Associazione Italiana Strumentisti

ISA Italy Section

ATI Associazione Termotecnica Italiana Sezione Lombardia

VALVOLE DI CONTROLLO E INTERCETTAZIONE, SISTEMI DI AZIONAMENTO, DISCHI DI ROTTURA E DISPOSITIVI DI SICUREZZA UTILIZZATI NELL'INDUSTRIA DI PROCESSO

Milano, 18 Aprile 2018

Auditorio TECNIMONT

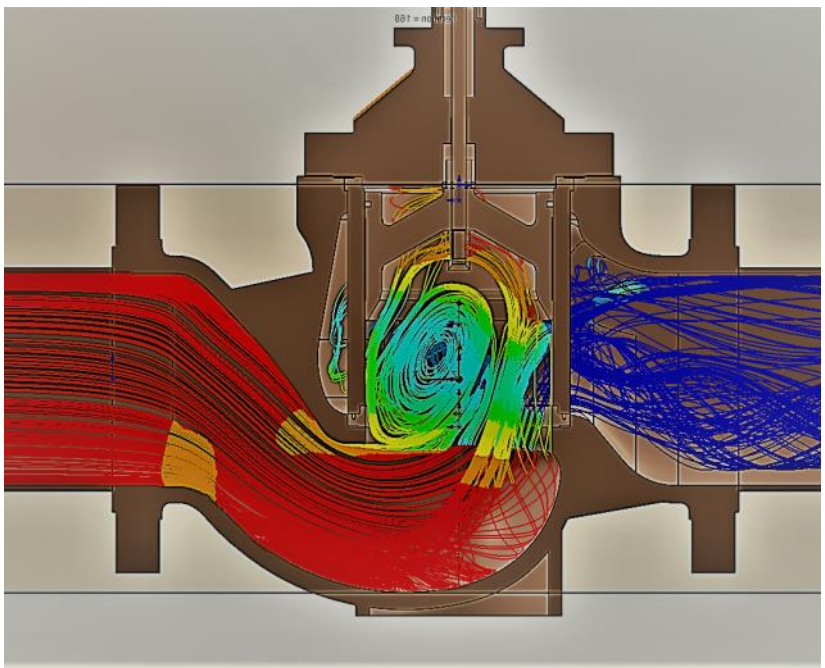
Typical Severe Service Application Challenges & Engineered Control Valve Solutions

Presented by Mr. Biju Simon, KSB MIL

All Rights Reserved
Strictly Confidential

© Copyright KSB SE & Co. KGaA 2018

Control valves – Typical Severe Service Application Challenges & Engineered Solutions



Severe Service Control valves take lot of energy out of a piping system and poor selection or design of such a valve can be detrimental to plant operation and performance.

The energy if not absorbed by the valve internal can shorten the valve life drastically if it is not the right valve for the application.

This presentation covers the typical challenges arising while tailoring control valves for Severe Service applications, the combinations of mechanisms that can effectively absorb the energy and protect the valve and downstream components from damage optimally.

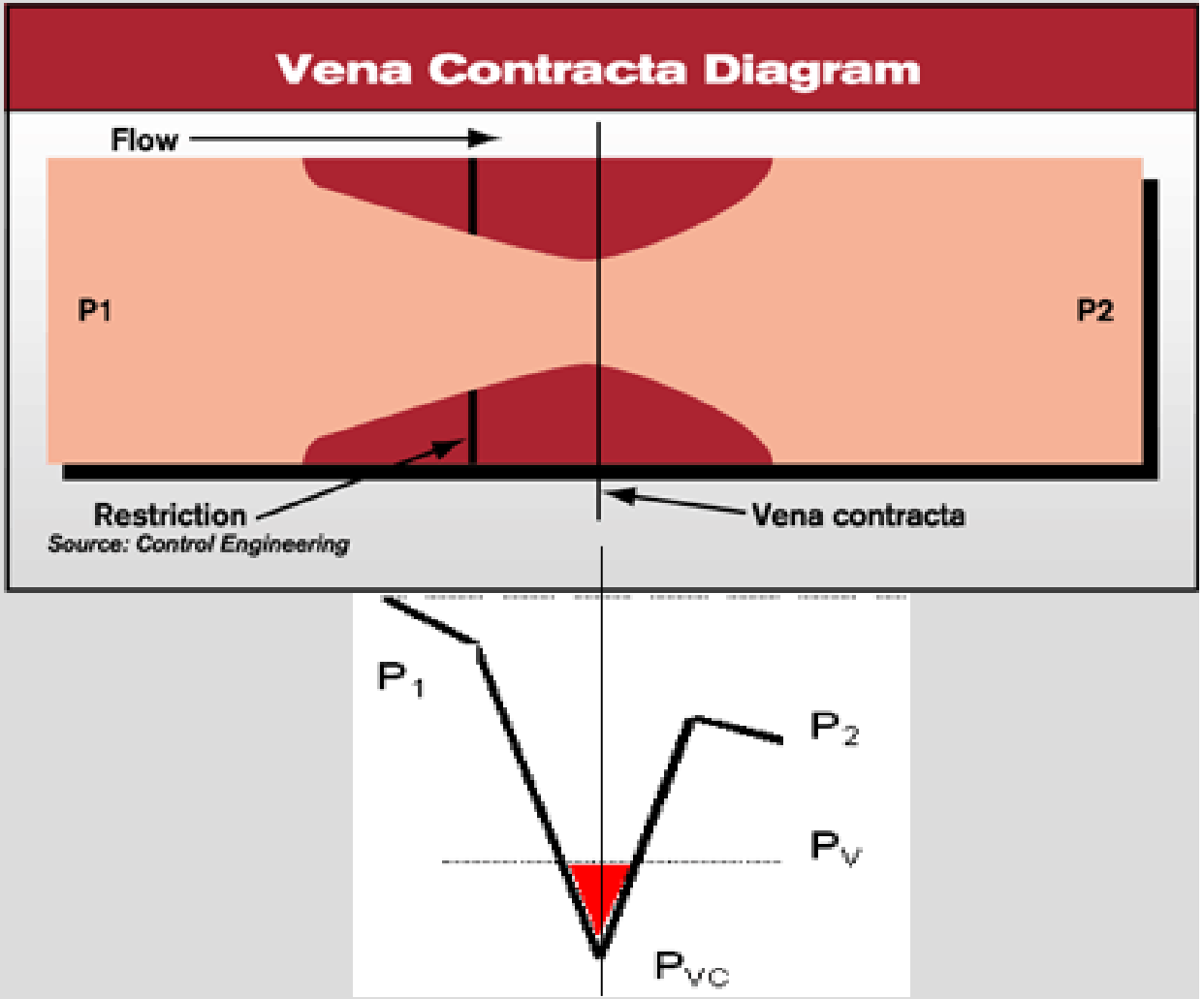
Typical Severe service Applications covered

1. High pressure drop cavitation
2. High pressure drop compressible fluid
3. High pressure drop with particulates
4. Outgassing

1. High pressure drop cavitation

High intensity cavitation can severely damage control valve internals in short term operation

