SMART IN FLOW CONTROL.

Title:
Evolution in control valves for severe services

Instituto Brasileiro de Petróleo, Gás e Biocombustíveis

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Reliability Performance Criteria—Severe service conditions are those which impact the valve's reliability. Severe service conditions include the following:
Cavitation or flashing High pressure drop, where the pressure drop exceeds the critical pressure
Cavitating services, where more than a two stage let-down trim is required to meet the noise limits without application of path treatment Flashing services with downstream vapor content exceeding 10% weight Two-phase flow services with downstream vapor content exceeding 10% weight
High piping vibration
Erosion, such as solids in the fluid, liquid particles in gas stream, and stream. High valve outlet velocity (liquids > 5 m/sec; gas/steam > 0.3 mach, Two phase flow, flashing > 60m/s (196 ft/s)

Topic of Valve World Converence Dec. 2005

High Performance Control Valves

“Key” valves This are valves with highest responsibility for production targets like quality and quantity as well as plant safety and economics.
Crude oil supply valves
Pump – and flow machine protection valves
Flare- valves
Feed water, cooling water and fire fighting valves.
Start up (process balance), shut down valves
Valves with high dynamic actions high anti-corrosion features high anti-abrasion features high demand on control quality (controllability) (e.g. insulin production,) Valves with unique design features and high replacement cost

Severe service definitions (liquid applications)

Severe service operating conditions

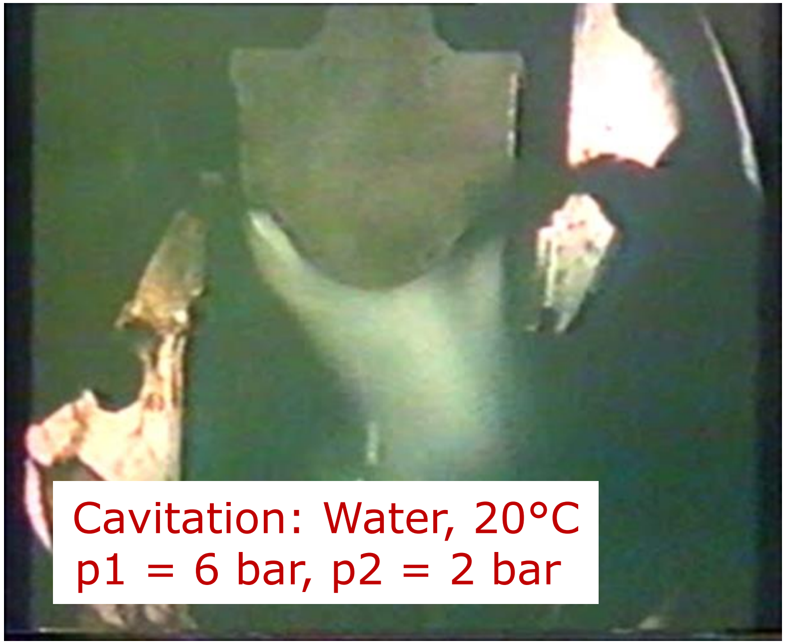
- Cavitation noise with sound pressure levels between 90 and 100 dB(A)
- Critical cavitation -> damage (plug, seat, body, pipe)
- Flashing -> damage (erosion) (plug, seat, body, pipe)
- Two phase medium at the valve inlet -> damage (erosion)
- Damage can be caused by:
    - Mechanical Sources
    - Hydrodynamic Sources
    - Erosive and Corrosive Service

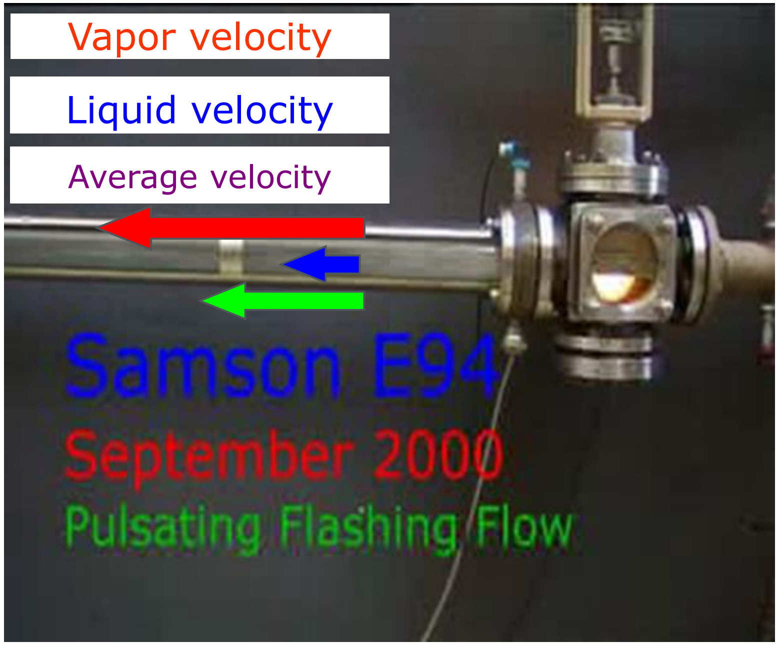
Damage potential in case of cavitation and flashing

Ranking list of damage potential :

4) Ideal gas/air
3) Overheated vapor/steam
2) Saturated vapor/steam
1) Wet vapor/steam

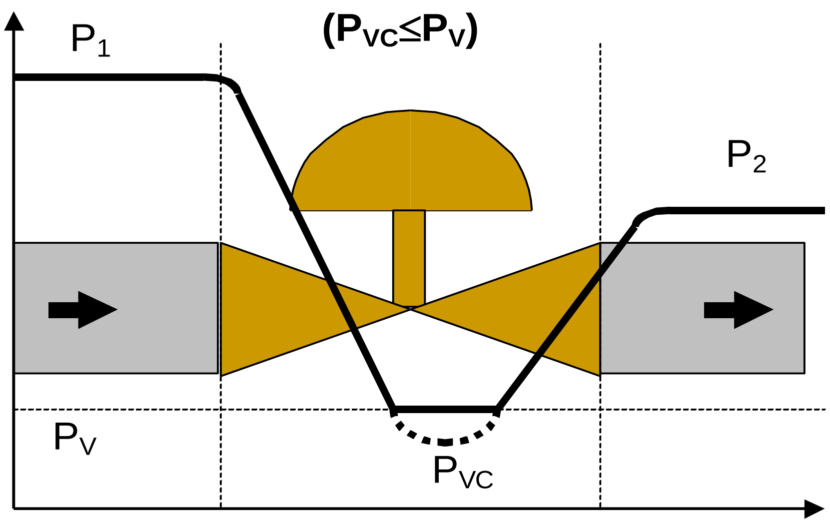
Cavitation and flashing convert liquid to Wet vapor/steam with the highest potential of damage !

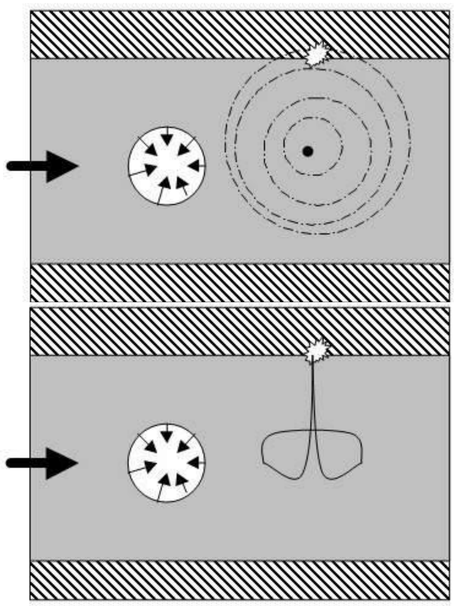




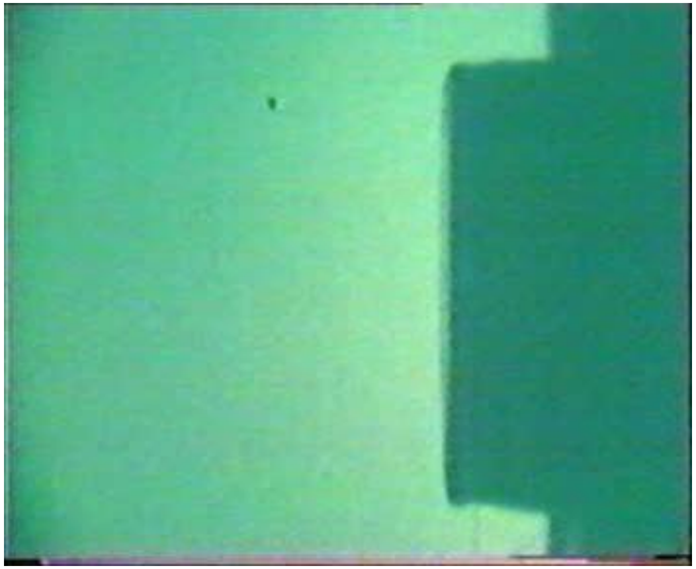
Cavitation

- The static pressure decrease below the vapor pressure forming vapor bubbles.
- Cavitation is the process where a (steam) bubble in a liquid rapidly collapses because the pressure in the liquid will get higher than the vapour pressure, producing a shock wave and a micro jet.

