Optimizing Hydraulic Control Valves for Extreme Low Pressure

Solutions for Low Pressure – Key Points

Why it matters
Hydraulic control valves rely on pressure differentials to operate. When pressure is too low, standard valves may fail to open or close properly, risking system malfunction.

Common low-pressure scenarios
- Elevated tanks and reservoirs.
- Tank discharge valves with low water levels.
- Remote terminal points in large distribution systems.

Key solutions
- Downstream orifice to create back-pressure - simple, no power required.
- Low-pressure diaphragm (for use with a DOROT S100 valve) - retrofittable, cost-effective.
- External, pressurized media - the valve can be controlled by implementing one of the following solutions:
  - Spring removal – requires an external pressure source.
  - Spring-assisted (30NO) or VAC systems - for zero-pressure opening.
  - Double-chamber – for use where technical specifications require, or where there is a need for a fast reaction.
- Bladder tank - where pressure conditions are intermittent, higher pressure can be stored in a bladder tank for use at times when pressure drops, as an effective alternative to installing an external media source.

Selection criteria
- The appropriate solution for any given environment will depend on pressure availability, system complexity, and control requirements.
- Start with simple mechanical options before considering powered systems.
- For a quick selection guide, see page 9.

A Deeper Dive

1. Introduction

Hydraulic control valves (HCVs) operate by harnessing inline pressure as an energy source to manipulate the valve mechanism to open and close. Acting on the surface area of the internal mechanism, the pressure produces a force (following Pascal's Law: Force = Pressure × Area) that translates into a movement of the internal trim.

The operation of these valves relies on sufficient pressure differentials to generate the forces necessary to overcome resistive forces such as friction, the weight of the mechanism, spring force etc. In standard conditions, the line pressure is sufficient to operate the valve effectively. However, when system pressure falls below minimum thresholds, the standard valve configurations may not function properly, as the available force may not be sufficient to overcome internal resistance.

There are several scenarios in which low-pressure conditions may occur, for example at elevated installations, such as hilltop reservoirs, where static head is naturally low and the dynamic head is even lower, or at the discharge point of a tank, where only the hydrostatic pressure of the water level above the outlet point is available. Such conditions require specialized approaches to ensure reliable valve operation.

This document outlines various solutions for operating hydraulic control valves in such low-pressure conditions, their implementation requirements, and selection criteria.

2. Understanding Low Pressure Requirements

2.1. Definition of "Low" Pressure

Two critical pressure-related parameters affect valve operation:
• Minimum Operating Pressure: The absolute pressure required at the valve inlet to generate sufficient force to fully open the valve.
• Minimum Pressure Differential: The difference between upstream and downstream pressures needed to overcome internal resistance and close a fully-open valve.

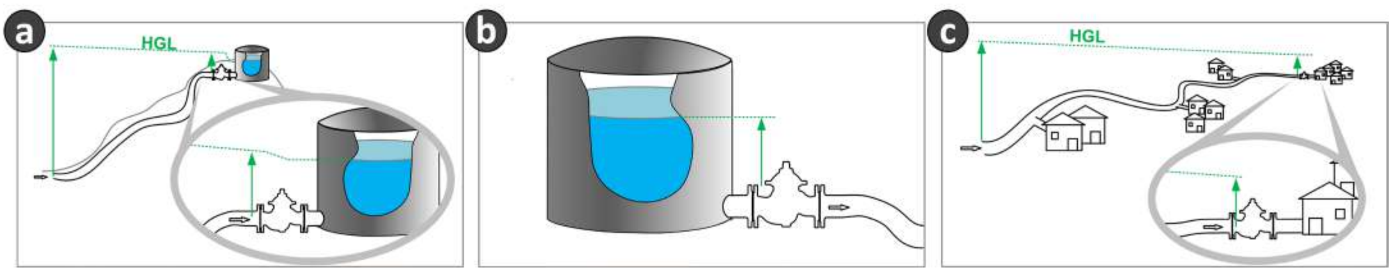
The table below compares minimum pressure requirements across DOROT valve models and typical competitor products:

	DOROT			Typical Competitor	
	S300	S500	S100	A	B
Minimum opening pressure	0.5 bar	0.5 bar	0.7-1.2 bar (varies by size)	0.5 bar	0.7 bar
Minimum pressure differential	0.5 bar	0.7 bar	0	0.2 bar	Assumed: 0.5 bar

When system pressure falls below these thresholds, valve functionality may be compromised.

