Planning Information for Pressure Booster Systems

Contents

Foreword

This brochure is intended for all involved with the planning, design and service of pressure booster systems (PBS).
Pressure booster systems are often found in modern office, residential and hotel buildings for general water provision and fire-fighting purposes.
Considering the various PBS design concepts such as

- cascade control (Hyamat K)
- variable-speed control for one pump (Hyamat V)
- variable-speed control for all pumps (Hya-Eco VP, Hyamat VP)

it is particularly important to select the right PBS concept for the specific project at the planning stage.
This brochure offers design guidance for pressure booster systems ensuring easy installation and uninterrupted water supply.
KSB justifies its status as a full-line supplier of pumps for building services by constantly developing its range of products according to the requirements of its customers.

Pressure booster systems have the following typical applications:

- Residential buildings
- Office buildings
- Hotels
- Department stores
- Clinics/hospitals
- Commercial and industrial plants
- Irrigation/spray irrigation
- Rainwater harvesting
- Small-scale domestic water supply units

A pressure booster system is required when the minimum pressure supplied by the local water provider is insufficient.
Pressure booster systems and their ancillary components must be designed and operated in such a way that neither the public water supply nor any other consumer units are interfered with – any degradation in the quality of drinking water must likewise be ruled out.

The regulations referred to in the brochure are based upon regulations in force in Germany at the time of writing.
To ensure compliance, reference should be made to local and current regulations.

1. Pressure booster systems for drinking water, fundamentals

Drinking water is a foodstuff, and therefore subject to strict legal regulations.
The essential requirements for drinking water quality are laid down in:
DIN 2000 Centralized drinking water supply
DIN 2001 Private and individual drinking water supply
IfSG Protection Against Infection Act
LMBG Foodstuffs and Commodities Act
TrinkwV Drinking Water Ordinance

The regulations for adequate water provision to consumers which are applicable to units situated in buildings and property are as follows:
AVB Wasser V General Water Supply Terms Ordinance
DIN 1988 Technical rules for drinking water installations
DIN EN 805 Water supply – Requirements for units and components outside buildings
DIN EN 806 Specifications for installations inside buildings conveying water for human consumption (Public drinking water supply, for which KSB also offers a comprehensive pump programme, is not dealt with here.)
In terms of the origins of drinking water, a difference must be made between centralised and/or local individual water supply units. The following discussion deals with both possible applications.
In all cases where the minimum supplied water pressure (SPLN) does not enable an unconditional supply to all extraction points, i.e.:

$$SPLN < \Delta p_{geo} + p_{min,flow} + \Sigma(R \cdot l + Z) + \Delta p_{wm} + \Delta p_{ap} \ [bar] \quad (1)$$

the deployment of a PBS is necessary.

Key:
SPLN = Minimum pressure available at the local water provider's hand-over point
Δp_{geo} = Static pressure loss
$p_{min,flow}$ = Minimum flow pressure at the least hydraulically favourable extraction point
$\Sigma(R \cdot l + Z)$ = Pipe friction and other individual losses
Δp_{wm} = Water meter pressure loss
Δp_{ap} = Apparatus pressure loss