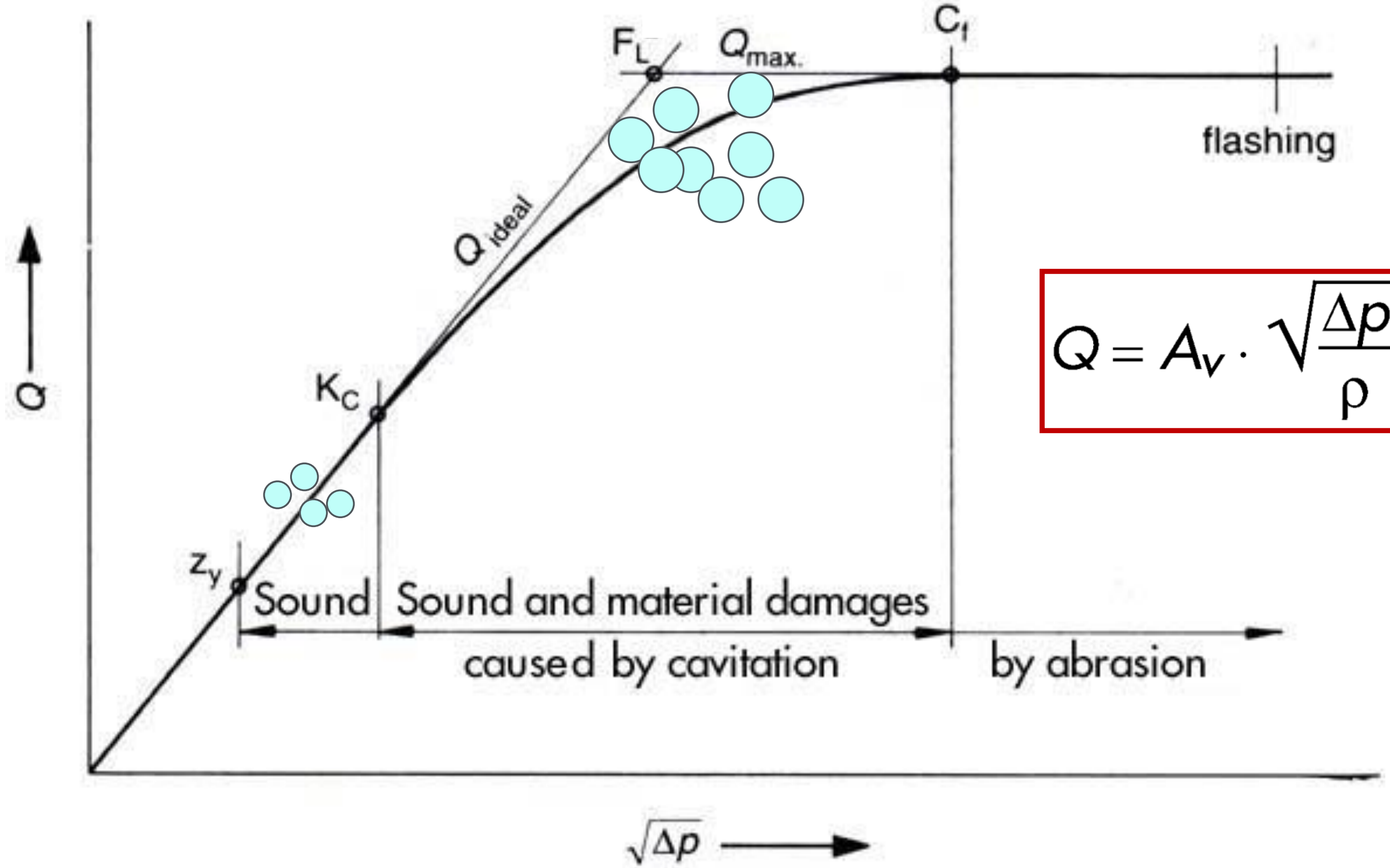




Classical cavitation damage

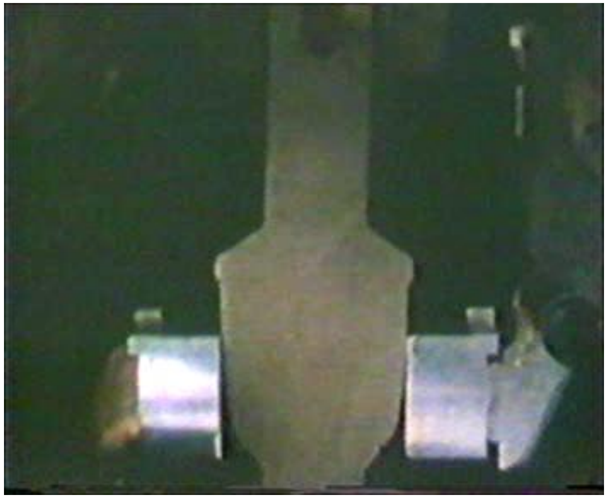


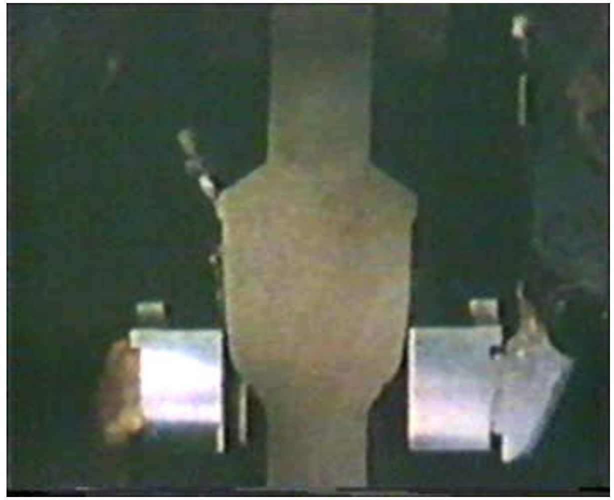
Flow measurement (liquid)



