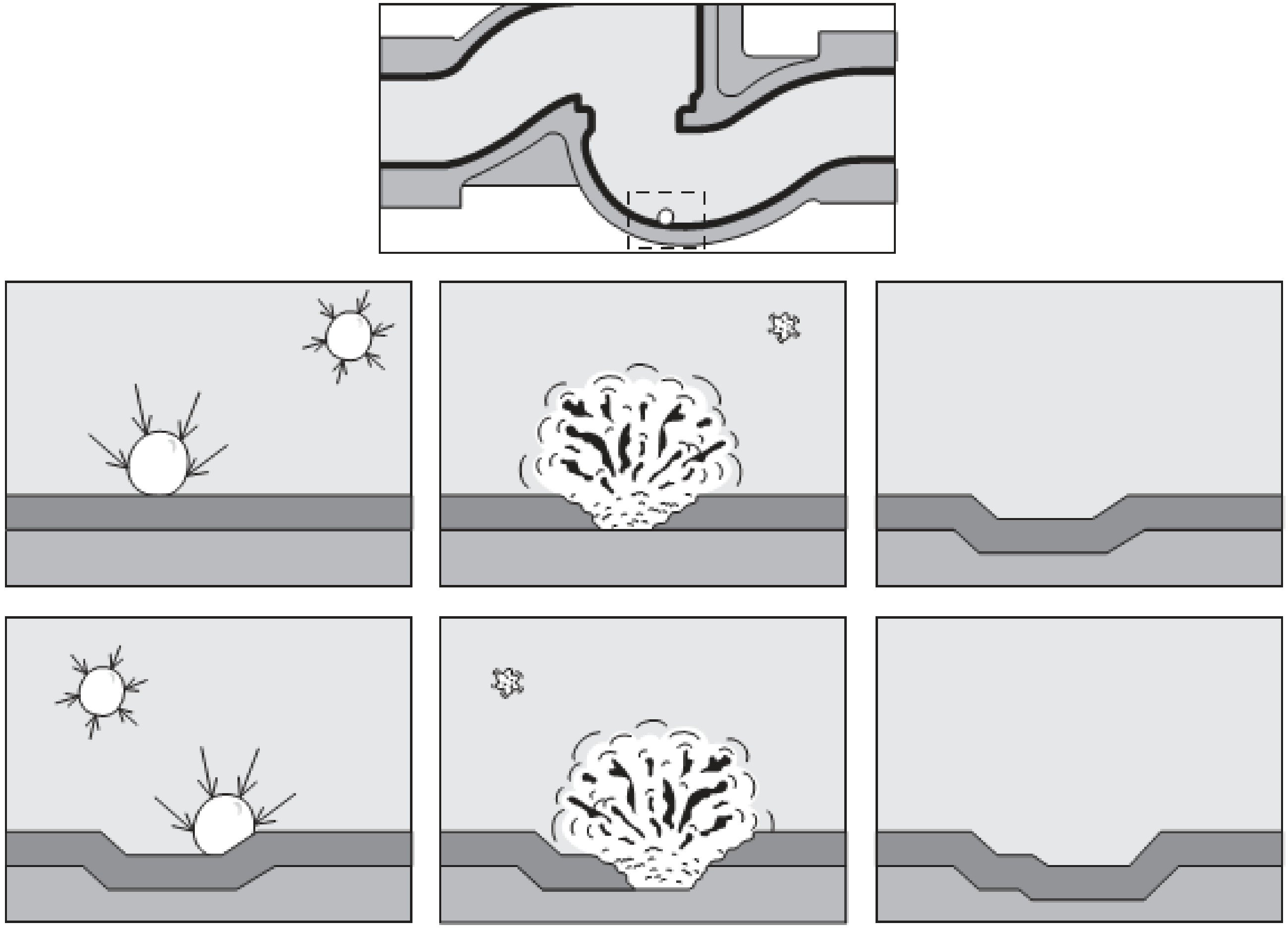
2. Cavitation

Cavitations problem:

Another possible long-term effect of cavitation is that it may attack a material's coating, film, or oxide, which will open up the base material to chemical or corrosion attack.



2. Cavitation



2. Cavitation

The hardness of the metal plays a large role in how easily the metal can be torn by the cavitation bubbles.

Soft materials, such as aluminum, yield easily to the forces generated by cavitation bubbles and tear away quickly.

Hardened materials are better able to withstand the effects of cavitation, and only after a period of time will they fatigue and begin to wear.

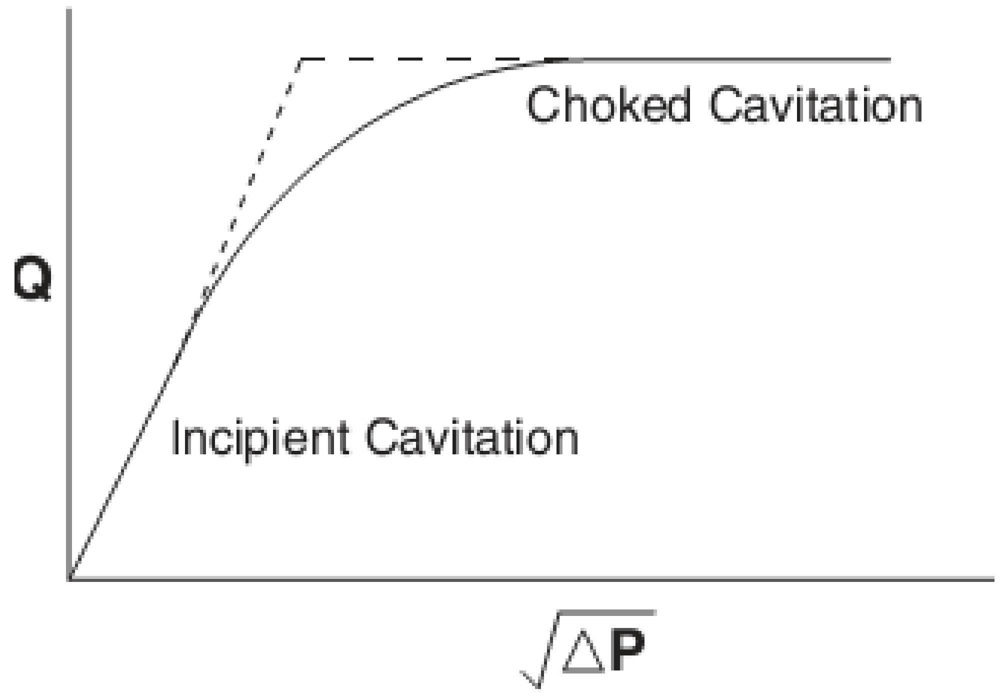
No material can resist cavitation indefinitely. Even the hardest materials will eventually wear away.

2. Cavitation

Incipient and Choked Cavitations.

$$Q = C_v \sqrt{\frac{\Delta P}{GS}}$$

where Q = flow rate
C_v = flow coefficient
ΔP = pressure drop
G_S = specific gravity



2. Cavitation

Over the years, cavitation experts have developed a number of cavitation indices to predict the possibility of cavitation in process equipment.

$$K_C = \frac{P_1 - P_2}{P_1 - P_V} = \frac{\Delta P}{P_1 - P_V}$$

where K_C = cavitation index
P_1 = valve inlet pressure
P_2 = valve outlet pressure
P_V = vapor pressure of liquid (at valve inlet and vena contracta)

2. Cavitation

several common KC values for a number of valve styles.

Table 9.1 Typical K_c Values†

Valve Style	K_c
Butterfly	$0.50\ K_M$*
Ball	$0.67\ K_M$
Rotary Plug	K_M
Globe with Hardened Trim (Cage Characterized)	K_M
Globe (Plug Characterized)	0.85
Globe with special trim	1.0

†*Data courtesy of Fisher Controls International, Inc.*

*K_M is equal to F_L^2 (valve recovery coefficient).

2. Cavitation

A more useful cavitation index for valves is , which was approved in 1995 by the Instrument Society of America. In general terms, is a ratio of forces that resist cavitation to forces that promote cavitation and is written as:

$$\sigma = \frac{P_2 - P_V}{P_1 - P_2}$$

where σ = cavitation index

P_1 = upstream pressure (measured one pipe diameter upstream from the valve)

P_2 = downstream pressure (measured five pipe diameters downstream from the valve)

P_V = liquid vapor pressure (at flowing temperature)

2. Cavitation

Incipient is the value that indicates when cavitation is beginning.

Choked is the value that indicates when choked flow or full cavitation is occurring.

Valve Style	Flow Direction	Trim Size	Incipient σ	Choked σ
Globe	over the plug	full area	0.73	0.38
	over the plug	reduced	0.93	0.56
	under the plug	full/reduced	0.52	0.52
Butterfly	60° open	full	1.40	0.73
	90° open	full	3.16	2.19
Ball	60° open	full	1.40	0.64
	90° open	full	5.20	2.19
Globe with special trim	under the plug	full/reduced	0.30 to 0.001	*

†*Data courtesy of Valtek International.*

‡*Note:* For estimation only; sigmas may vary according to particular valve design.