2.2. Typical Low-Pressure Applications

Low-pressure conditions commonly arise in the following scenarios:
a) Tank and Reservoir Level Control - when level control valves are used to fill tanks or reservoirs situated at elevated locations, such as a hill top, the elevation difference naturally reduces available pressure head, while friction losses due to high demand through long supply lines further diminish inlet pressure.
b) Tank Discharge Applications - valves at the tank discharge point rely solely on the hydrostatic upstream pressure from the water level above them. For low-elevation tanks, or as the water level in the tank decreases, available pressure drops proportionally.
c) Remote Distribution Networks - terminal points in lengthy distribution networks may experience significant pressure reduction due to pipe friction losses.



* HGL: Hydraulic Grade Line - the line representing the available head (sum of the pressure and elevation) at any point in the system.

3. Understanding Low Pressure Requirements

3.1 Low-Pressure Solutions

Technical Principle

Adding a downstream orifice plate or similar restriction creates back pressure that increases the opening force by allowing downstream pressure to act on the valve's internal trim. Additionally, the restriction reduces flow rate, which minimizes pressure losses in the supply system and consequently increases the available inlet pressure.

Implementation Requirements

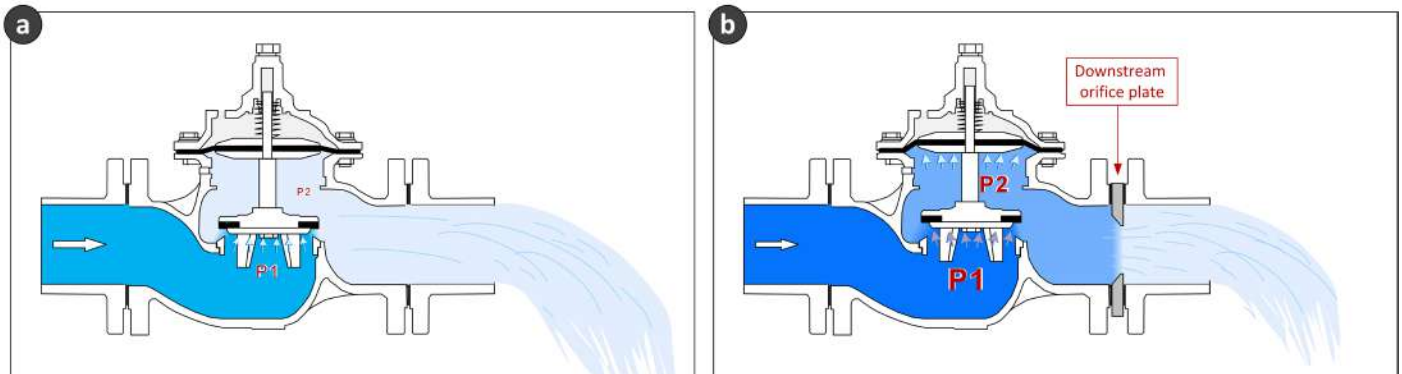
- Ensure the orifice plate is sized according to flow requirements (preferably one that produces >2mwc at the required flow rate).
- Install the orifice plate downstream of the valve. For tank/reservoir-filling valves, the best location is at the outlet of the pipe into the tank or reservoir. In other cases, the orifice plate can be located between the flanges on the downstream side of the valve.
- Verify sufficient clearance for maintenance access.

Benefits

- Simple implementation.
- Low cost (relative cost index: 2/5).
- Minimal maintenance requirements (complexity index: 1/5).
- No external power sources needed.

Notes

- This method increases the resistance, i.e adds pressure losses to the system, and reduces the maximum flow capacity under high demand.
- It is less effective in systems with widely varying flow requirements.



Without Orifice
No downstream orifice means downstream pressure is near zero, so no assistive force acts on the diaphragm (Force = P_2 × Diaphragm_Area, where $P_2 \approx 0$).
The valve opens only until the force of upstream pressure (Force = P_1 × Plug_Area) balances spring, weight, and friction.