Cavitation



- Cavitation is a two stage process consisting of formation of vapour bubbles when the pressure of the liquid falls below the vapour pressure and the collapsing of the bubbles (cavities) when the pressure recovers above the vapour pressure.
- In valves , when the outlet pressure is close to vapour pressure , at the Vena Contracta, pressure may fall below vapour pressure leading to formation of bubbles .
- These bubbles are carried by the flow downwards and as the pressure recovers towards the outlet , these bubbles implodes , releasing large amount of energy , tears away the material causing erosion and pitting

Cavitation Damage

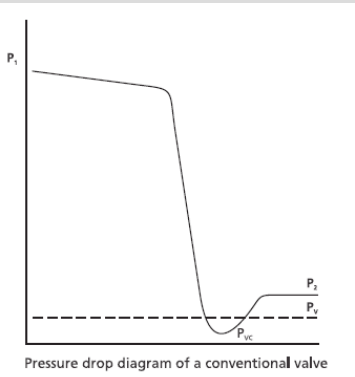
The two main causes of Cavitation damage are

Cavitation Micro-jet impingement ➔ Leads to **Erosion** near the material surfaces of trims and/or body. The typical appearance of a surface exposed to damaging cavitation is a crater-like, pitted appearance

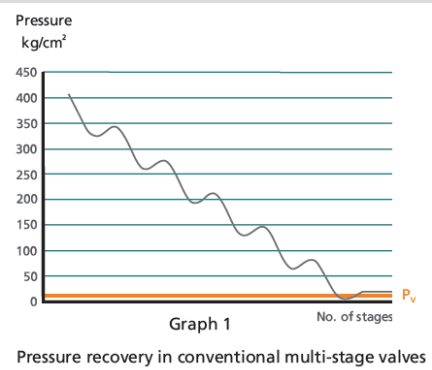
High pressure shock waves and pressure fluctuations from high velocity collapse➔ Leads **vibration, noise** as well as **limited valve capacity** and in severe cases to **material fatigue**. Even though cavitation is generated in the valve throttling area, the pressure fluctuations can radiate into the downstream pipe as noise. As the cavitation increases the magnitude of these pressure fluctuations also increase. This can result in not only component damage but also pipe wall vibration (noise) and system vibrations.

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

Anti - cavitation Design principles



Pressure drop diagram of a conventional valve



Graph 1

Pressure recovery in conventional multi-stage valves

Pressure recovery in conventional single stage and multi-stage valves

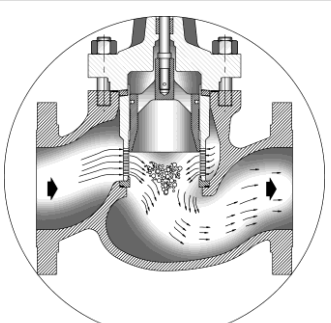
The cavitation potential of a valve is a direct derivative of its pressure recovery characteristics. This is defined in terms of a dimension-less index called the Pressure Recovery Factor, (C_f or F_L) the ratio of the total pressure drop across the valve to the pressure drop at Vena Contracta.

Conventional anti - cavitation trim designs are not effective in extremely high pressure drops beyond 400 bar (as typically seen in supercritical thermal power plants)

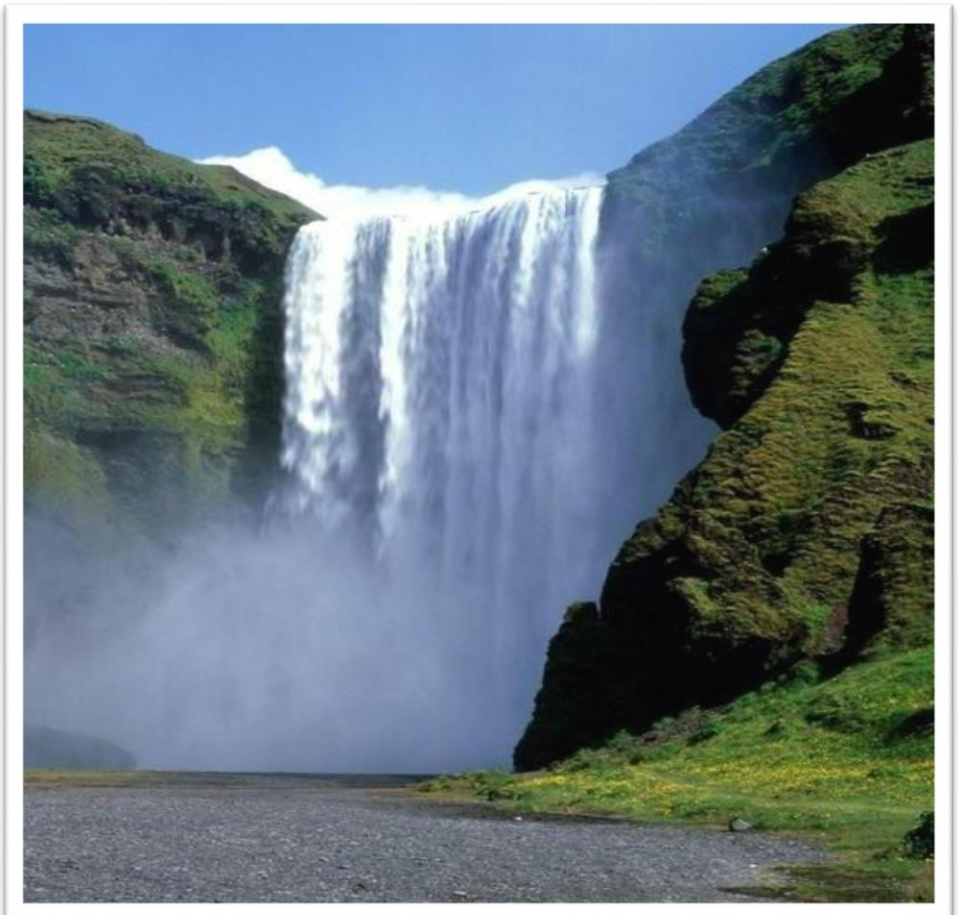
It is seen that C_f factor as high as 0.999 and higher number of pressure and velocity reduction stages are essential for satisfactory valve performance.


Max. 6 to 8 pressure reductions stages

Conventional anti - cavitation trim designs are not effective in very high pressure drops