*Choking will not occur when properly applied.

2. Cavitation

To show an application of incipient σ and choked σ, the following example is used:

Fluid	Water
Temperature	80°F
Vapor pressure P_V	0.5 psia
Upstream pressure P_1	200 psia
Downstream pressure P_2	55 psia
Valve type	Single-seated globe valve, 100 percent open, flow-over-the-plug

2. Cavitation

The value for σ is

$$\sigma = \frac{P_2 - P_V}{P_1 - P_2} = \frac{55-0.5}{200-55} = 0.38$$

Referring to Table 9.2, incipient σ begins at σ = 0.73 (for a single-seated globe valve that is at 100 percent open with flow under the plug) and the choked σ occurs at σ = 0.38. In this example severe cavitation damage is occurring and the valve is choked and cannot increase flow any further.

2. Cavitation

Using the same valve in example A, new service conditions are applied to illustrate a cavitating, but nonchoking, situation:

Fluid	Water
Temperature	80°F
Vapor pressure P_V	0.5 psia
Upstream pressure P_1	500 psia
Downstream pressure P_2	200 psia
Valve type	Single-seated globe valve, 100 percent open, flow-over-the-plug

2. Cavitation

Using the σ index equation for these operating conditions, we find that σ is significantly higher:

$$\sigma = \frac{200 - 0.5}{500 - 200} = 0.67$$

This σ value is above the choked σ value for this valve (which is σ = 0.38) and indicates that the valve is not experiencing choked flow. However, this value is below the incipient σ value, which indicates that the valve is experiencing cavitation and damage may be occurring in the valve.

Cavitation controlled or eliminated

Cavitation can be controlled or eliminated by one of three basic methods:

1. first, by modifying the system;
2. second, by making certain internal body parts out of hard or hardened materials;
3. third, by installing special devices in the valve that are designed to keep cavitation away from valve surfaces or prevent the formation of the cavitation itself.

Cavitation controlled or eliminated

Back-pressure device used with globe valves.

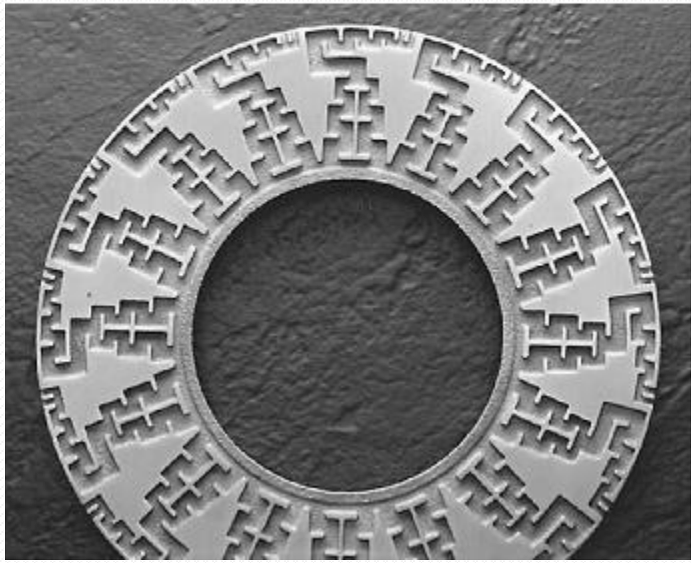
Back-pressure device used withrotary valves

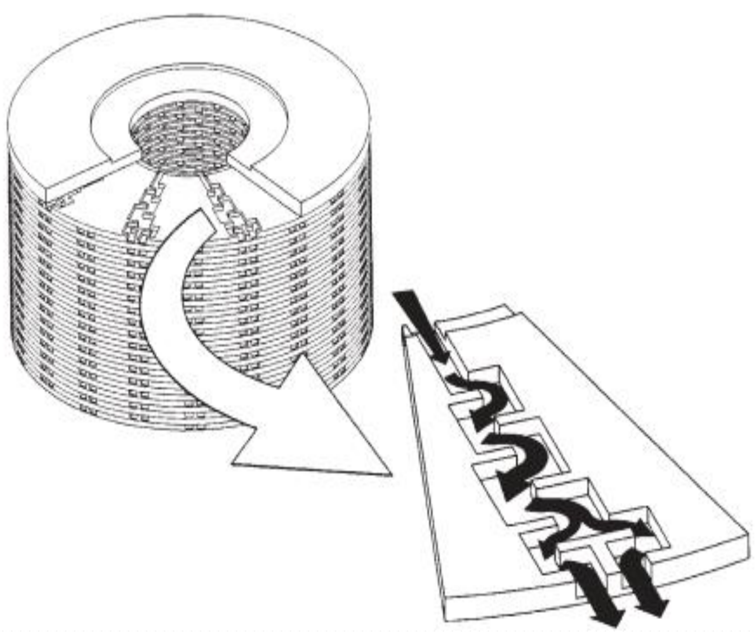
Cavitation controlled or eliminated

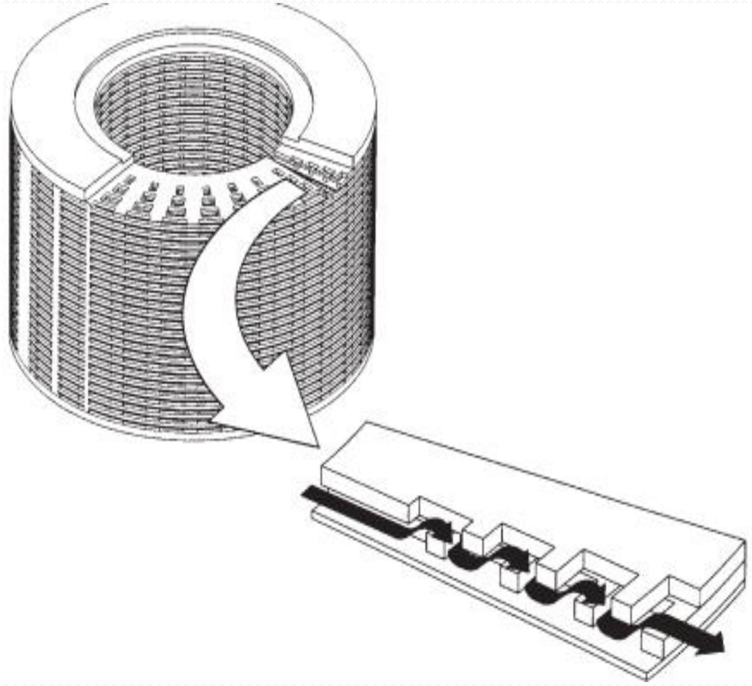
Cavitation controlled or eliminated

Some valves are designed to prevent the formation of cavitation alto-gether. Although it is a more expensive option, in some applications anticavitation design features are the only choice. Globe-style valves can be designed with special retainers or cages, which use either (or a combination of) a tortuous path, pressure-drop staging, and/or expanded flow areas to decrease the pressure drop through the valve and to prevent cavitation.

Cavitation controlled or eliminated

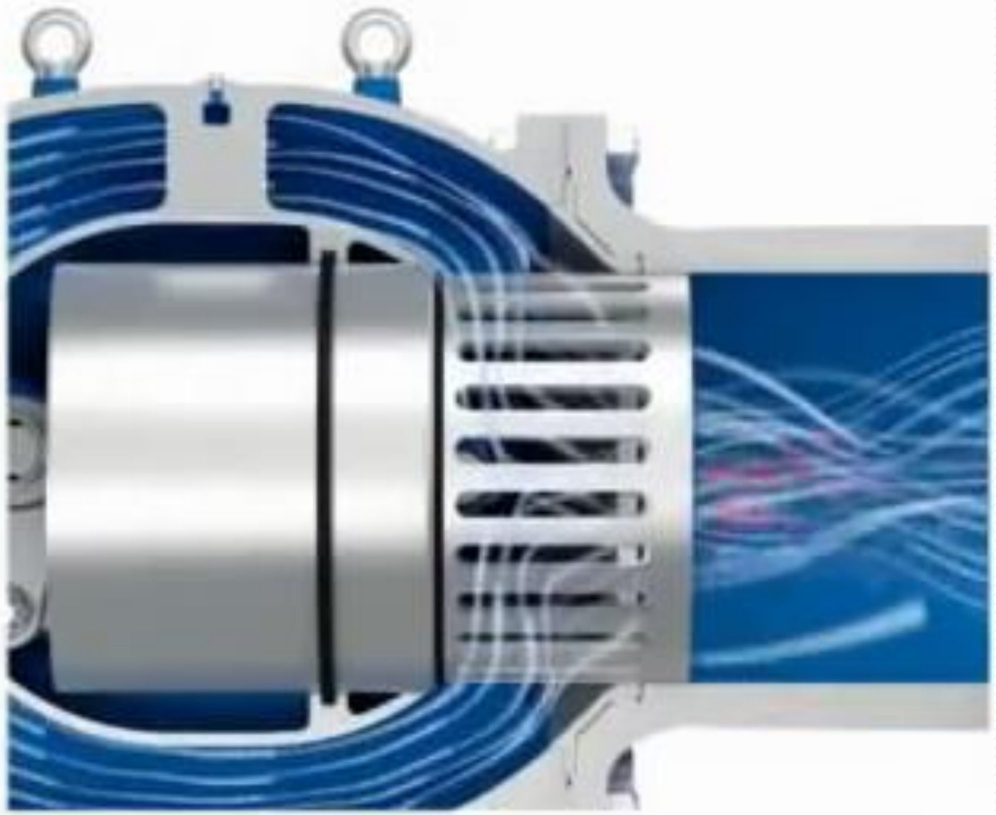






Tortuous-path trim for velocity reduction.