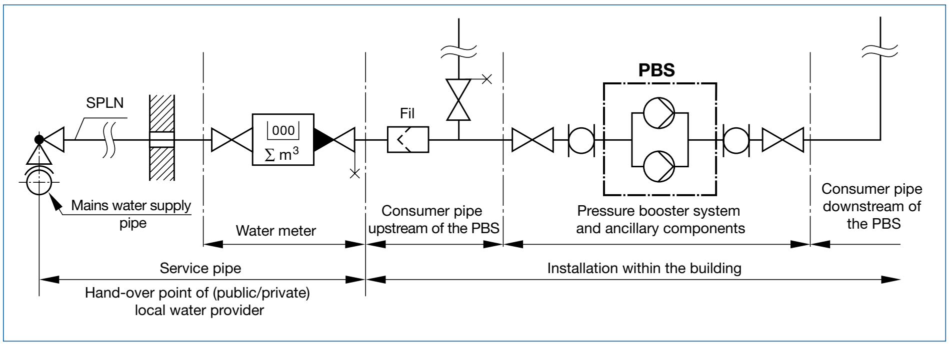


Fig. 1: Flow diagram, pressure booster system (PBS): direct connection

The configuration and function of the PBS are described in DIN 1988-500. This standard applies to centralised and individual water provision systems. It prescribes, amongst other things, built-in stand-by pumps suitable for immediate operation for the transportation of drinking water. Permanent operating reliability is required according to DIN EN 806 Part 2.
Omitting the installation of a stand-by pump alongside a PBS for drinking water supply may be justified when the breakdown of a PBS does not seriously affect residents' requirements, e.g. in the case of weekend houses. Here, a PBS may be installed and operated without a stand-by pump.

Permission must however always be sought from the responsible Water Authority.

As a rule, the PBS (Fig. 1) must be integrated in such a way that adverse hydraulic effects on the public water supply network are minimised. This is facilitated through the selection of suitable components, which in turn relies on knowledge of inlet pressure fluctuation and the maximum connection capacity of the service pipe together with an examination of the flow velocity in the house service pipe.

Anti-vibration mounting of the PBS (e.g. expansion joints with length limiters, anti-vibration mounts) markedly contributes to a reduction in solid-borne sound transmission.

Fluctuating inlet pressures

Fluctuations in the supply pressure have a considerable effect on the operating characteristics of the PBS. These range from a dramatic rise in the number of pump start-ups (excessive on/off) to increased levels of discharge pressure fluctuation.
In certain cases, the rated pressure of the system components can be exceeded. This leads in all cases to pressure surges and consequent wear on all associated parts. If the inlet pressure fluctuations lie beyond +0.3/-0.2 bar the following remedial action is possible and may be necessary:

- Pressure controller/reducer upstream of the PBS (type series Hyamat K)
- PBSs with variable speed base load pump (type series Hyamat V)
- For major inlet pressure fluctuations: PBS with speed control on all pumps (type series Hyamat VP)

Distribution of flow volume

Decisive for sizing the individual pumps of a PBS is the relationship between the PBS' design flow rate and the maximum connection capacity of the service pipe.
Particularly in the case of PBSs with cascade control (Hyamat K range), it is important to ensure that the velocity change in the service pipe does not exceed 0.15 m/s when the individual pumps are started and stopped.
Possible remedial measures:

- Incorporating membrane-type accumulators on the inlet side
- Indirect connection via break tank with type AB air gap to DIN EN 1717
- PBS with one variable speed base load pump (Hyamat V)
- PBS with speed control on all pumps (Hyamat VP)

Demand fluctuations

Sudden changes in demand downstream of a pressure booster system can lead to pressure surges/noises in the consumer pipe.
Pressure surges can sometimes trigger safety devices or even cause damage to apparatus or lead to burst pipes and increased wear on pumps, valves, and piping.
Reduction in the highly dynamic levels of consumption is the most effective remedy (e.g. through the replacement of solenoid valves with motor-operated valves).
Just as important is the adequate sizing of the pump in relation to its nominal flow rate.

$$\Delta Q_{Pu} > \Delta Q_{max,dyn} \quad [m^3/h]$$

Key:

$\Delta Q_{max,dyn}$ = Change of flow rate of a highly dynamic consumer

ΔQ_{Pu} = Change of nominal flow rate of each pump

In addition, membrane-type accumulators fitted directly upstream of dynamic consumers reduce the aforementioned effects.
These must be of the direct-flow type. Pressure booster systems incorporating continuously variable speed control on all pumps (Hyamat VP) can respond better to high consumer fluctuations due to the synchronised operating mode of the pumps.

Noises

Modern pressure booster systems are expected to operate with a minimum of noise.
Operating noise (airborne sound) is mainly generated by the electric motor fans (see Hyamat V/K)
Acoustic cladding can considerably reduce noise emission.