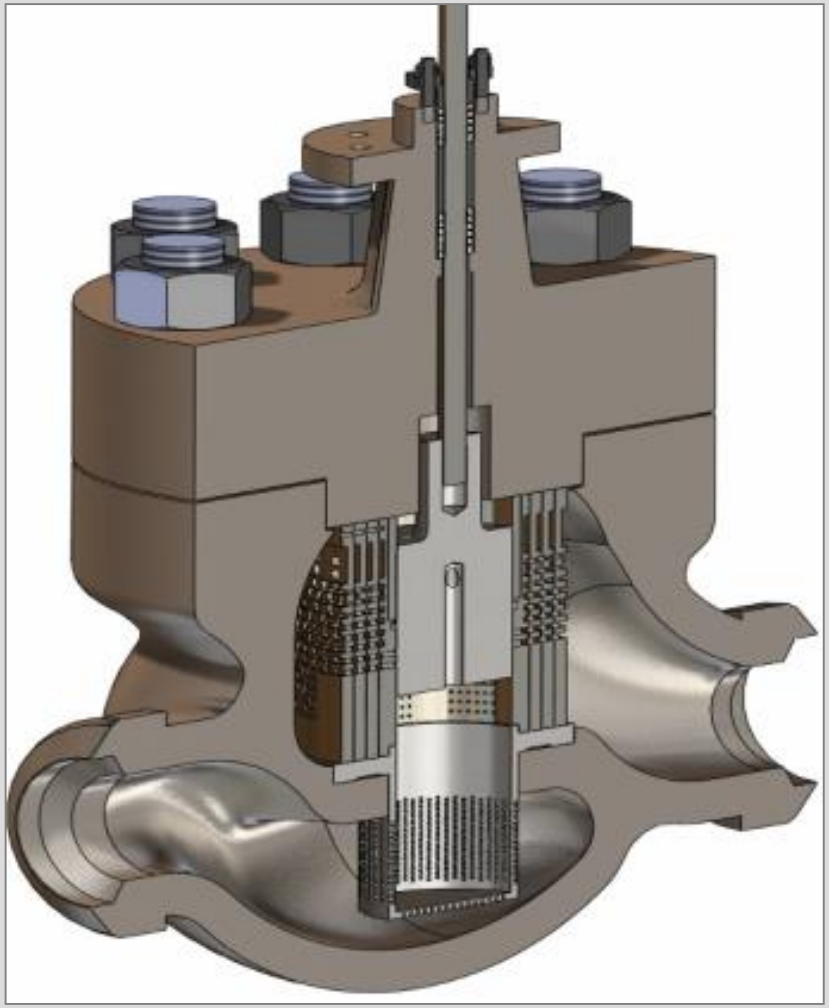

Localizing cavitation

Anti-cavitation Design principle - summary



Single stage pressure reduction

Multi-stage, multi-path, tortourus path



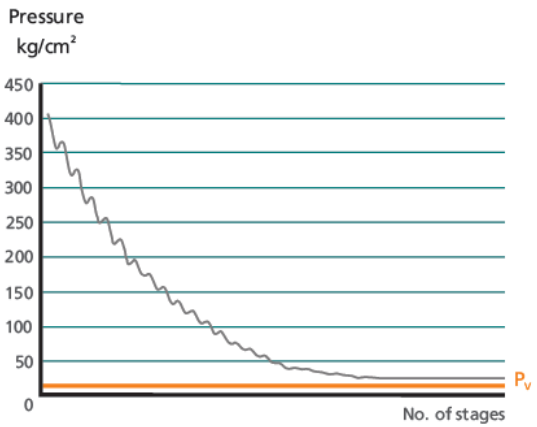
Typical cut away section of a multi-stage, multi-path technology control valve with axial flow and higher number of stages

More Rugged & Intense design with

- Higher number of Pressure / Velocity reduction stages
- Lesser Pressure drop per Stage for increased longevity of internals
- Harder material of construction
- No Cavitation damages to leading edges of Plug

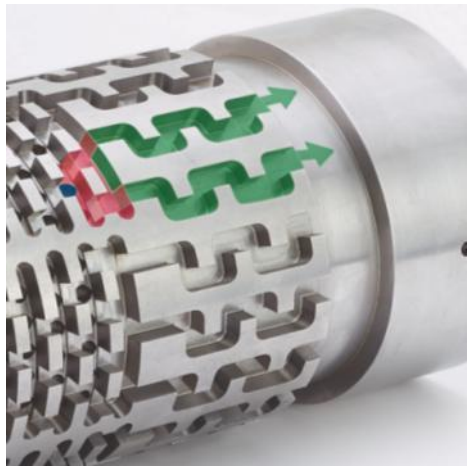
Application	Pressure & Velocity Stages
BFP Min Flow valve 210/250 MW	10-15
500 / 600 MW	15-25
660 MW	25-30

Superior Features in multistage multipath axial flow valves



Expanding flow area

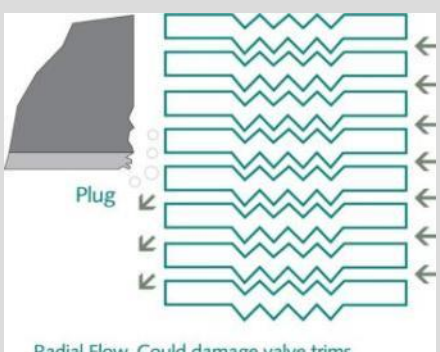
The area allocation in successive stage increases as the fluid progresses downstream, thereby providing an expanding flow passage, reducing the pressure to a point where cavitation would not occur and trim exit velocities are within safe limits.



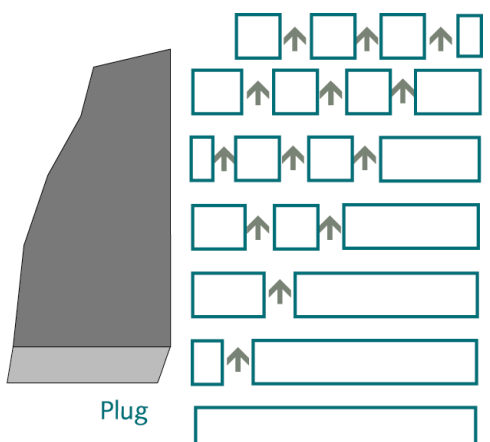
Ingenious flow path

- Irregular pattern of the flow channels designed to offer maximum resistance
- Discrete velocity reduction stages which can take care of higher pressure drop also

Failed trims in 660MW Power Plant in BFP Min. Flow Application



Last Stage Pressure Drop & Cavitation against leading edges of the plug can happen in a Radial Flow-to-Close valve



Axial flow eliminates cavitation damage to sealing surfaces

With Axial Flow direction, last stage pressure drop is directed away from the trim assembly ensuring unmatched longevity to Sealing surfaces

Control Valves (>2500# ASME and pressure drop >400 bar) for Boiler feed pump recirculation

Project:

- For various 660 MW / 800MW Coal based Supercritical Thermal Power stations

Product Highlights:

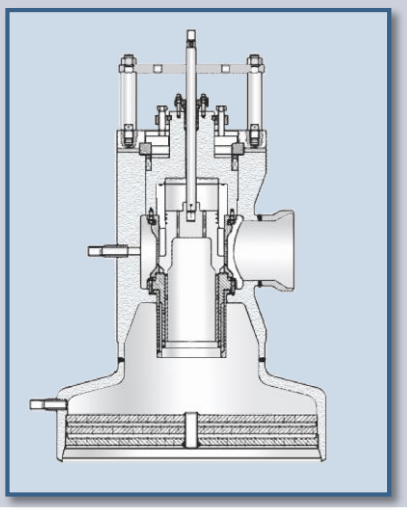
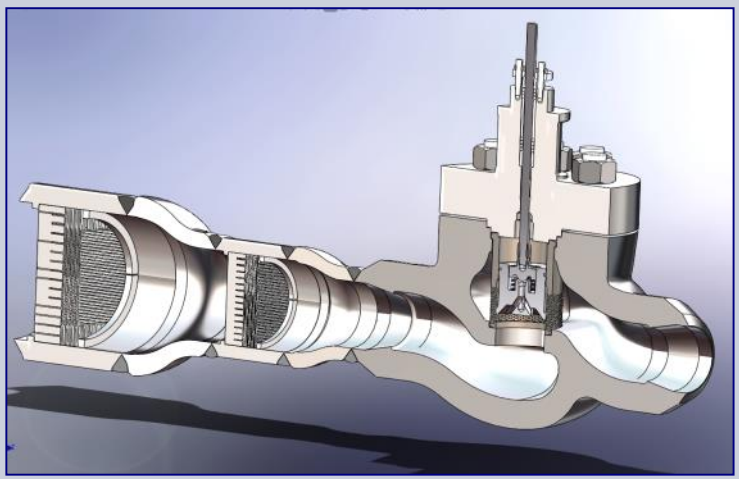
- Size & Rating: 8“- 12“, upto 3400# ASME
- Function Mode: Modulating
- Max. Design Pressure: 550 bar
- Max. Inlet Pressure: 500 bar
- Max. Pressure Drop: 490 bar
- Body material: ASTM A 217 Gr WC9 / F 22

2. High pressure drop compressible flow

Multi stage, Source treatment valves	Multi stage valves with additional path treatment
Source Treatment means using a Special Noise valve design. For Noise Control, Multi-stage valves are available, but they are not common. The reason for this is that the trim can be complex and expensive to manufacture and the trim size and elongated shape results in an inefficient valve body space envelope.	Properly selected Multi-stage valves can provide noise attenuations upto about 20 dBA, provided the PI/P2 pressure ratio is limited to 3 to 4 maximum. Above these ratios, the exit velocity will exceed 0.3 Mach and may require additional path treatment, such as an in-line silencer or the reduction of the pressure ratio through an in-line restrictor plate or diffuser. The economics of the overall system can be effectively benefitted by using a noise reduction valve followed by a restrictor plate and a final atmospheric vent attenuator element as applicable

Ref. ISA Handbook for Control Valves - Practical Guidelines for Measurement and Control (Current Edition)

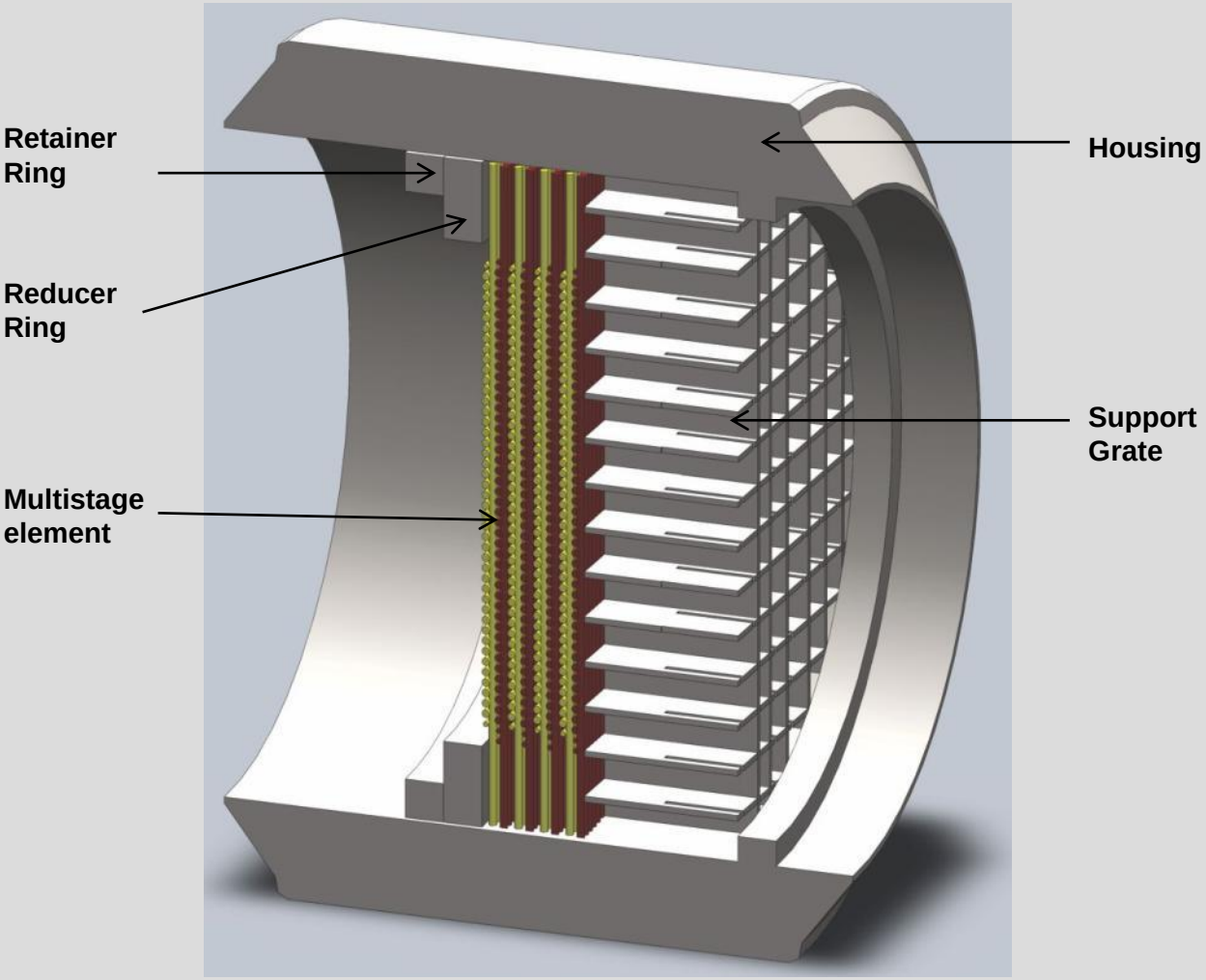
High pressure drop incompressible flow

Multi stage, Source treatment valves	Multi stage valves with additional path treatment
	

Page 242
These restrictor plates have special orifices and orifice patterns that serve to enable the plate act as both a pressure restrictor and noise reducer ..... They are in Wafer form; they are very compact and offer installation economy. Good results are obtained in properly selected applications with attenuations up to 20dBA. They can be used to advantage with both conventional and source treatment noise valves.

Page 243
A severe-service, 1500-psig superheated steam vent system to atmosphere was designed using a restrictor plate situated ..... This combination system gave excellent results over many years at a much lower overall cost than a special high performance level source treatment valve.

Source: ISA Practical Guidelines for Measurement & Control (Current Edition)



Solution

High pressure Steam Vent with Low Noise Pak

The multi-stage LNP’s uses grilled layers which create micro turbulent flow by dividing the compressible flow into large number of small passages which provides progressive pressure reduction. The grilled structure provides optimum porosity and foreign particles may pass through these cartridges. Cartridges are also very compact and offers good installation economy.