Cavitation controlled or eliminated

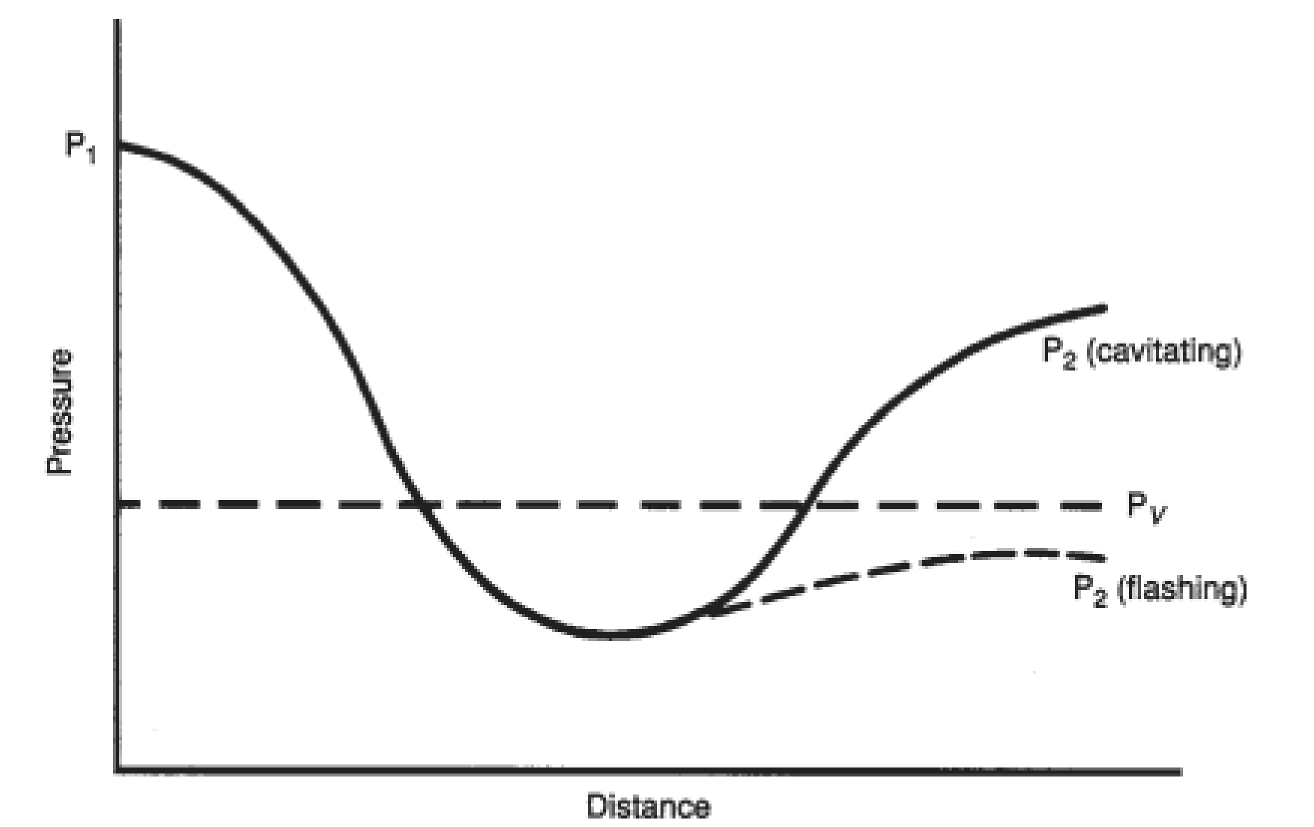


Cavitation controlled or eliminated

3. Flashing

In liquid applications, when the downstream pressure is equal to or less than the vapor pressure, the vapor bubbles generated at the vena contracta stay intact and do not collapse. This happens because the pressure recovery is high enough for this to happen.

3. Flashing



Pressure curve showing outlet pressure below the vapor pres-sure, resulting in flashing.

3. Flashing

When flashing occurs, the fluid downstream is a mixture of vapor and liquid moving at very high velocities, resulting in erosion in the valve and in the down-stream piping.

Plug damaged by flashing

Controlling Flashing

eliminating flashing completely involves modifying the system itself.

Anticavitation plug for quarter-turn plug valves.

When flashing occurs, no solution can be designed into the valve, such as is the case with anticavitation or cavitation-control trim, except to offer hardened trim materials.

4. Choked Flow

Choked flow occurs in gases and vapors when the velocity of a process fluid achieves sonic speeds in the valve or the downstream piping.

As the fluid in the valve reaches the valve restriction, the pressure decreases and the specific volume increases until sonic velocities are achieved. When choked flow occurs, the flow rate is limited to the amount of flow that can pass through the valve at that point and can-not be increased unless the service conditions are changed.

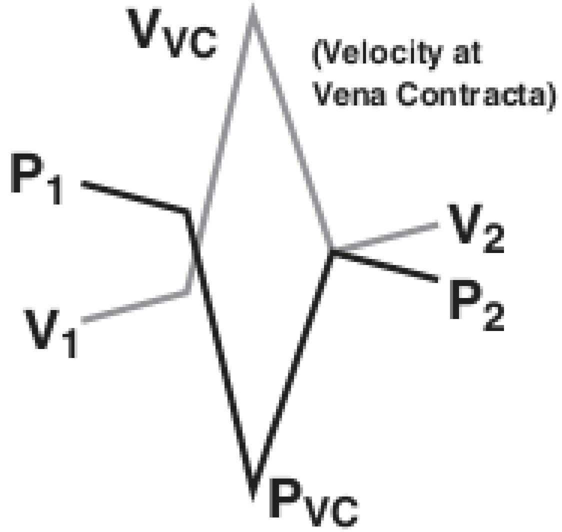
choked flow must be considered when sizing a valve, especially when considering ΔP allowable and the valve recovery coefficient KM

5. High Velocities

large pressure differentials create high velocities through a valve and in downstream piping. This in turn creates turbulence and vibration in liquid applications and high noise levels in gas applications.

The velocity is inversely related to the pressure losses and gains

as the flow moves through the vena contracta



Velocity and pressure profiles as flow travels through an orifice restriction.

5. High Velocities

Velocity Limits

The following general rules apply to velocities: Liquids should generally not exceed (15.2 m/s) (9 m/s in cavitating services).

Gases should not exceed sonic speeds (Mach 1.0). And, mixtures of gases and liquids (such as flashing applications) should not