In operation, pumps create vibrations, flow noise and solid-borne noise. The provision of adequate sound insulation of the piping from the pressure booster system is therefore of primary importance, and every PBS must be separated from the piping and structure surrounding it by suitable sound insulation (i.e. expansion joints with length limiters, anti-vibration mounting using rubber-bonded metal elements).
Expansion joints must be easily replaceable. With regard to flow noises, a moderate flow velocity in piping, apparatus and pipe fittings should be ensured.

Hygiene

In view of hygiene requirements, a distinction should be made between systems dealing with drinking water and those handling service water.

Drinking water:

According to the Drinking Water Ordinance (excerpt) drinking water is “water for human consumption and use."
Drinking water is to be understood as water in its original condition or after treatment which is used for drinking, cooking, preparing meals and beverages, for personal hygiene and for the cleaning of objects which are destined to be used with food and those which will be in contact with the human body for any period of time.

Service water:
"Water to serve commercial, industrial, agricultural or similar purposes with varying levels of quality which can include drinking water." When operating a PBS it is important that water quality is not impaired. An essential requirement is: Operation of the PBS and its associated components should not allow stagnation. As a closed system rules out any health risk resulting from external contamination of drinking water, systems with direct connection should be preferred to those with indirect connection.

The following measures reduce the chance of water stagnating:
- Direct-flow membrane-type accumulators (dual connection)
- Automatic switchover between all pumps
- Smallest possible dead spaces in components handling water
- Forced flushing of pipe sections where stagnation could occur

A further aspect of hygiene is the temperature of the fluid. The following factors can lead to a temperature increase of the water inside PBS components – break tank, pumps, pipe components and membrane-type accumulators:

- Increased ambient temperature at the site of installation
- Long periods of minimum consumption (office buildings at the weekend).
- Temperature increase due to the pumping operation (heat losses).

These factors can be eliminated through the selection of an appropriate location and the prompt stopping of pumps at minimum/zero consumption.
The materials and auxiliary equipment used in the construction of a PBS must be in line with the relevant regulations regarding the compatibility with drinking water (as stipulated, for example, by the German LMBG, KTW, DVGW regulations).
Cleanliness during construction, transport, installation and commissioning of a PBS and its associated components, together with the final flushing of the entire system according to DIN 1988-200 or the ZVSHK technical instruction leaflet, are mandatory requirements for water according to DIN 2000 which is:

- Absolutely hygienic
- Cool
- Neutral in terms of taste and odour
- Clear
- Free from foreign substances

2. Calculation example: Drinking water supply system for a residential building

The calculation is performed on the basis of DIN 1988-300.

The assumptions are as follows: High-rise residential building with basement, ground floor and a further 14 floors, see Fig. 3, page 11.

75 identically equipped living units have to be supplied with drinking water.
The living units (LU) are equipped as follows:

Per living unit (LU):
2 toilets with cisterns, DN 15
1 bath tub, DN 15*
1 shower, DN 15*
2 sink units, DN 15
1 washing machine, DN 15
1 dishwasher, DN 15
1 kitchen sink, DN 15

*As per DIN 1988-300, only one extraction point is taken into account if a living unit comprises both bath tub and shower.

The local water provider provides the following information for a drinking water installation:
SPLN = 2.9 bar
$p_{max,V}$ = 4.8 bar
Nom. diameter of service pipe: DN 50
Direct connection of PBS
Turbine flowmeter