With Orifice
The resistance of the orifice, increases downstream pressure (P_2), creating assistive opening-force on the bottom area of the diaphragm (Force = P_2 × Diaphragm_Area).
The valve opens fully when the combined forces from P_1 and P_2 overcome internal resistance.

3.2 Low-Pressure Diaphragm Solutions

For DOROT S100 valves, replacing the standard diaphragm with a low-pressure (LP) diaphragm can significantly reduce the minimum pressure required for proper operation.

Benefits

- Ideal for DOROT S100 valves (direct sealing diaphragm, weir type valves).
- Simple retrofit to existing installations of the same valve model.
- Cost-effective alternative to more complex solutions (relative cost index: 1/5).
- Low maintenance complexity (index: 1/5).

Notes

- Low-pressure (LP) diaphragms in valves that may experience moderate or high differential pressures are not recommended for regulation applications (e.g., pressure or flow control), as they can become unstable-exhibiting chattering and vibration under such conditions.
- The maximal operating pressure of a valve that has an LP diaphragm is lower than the standard configuration. (Please refer to DOROT S100 publications for technical specifications.)
- Ideally, the LP diaphragm should be combined with a downstream orifice (even if doing so produces a △P as low as 1 mwc), to achieve optimal performance.

Operating Pressures of DOROT S100 Diaphragms (pressure values in bar)

	Standard Diaphragm		LP* Diaphragm	
Valve Size	Min. Opening	Max. Pressure	Min. Opening	Max. Pressure
	1.2	16.0	0.5	10.0
25mm / 1"	1.2	16.0	0.5	5.0
40mm / 1½"	1.5	16.0	0.4	10.0
50mm / 2"	1.5	16.0	0.4	10.0
65mm / 2½"	1.2	16.0	0.4	10.0
80mm / 3"	1.2	16.0	0.4	10.0
100mm / 4"	2.0	16.0	0.5	10.0
150mm / 6"	0.2 (Super.LP*)			6.0 (Super.LP*)
200mm / 8"	0.7	16.0	0.2	10.0
250mm / 10"	0.7	16.0	0.2	5.0
300mm / 12" to 350mm / 14"	0.7	16.0	0.2	10.0
400mm / 16" to 600mm / 24"	1.0	25.0	0.2	10.0

* Note: LP = Low Pressure; Super.LP = Super Low-Pressure diaphragm option.

3.3 External Media Solutions

When line pressure is insufficient for valve operation, external pressurized media, such as compressed air or water, can be used to force open the valve. To use this option, the valve and/or the control-trim design needs to be modified to one of the following options:

3.3.1 Spring Removal

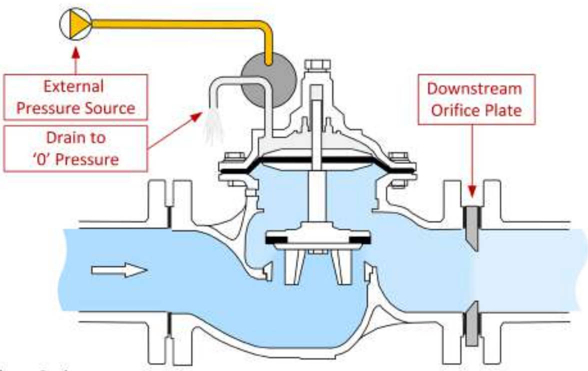
The spring is removed from the control chamber of a standard control valve, eliminating the downward spring force which resists the opening, thereby enabling full opening of the valve at lower pressures. External control pressure, somewhat higher than the inline pressure, must be applied to ensure valve closure in the absence of the closure-assisting spring.

Benefits

- Enables DOROT S300 and DOROT S500 valves to operate at pressures as low as 0.2 bar.
- Enables DOROT S100 valves with LP diaphragms to operate with inline pressure as low as 0.1 bar.
- Simple retrofit to existing installations.
- Cost-effective alternative to more complex solutions (relative cost index: 2/5).
- Low maintenance complexity of 2/5.

Notes

- External media pressure requirement: at least 0.5 bar higher than maximum inline pressure.
- For DOROT S100 valves, external pressure should not exceed inline pressure by more than 1.5 bar.
- The control-loop must vent the control-chamber to atmospheric pressure (use 3-way control).
- Ideally, the spring-removal solution should be combined with a downstream orifice (even if that produces a △P as low as 1 mwc), to achieve optimal performance.