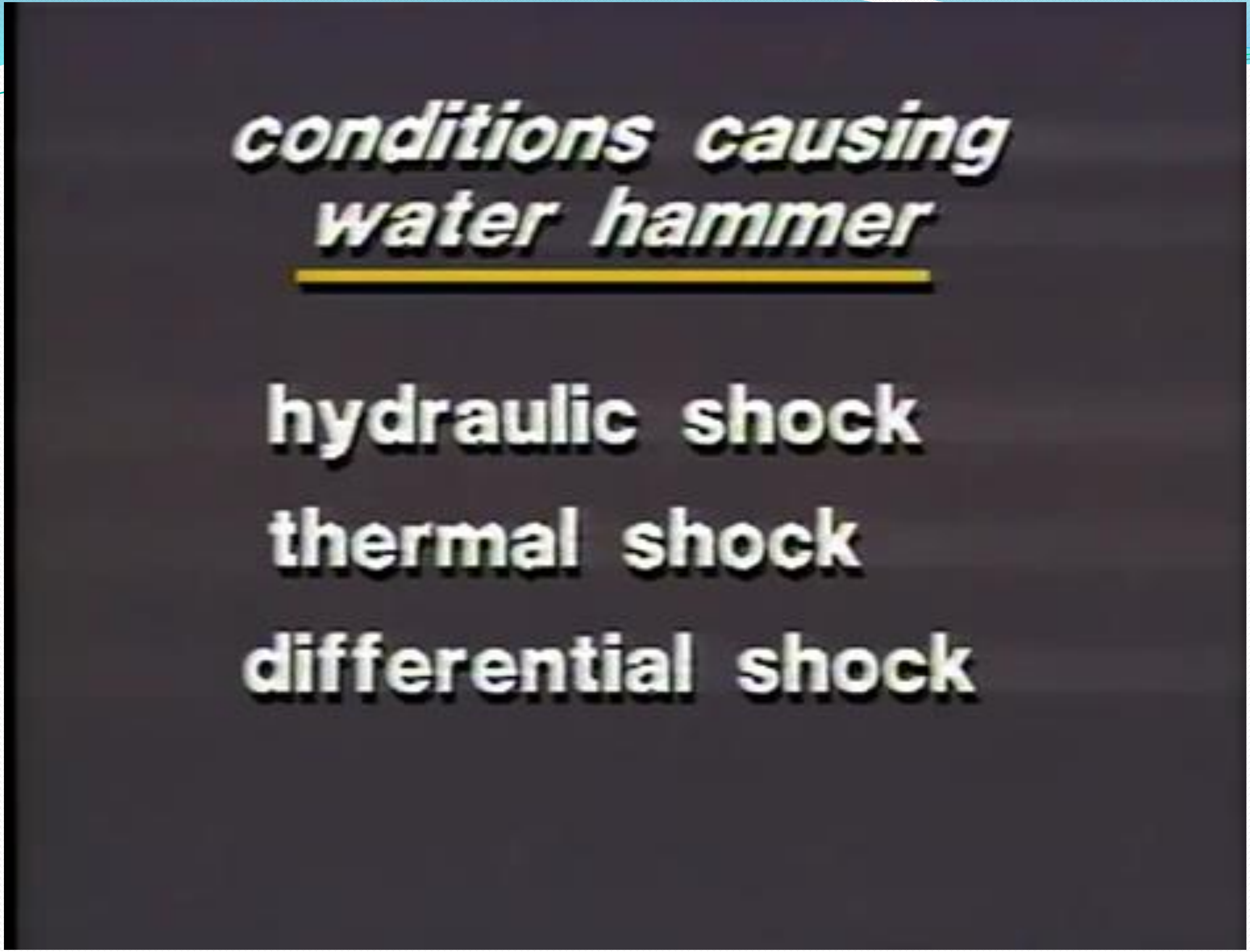
Exceed (152 m/s).

These general rules can vary, however, according to the size of the valve. For example, smaller-sized valves can normally handle higher velocities, while larger valves only handle lower velocities.

6. Water-Hammer Effects

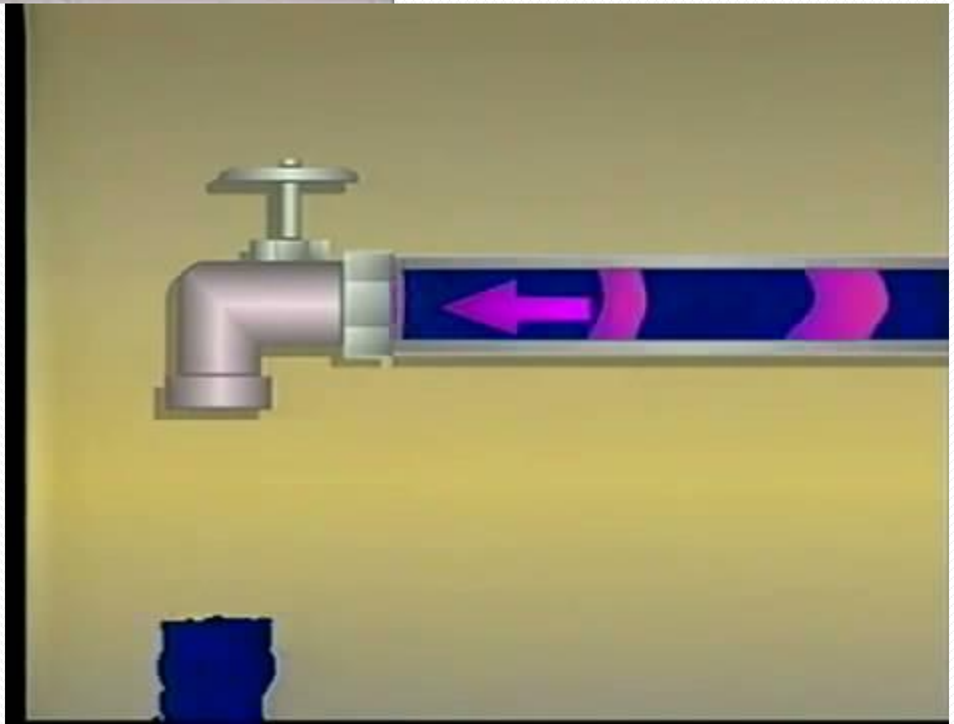
In liquid applications, whenever flow suddenly stops, shock waves of a large magnitude are generated both upstream and downstream. This phenomena is known as the water-hammer effect.

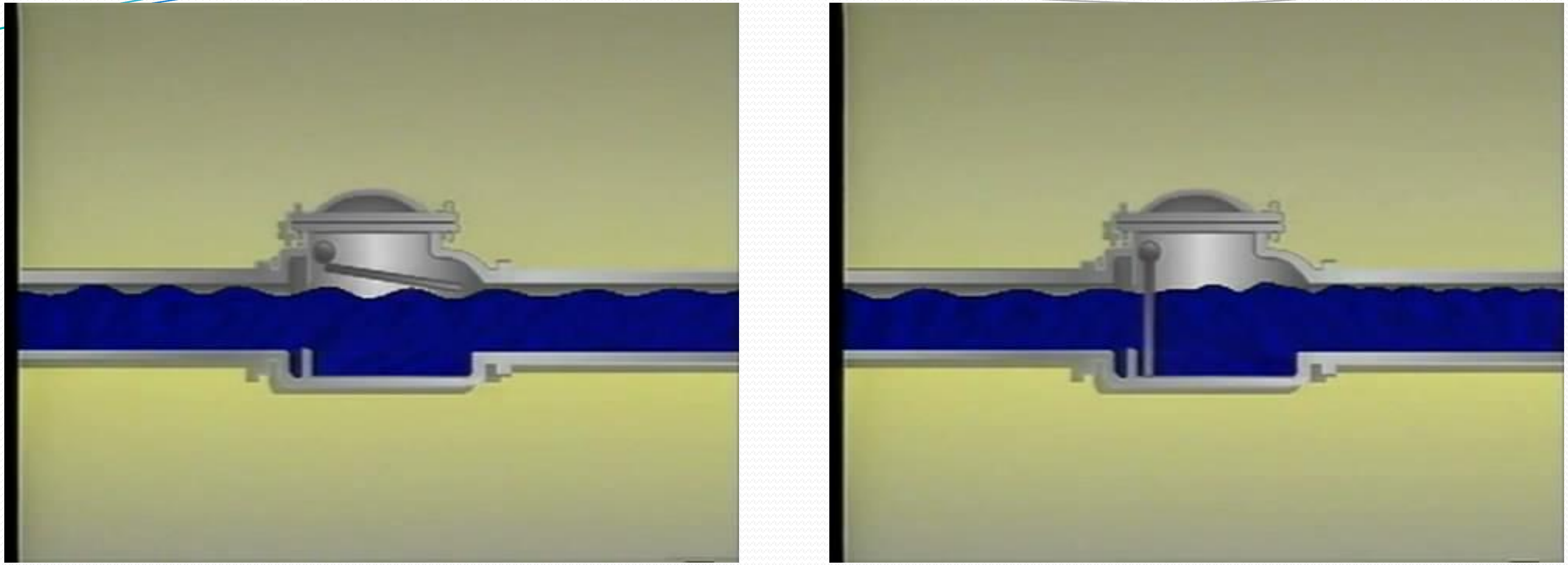

Bi-phase mix
heat exchangers
tracer lines
steam mains
condensate return lines
pump discharge lines


