THE HUMBLE CHECK VALVE

Selection of Check Valves for Pumped Systems

By Geoffrey D Stone C.Eng FIMechE; CP Eng FIEAust RPEQ
Design Detail & Development

http://waterhammer.hopout.com.au/ **Skype address** geoffrey.stone@yahoo.co.uk

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

ENGINEERS AUSTRALIA
SYDNEY DIVISION

ASME
SETTING THE STANDARD

Why do we need check valves?

- To prevent reverse flow
- To stop a pipe or tank emptying when a pump stops
- To prevent pressure transients damaging the pump
- To prevent parallel pumps rotating in reverse
- To prevent contamination in complex networks or in the home
- To hold pressure in the line
- For positive displacement pump operation
- To provide waterhammer mitigation
- To prevent flooding

Avoiding Check Valve Slam

- " *Check valves are sometimes selected without proper thought to their response under transient flow conditions.*"
- "*In reality , check valve slam is caused by valves that are not matched to the system of which they are an integral part.*"

Fluid Transients in Pipeline Systems Prof. ARD Thorley

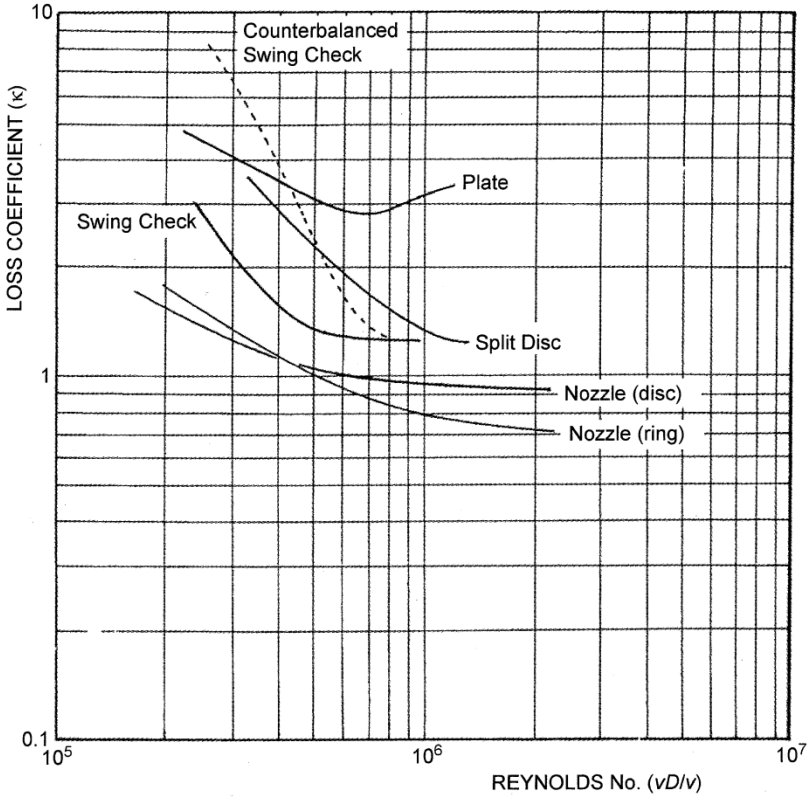
A Check Valve's Selection and Performance

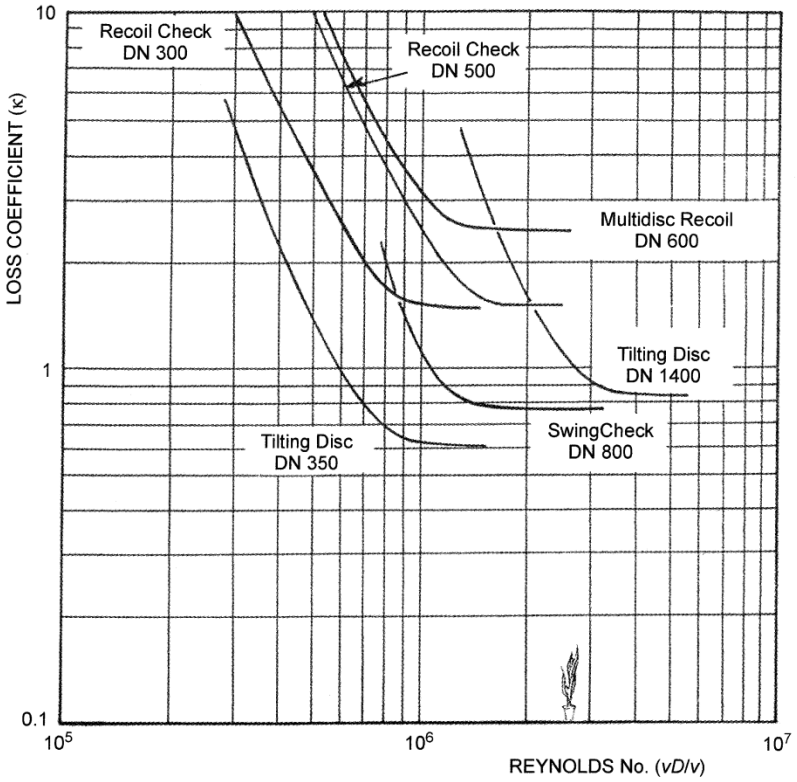
- Most check valves are selected based on industry practice & lowest cost
- A low level of engineering effort is made in selecting a check valve
- Unless a surge analysis is done little is known of the behaviour of a check valve in a pumped system
- A check valve can be as important as a safety relief valve if it mitigates surge

- Many manufacturers cannot provide technical data such as:-
  - Head loss vs. flow
  - Reverse velocity vs. deceleration
  - Closing time
  - Velocity to close
  - Pressure to fully re-open after closure

Loss Coefficients for Different Valves

A common way of selecting a valve





Systems Most at Risk of Check Valve Slam

- Parallel pump systems
- A pump trip in a rising main protected by an air vessel
- Systems with an initial vertical lift followed by a long horizontal pipeline
- Networks with varying conditions
- High head systems
- Systems fitted with check valves with long travel distance and a high mass of component parts
- Systems that have not had a dynamic analysis. (Murphy's Law)

NB A resilient seated valve can make as much noise in check valve slam as a metal seated one!

