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High differential pressure control valve for desalination service

Control valves selection requires a certain level of knowledge and experience, in extreme cases, when it comes to sizing a control valve for high differential pressure in a desalination plant the challenge is much complex. Numerous parameters influence the control valve behavior and its life expectancy; The type of flow and its velocity, differential pressure over the valve, presence of dissolved gas and suspended solids in the flow, and the salinity of the flow, to name a few. Valve selection properly made affects the desalination process and the stability of drinking water production.



Case study

Process condition

- Media: Brackish water 12000 mg Chloride / Liter
- Upstream pressure: 25 bar
- Downstream pressure: 10.5 bar
- Maximum flow: 100 m³/h
- Nominal flow: 65 m³/h
- Minimum flow: 40 m³/h

Design constraints

- Line size: 3"
- Maximum allowable Face to face: 330 mm
- Flange connection: EN1092 PN64
- Material of construction: ASTM A351 Super Duplex CE3MN

Problem definition

Calculation of the various process condition resulted with 'Critical Cavitation', 'Incipient Cavitation' and high noise level, above 80 dB(A). valve and pipeline vibration are expected, as well as development of cavitation condition, i.e., implosion of gas bubbles downstream of the 'vena-contracta' and pitting damage on the inner surface of the valve, subsequently, unstable control behavior and short time to failure.

Solution provided

To avoid cavitation damage and high noise level, a multiple pressure breaker comprises of three elements was designed; one dynamic on the upstream side, and two static elements on the downstream side. The dynamic element was built with metallic ball-seats set; round seat on the upstream and 90 degrees segmented V-Port on the downstream. The ball and seats were lapped together to a perfect match, bubble tight shut-off, and smooth operating condition.

Part of the design process the nominal working point was examined as well as the extreme points; i.e., maximum flow capacity at minimum differential pressure, and minimum flow capacity at maximum differential pressure. The design process is iterative, to a point where an optimal control valve is selected to the process.



Equal Percentage Control

V-Port Seat to the downstream side, and round seat to the upstream side. (MOC: Super Duplex)



Segmented seat and a strainer installed inside the tail-pcs.

The static elements were built part of a strainer, with different pattern and number of holes which forces the flow line through the passage between the static elements in a labyrinth form. The strainer reduces the noise level, and forces a back-pressure at the downstream of the V-Port seat, subsequently gain a lower differential pressure over the dynamic control element.

The double plates strainer is threaded into the control valve tail-piece, in such a way that the valve face-to-face does not exceed the ASME B16.10 definition for 3" Class 300 face-to-face (282 mm).



Double plates strainer threaded into the control valve tail-piece.

Material of construction

Body casting – ASTM A995 Super Duplex CE3MN Grade 5A (PREN>40)

Ball, Seats, Stem and Strainer – ASTM A182 Super Duplex UNS S32750 Grade F53 (PREN>40)

Hydraulic calculation

Operating data				
	Maximum flow	Mean flow	Minimum flow	
t1	20.0	20.0	20.0	°C
t2	20.112	20.075	20.063	°C
p1	25.0	20.0	15.0	bar(g)
● p2	21.0	15.642	12.179	bar(g)
p2,end	10.5	10.5	10.5	bar(g)
Kv	✓ 49.984	✓ 33.517	✓ 23.802	m ³ /h
○ qm	99,935.0	69,938.0	39,956.0	kg/h
● qv	100.0	70.0	40.0	m ³ /h
Δpc	20.671	17.29	13.54	bar
Δp	4.0	4.3578	2.8211	bar
	<i>Turbulent flow</i>	<i>Turbulent flow</i>	<i>Turbulent flow</i>	
	✓ <i>Non-critical</i>	✓ <i>Non-critical</i>	✓ <i>Non-critical</i>	

P1 – Pressure at the valve inlet.

P2 – Pressure at the V-Port downstream

P2, end – Pressure at the valve outlet, downstream to the pressure breaker.

At the maximum flow condition, the pressure drop over the V-port is 4 bar, and 10.5 bar on the pressure breaker. The process Kv ranged between 23.8 m³/h and 49.9 m³/h. of non-Critical condition in all flow conditions.

Load-dependent values				
	Maximum flow	Mean flow	Minimum flow	
s/s100	64.064	55.314	48.198	%
Kv,tot	26.281	22.718	18.856	m ³ /h
u2	✓ 6.0924	✓ 4.2647	✓ 2.4368	m/s
LpAe	68.7	65.4	✓ 55.8	dB(A)
La,res	75.1	66.6	51.9	dB(A)
La,tot	✓ 76.5	✓ 68.6	55.7	dB(A)
P,tot	40.278	18.472	5.0	kW
Ri	✓ 0.0	✓ 0.0	✓ 0.0	-

Valve opening percentage spreads on a range of 48% to 64%. The calculated sound level at its maximum point is 76.5 dB(A).

Epilogue

Two control valves 3" size, flanged drilled to EN1092 PN64 and ANSI #300 F-t-F, made of Super duplex were supplied to a desalination plant. Each valve was built with a 3-phase, 400 VAC, 50Hz, electric actuator designed for control service.

The actuator designed with a minimum safety factor of 50% and operability of 1500 starts per hour.

Valves are in service since April 2022 to client full satisfaction.