conditions causing
water hammer
hydraulic shock
thermal shock
differential shock

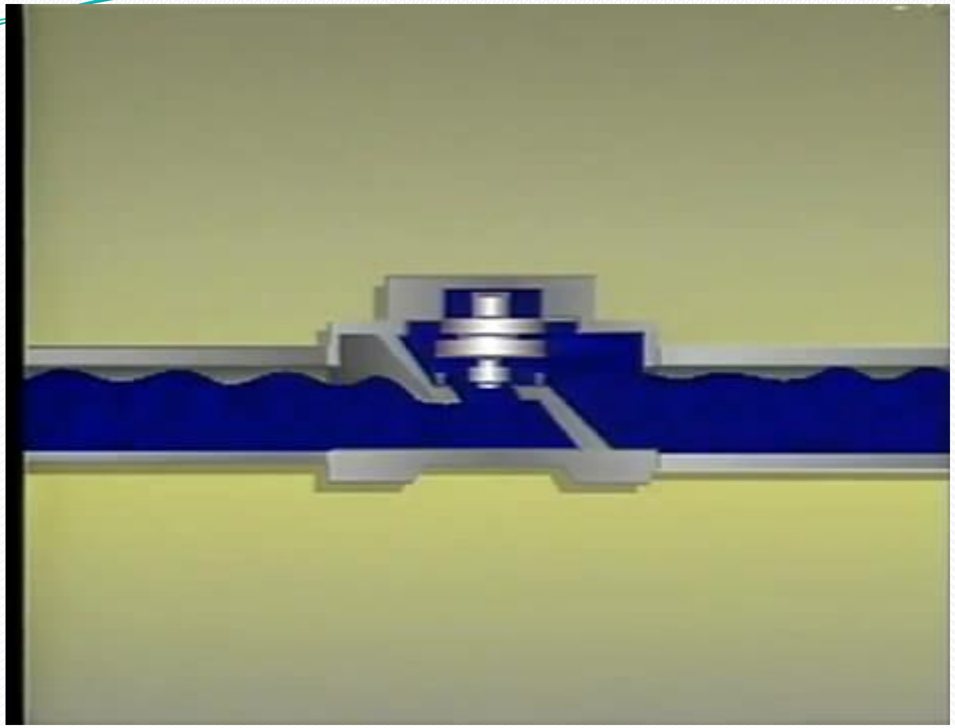

HYDRAULIC
SHOCK


100 lbs
45.5 Kg





Swing check valve



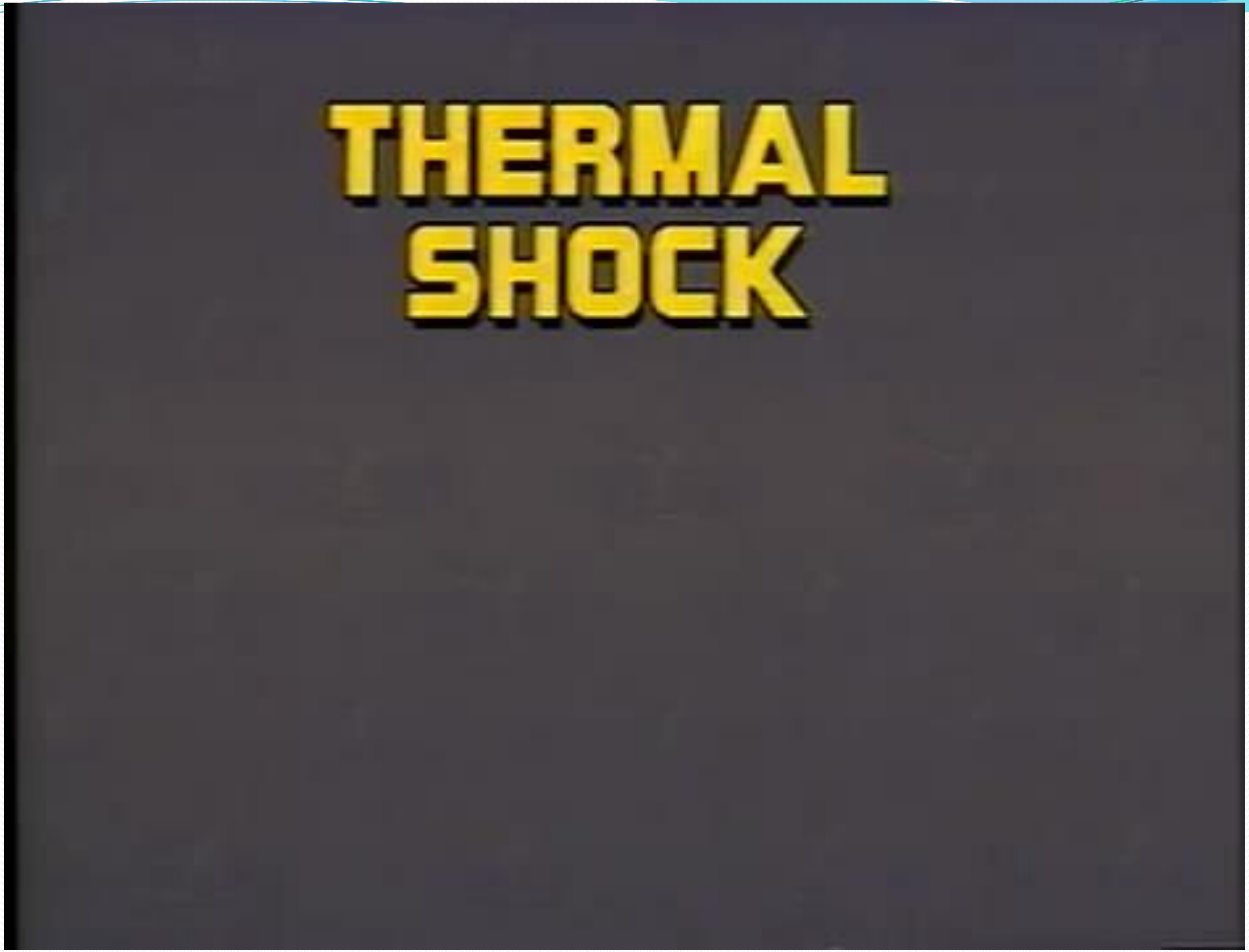
Silent check valve

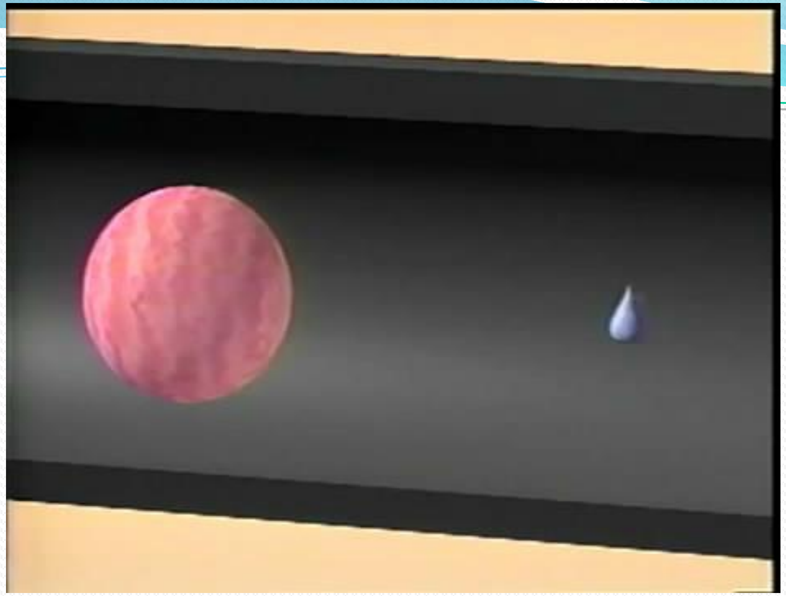
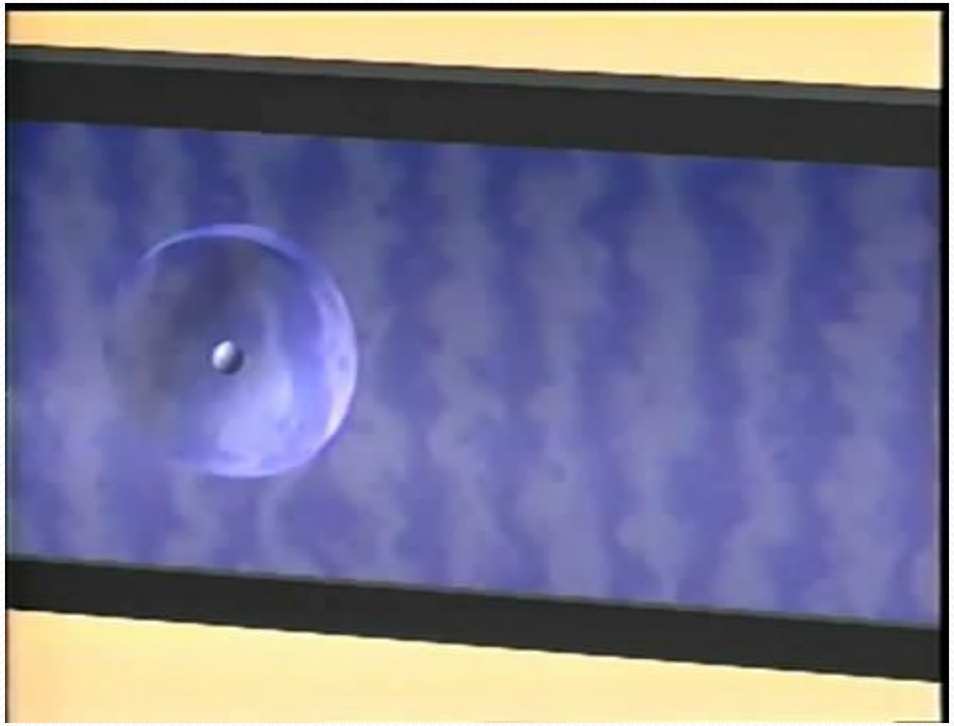
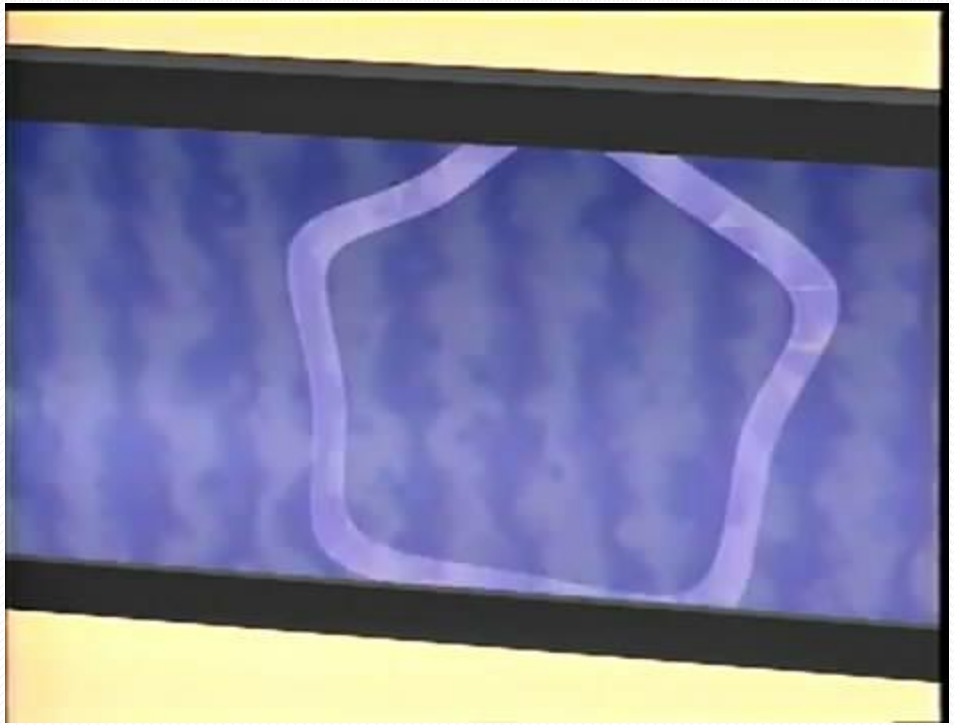
Water hammer arrestor