Why avoid check valve slam?

- Reduce damage to seats, discs and springs
- Eliminate vibration in adjacent piping
- Reduce damage to pipe supports and trust blocks
- Eliminate noise
- Reduce fear amongst operators and asset owners

How should we select a check valve?

- Undertake system dynamic modelling to determine:
  - Reverse velocity
  - Fluid deceleration on pump stop
- Establish the acceptable head rise based upon the pipe rating, design code and/or thrust block design criteria.
- Determine the maximum allowable reverse velocity using the Joukowsky equation below
-

$$H = \frac{c \times \Delta V}{g}$$

where c =celerity m/s; ΔV =change in velocity m/s & g = acceleration due to gravity m/s^2

- Establish which valves have data available

Delft Laboratories Studies

Studies at Delft Labs concluded that valve geometry affected the magnitude of pressure surges and reverse velocities.

The conclusions were:-

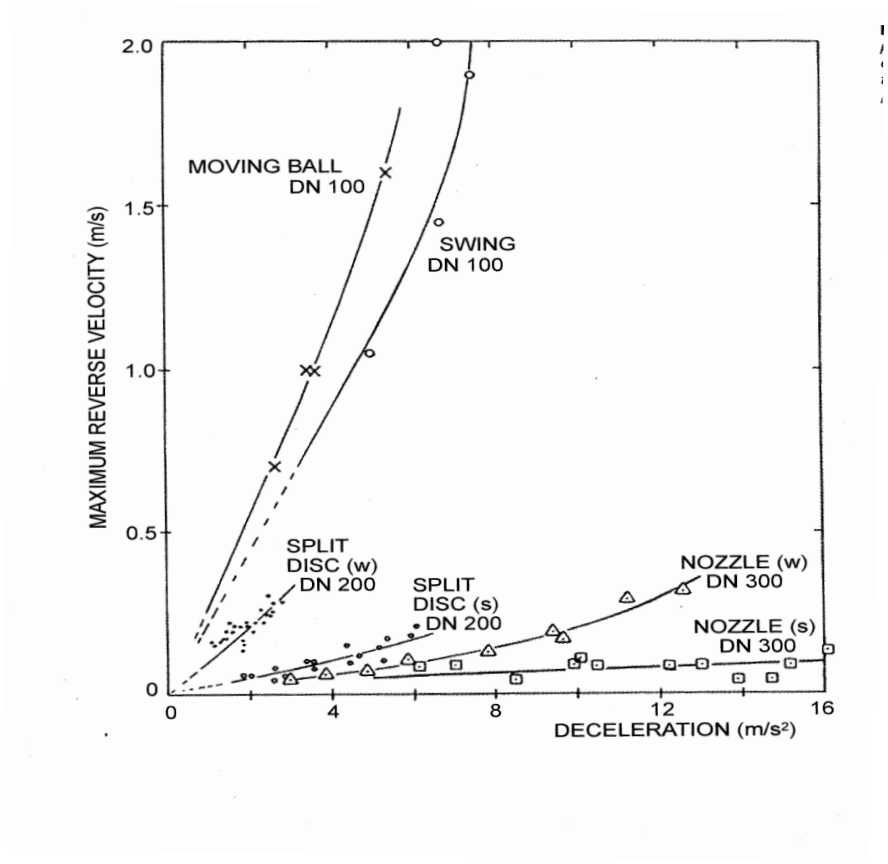
(1) Reverse velocities and pressure surges are greater for valves with a larger mass of valve components.

(2) Reverse velocities are greater for valves with larger strokes or travel of components to close.

(3) Reverse velocities are less for valves that were spring assisted to close.

These conclusions are justified because of the increased time necessary to accelerate and overcome the inertia of valve internals and the distance they must travel.

Compare Maximum Reverse Velocity & Deceleration for Different Valves



- Draw a line from the left of the graph of the computed maximum reverse velocity from the acceptable head rise
- Draw a line up from the computed deceleration
- Select any valve who's plot falls below the intersection of these two lines.
- A reverse velocity of 0.15 to 0.3m/s will unlikely result in check valve slam

Using Dimensionless Criteria

This is used when data is only available for one size of valve from the manufacturer and another is used in the design