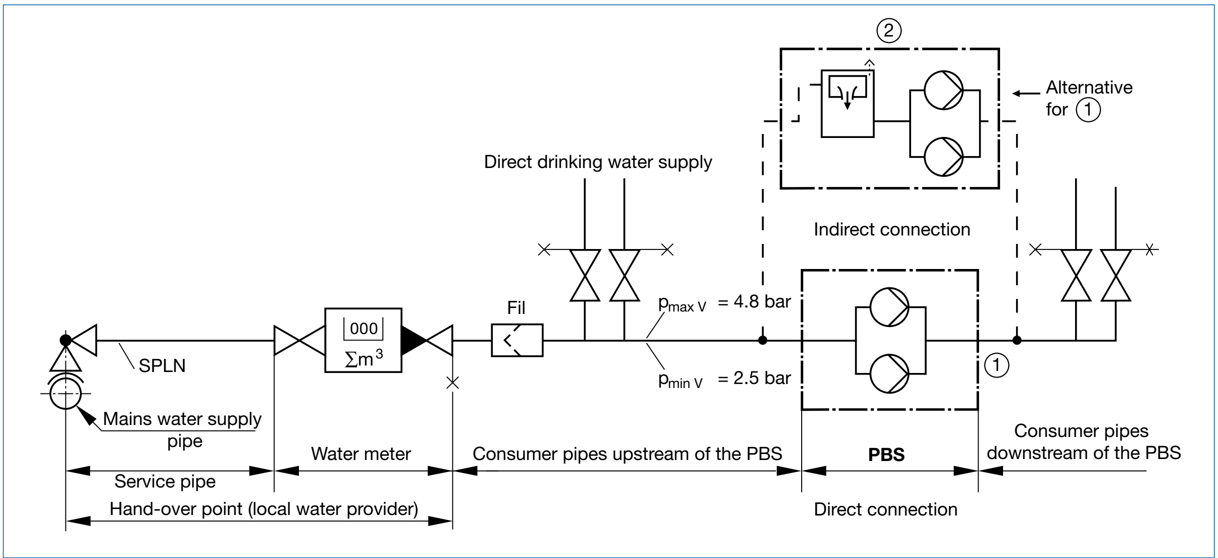


Fig. 2: PBS flow diagram with pressure values

2.1 Calculating the flow rate of a pressure booster system

The required total flow ΣV_{cal} should as a rule be established on the basis of the specifications made by the taps, showerheads and fittings manufacturers.
If in a specific case such information is not available, the total flow can be calculated by means of Worksheet No. 1, page 39.

According to this Worksheet ΣV_{cal} is as follows:
Calculation flow rates
2 toilets 0.26 l/s
1 bath tub 0.00 l/s
1 shower 0.30 l/s
2 sink units 0.28 l/s
1 bidet 0.14 l/s
1 washing machine 0.15 l/s
1 dishwasher 0.07 l/s
1 kitchen sink 0.14 l/s

This gives a required flow per living unit of: 1.20 l/s
The total calculated flow for 75 living units is:

$$\Sigma\dot{V}_{cal} = 75 \cdot 1.20 \text{ l/s} = 90 \text{ l/s}$$

In practice, total flow is never required.
For the determination of a realistic peak flow $\dot{V}_{peak}$ the following equation to DIN 1988-300 is applied:

$$\dot{V}_{peak} = a \cdot (\Sigma\dot{V}_{cal})^b - c \qquad (2)$$

Key:
$\dot{V}_{peak}$ is the peak flow rate
$\dot{V}_{cal}$ is the calculation flow rate
a, b, c represent the constants as shown in Worksheet 2, page 40.

The resultant peak flow is:
$\dot{V}_{peak} = 2.54$ l/s

The PBS to be selected must be capable of handling at least this peak flow. The following equation is therefore applied:

$$\dot{V}_{peak} \mathrel{\hat{=}} \dot{V}_{max,P} \mathrel{\hat{=}} Q_D \; 2.54 \text{ l/s} \approx 9.14 \text{ m}^3\text{/h}$$

In pumping technology, the peak flow (V_{peak}) corresponds to the design flow rate of the PBS (Q_D).

2.2 Calculating the minimum, maximum and inlet pressure fluctuations upstream of the PBS (p_{inl})

Minimum pressure:
This level is reached under min. supply pressure SPLN and simultaneous max. water consumption V_{peak} conditions. This requires that the dynamic pressure losses in the installation between hand-over point (local water provider) and PBS inlet be taken into account.