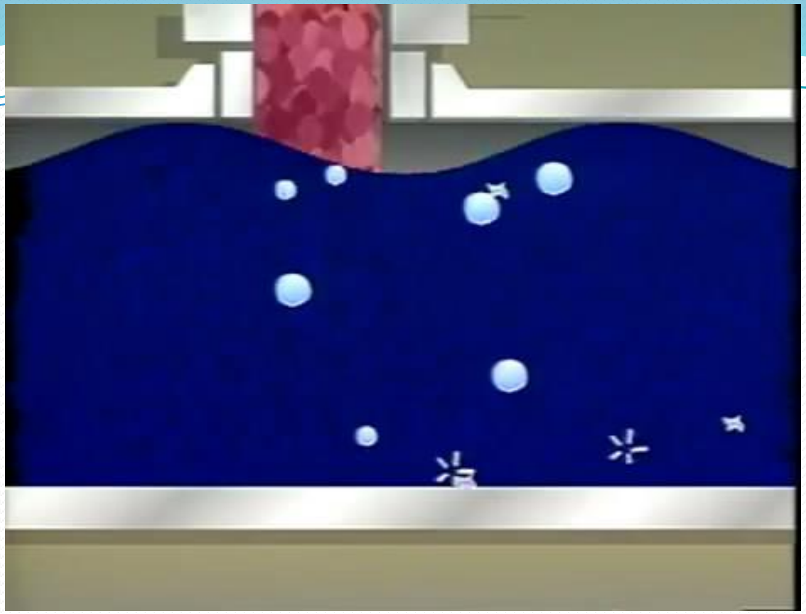
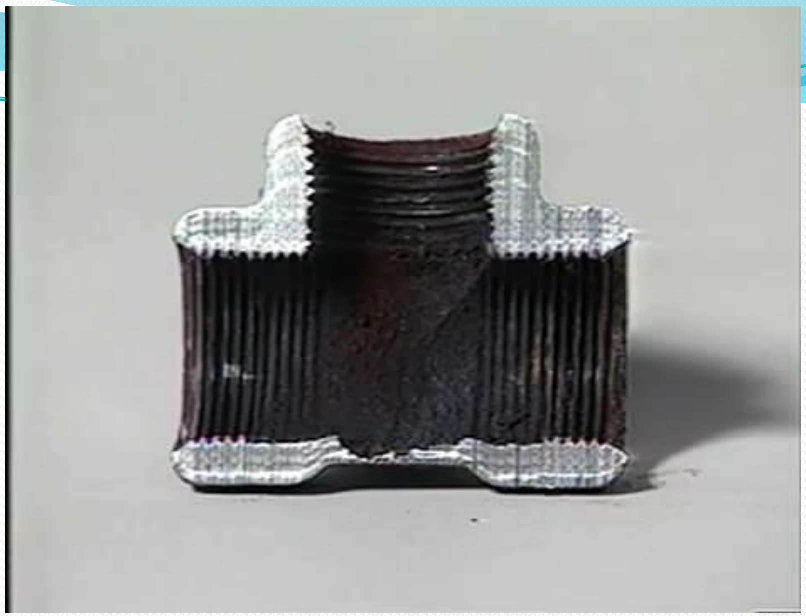
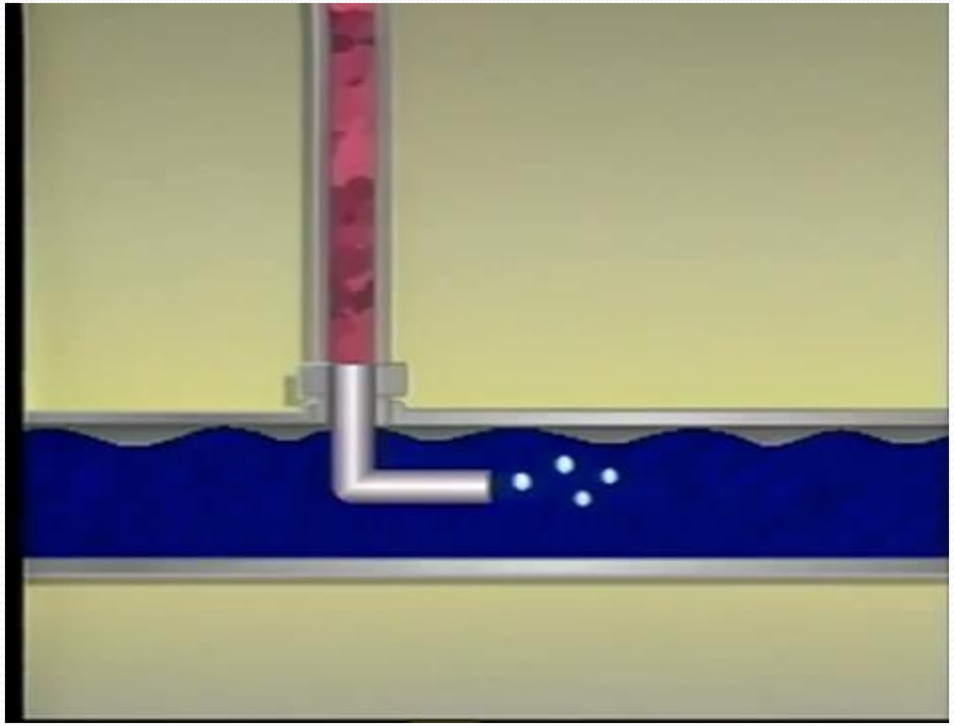
6. Water-Hammer Effects

It is typically caused:

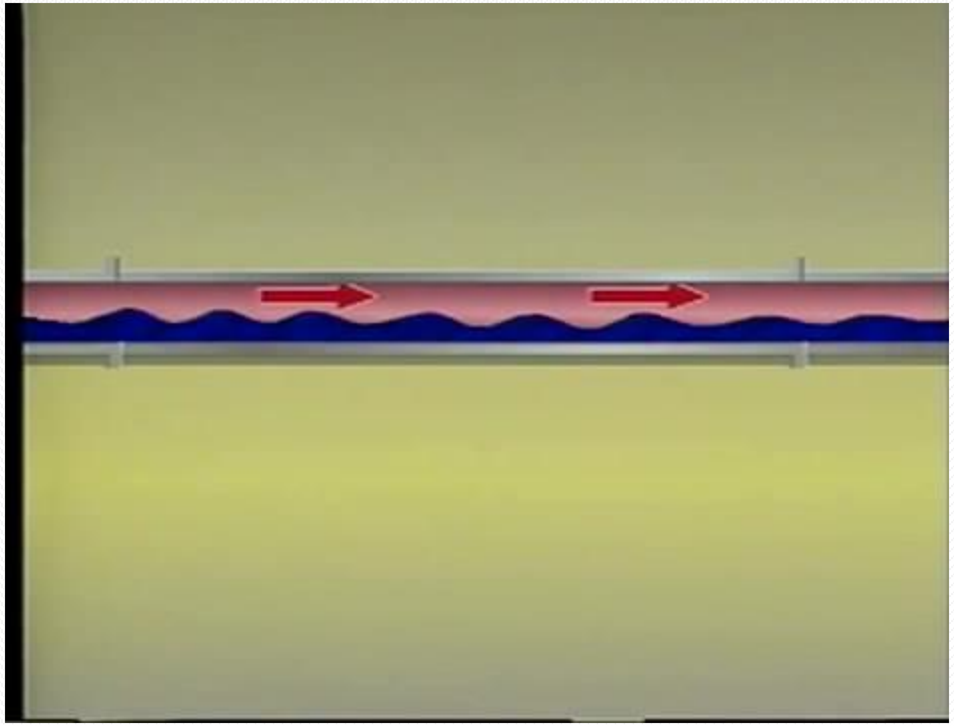
- by a sudden pump shutoff or a valve slamming shut
- In control valves, the bathtub stopper effect is caused by a low-thrust actuator that does not have the stiffness to hold a position close to the seat
- valves with a quick-open or an installed linear flow characteristic can also cause water-hammer Effects.