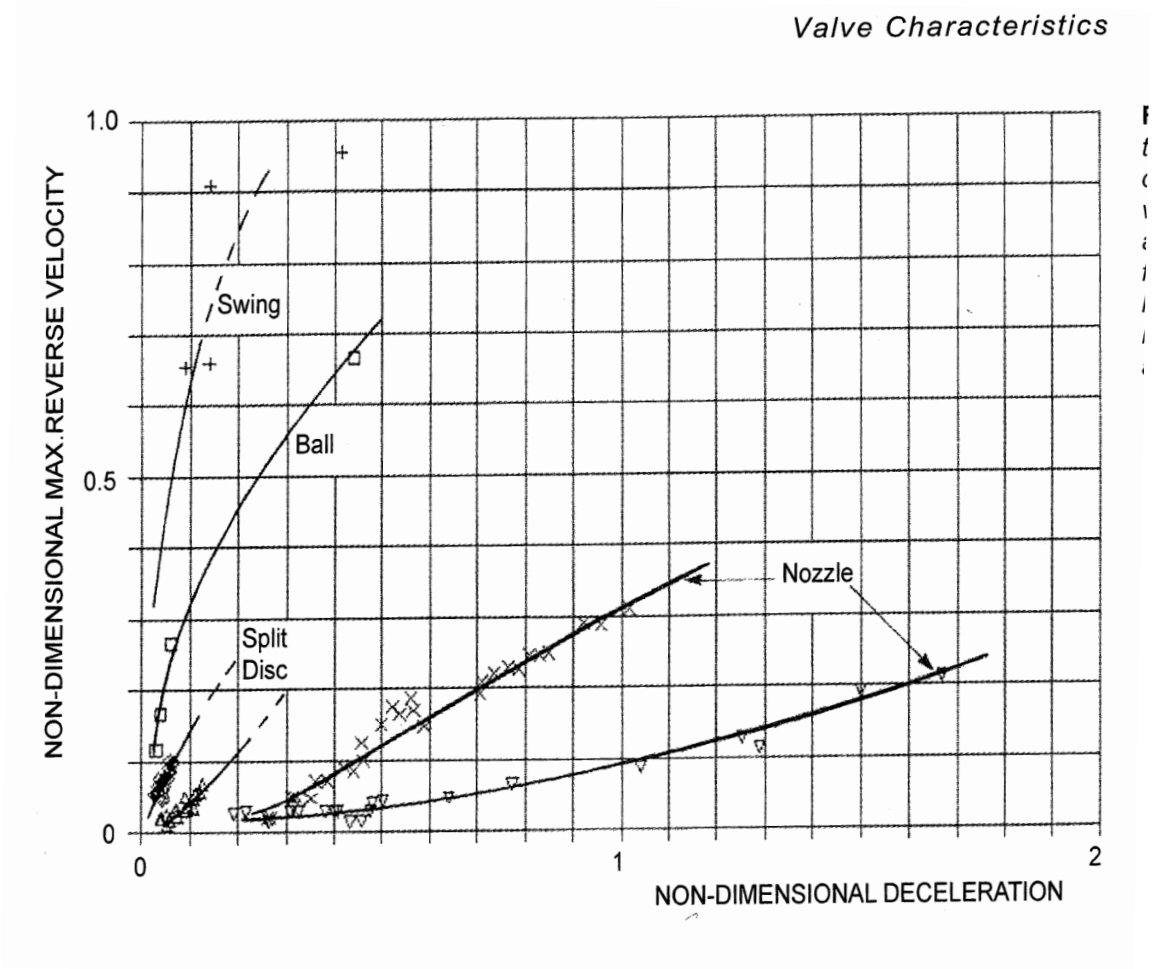
- *MRV* = Dimensionless maximum reverse velocity

$$MRV := \frac{\nu R}{v0}$$

- *Decln* = Dimensionless deceleration

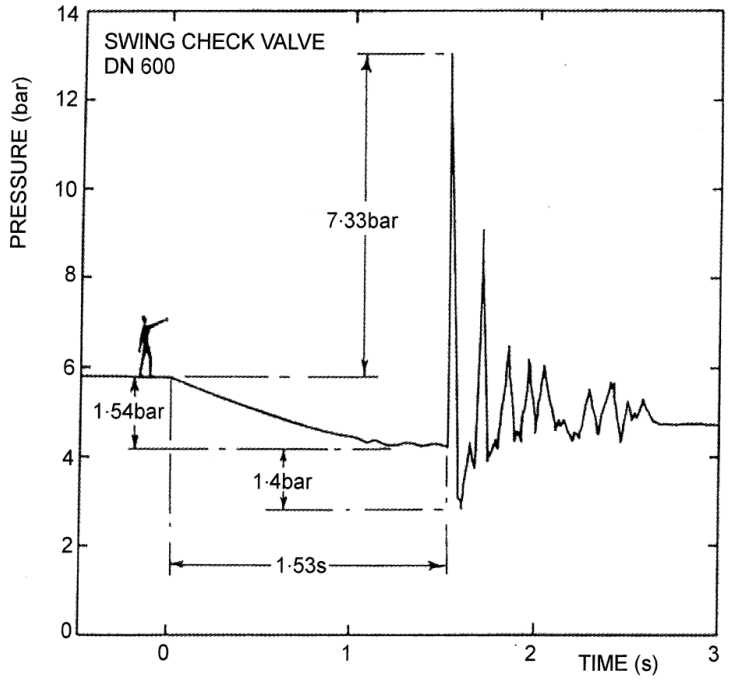
$$Decln := \frac{\ddot{A}v}{t} \cdot \frac{D}{(v0)^2}$$