$$Q = A_v \cdot \sqrt{\frac{\Delta p}{\rho}}$$

Cavitation sound level



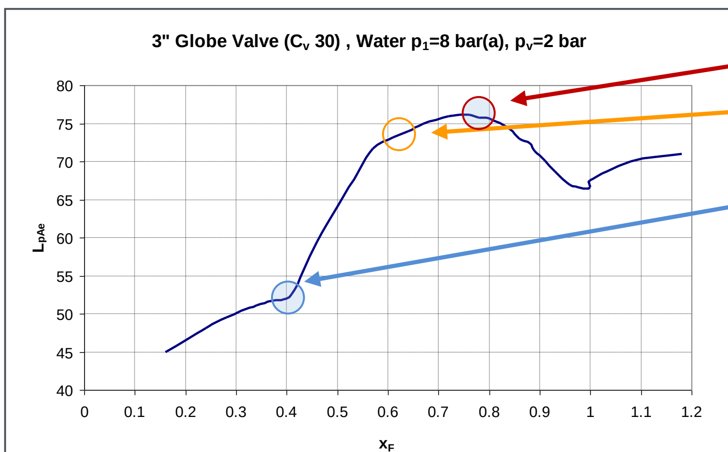


Approx. $1/\sigma_i = x_{Fz} = (x_{Fi})$

ISA RP 75.23

$1/\sigma_{id} = K_c = FL^3 = (x_{Fid})$

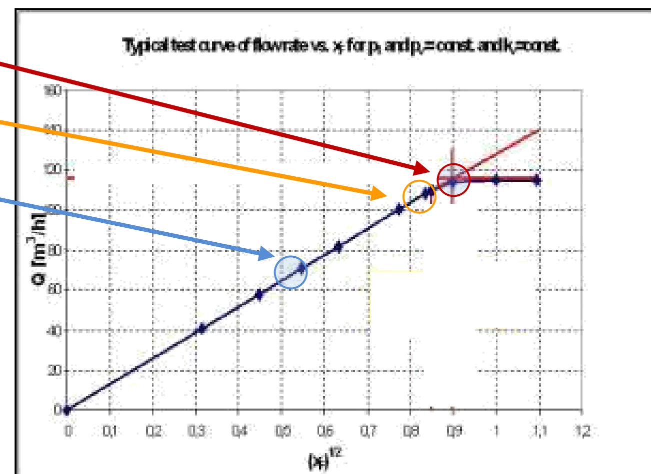
$1/\sigma_{ch} = FL = (x_{Fch})$



FL

K_c

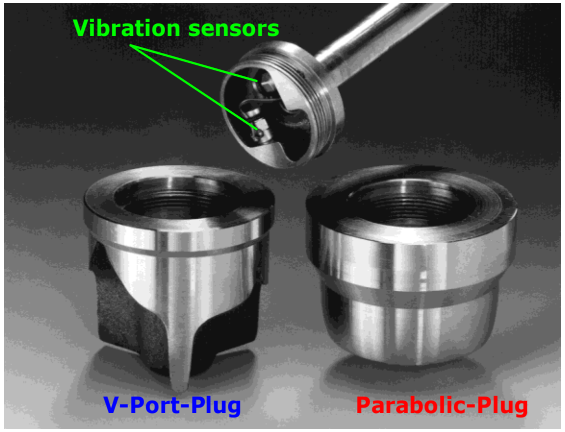
x_{Fz}



Sound measurements IEC 534 8-4

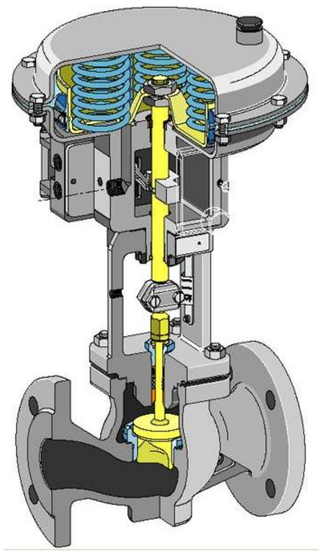
Flow measurements IEC 534 2-1

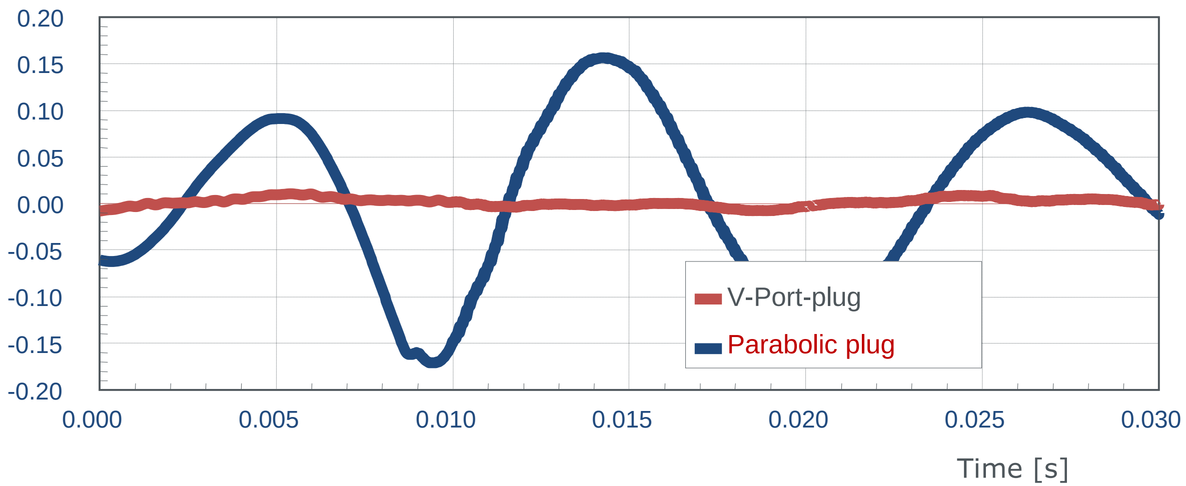
Damage due to vibration behaviour
V-Port- und Parabolic plug



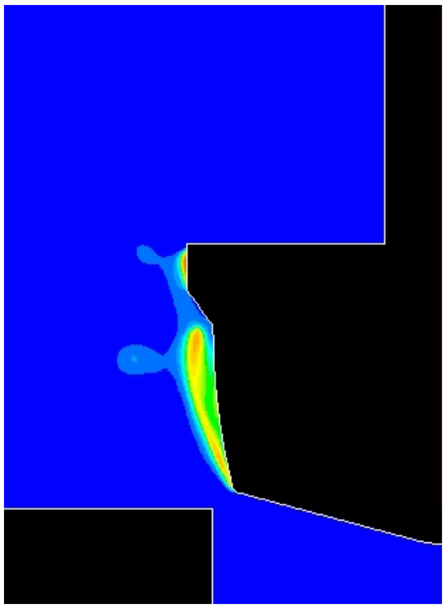
Parabolic plug
- symmetric
- outlet through ring gap

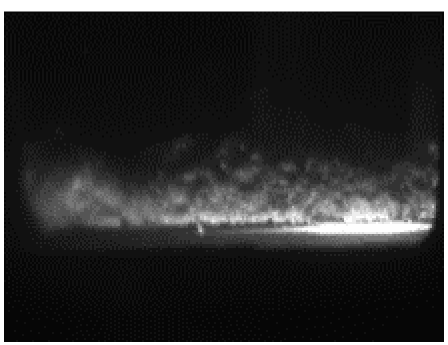
V-Port-plug
- asymmetric
- defined outlet

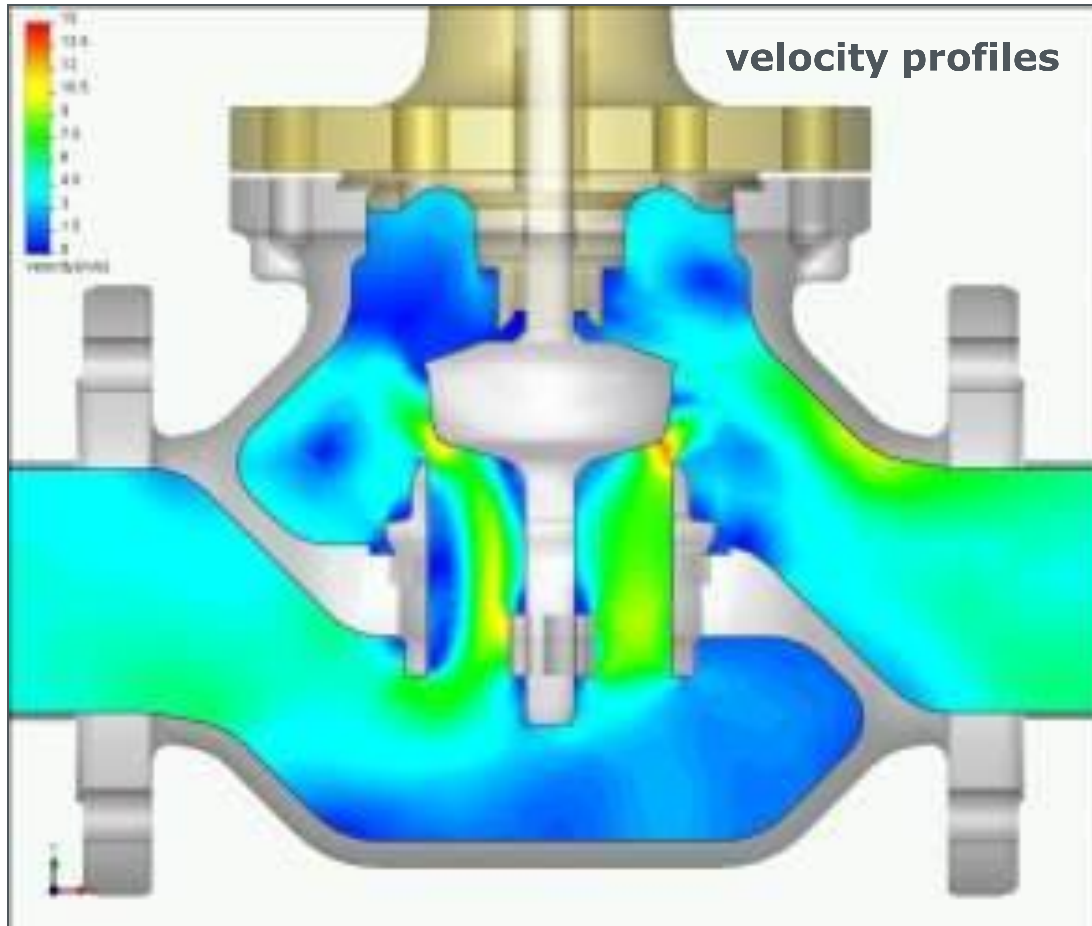




Optimization of the plug and seat geometry to reduce cavitation noise (increase of x_{Fz}-value)