Typical Start up vent system comprising of control valve and downstream expanders and vent silencer

Typical applications

- High pressure Steam Vent
- Steam pressure control in Pressure Reducing Desuperheating Stations

Coke fines generated in C2+ Naphtha cracking process

Polymeric Slug catcher train

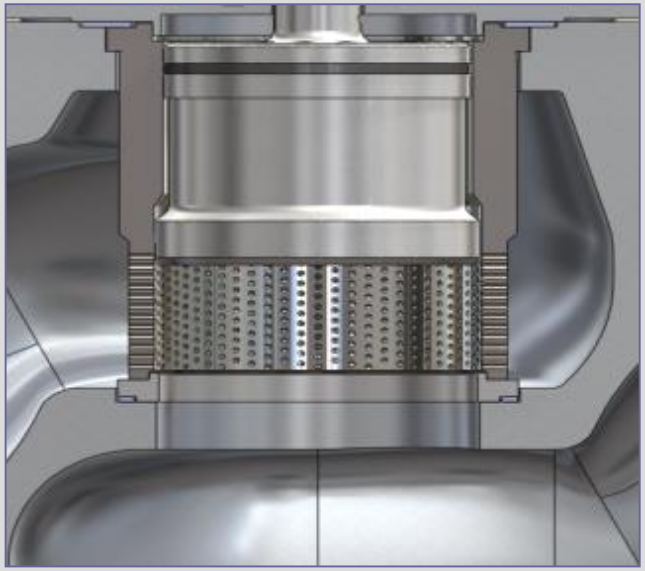
3. High Pressure drop, with particulates

Problems faced

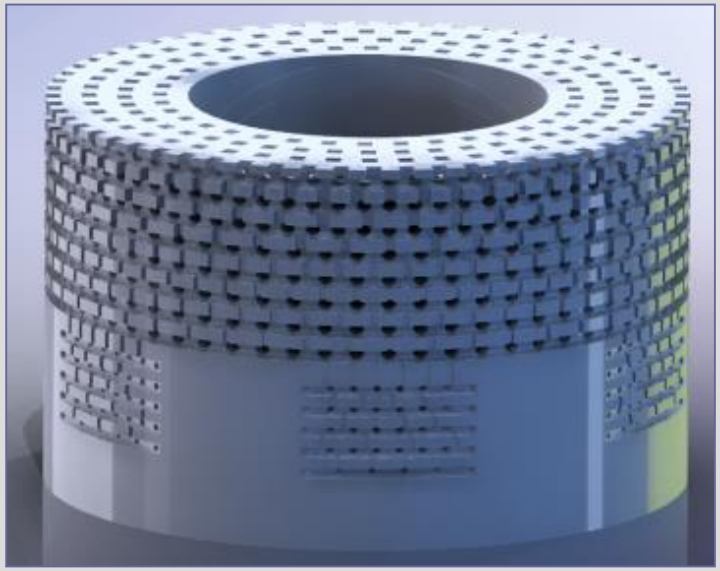
Solid particulates / Slurry / Catalyst / Coke fines which is a process element clogs conventional drilled hole trims

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

Challenge



Cage guided valve with anti-cavitation / low dB trim



Multi stage Multipath Cage assembly

Small passage drilled-hole and tortuous-path control valve trims are effective for severe service

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

Challenge

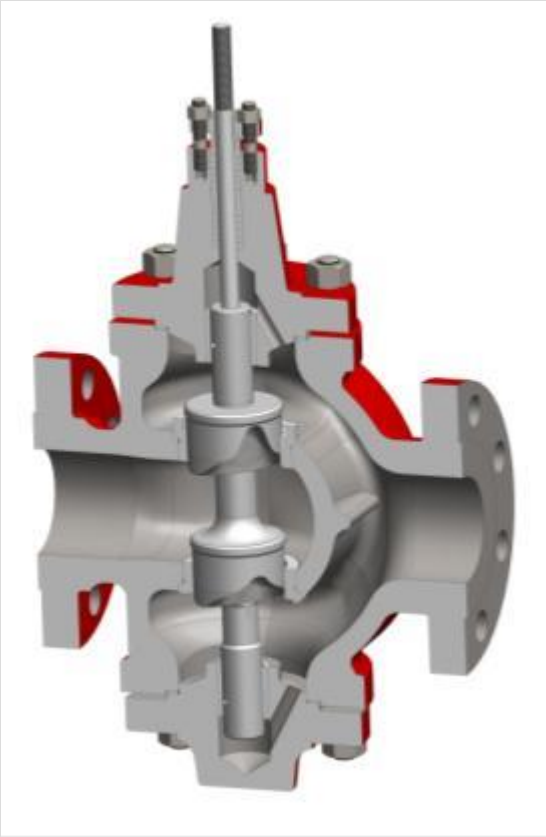
Small passage drilled-hole could clog if exposed to flow-stream with debris.

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential

Solutions for moderate pressure drop applications

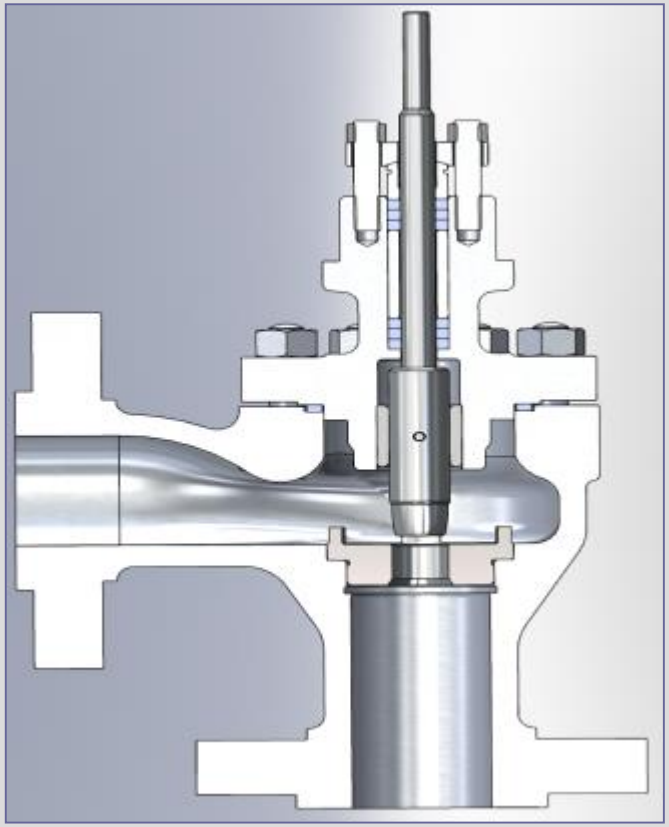
Angle and double ported semi-balanced designs

Top guided globe angle valves can be successfully used for higher sizes. Double ported semi-balanced can be successfully employed, avoiding close fit cage guiding.



Typical Double ported design showing Top & Bottom guiding, larger flow area and bottom flange.