Dimensionless Criteria for Different Valves

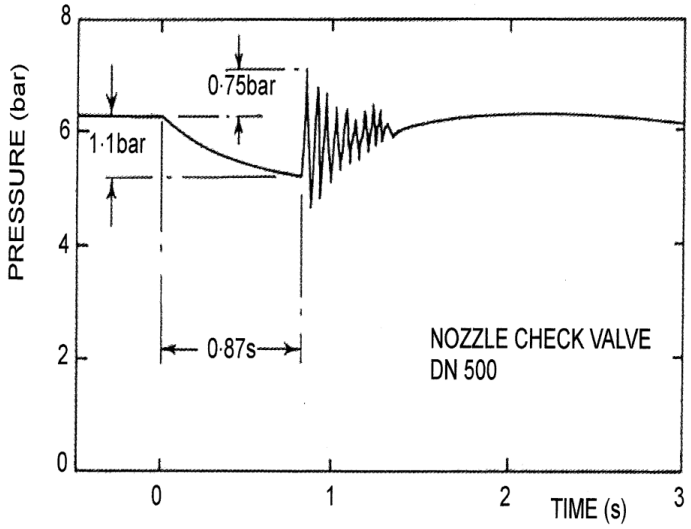


Comparison Swing vs. Nozzle Check Valve

Swing Check Valve



Nozzle Check Valve



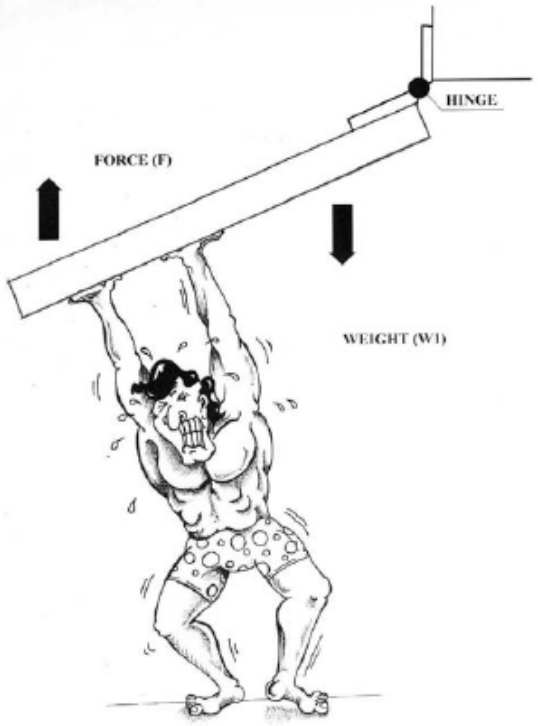
Types of Check Valves

Swing
Tilt
Dual Plate
Flexible Flap
Nozzle (Disc)
Nozzle (Ring)
Diaphragm
Hydraulic
Ball
Piston
Lift
Duckbill
Wafer Plate
Heart Type

Different Principles of Operation

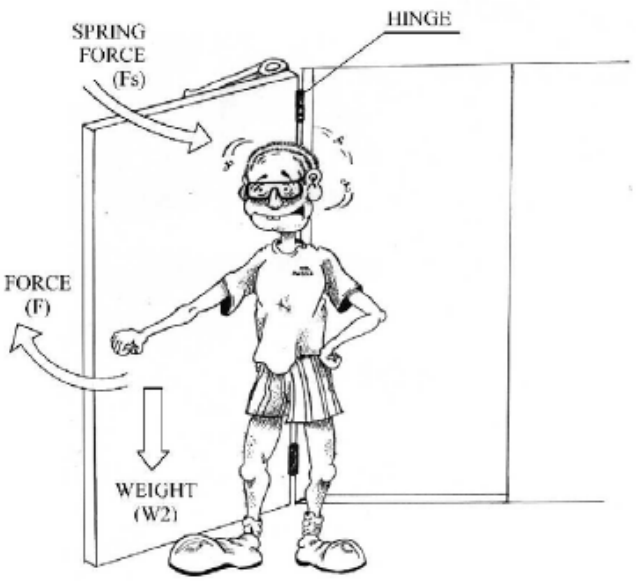
Swing Check

Conventional "Swing check" valve principle



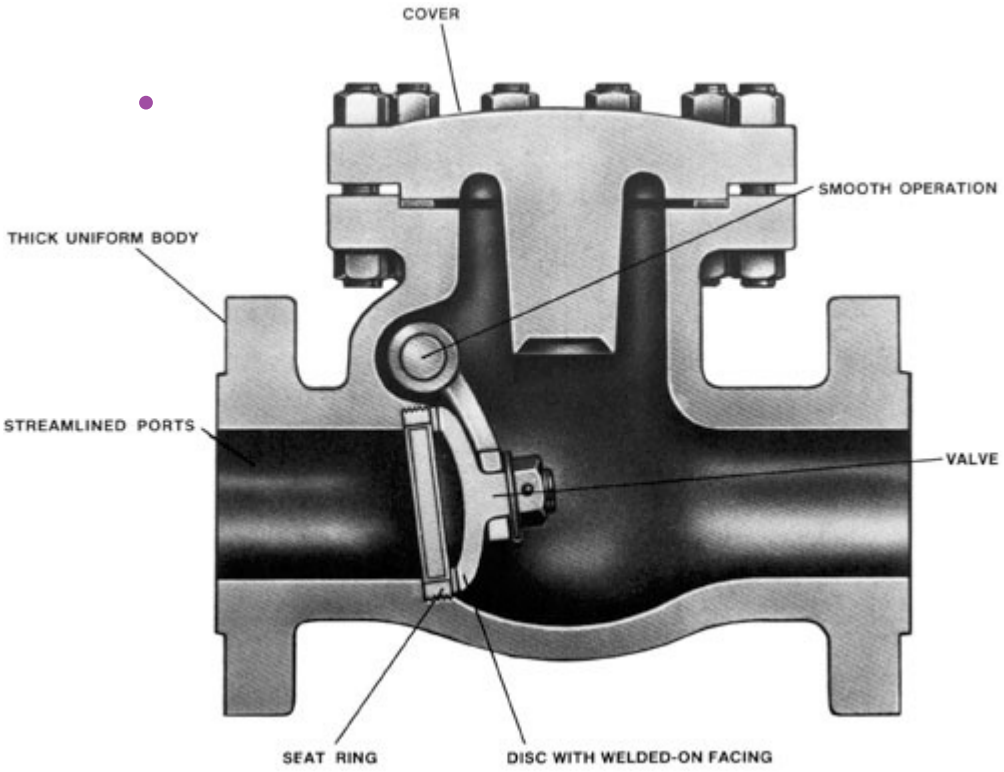
Duo Check

"Dual Plate" check valve principle



Swing Check

- Economic
- Corrosion resistant materials or coated for same
- The most common type
  - Metal or Soft Seated
  - Full Bodied or Wafer
  - Gravity or Spring
- Hinged flap
- Extended Spindle for:-
  - Counterweight
  - Hydraulic dampener
  - Limit switches
  - Position indicator

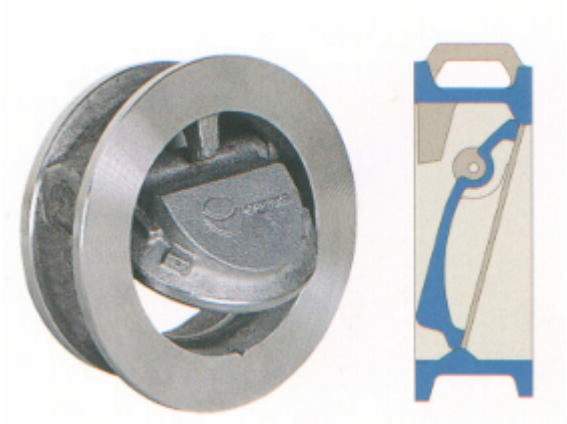


Swing Check (Counterweight)