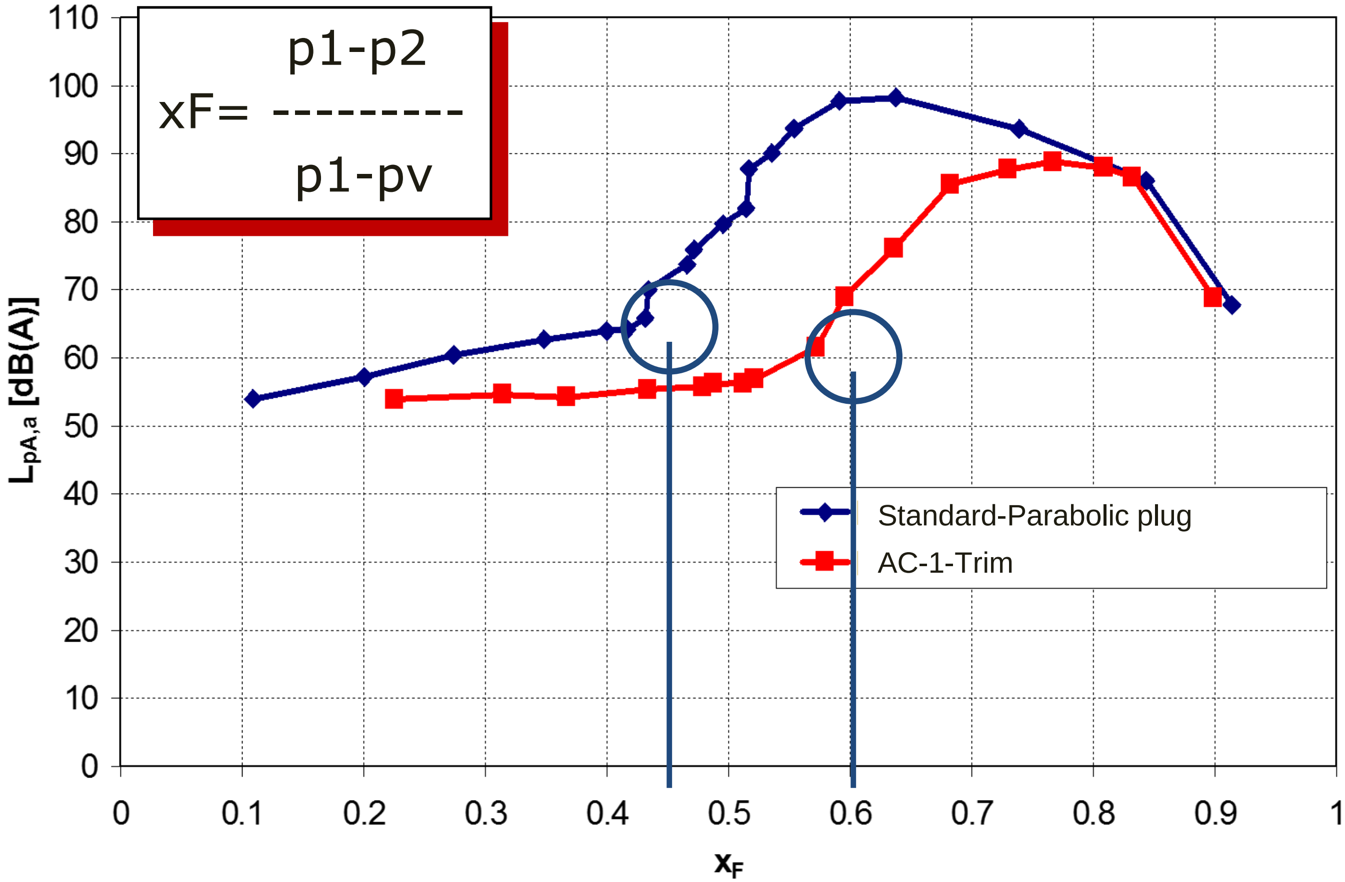






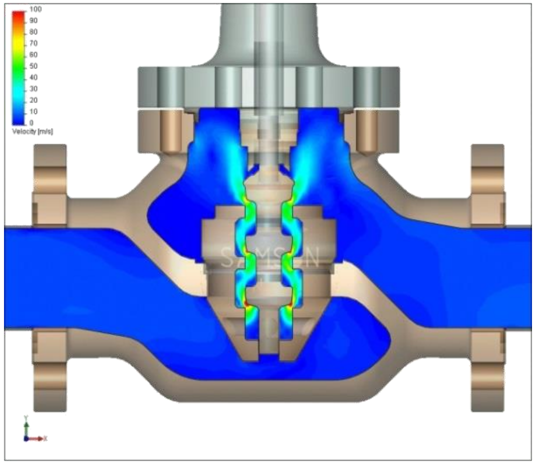
Higher X_{Fz}- values

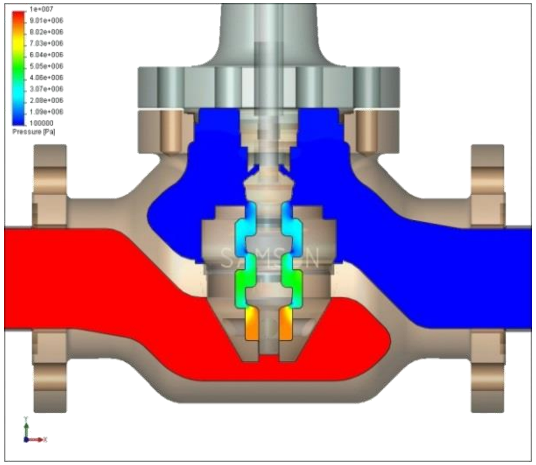
Increasing X_{Fz}- value of about 0,15 can reduce the sound pressure level in approx. 20-30 dB(A).



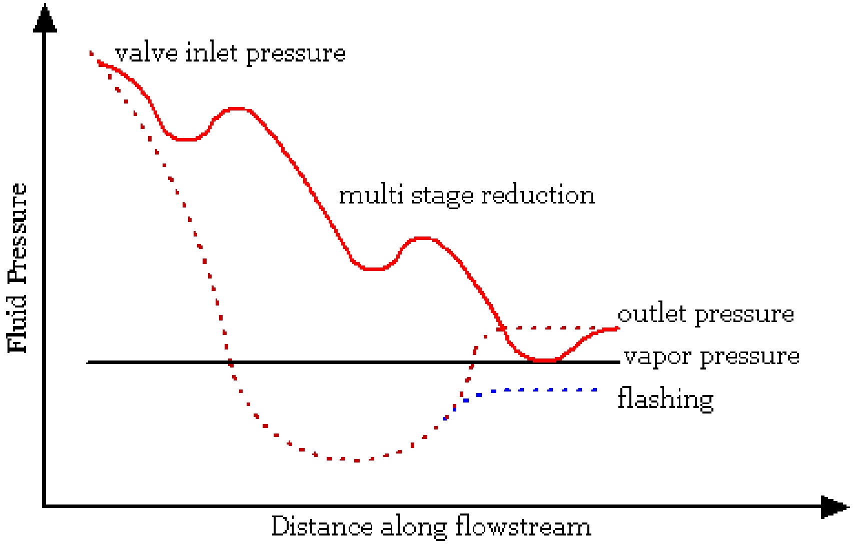
Solutions in case of severe cavitation

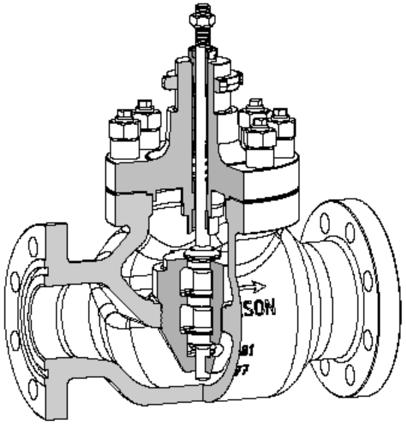
CFD optimization



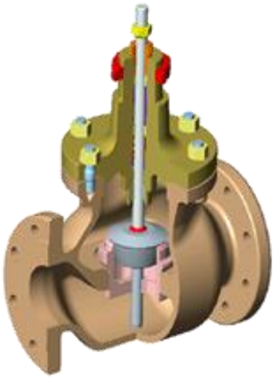


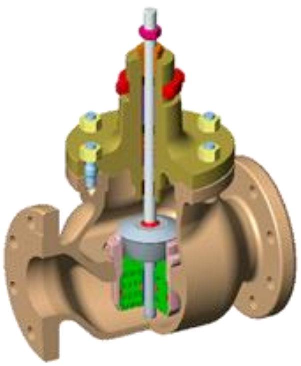
pressure reduction in steps

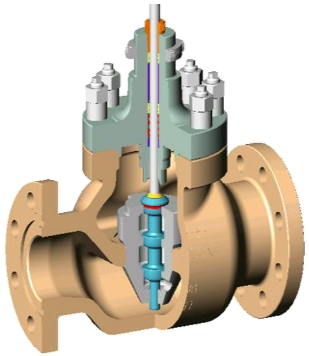


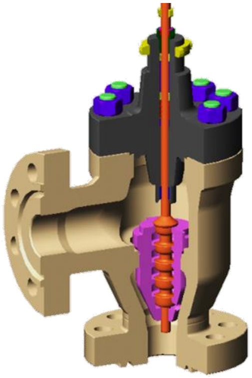


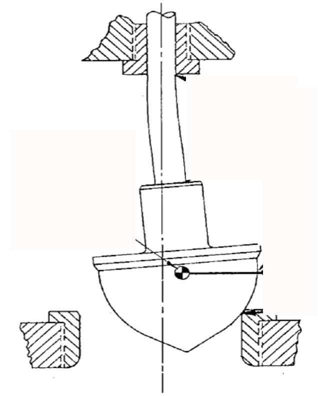
Anti cavitation trims









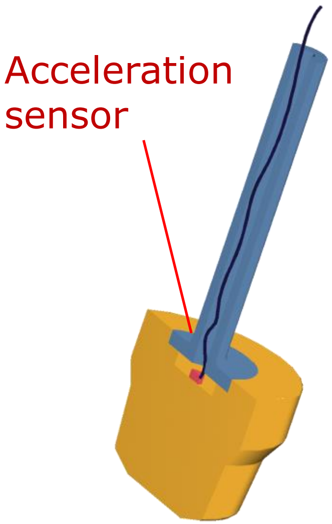


SOURCE OF FORCES CREATING STEM BENDING FATIGUE DURING LATERAL VIBRATION OF PLUG

AC 1	AC 2	AC 3	AC 5
Max Δp = 25 bar		Max Δp = 100 bar	Max Δp = 200 bar

Globe valve type	X_{Fz} for valve 75% load	X_{Fz} for valve << 75% load	Resistance to con-tamination	Vibration be-havior
Parabolic plug	0.25 to 0.35	clearly up to 0.8	high	poor for single-guided plugs
Piston-balanced plug with cage	0.25 to 0.35	up to 0.5	low	good
V-port plug	0.25 to 0.35	up to 0.5	high	excellent
Perforated plug	0.25 to 0.35	0.25 to 0.35	low	good
AC Trim System	0.35 to 0.5	clearly up to 0.85	high	good