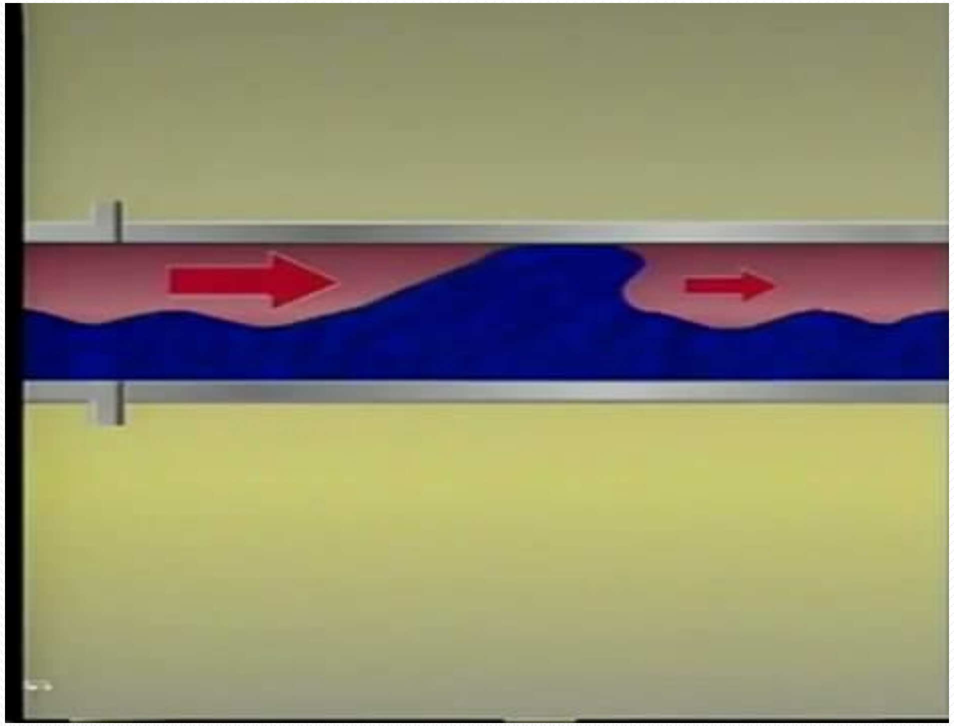

THERMAL
SHOCK

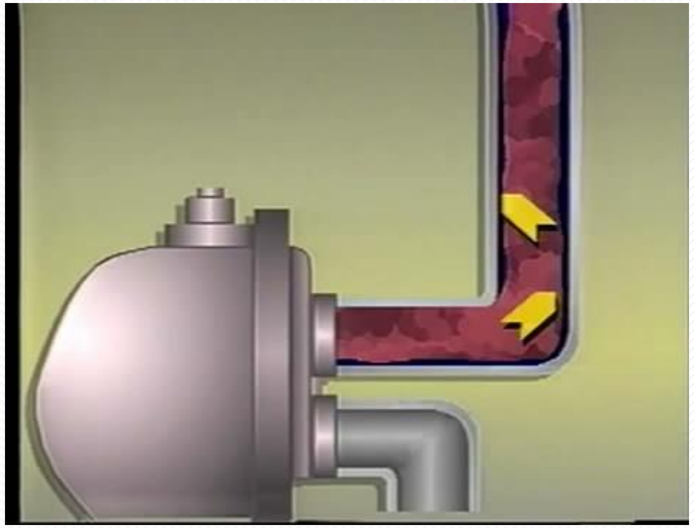
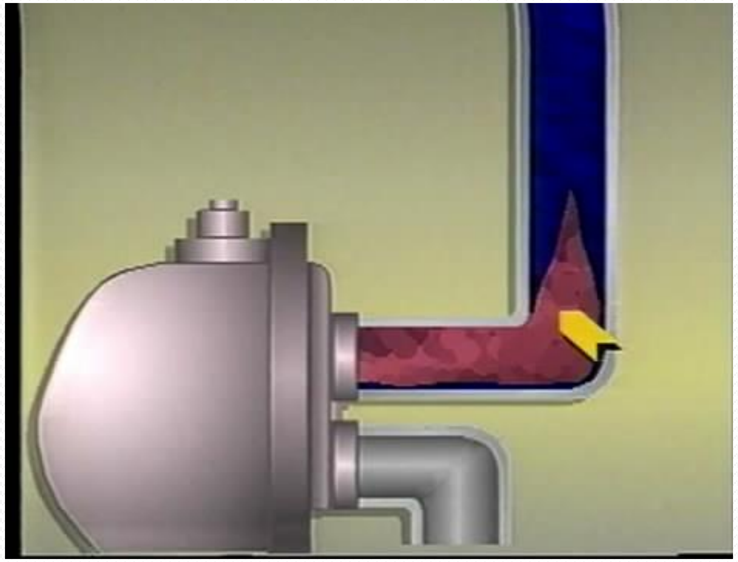