- Complicated swing check
- Fitted with Counterweight
- Fitted with pneumatic or hydraulic dampener
- High maintenance to remain effective
- High mass & inertia
- Long travel distance to close
- Counterweights increase head loss
- High cost

Tilt Type

- Common in the water industry
- Large Diameter
- Full bodied type
- Soft or metal seats
- Coated for corrosion resistance
- High mass
- Extended spindle for :-
  - Counterweight
  - Hydraulic dampener
  - Limit switches
  - Position indicator

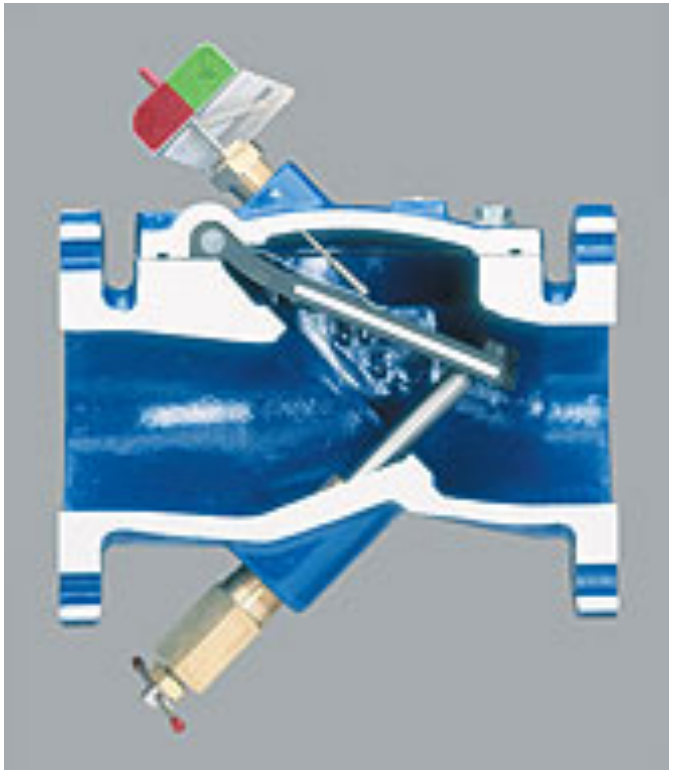


Dual Plate

- Economic
- Wafer bodied
- Variety of spring stiffness's
- Corrosion resistant materials

Flexible Flap

- Economic
- Use in water, sewage & mining industries
- Coatings for corrosion resistance
- Full bodied type

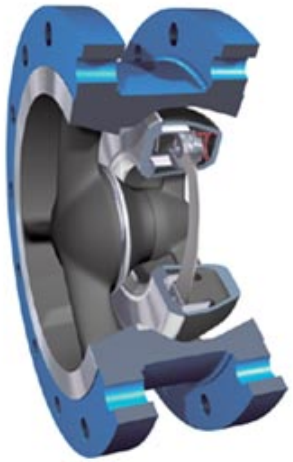


Nozzle (Disc)

- Universal application for clean fluids
- Original design of non slam valve
- Low head loss
- Used for gas and liquids

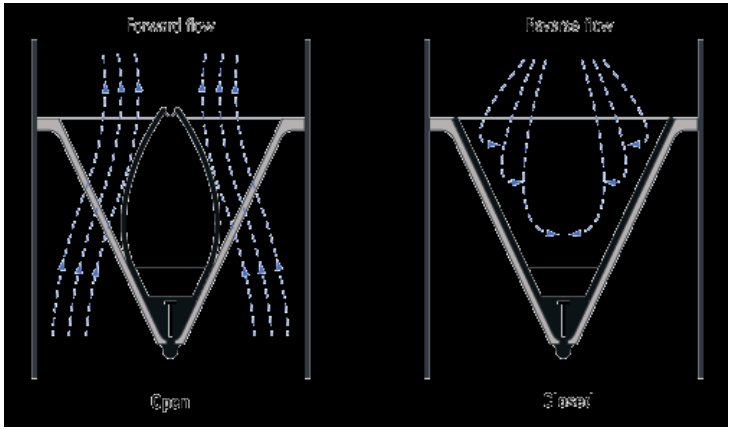
Nozzle (Ring)

- Universal application for clean fluids
- Modern design for surge mitigation
- Low mass
- Short travel
- Tight shut off
- Low head loss
- Available in corrosion resistant materials



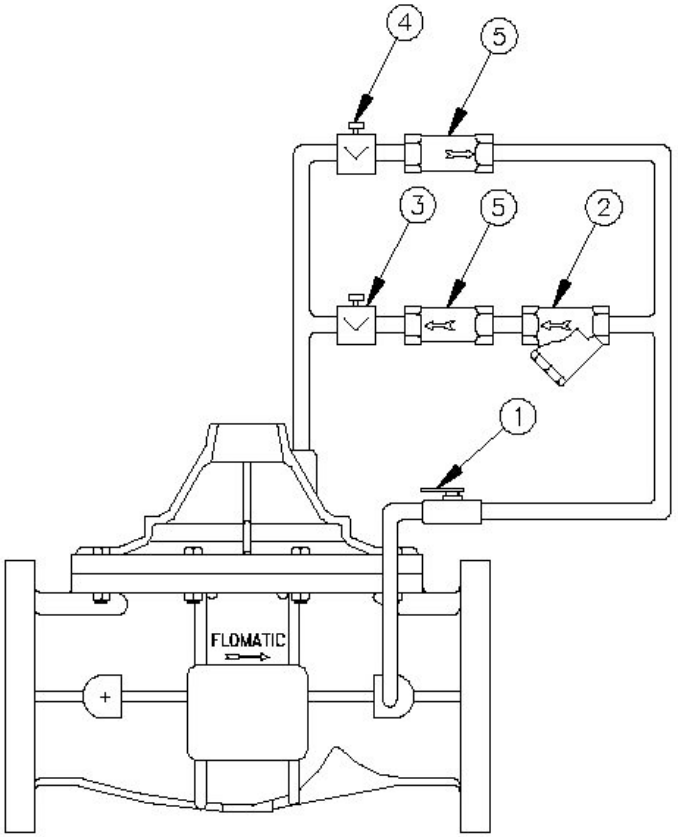
Diaphragm Type

- Solids bearing fluids
- Positive displacement pump operations
- Corrosion resistant materials
- Limited life