Pipe friction and other individual losses in the house service pipe

$\Delta p_{HSP} = 0.2$ bar

Pressure loss calculation - Water meter

$$\Delta p_{wm} = \left(\frac{\dot{V}_S}{\dot{V}_{max}}\right)^2 \cdot \Delta p \qquad (3)$$

$$\Delta p_{wm} = \left(\frac{9.14}{20}\right)^2 \cdot 1000 \frac{1}{1000} \text{ bar}$$

$$= 0.21 \text{ bar}$$

(Turbine flowmeter, vertical, DN 50, see **Worksheet** 3, p. 41)

Pressure loss calculation - Filter

$$\Delta p_{ap} = \left(\frac{\dot{V}_S}{\dot{V}_{max}}\right)^2 \cdot \Delta p \qquad (4)$$

$$\Delta p_{ap} = \left(\frac{9.14}{20}\right)^2 \cdot 200 \frac{1}{1000} \text{ bar}$$

$$= 0.04 \text{ bar}$$

(Filter: nom. throughflow 30 m³/h, see **Worksheet 4**, p. 42)

$$p_{inl,min} = SPLN - \Delta p_{HSP} - \Delta p_{wm} - \Delta p_{ap} \quad [\text{bar}] \qquad (5)$$

Result:

$p_{inl,min} = 2.9 - 0.2 - 0.21 - 0.04$
$= 2.45$ bar
$p_{inl,min} \approx 2.5$ bar
$p_{inl,max} = 4.8$ bar
$\Delta p_{inl} = 4.8 - 2.5 = 2.3$ bar

The PBS must be able to operate reliably with an inlet pressure fluctuation of $\Delta p_{inl} = 2.3$ bar.

The inlet pressure p_{inl} upstream of the PBS fluctuates to a greater extent than the supply pressure at the hand-over point (local water provider). Therefore, it must be possible to operate the PBS with a supply pressure fluctuation Δp_{inl}. This must be examined for each specific unit and, if necessary, appropriate measures should be taken to properly protect the system (e.g. pressure reducers).

Maximum pressure:
This level is reached under maximum supply pressure $p_{max,V}$ and simultaneous minimum water consumption conditions.

The dynamic pressure losses in the supply-side installation can be disregarded.

$$p_{inl,max} = p_{max,V} \quad [\text{bar}] \qquad (6)$$

2.3 Calculating the number of floors which do not require a PBS

$$N_{\text{without PBS}} \leq \frac{p_{\text{inl,min}} - p_{\text{flow}} - \Delta p_{\text{dyn}}}{\Delta p_{\text{fl}}} \quad (7)$$

$$N_{\text{without PBS}} \leq \frac{2.45 - 1.0 - 0.2}{0.3}$$

$$N_{\text{without PBS}} = \quad 4.16$$

Rounded down:

$N_{\text{without PBS}} = 4$

Counting from the branch (upstream of the PBS inlet pipe), the first 4 floors (ground floor, 1st, 2nd and 3rd floor) can be supplied directly, see Fig.3. Water supply by means of a PBS is required from the 4th floor, see Fig. 3.

Key:

$N_{\text{without PBS}}$ = Number of floors which can be supplied without PBS

$p_{\text{inl,min}}$ = Minimum pressure available upstream of the PBS

p_{flow} = Flow pressure at consumer

Δp_{dyn} = Dynamic pressure difference

Δp_{fl} = Pressure loss per floor

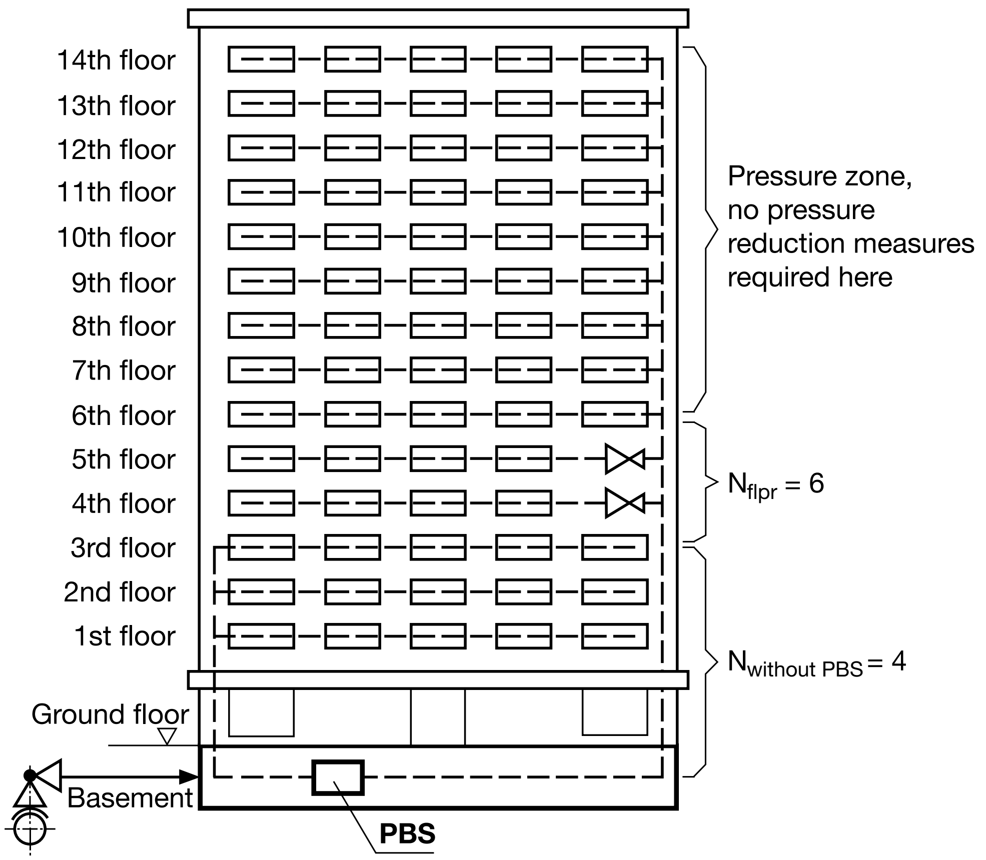


Fig. 3: Diagram depicting pressure zones

Calculating the required pressure downstream of the PBS ($p_{discharge}$)

Calculation example:
The residential building is provided with 75 identical living units.
All floors – basement, ground floor and a further 14 floors – have a floor height of 3 m.

$$p_{discharge} = \Delta p_{geo} + \Sigma(\Delta p_R + \Delta p_E) + p_{min,flow} + \Delta p_{ap} \quad [bar] \quad (8)$$

Calculation procedure:
The static head loss is calculated on the basis of the number of floors (N) and the floor height (Hfl).

$$\Delta p_{geo} = \frac{N \cdot H_{fl}}{10} \quad [bar] \quad (9)$$

see Appendix, **Worksheet 5**, p. 43

$$\Delta p_{geo} = \frac{15 \cdot 3}{10} = 4.5 \text{ bar}$$

The measured pipe length from the PBS to the least hydraulically favourable extraction point is approx. 70 m.
(Exact calculation acc. to DIN 1988-300)

(Estimation, see Appendix, **Worksheet 4**, p. 42)

$\Delta p_{frict} + \Delta p_{indiv} \approx 15$ mbar/m

$$\Sigma(\Delta p_{frict} + \Delta p_{indiv}) = \frac{70 \cdot 15}{1000} = 1.05 \text{ bar}$$

The tap requiring the highest pressure determines the required minimum flow pressure ($p_{min,flow}$).

$p_{min,flow} = 1.0$ bar
(see Appendix, **Worksheet 1**, p. 39)

$\Delta p_{ap} = 0$ (assumption: no further apparatuses built into piping)

Above values inserted into the formula:

$$p_{discharge} = 4.5 + 1.05 + 1.0 + 0 = 6.55 \text{ bar} \approx 6.6 \text{ bar}$$

Key:
$p_{discharge}$ = Required pressure downstream of the PBS
Δp_{geo} = Pressure loss from static head difference
$\Sigma(\Delta p_{frict} + \Delta p_{indiv})$ = Pipe friction and other individual losses downstream of the PBS
Δp_{wm} = Water meter pressure loss
$p_{min,flow}$ = Minimum flow pressure at consumer
Δp_{ap} = Apparatus pressure loss (e.g. individual water meter)
N = Number of floors
H_{fl} = Floor height