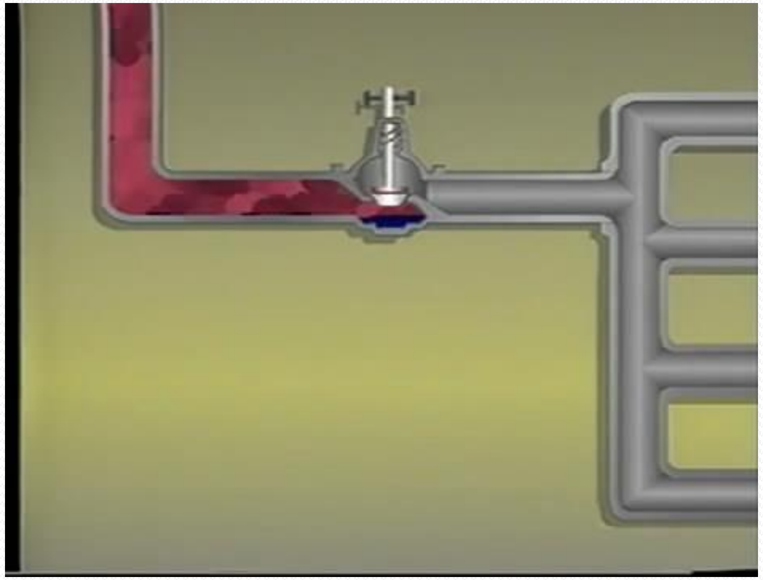




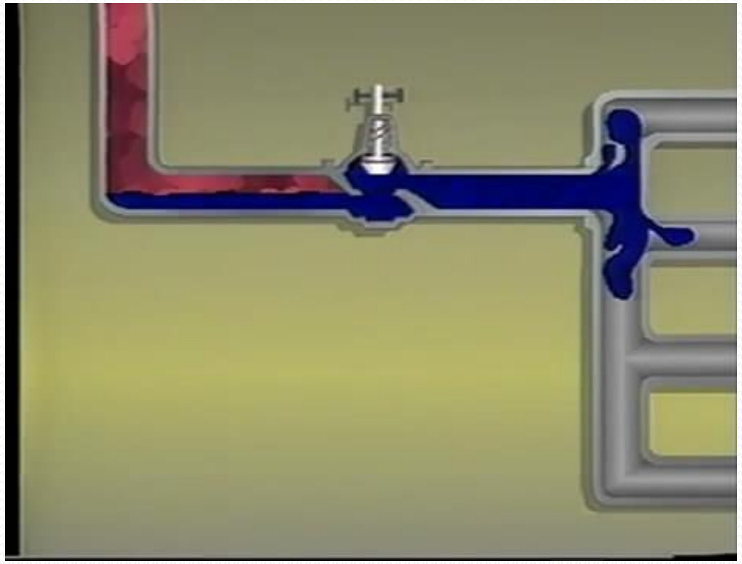

DIFFERENTIAL
SHOCK









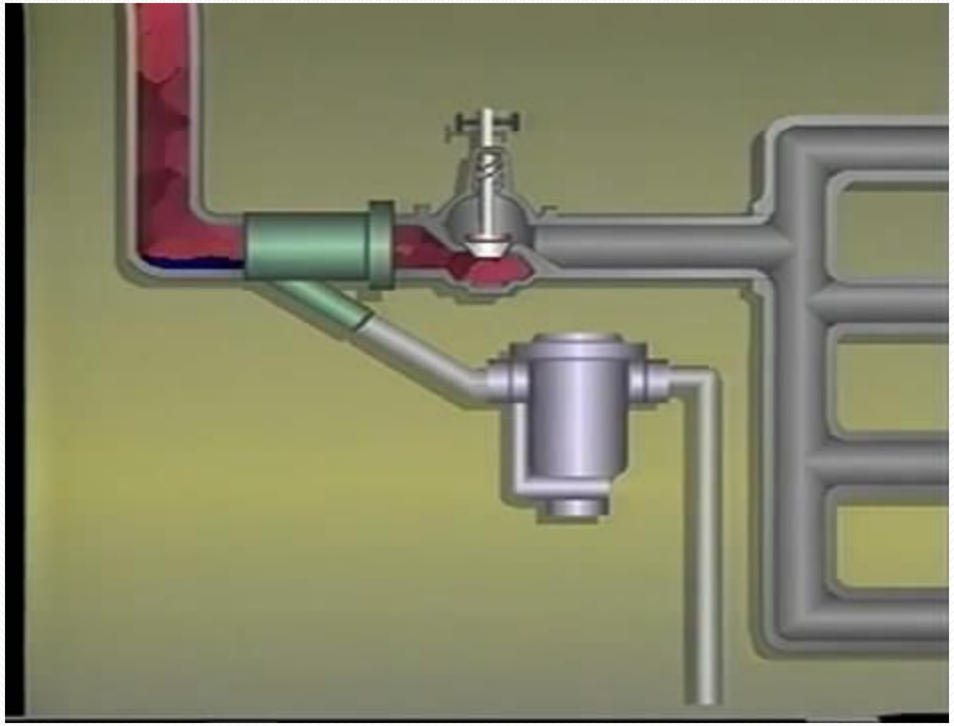
solutions

Correct sizing condensate pipe line

solutions

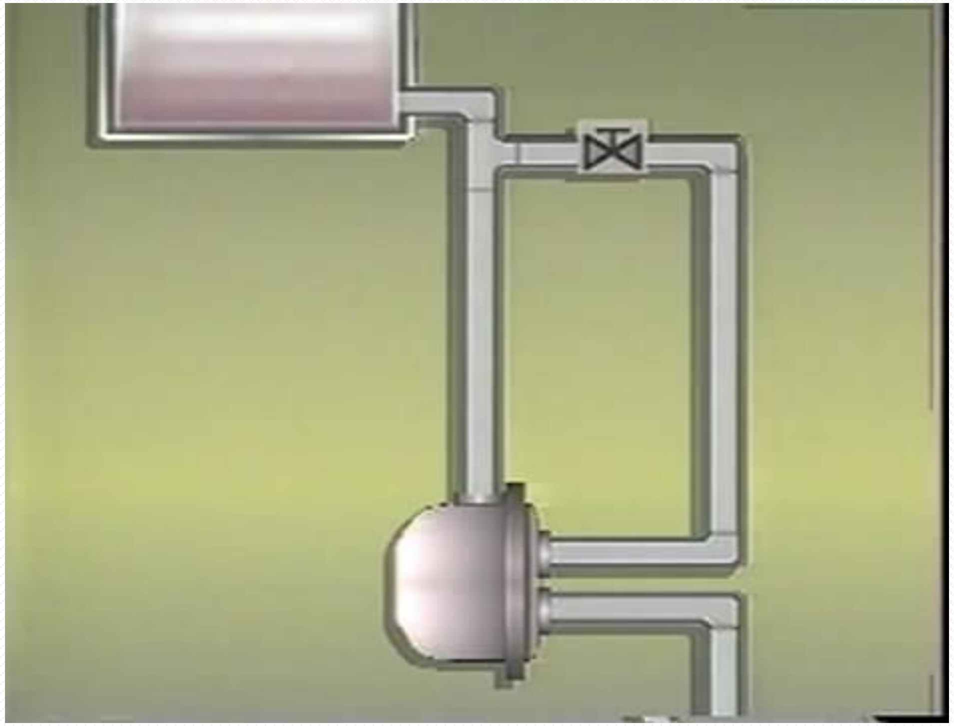
Insulate all piping

solutions



Valve up stream condensate line

solutions



Maintain vertical line

6. Water-Hammer Effects

Effect of water hammer:

1. Damage occurs through mechanical failure.
2. burst piping or damage piping supports as well as damage piping connections.
3. water hammer can create severe shock through the trim, which can cause trim, gasket, or packing failure.

Damage equipment

burst piping or damage

6. Water-Hammer Effects

Water-Hammer Control

With valves, the best defense against water hammer is to prevent any sudden pressure changes to the system.

To avoid pressure surges, the valve should be closed with a uniform rate of change.

Adding some type of surge protection to the piping system can also reduce water hammer. This may be accomplished with a pressure-relief valve or a rubber hose containing a gas, which can be run down the length of the piping. In addition, gas may be injected into the system.

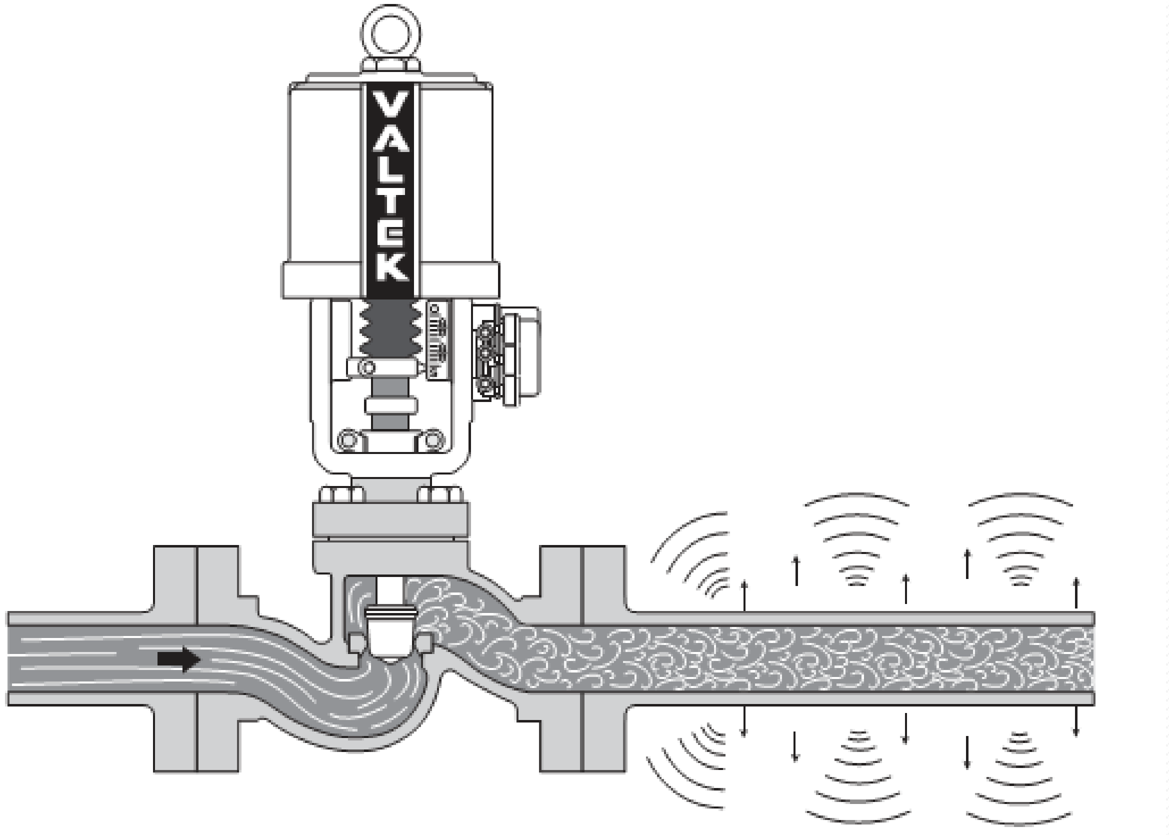
7. High Noise Levels

One of the most noticeable and uncomfortable problems associated with valves is noise.

it can also cause permanent hearing loss and unsafe working conditions.

noise and the accompanying vibration can affect the valve's performance and cause fatigue in the valve, piping, and nearby process equipment.

7. High Noise Levels



Downstream pipeline vibration caused by valve turbulence.