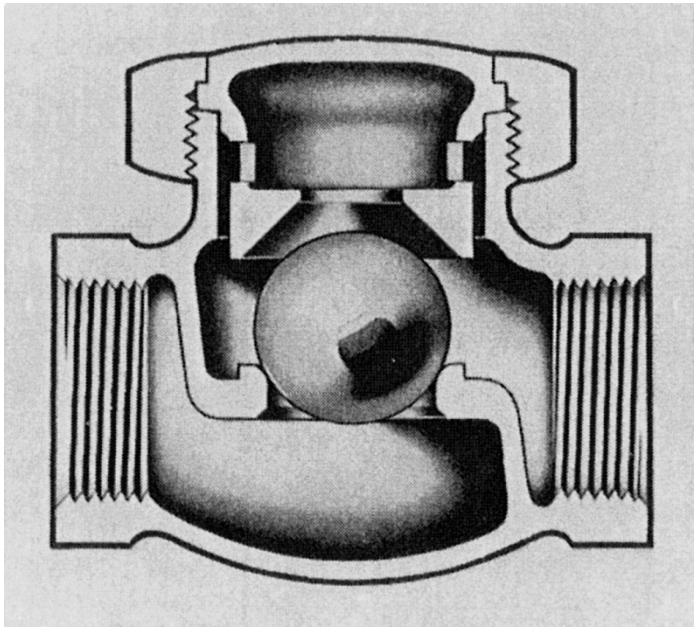
Hydraulic

- Economic
- Used in the water and aviation industry
- Combination valve with functions such as:-
  - Flow control
  - Altitude control
  - Pressure Control
  - Surge anticipation



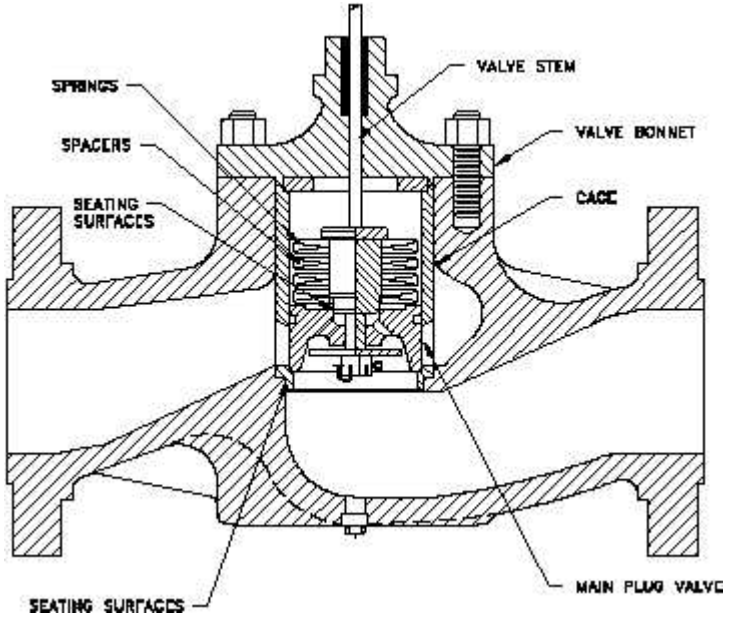
Ball Type

- Economic
- Simple construction
- Balls easily damaged



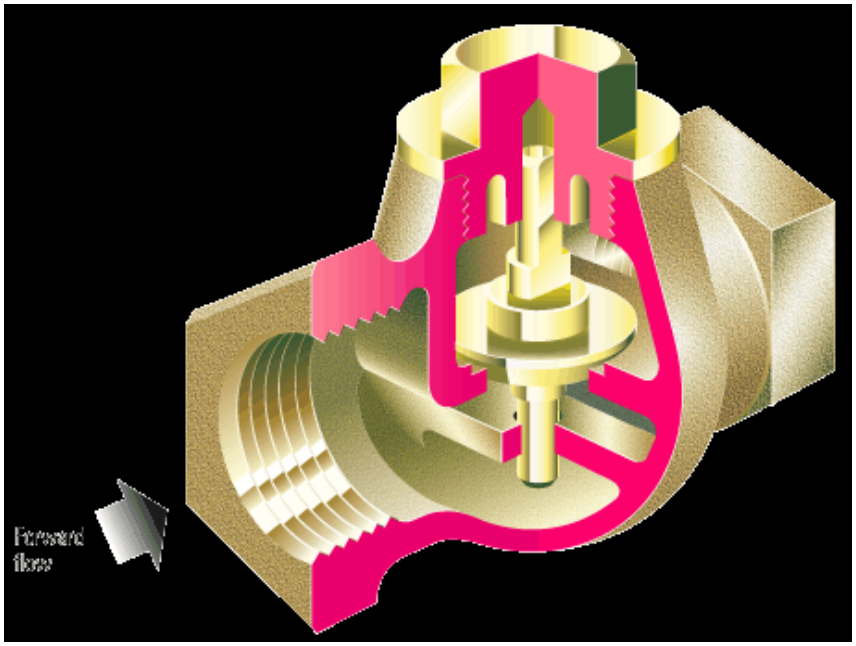
Piston Type

- Use in steam and petro-chem service



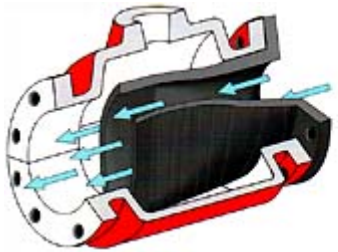
Lift Type

- Simple
- Generally small bore
- Gravity or spring operation
- Used in steam or water systems