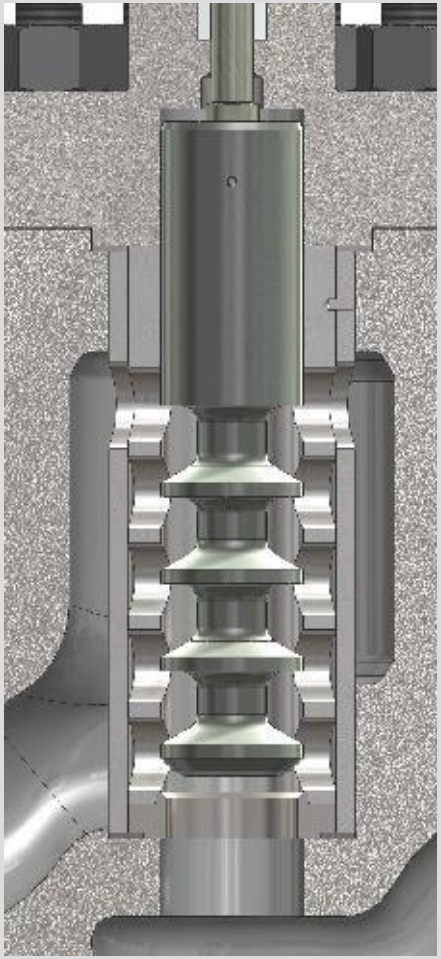
Balanced Design



Typical Heavy top guided (post guided) control valve which can be used for moderate pressure drops allowing small particles.

Unbalanced Design

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential



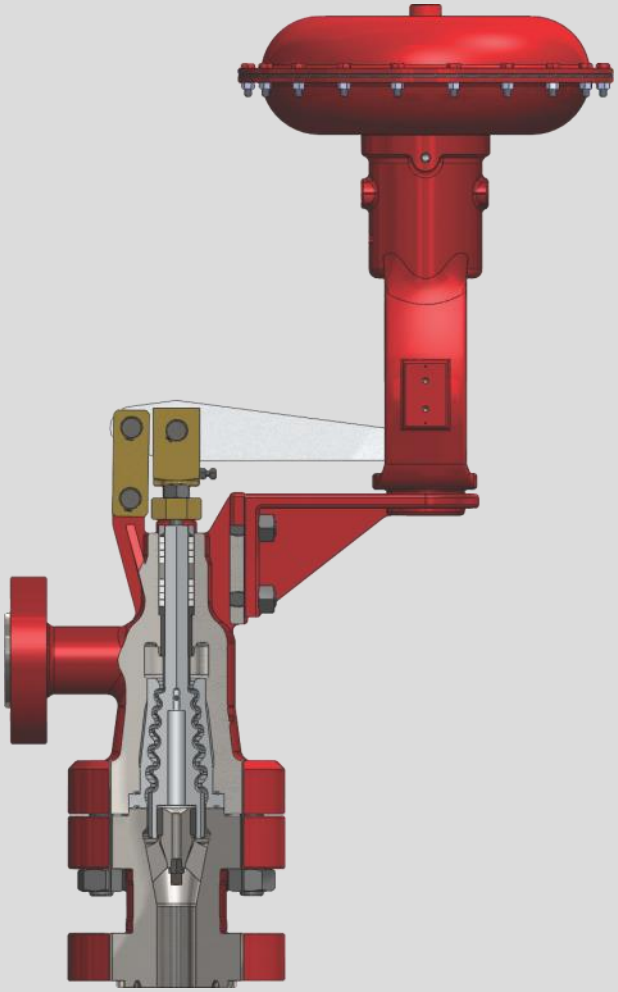
Typical multi-step design for liquid service, with relatively larger flow area compared to stack technology valves.

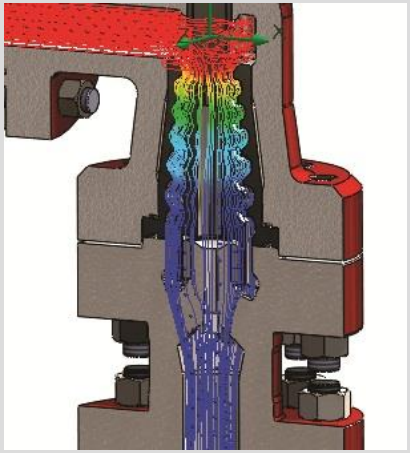
Solutions

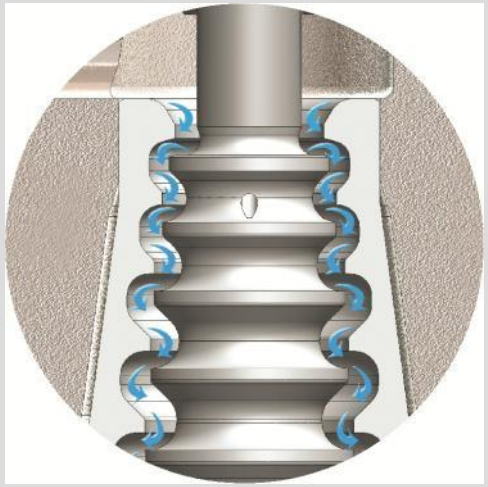
High pressure drop particulate tolerant solutions - Liquids

Multistep angle valves are used for Hydrocarbon applications, the larger flow area helping passage of fine particles which would otherwise clog cage guided valves

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential







Typical Multi-stage, Labyrinth type expanding trim design for High Pressure Gas/ Flashing applications; their hardened trims and clear flow path allows passage of abrasive particles.

Solutions

High Pressure drop, Particulate Tolerant solutions – Gases, Mixed flow

For gases or liquid with dissolved gases where high vibrations are also envisaged, labyrinth trims with expanding flow area is more ideal.
This is also suited for fluid with particulates

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

6” X 8”, 1500# ASME
Refinery Complex, Kuwait

4” X 6”, 1500# ASME
Refinery Complex, India

Typical Applications

High Pressure Separator Let Down Valve

Process Media

Processed hydrocarbon liquid that is lighter than straight gas oil and cleaner (e.g. gasoline and diesel)

Special Considerations:

- Severe service valve (High pressure drops, outgassing, corrosive due to entrained sulfur and H_2S)
- Fluid containing catalyst fines from reactor bed.

Process Impact

- Valve control has significant influence on the pressure of the High Pressure Separator and the Low Pressure Separator.
- Poor performing valve in this application can restrict flow to the Low Pressure Separator because of uncontrolled outgassing.

Highlights

Pressure Range: 1500 – 3500 psi

Temperature Range: 400 – 850 F

Body Material: ASTM A351 Gr. CF8C

Trim Material: SS 347 + Stellite

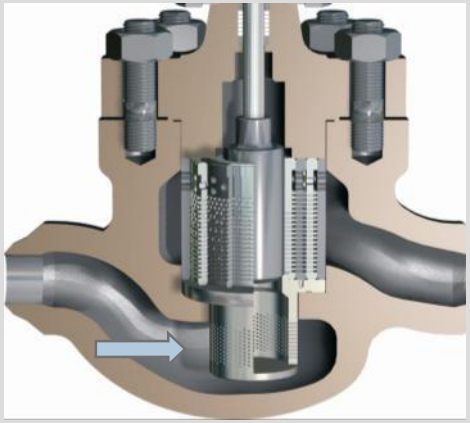
© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

3.1. External particles

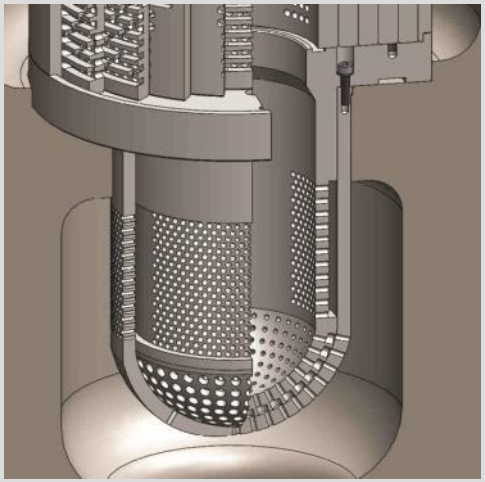
Very often improper Flushing/ cleaning results in foreign material getting stuck up inside the valve internals resulting in permanent damage/seizing of the valve.