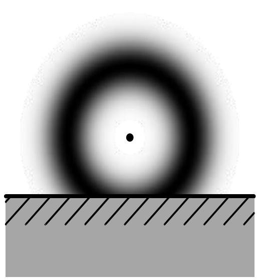
Plug acceleration tests and calibration via pit density

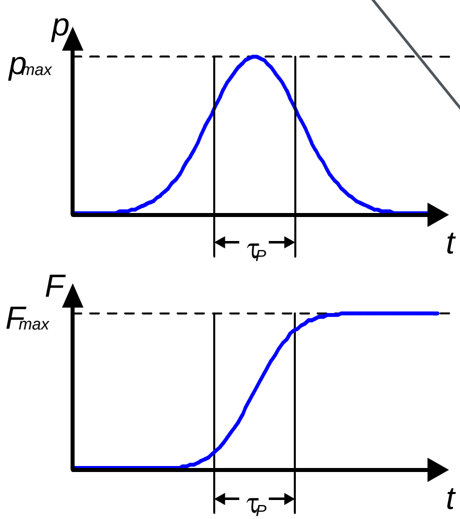


Implosion energy,

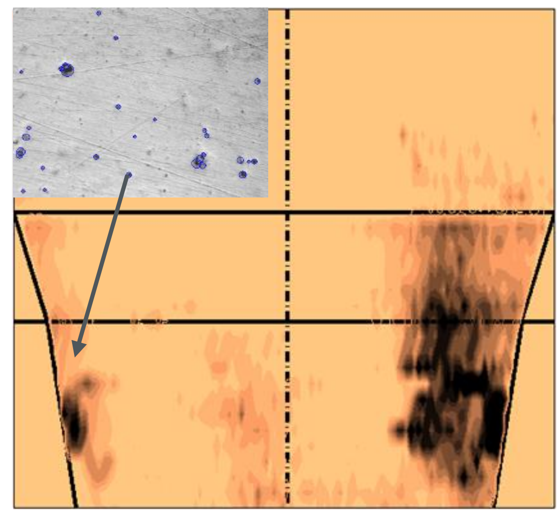
f >> 20 kHz

$$E_S = \frac{\hat{F}^2}{\pi \rho c^3 \tau_P}$$



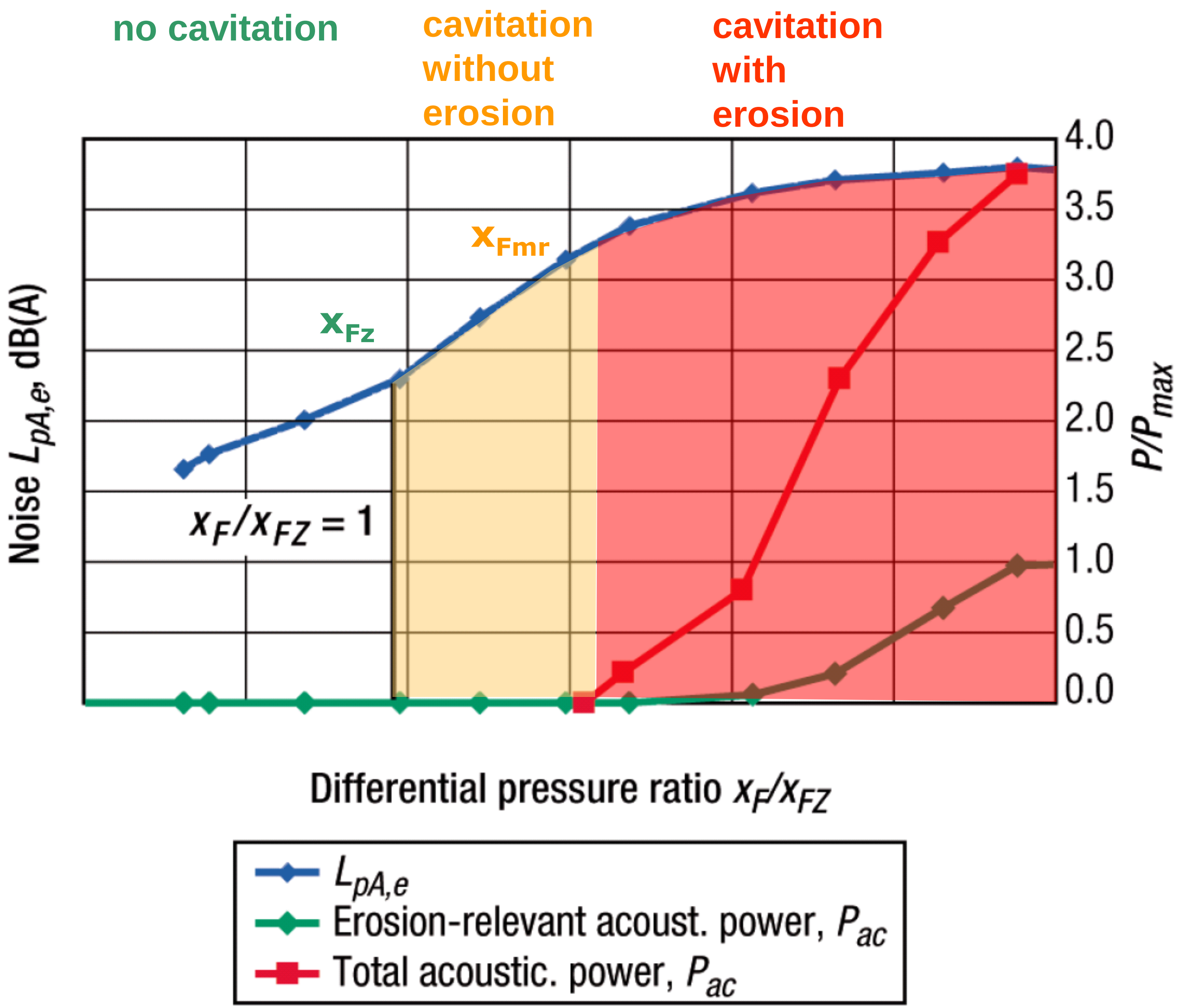


Optical registration of pit density for calibration



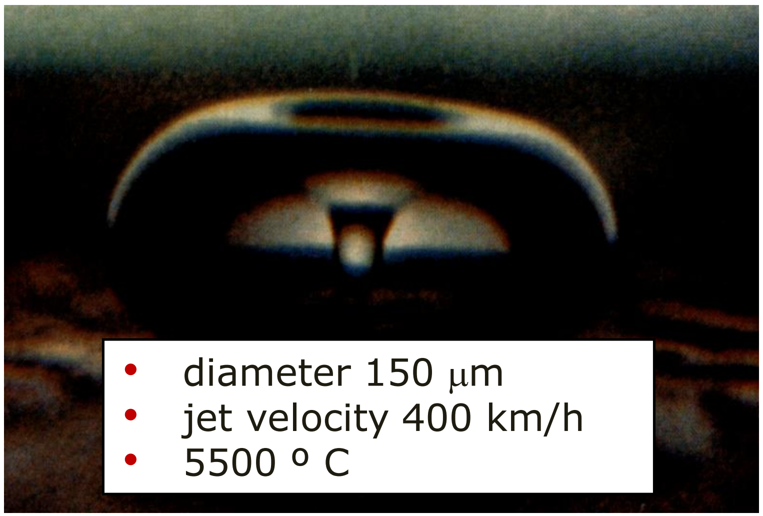
$$E_S = E_{S0}\left(1 + \frac{R_{10\%}}{R_{ref}}\right)^3$$

Cavitation damage research
x_{Fid} via acceleration measurement inside plug



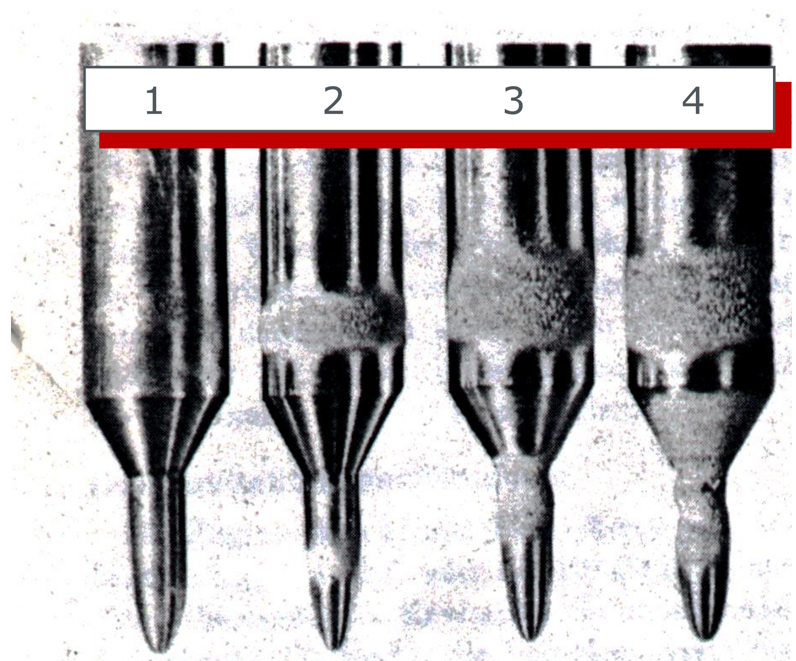
Cavitation damage research

Cavitation damage in globe valves



- diameter 150 µm
- jet velocity 400 km/h
- 5500 º C

1: Dp = 33.4 bar, p1 = 35.2 bar
2: Dp = 66.8 bar, p1 = 70.3 bar
3: Dp = 101.6 bar, p1 = 105.5 bar
4: Dp = 133.6 bar, p1 = 140.6 bar