Duckbill Type

- Used for solids bearing fluids
- Large diameters
- Corrosion resistant materials
- In line or connected to end of pipe
- High head loss
- Closes against solids

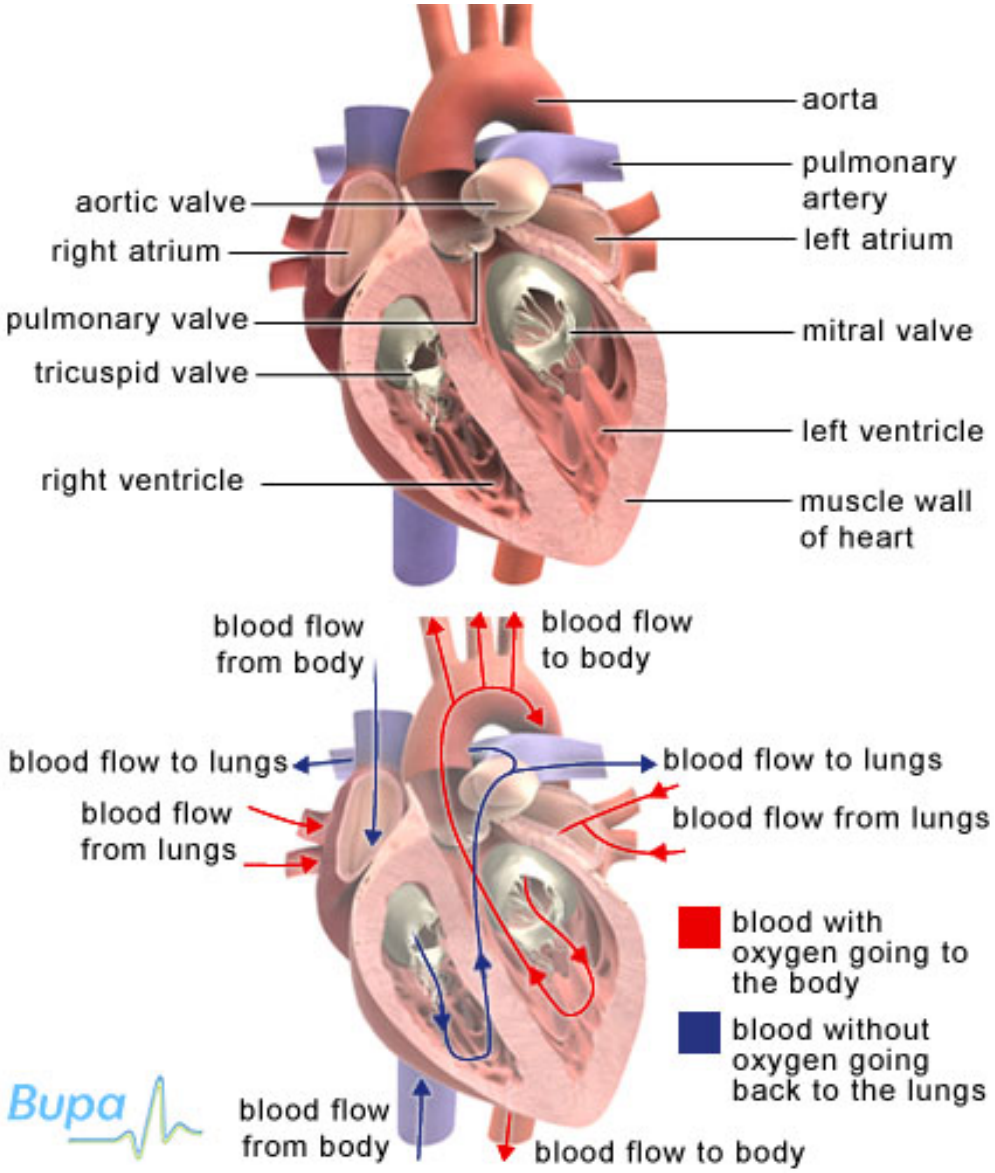


Wafer Plate Type

- Economic
- Large diameter
- High head loss
- Low pressure applications
- Corrosion resistant materials

Heart Valve

- We all have them
- Considered the most important of check valves
- Artificial heart valves developed in Australia
- These check valves allow the positive displacement heart pump to function with pressure transients
- Maintains pressure in the system