Without Spring
In the standard valve, a spring opposes the opening force. Removing the spring increases the net opening force for a given inline pressure. A higher control pressure is then required to ensure valve closure in the absence of the spring's assistive force.

3.3.2 Spring-Assisted Opening (Model 30NO)

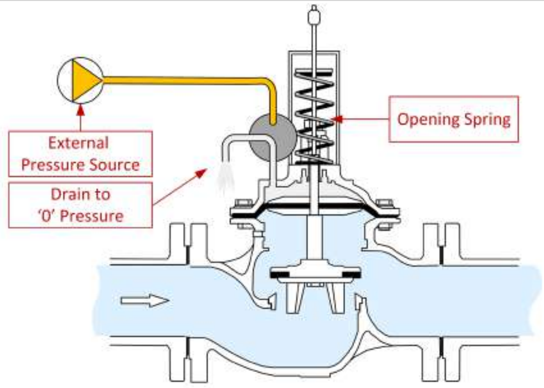
This single-chamber valve, is held in the open position by an external spring. The valve remains open unless actively commanded to close. Closure requires a high enough external pressure-source to overcome both the spring force and the internal opening force.

Benefits

- Normally-open configuration (fully-open even at zero inline pressure).
- Minimal internal dynamic sealing and high long-term reliability.
- Maintenance complexity index: 3/5.
- • Relative cost index: 4/5.

Notes

- The external control media is required to be at a pressure that is at least 0.8 bar higher than maximal inline pressure.
- An additional 50cm clearance is needed above the valve for spring assembly.



Spring-Assisted Opening
In this non-standard valve, a spring provides the opening force. Any inline pressure that exists helps the opening. A higher control pressure is then required to ensure valve closure opposing the spring and internal line-pressure's opening force.

3.3.3 VAC Control Loop Systems

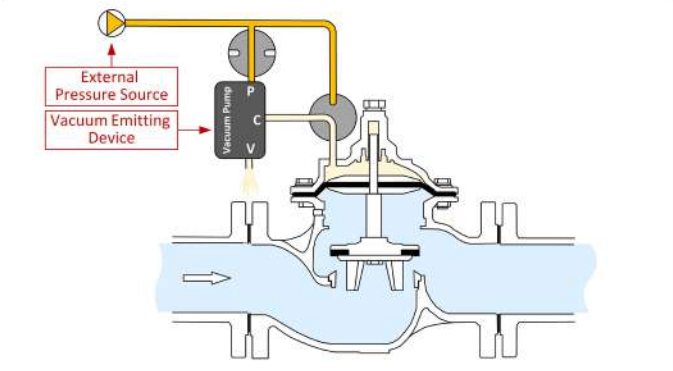
This single-chamber valve, is held in the open position by an external spring. The valve remains open unless actively commanded to close. Closure requires a high enough external pressure-source to overcome both the spring force and the internal opening force.

Benefits

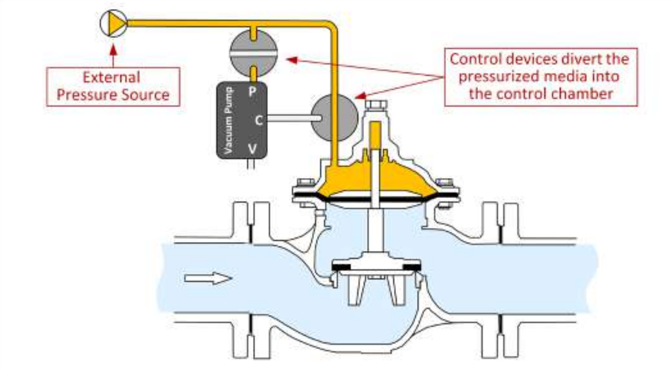
- A suction effect pulls the internal trim to the open position, even at 'zero' pressure.
- When controlled to close, the operation is reversed by admitting the control pressure into the control chamber.
- Applicable to virtually any valve type.
- Requires very little or no modification to the valve structure and design (spring is normally removed).
- In some cases, the system can be used for modulating/regulating functions.
- Relative cost index: 4/5.
- Maintenance complexity index: 3/5.