Cavitation intensity

- higher for x_F->K_c (more bubbles)
- higher with Δp (kinetic energy)
- critical Δp

Flashing test rig in SAMSON's development center

Problem:

- Volume and velocity increase in the mixture during the expansion
- The mixture has, in comparison to each single component, a lower sonic velocity

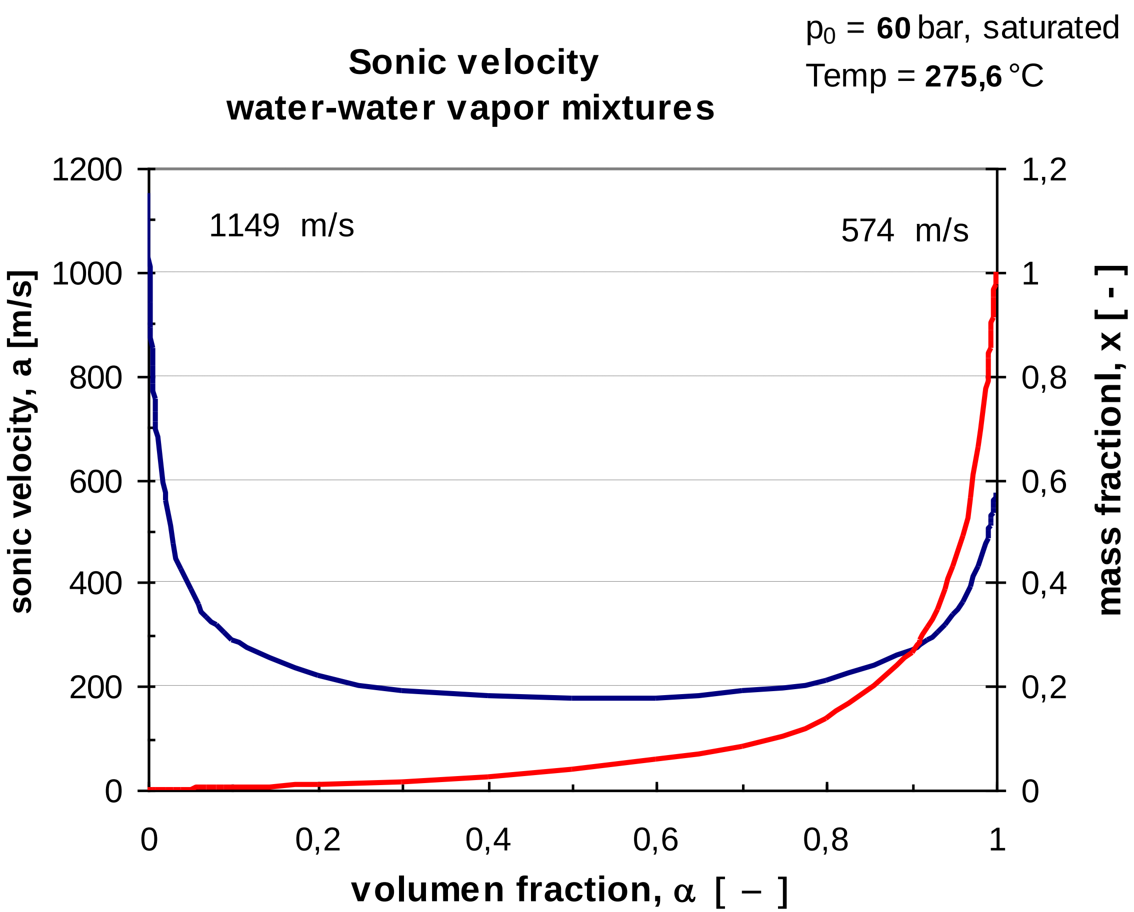
A wrong selection rapidly leads to unstable flow characteristics with high vibration and mechanical loading.

The mixture has, in comparison to each single component, a lower sonic velocity

In case of flashing, wet vapor can reach sonic velocity.

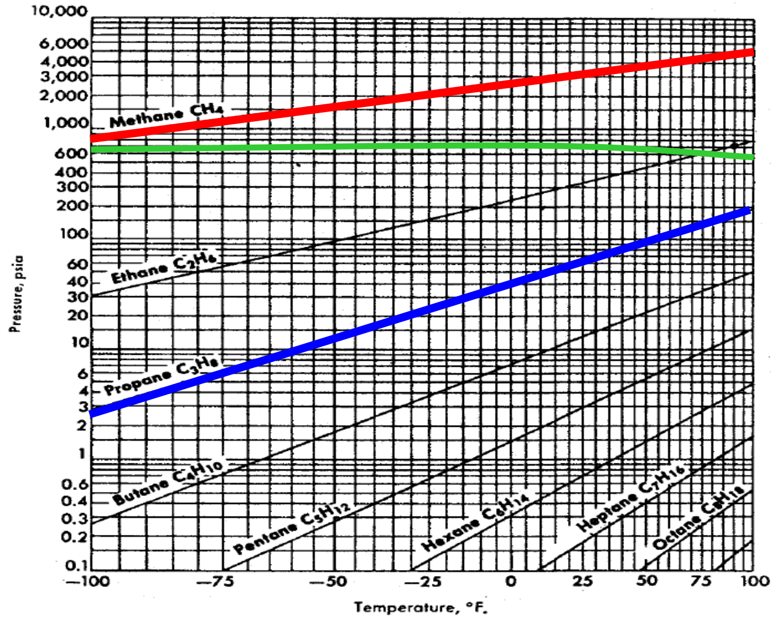
Recommended max. trim outlet velocity about 60 m/s (200 ft/s) with choked flow.

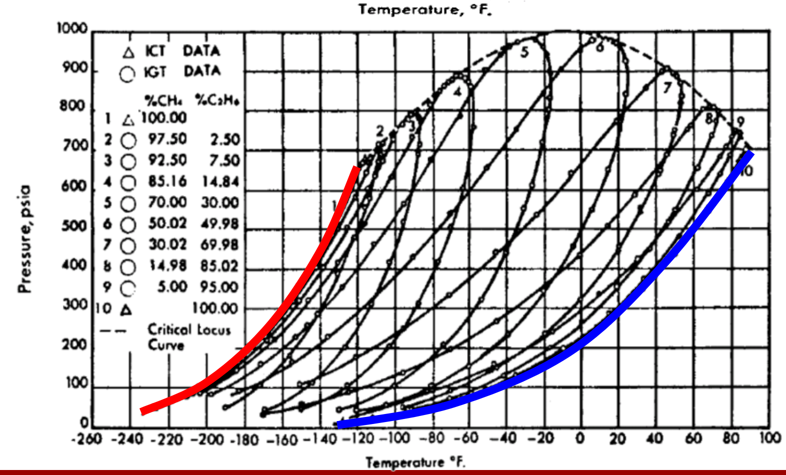
Flashing liquids, or liquid-vapor mixtures have significantly lower sonic velocities than each single phase.



Special requirement for HPI flashing applications

2-phase flow at the valve outlet with n-components



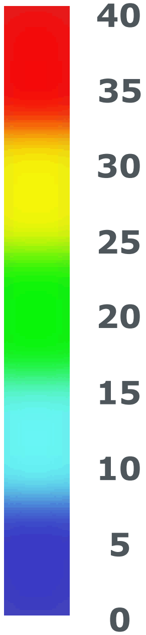


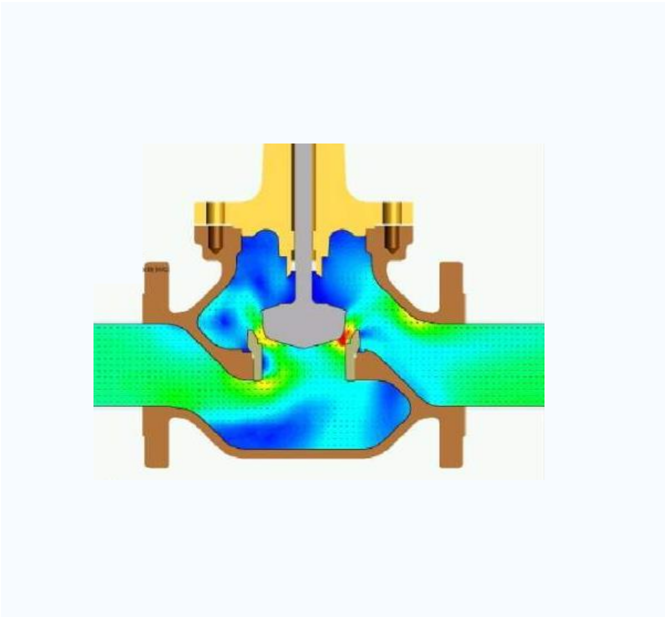
Recommendation:

↗ Δp & $p_2 << p_v \Rightarrow$ angle valve

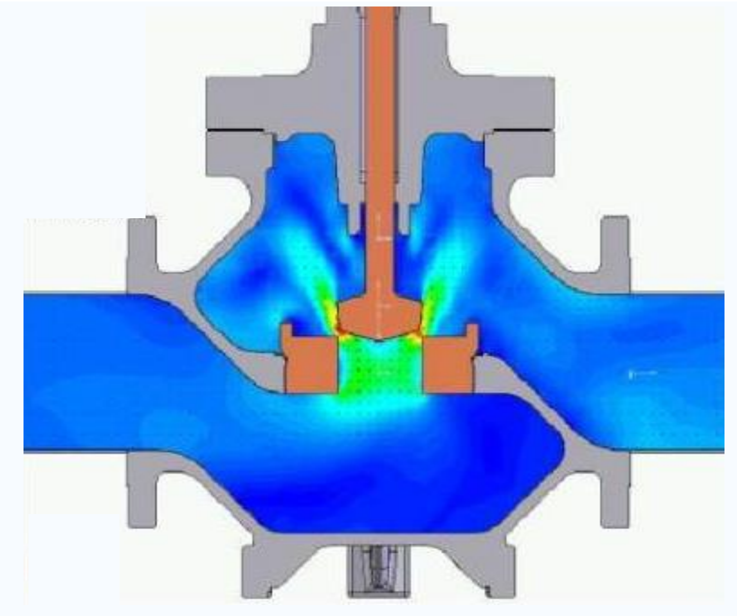
$DN_{valve}=DN_{pipe}$

In the case of flashing critical valve outlet velocities needs attention





DN3” ⇨ 16 m/s



DN6” ⇨ 4.8 m/s

Single stage valves with reduced seat size to provide as much space as possible to the flow at the valve outlet show a continuous and erosion free operating behaviour.

The seat guided V-port plug avoids flow vibration and resonance oscillations through it strong guiding and asymmetrical form.

Liquids:

$\triangle p < \triangle p_{crit.\_cav.} = 25$ bar (Globe valves, single stage plug)

- **< 5 m/s, if partial cavitation occurs: xFz < xF < Kc;**
- **< 3 m/s, if severe cavitation occurs: xF > Kc,**

$\triangle p > \triangle p_{crit.\_cav.} = 25$ bar (Globe valves, multi stage plug)

- **< 3 m/s, if cavitation occurs: xF > xFz,**

Corrosive liquids like acids:

- **avoid cavitation: xF < xFz**

if no risk of cavitation v < 6 m/s

General for non corrosive fluids,
free of cavitation PN <= class 600 v < 8 m/s
if flashing* occurs: xF > 1; v < 60m/s

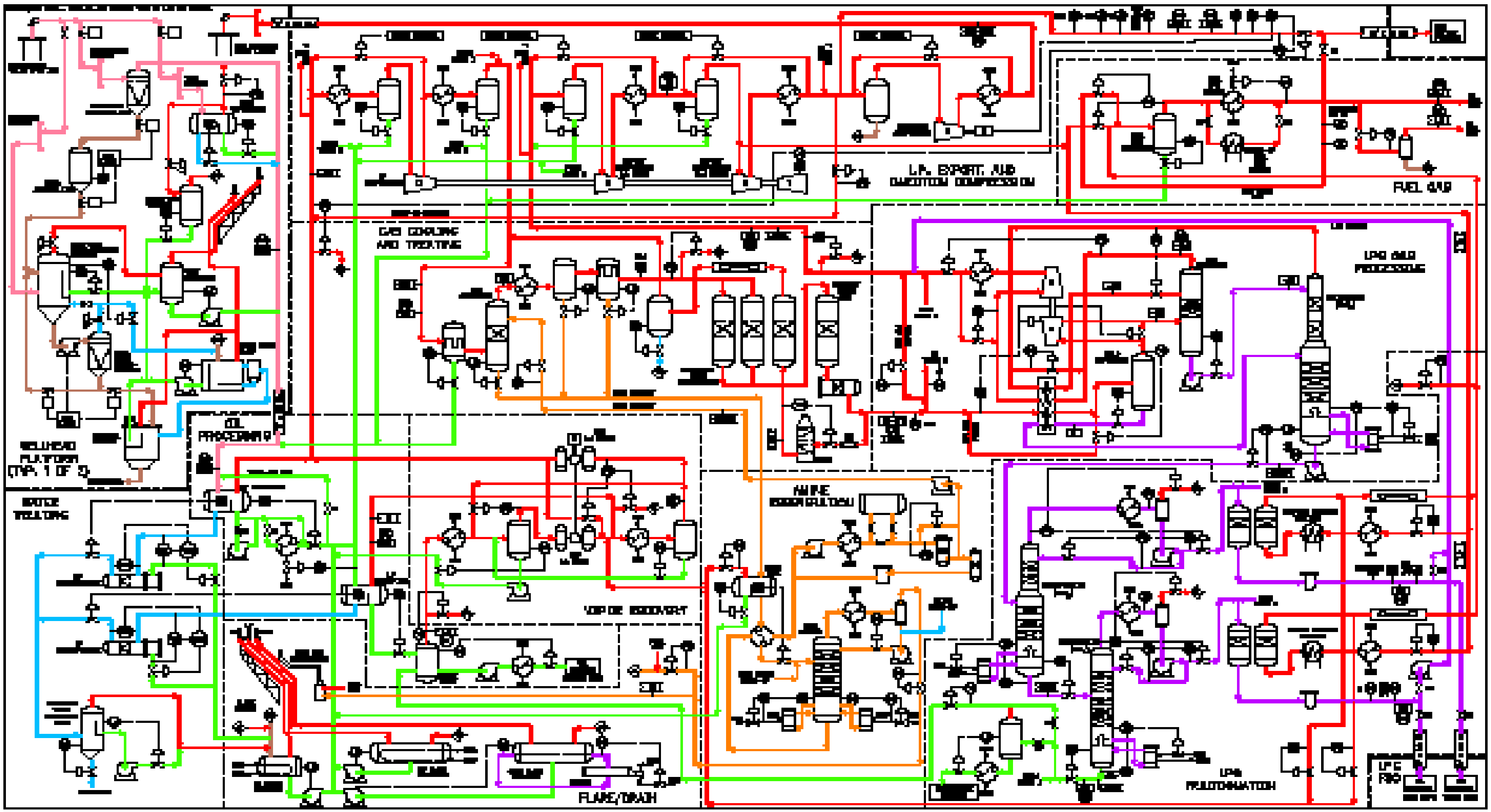
Gas and Steam, Vapors:

- **< 0,3 Mach, general, but important with low noise devices**
- **0,3 < Ma < 0,6 , short operation time**

***see publication: Dr. Kiesbauer and Samson-Valve Sizing**

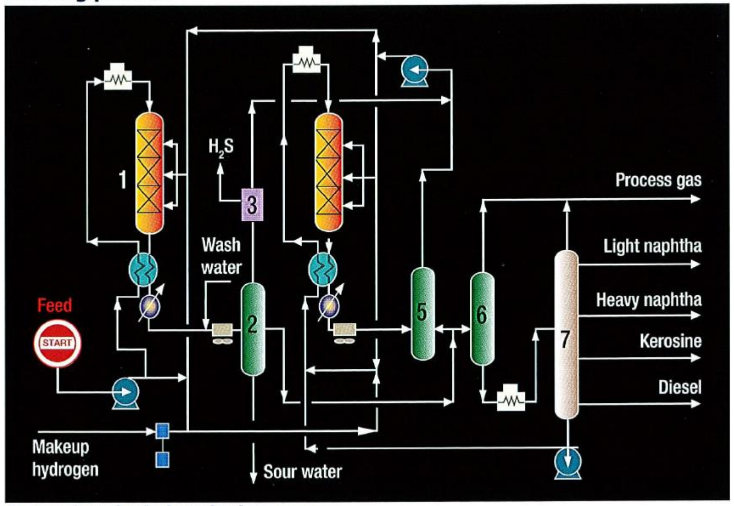
An Overview ....

Even if the single process seems to be simple, a modern refinery is a complex process plant, which requires a specific know-how.