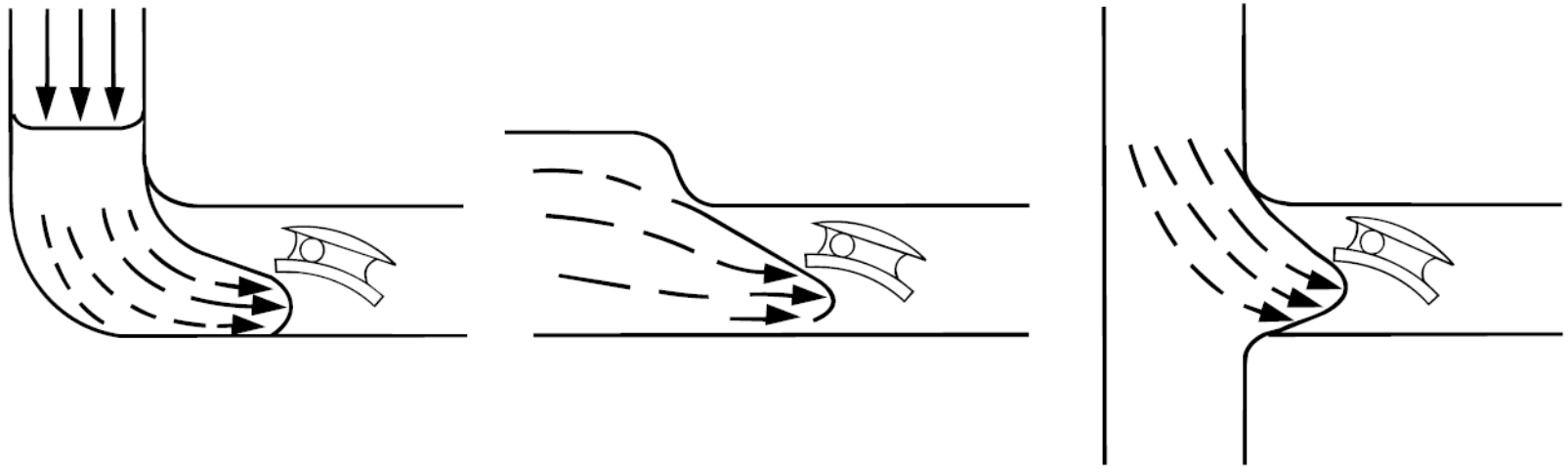


Installation Criteria

- Pipe Fittings
- Two Elbows
- Pumps

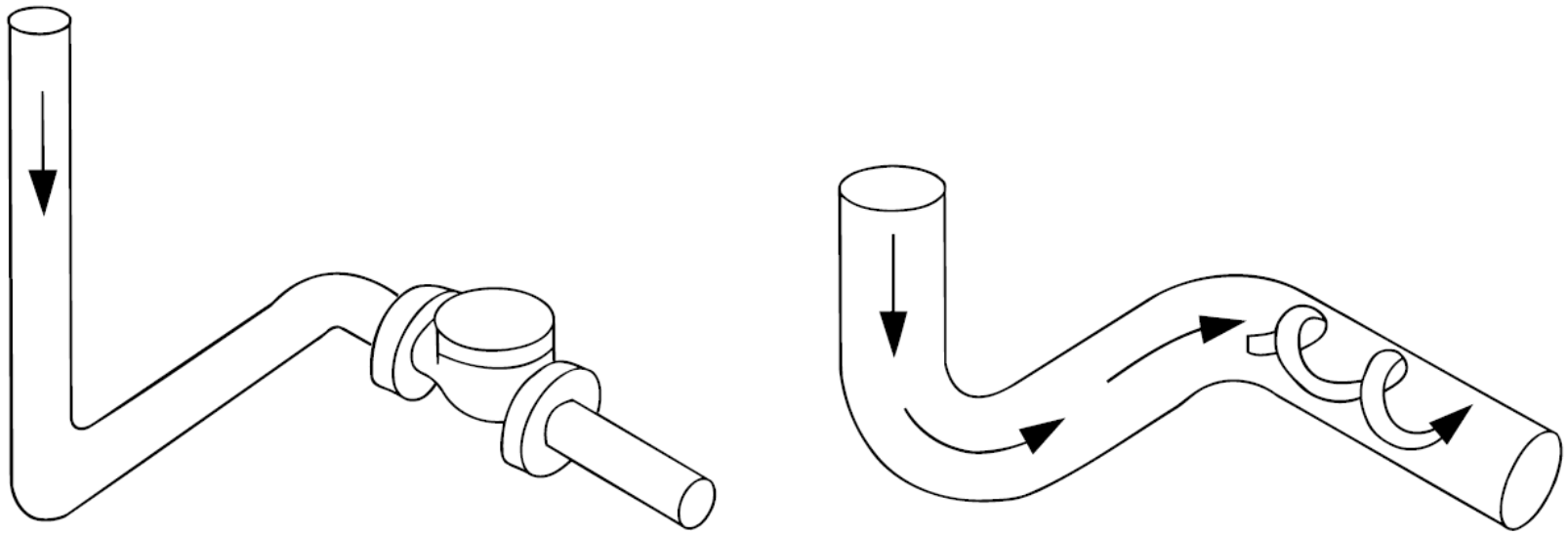
Instability at Pipe Fitttings

Figure 5
Pipe fittings near valves may produce
instability because of velocity profile distortion



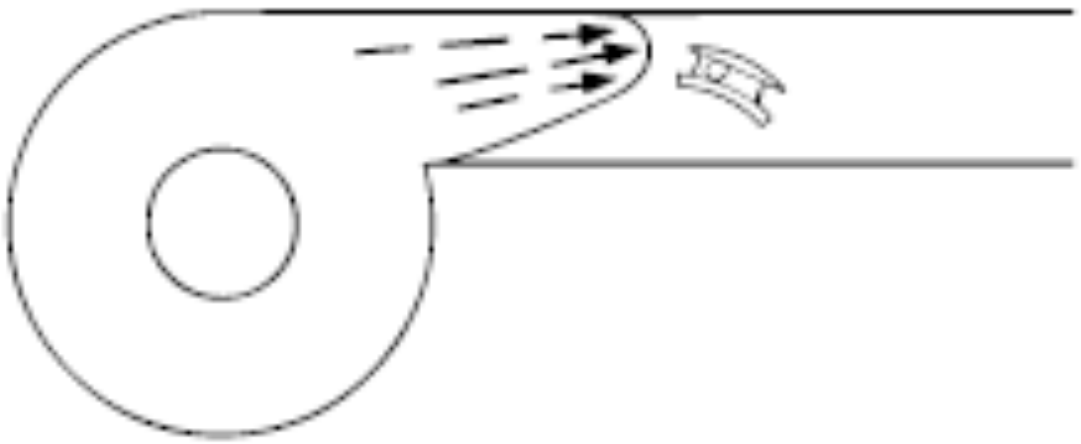
Instability Near Elbows

Figure 7
Elbows in two places cause swirl which can promote instability.



Instability at Pump Discharge

Figure 6
Non-uniform velocity profile at blower or pump discharge can affect stability.



Questions

Is data available from check valve suppliers?

Yes & No, The more technically proficient have undertaken tests

Can I assume that there will not be check valve slam?

If the system is very similar to an existing system this is possible.

The End

Thanks are extended to Prof ARD Thorley for his very informative book *Fluid Transients in Pipeline Systems* for the valuable graphs & insights in dynamic behaviour of check valves.

Also I would like to thank those check valve suppliers who publish data on the internet or provide such to engineers.

These include but are not limited to:-

- *Noreva, Mokveld, Tyco, Crane, Red Valve, AVK, Apco, Valmatic, Cla-Val & Valmatic*