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential

Virtually Clog - Free



Strainers can be inbuilt to the seat ring at the inlet to the trims to protect the valve trims from foreign material.



To enhance effectiveness, multi-stage strainer, which is detachable without welding can be used. This acts as a pressure dropping stage apart from a strainer. The two 90 deg turns inside this cages effectively prevent and entry of small size debris also. The trims and stack are always protected from foreign material.

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential

4. Out-Gassing

Seemingly non-critical pressure drops can lead to valve failure due to :

- Outgassing of CO_2 or H_2S when pressure drops
- 2-phase flow produces excessive turbulence and vibration that can lead to valve stem breakage
- Flashing induces erosion damage on trim parts and body
- High outlet velocity induces erosion on body
- Corrosion

Typical Applications

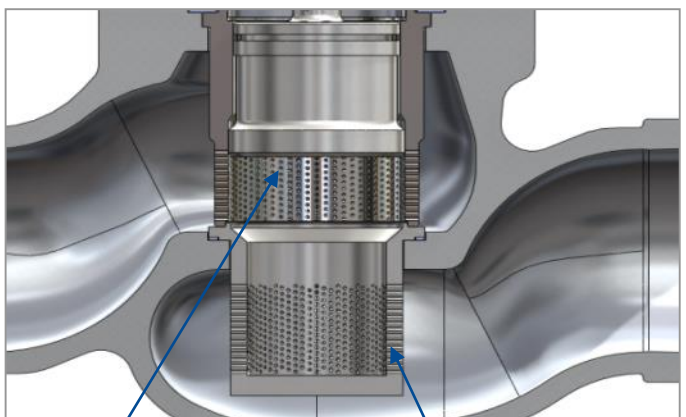
- Amine and/or CO_2 removal units
- Gas / LNG plants – Amine units (H_2S removal)
- Ammonia plants – CO_2 removal units
- Crude Oil Production Facilities (H_2S removal)

Common Absorbing media

- H_2S: Amines (MEA, DEA, MDEA etc)
- CO_2: Potassium Carbonate solutions like (Benfield, Vetrocoke etc)

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

Out-Gassing (CO_2/H_2S Removal)



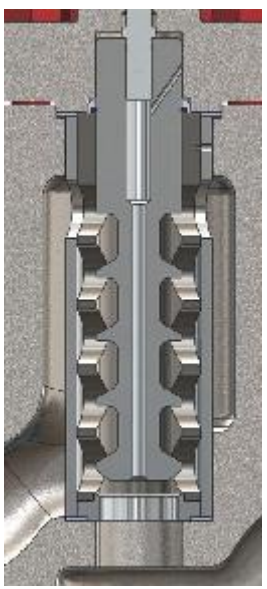
Single phase inside the cage

Anti-Cavitation cages breaks up the flow stream

Two phase outside the cage.

Out-gassing takes place inside the static diffuser seat.

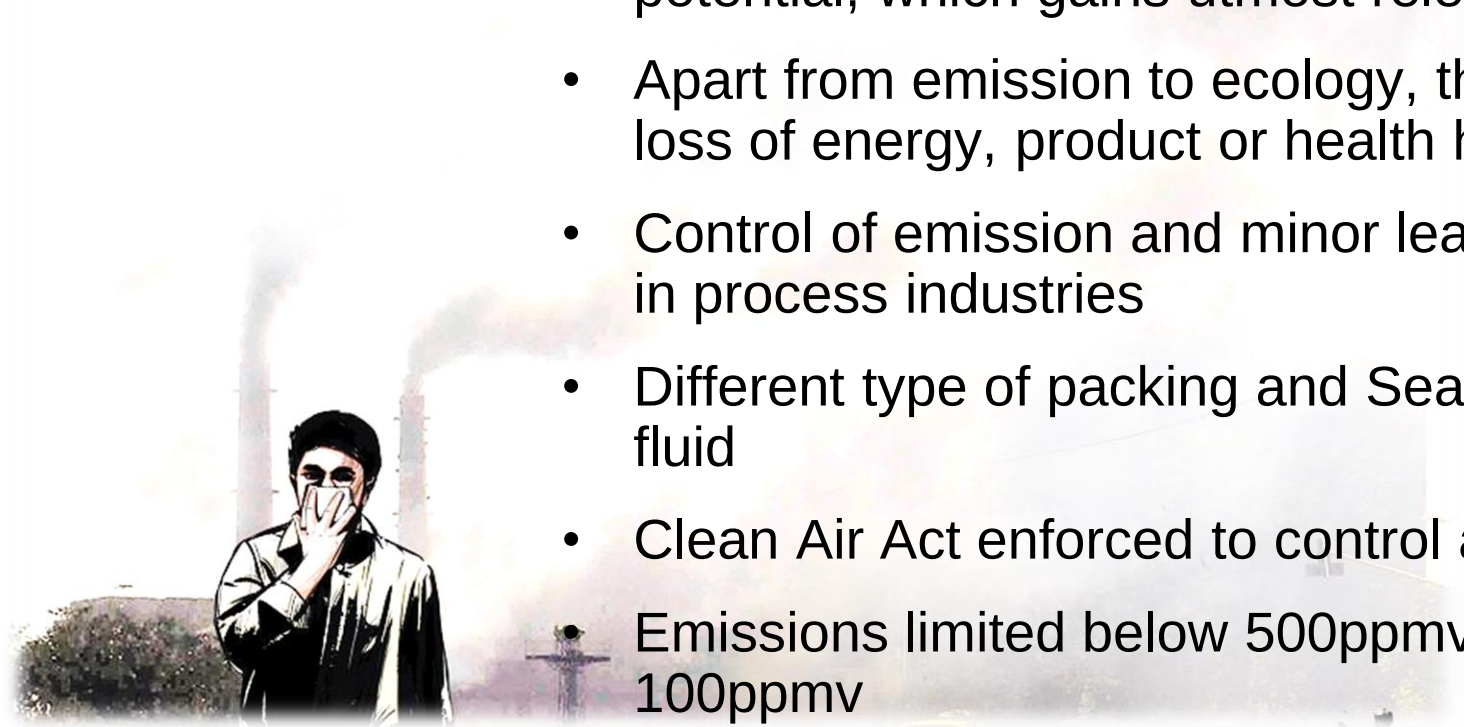
Amine Regeneration Control Valve



For higher pressures typically around 150-180 bar, as seen in Amine regeneration units, Multistage valves are successfully employed