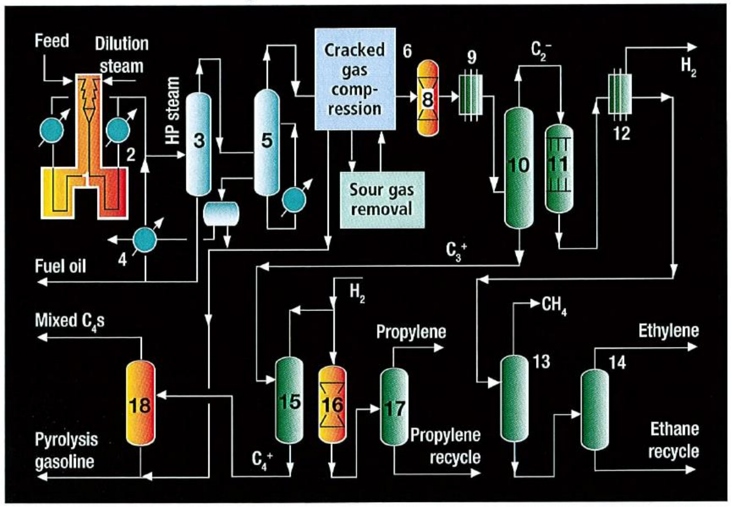


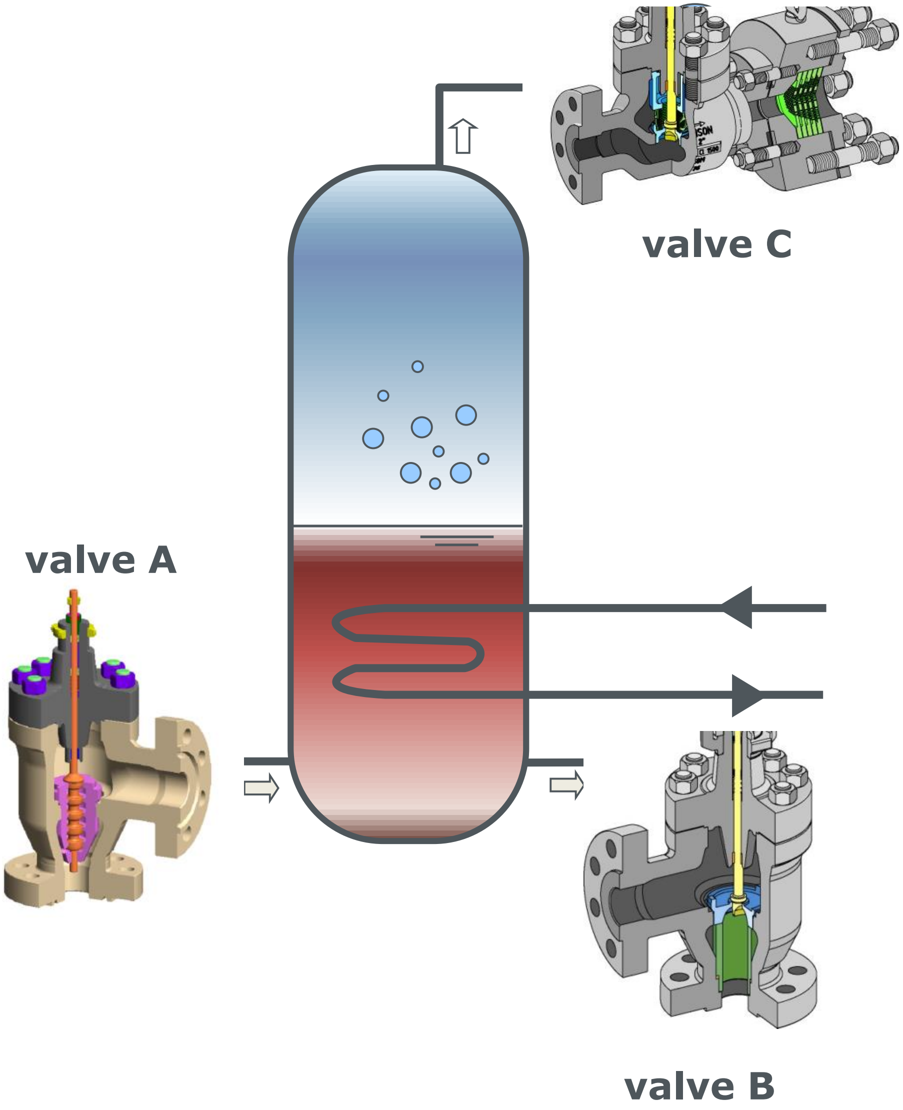
Simplified HPI Units

Refining process



Petrochemical/chemical process





Detail engineering-sources for plant-and valve designers dried out !

- Valve specification sheets are often from low quality: operating points are missing or not logical sorted to qmax, qnorm, qmin.
- Important property data, worst case conditions like start up conditions, control loop information, ”identification of *key valves*” - etc. are missing.
- The specification volume including increasing paperwork of standards, special regulations, and tailored customer requirements have more than doubled.
- Time for huge project offers is more than halved.

Detail engineering-sources for plant-and valve designers dried out !

- Plant- and valve designers need time to select control valves, sound level and economic aspects. Serious control valve selection requires detail engineering with competence.

- Control valve engineers need long-term experience and high skills in measurement and control, mechanical engineering and thermodynamics.

- No time for detail engineering will increase the risk of “quick and dirty” sizing.

Total Cost of Ownership TCO

This slide shows some work done on control valve Total Cost of Ownership by a team from Heritage Amoco

Spend profile over lifetime Cost element	1998 % of TCO
Purchase Price	12.0
Procurement	0.9
Engineering	8.9
Installation Cost	5.3
Maintenance	65.0
Spares	5.3
Utilities	2.5

- 13% of the cost of the valve is related to the initial purchase,
- 14% relates to the engineering and installation and the remainder,
- 73% relates to the maintenance and the ongoing valve operations.

Dow Chemical Presentation
(Valve World Conference 2004)

Valve World

Diagnostic and Reliability of Automated Valves

General Observations

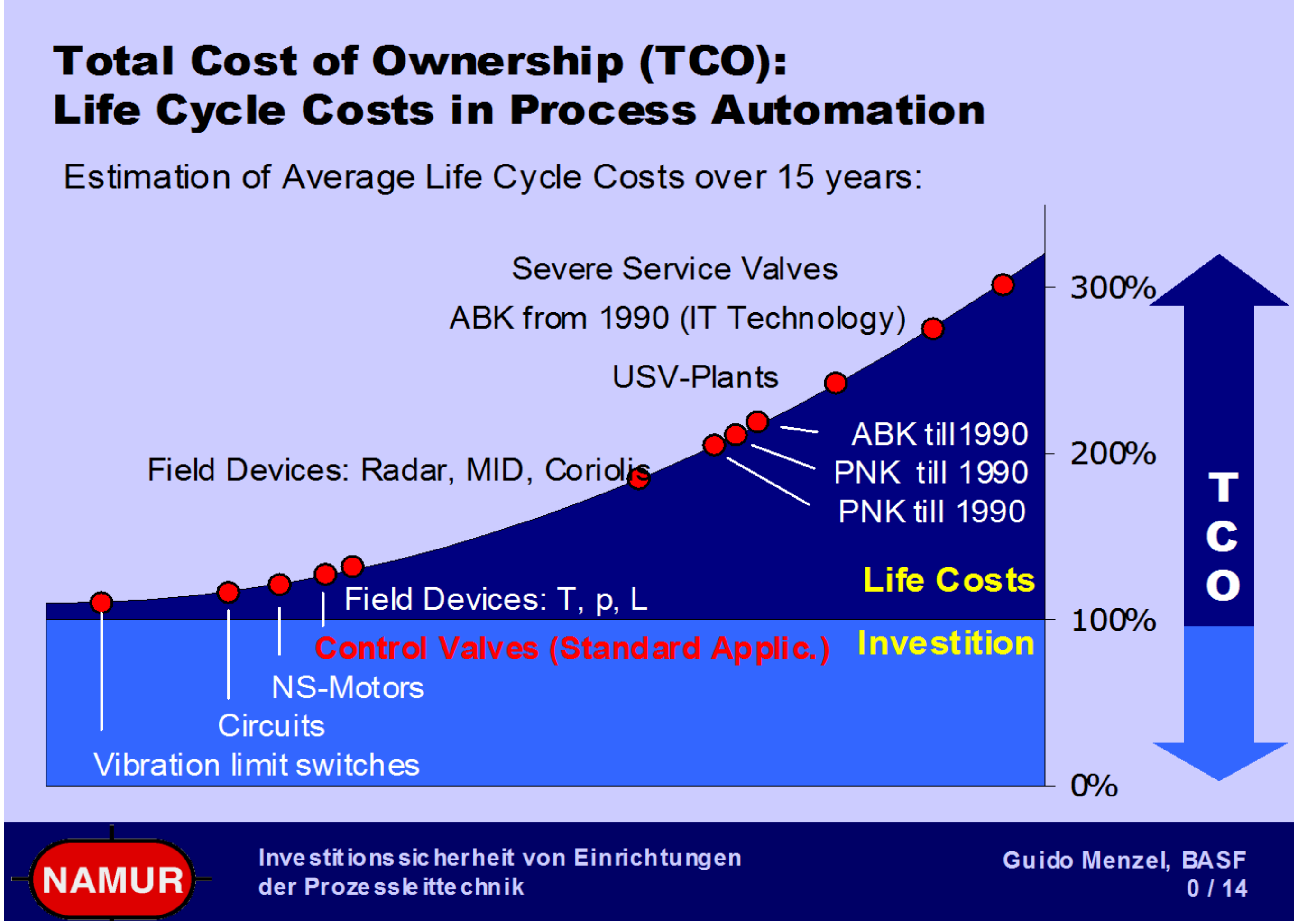
- Costs related to control valves:
  - initial cost + installation = 10-20% of total life cycle cost
  - valve wetted parts count for 80+% of valve revision cost
  - every year ± 7% of installed base in "revised"
  - average revision cost per valve ± $1500

"There is a real potential for digital devices"

DOW | " Be not only smart but also clever" | CM , 11.11.2004 Page 5

TCO comparison

Life Cycle Costs for BASF
(approx. 50,000 Samson Control Valves)



Maintenance and repairs costs vs. initial purchase price

Users of competitors valves

	Purchase Price	Maintenance
DOW	100%	567%
AMOCO	100%	450%

SAMSON User

BASF – 50,000 Valves

Standard Applications	100%	30%
Severe Service	100%	200%

Muito obrigado pela sua atenção