Notes

- This solution requires some expertise in control loop design to divert the pressure of the external media through the vacuum-emitting device or redirect it into the control chamber of the valve, to open and to close the control valve.
- The control loop design should account for sufficient pressure supply to drive the required sub-atmospheric pressure valve. In the case of DOROT S100 valves, the maximal closing pressure must be limited to P ≤ maximal inline pressure plus 1.5 bar. Example: if the maximal inline pressure is 2 bar, the control pressure must be 2 ≤ P ≤ 3.5 bar.
- In most cases, it is recommended to remove the internal spring. Here, the control pressure must be higher than the maximal inline pressure plus 0.5 bar. In the above example, this would be 2.5 ≤ P ≤ 3.5 bar.
- For DOROT S100 valves, it is recommended to use a low-pressure diaphragm.



VAC Operated to Open
Pressurized control media (water or compressed gas) flows through a pressure-operated vacuum-emitting device. The induces a sub-atmospheric pressure in the valve's control chamber, pulls the internal trim to a fully-open position.



VAC Operated to Close
The vacuum-emitting device is isolated and the pressurized control media (water or compressed gas) is diverted into the valve's control chamber. The control pressure pushes the internal trim to a drip-tight closure.

3.3.4 Double-Chamber Configurations with 4-Way Control

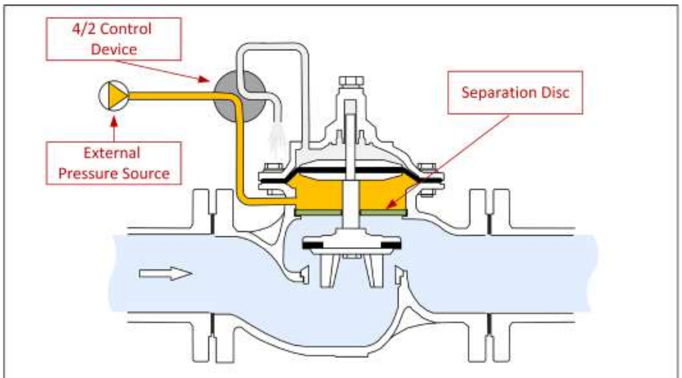
Here, a double-chamber version of the DOROT S300 valve is implemented, by inserting a separation disc between the diaphragm and the sealing plug. This forms a second control chamber below the diaphragm, into which external control pressure can be applied to force the internal trim upwards while the top control chamber is de-pressurized. Venting the lower control chamber and pressurizing the top one forces the valve into a drip-tight closed position.

Benefits

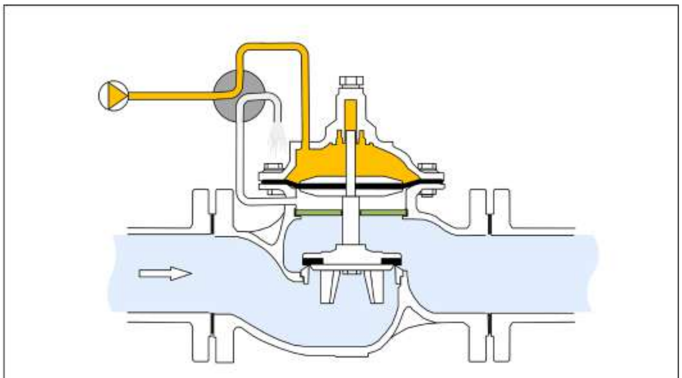
- Utilizes DOROT S300 models 30D, 31D, or 32D.
- A patented design enables the conversion of a standard single-chambered valve into a double-chambered design with a simple separation disc addition, requiring no other parts to be replaced.
- Fully-open position, even with zero inline pressure.
- Relative cost index: 5/5.
- Maintenance complexity index: 5/5.