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

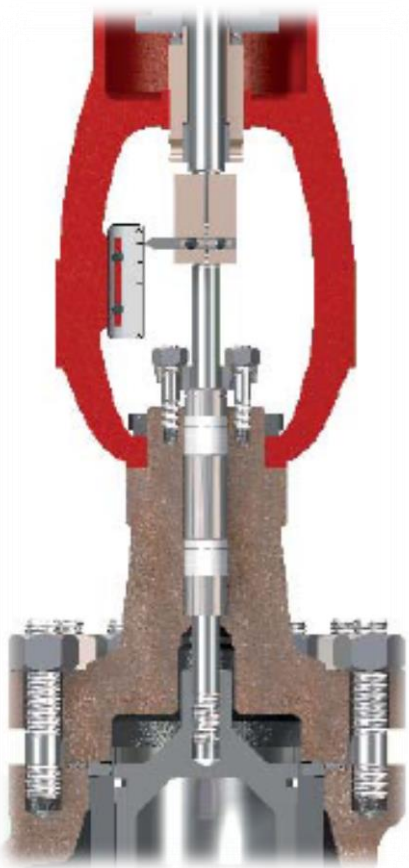
Fugitive Emission & Mitigation in Control Valves



- Often forgotten aspect during design phase is the gland leak potential, which gains utmost relevance
- Apart from emission to ecology, the leakage also can lead to loss of energy, product or health hazard
- Control of emission and minor leakage is a major challenge in process industries
- Different type of packing and Seals are used to isolate the fluid
- Clean Air Act enforced to control air pollution – EPA, USA
- Emissions limited below 500ppmv in stringent cases to 100ppmv

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential

Higher Leakage Potential in Reciprocating Stem Control Valves



Reciprocating stem in Control valves

- Makes intermittent contact with the service fluid and atmosphere
- Stem also draws dirt, dust and other particles from atmosphere

Control valve glands maintenance

- Leakage can be arrested by loading the gland follower
- Tight packing will create high friction on the valve stem
- Balance between control performance and good gland sealing capability

Other Reasons for Leakage

- Poor finish of the stem and the packing box, improper packing compression, alignment, chemical attack
- rapid/ wide thermal cycling and simple mechanical wear

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential

International Standards for Fugitive Emission

- Clean Air Act in North America and TA Luft in Europe
- ISO 15848- Part 1 & Part 2
- API 622 & API 624 is a packing test using methane
- Shell Standard MESC SPE 77/312
- Other custom standards like Chevron, Total also available
- The API test procedures have more industry wide applicability but ISO 15848 is more demanding and elaborate

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential

Common International Standard for Fugitive Emission Control

ISO 15848 Part 1 & Part 2 Comparison		
Standard	ISO 15848 Part 1	ISO 15848 Part 2
Significant mainly to	Type Test Qualification	Production test
Pass Criteria	Class A, B, C as per MOC	-
Equipment	Valve being qualified	Valve being qualified
Media	Helium or Methane 97% minimum purity	Helium or Methane 97% minimum purity
Temperature	200°C or 400°C as per MOC	ambient
Pressure	As per valve rating	6 bar
Number of valve stem actuations	As per valve type/ Class	-
Number of thermal cycles	As per Leakage Class	-
Leak measurement method	Hood/ Sniffer	Sniffer
Leak measurement details	Done with stem in static state	Done with stem in static state
Leak measurement frequency	Before and after thermal cycles	After cycles

Copyright 2018. ISA All rights reserved. www.isa.org

No part of this work may be reproduced, stored in a retrieval system, or transmitted in any form or by means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the publisher.

Common International Standard for Fugitive Emission Control

Class	Measured leak rate (Mass flow)	Measured leak rate (Vol. flow)	Remarks	Measured leakage (using Sniffing method)	Class
	mg·s−1·mm−1 stem dia.	mbar·l·s−1 mm−1 stem dia.		ppmv (Methane)	
AH	≤3,14·10−8	≤1,78·10−7	Typically achieved with bellow seals or equivalent stem (shaft) sealing system for quarter turn valves	≤50	AM
BH	≤3,14·10−7	≤1,78·10−6	Typically achieved with PTFE based packing or elastomeric seals	≤100	BM
CH	≤3,14·10−5	≤1,78·10−4	Typically achieved with flexible graphite based packing	≤500	CM

written permission of the publisher.

BELLOWS SEALED DESIGN

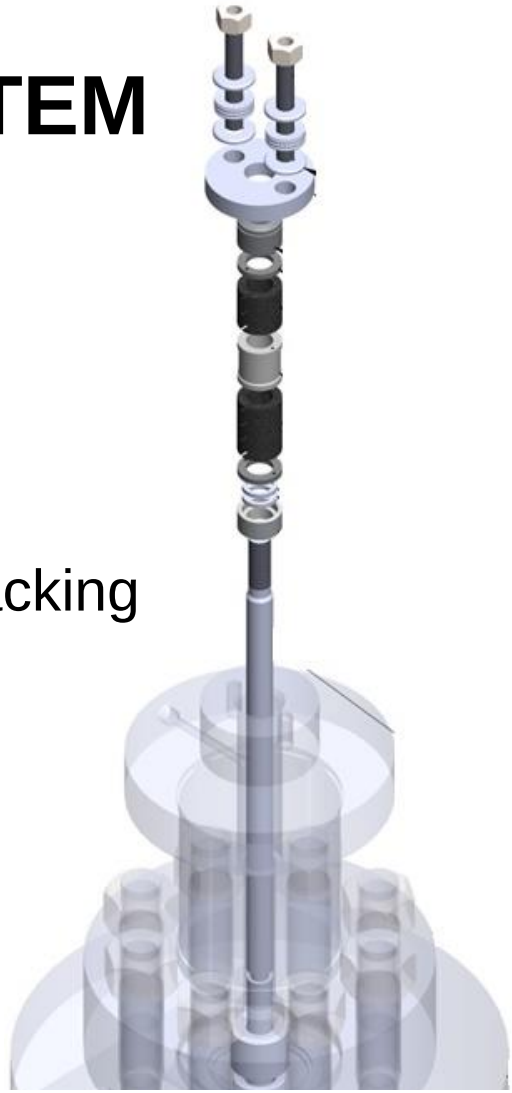
- Valve handle toxic fluids or the process fluid is to be completely sealed off
- Valves used in in-accessible locations
- Periodic inspection of the valve packing is practically impossible
- The conventional gland packing is replaced by a metallic bellows welded to the valve stem
- The bellow sealed design thus eliminates any sliding or rotating seals through which process fluid can pass
- Expensive
- Limitations like long travel, extreme process conditions
- Choice of bellow sealed or gland sealed valve

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential

ECOLOCK PACKING SYSTEM

Key Design Criteria

- Optimised Geometric tolerances and precise manufacturing of valve components
- Anti-extrusion rings and guides for supporting the packing
- Combination of variable density packing for uniform compression throughout the bore
- Wiper rings and special Lantern rings
- Precise packing stud tightening
- Live loading to compensate load differences



© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved Strictly Confidential

Thank You

© Copyright KSB Aktiengesellschaft 2014
All Rights Reserved
Strictly Confidential