Notes

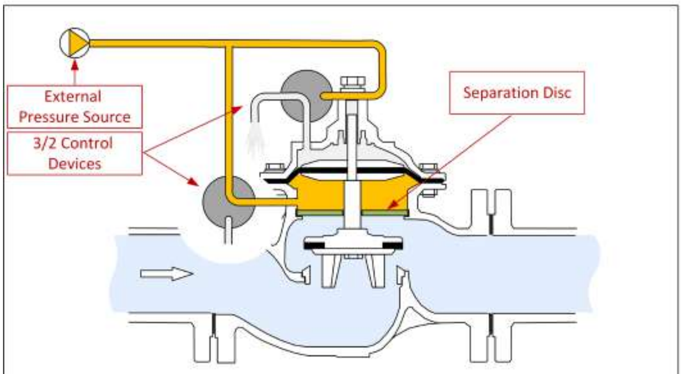
- Any double-chamber valve design of any make requires the shaft to move through internal dynamic seals. The additional friction and seal wear and tear reduces the reliability of the basic valve.
- Care should be taken to avoid water hammer due to the potentially rapid closure speed.
- Requires a 4/2 or dual 3/2 control devices. Optional control may be designed more simply, depending on site conditions.



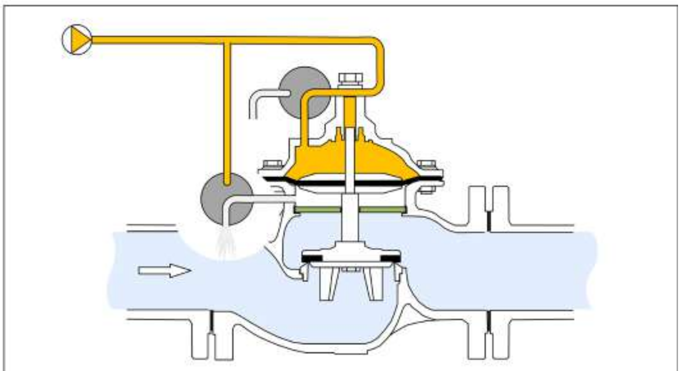
30D Operated to <u>Open</u> using a 4-way control-device
The top control chamber is vented while external control pressure is simultaneously applied to the bottom control chamber, forcing the diaphragm and internal trim upward to fully open the valve.



30D Operated to <u>Close</u> using a 4-way control-device
The bottom control chamber is vented while external control pressure is simultaneously applied to the top control chamber, forcing the diaphragm and internal trim downward to close the valve drip-tight.



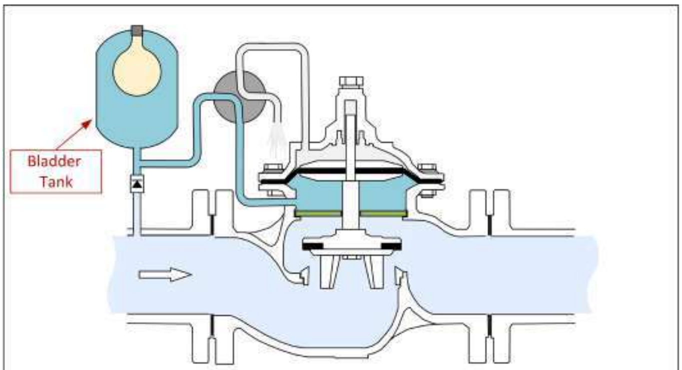
30D Operated to <u>Open</u> using a dual 3-way control-devices
The top control chamber is vented while external control pressure is simultaneously applied to the bottom control chamber, forcing the diaphragm and internal trim upward to fully open the valve.



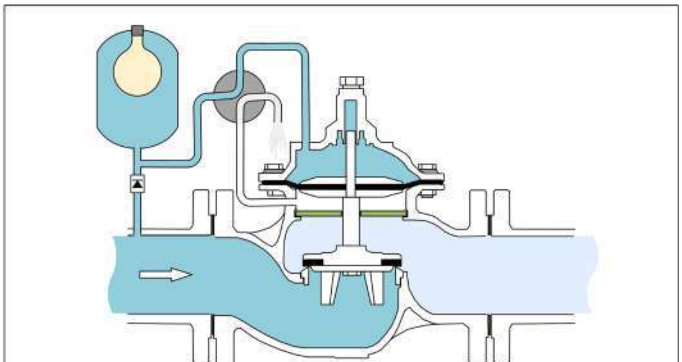
30D Operated to <u>Close</u> using a dual 3-way control-devices
The bottom control chamber is vented while external control pressure is simultaneously applied to the top control chamber, forcing the diaphragm and internal trim downward to close the valve drip-tight.

3.3.5 When External Pressurized Control Media is Unavailable – an Optional Solution

Where low-pressure conditions are intermittent, a bladder tank with a non-return valve can store higher pressure from the system during normal-pressure operation. This stored pressure can later be used to operate the valve when low-pressure conditions exist.



30D Operated with Pressure Accumulator to Open
The pressure stored in the bladder tank is used to open the valve. Even if the inline pressure drops as the valve begins to close, the pressure accumulated in the bladder tank forces the valve to a fully-open position.



30D Operated with Pressure Accumulator to Close
The pressure stored in the bladder tank (accumulated while the valve was previously closed) is used to initiate valve closure. When the valve begins to close, the inline pressure increases (e.g., due to reduced supply-line friction losses). This higher static pressure is stored in the bladder tank for future use.

4. Solution Selection Guide

4.1. Comparison Matrix

Solution	Relative Cost Index (1-5)	Maintenance Complexity Index (1-5)	Minimum Operating Pressure	External Media Required *	Footprint
Downstream Orifice	2	1	Opening pressure may be reduced by 0.2–0.3 bar compared to standard.	No	Minimal
LP Diaphragm (DOROT S100)	2	1	~0.3-0.5 bar (function of size)	No	None
Spring Removal	2	1	0.2 bar (DOROT S300/S500)		
0.1 bar (DOROT S100 w. LP Diaphragm)	Yes	None			
Spring-Assisted (30NO)	4	3	0 bar	Yes	+50cm above valve
VAC Control Loop	4	3	0 bar	Yes	Minimal
Double-Chamber (DOROT S300: 30D , 31D, 32D)	5	5	0 bar	Yes	Minimal
Bladder Tank System	3	2	Usable with 30D or LP diaphragm	To be used where external media is not available	Space for tank

(*) Note: External media system costs are not included in the above relative cost ratings, and may vary significantly depending on whether suitable pressure sources already exist on site.

4.2. Selection Methodology

Selection of the most appropriate low-pressure solution should follow these prioritized criteria:

1. **Performance requirements**: Select a solution that enables operation at pressures lower than the minimum expected at the valve inlet.
2. **Simplicity and reliability**: Preference should be given to simpler solutions that minimize potential points of failure.
3. **Cost efficiency**: Consider both initial implementation and long-term operational costs.
4. Compliance: Ensure that the solution meets customer-specifications and site requirements.

How to Choose the Right Solution

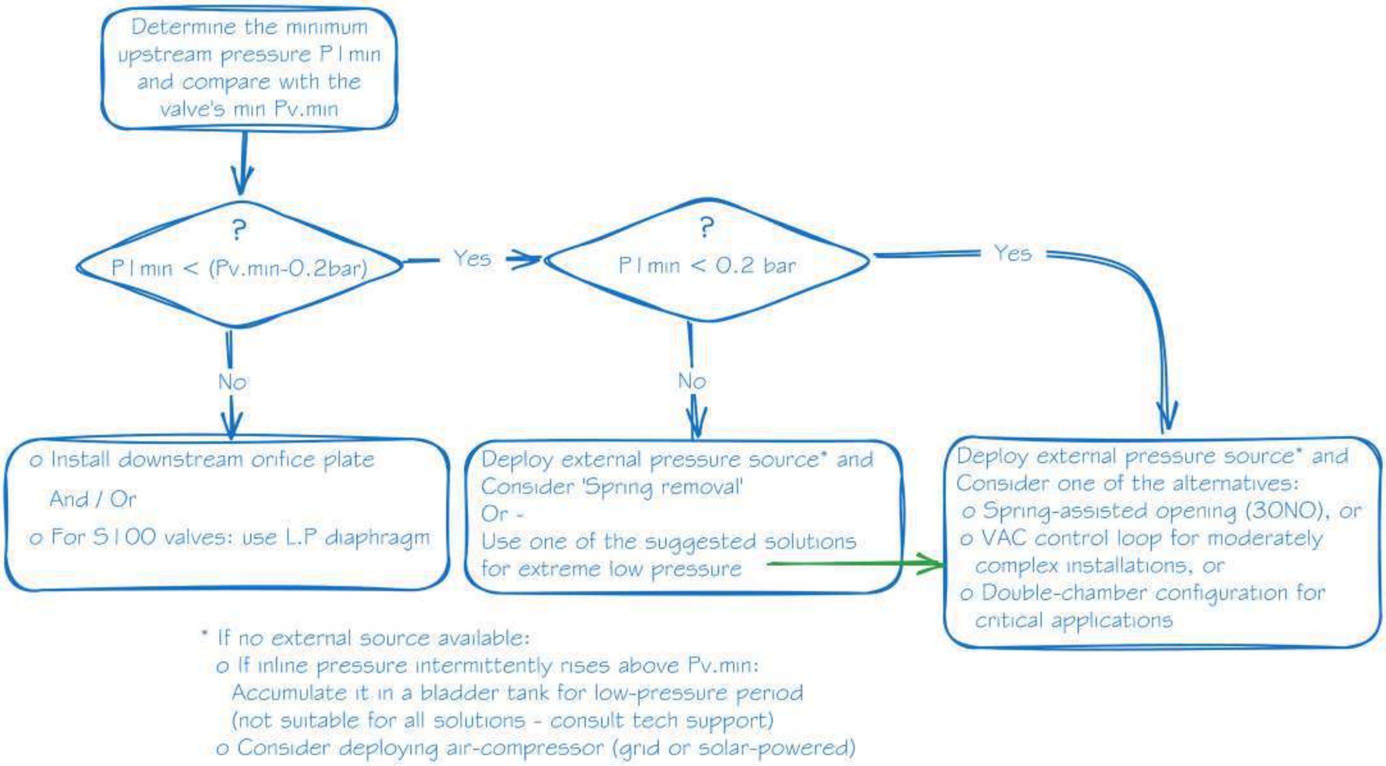
First, determine the minimum expected line pressure at the valve location. Then take the relevant course of action from the list below:

1. Pressure is only marginally below standard operating requirements, consider:
- Adding a downstream orifice plate (the simplest solution), and/or
- Installing a L.P diaphragm for DOROT S100 valves

2. Pressure is significantly below standard requirements, consider:
- Spring removal with an external pressure source (if available), or
- Spring-assisted opening (30NO), or
- VAC control loop (for moderately complex installations).

3. Zero or near-zero pressure applications, implement:
- Spring-assisted opening (30NO), or
- VAC control loop for moderately complex installations, or
- Double-chamber configuration (for critical applications).

4. Pressure drops below minimal value intermittently - consider deploying a bladder tank as a temporary pressure-accumulator for use during low-pressure conditions.



Important Note: Compare actual and designed pressure conditions to the specific valve in use. It is malpractice to require special and non-standard low-pressure valve configuration when simpler solutions may suffice. Always consult Aquestia technical support when conditions appear to require complex solutions, as DOROT valves often offer wider operating ranges than competitor products

5. Case Studies

Filtration Tank Drainage Control

Challenge
A set of media filtration tanks required drainage as part of its flushing sequence. When drained, the available line pressure reduces to zero. The control valve needs to keep the drainage fully open under these conditions, and close drip tight when regular filtration process is active.

Solution
An electrically actuated DOROT S300 valve model 30NO-EL with spring-assisted opening was installed, using the higher upstream water supply from the existing facility as the control pressure.

Outcome
Consistent control was achieved, with minimal additional infrastructure investment.

Media Tank Level Control in a Municipal WTP

Challenge
Flow needed to be regulated as a function of level at the discharge of open media filtration tanks. The low head in the supply tanks was not enough to force the valve to open. The flow had to be controlled so that the level in the tanks would be kept within a narrow range of just 3m ±5cm above the valve's location.

Solution
18 units of DOROT S300 valves were installed - one per tank – with the springs removed. The model 30-EC valves supplied are electronically controlled by a specialized Aquestia ConDor controller, and are operated using external pneumatic pressure.

Outcome
Reliable and accurate operation was achieved throughout operation cycles, despite variations in tank inflow.

Conclusion
Hydraulic control valves can be successfully deployed in low-pressure environments, with appropriate adaptation. The range of solutions presented in this guide allows for customized approaches based on site conditions, available resources, and operational requirements.

Aquestia valves offer superior low-pressure capabilities compared to the market benchmark, with the DOROT S300 and DOROT S500 series operable at pressures as low as 0.2 bar with simple modifications, and effectively zero pressure through use of appropriate control systems.

Contact the Aquestia team for application-specific technical support, at https://www.aquestia.com/contact-us/