2.5 Calculating the discharge head of the PBS

In the case of direct PBS connection, the inlet pressure p_{inl} can generally be used.
The following applies to the calculation of the pump discharge head H:

$$H = (p_{discharge} - p_{inl,min}) \cdot 10 \ \ [m] \qquad (10)$$

Key:

H = Pump head
$p_{discharge}$ = Required pressure downstream of the PBS
$p_{inl,min}$ = Minimum pressure available upstream of the PBS

The minimum permissible inlet pressure $p_{inl,min}$ (or the inlet pressure fluctuation) depends on the PBS control mode:

- For cascade controlled PBSs (Hyamat K) installing a pressure reducer upstream of the PBS is often essential. This is assumed for our example. The overall pressure reduction achieved by the pressure reducer is $\Delta p_{pressred}$ = 0.7 bar.

Above values inserted into the formula (10):

$$H = [6.6 - (2.5 - 0.7)] \cdot 10 = 48 \text{ m}$$

- For variable speed PBSs (Hyamat V, Hyamat VP) installing a pressure reducer on the inlet pressure side is normally not required.*)

Above values inserted into the formula (10):

$$H = (6.6 - 2.5) \cdot 10 = 41 \text{ m}$$

2.6 Calculating the number of floors which require pressure reducers to protect the consumers

Assuming a constant supply pressure downstream of the PBS of $p_{discharge} \approx 6.6$ bar, a rough check of protective measures required can be made as follows. **The maximum permissible static pressure in residential buildings is max. 5.0 bar** (safety valves, noises, toilet cisterns). Since this maximum pressure of 5.0 bar must not be exceeded and the highest static pressure level will be reached at zero consumption ($Q \approx 0$), the dynamic pressure losses will be $\Sigma(\Delta p_{frict}+\Delta p_{indiv}) = 0$. In order to find out up to which floor the consumers have to be protected by means of pressure reducers against a pressure of ≥ 5.0 bar, the following calculation can be applied:

$$N_{flpr} \geq \frac{p_{discharge} - p_{max,flow}}{\Delta p_{fl}} \qquad (11)$$

$$N_{flpr} \geq \frac{6.6 - 5.0}{0.3} = 5.3 \text{ bar}$$

(This value must be rounded up to 6.)

At least the first 6 floors have to be protected with pressure reducers installed in the consumer pipes downstream of the PBS. In this case, this applies to floors 4 and 5, since the lower floors are supplied directly, cf. Fig. 3, page 11.

This consideration only applies to pressure booster systems with a constant, variable-speed controlled discharge pressure.

Key:

N_{flpr} = Number of floors which have to be protected against inadmissible pressures by means of pressure reducers
$p_{discharge}$ = Required pressure downstream of the PBS
$p_{max,flow}$ = Maximum permissible flow pressure at consumer
Δp_{fl} = Pressure loss per floor

*) *Whether this approach is hydraulically permissible must, however, be checked by means of the pump's characteristic curve.*

3. Choosing the correct PBS variant (configuration)

The following examples present the different control modes.

$Q \quad = 24\ m^3/h$
$\Delta p_{geo} \quad = 3.3$ bar
$\Sigma(\Delta p_{frict}+\Delta p_{indiv}) = 1,1$ bar
$p_{min\ flow} = 1.0$ bar
$p_{min,V} \quad = 2.2$ bar
$p_{max,V} \quad = 3.5$ bar

3.1 PBS with cascade control (Hyamat K)

Features

- Pumps are started/stopped as a function of pressure
- Pumps run at full speed
- Auto-changeover of pumps
- Discharge pressure fluctuates by min. $(p_{co} - p_{ci})$ and by max. $(p_0 - p_{ci}) + \Delta p_{inl}$
- Excessive on/off ("hunting") occurs when the water demand falls below a min. capacity Q_{min} (p_{co})
- The range of excessive on/off operation is enlarged with increasing p_{inl} (inlet pressure). This is particularly noticeable in the case of pumps with fewer stages (flat pump curve)
- In the case of inlet pressure fluctuations, potential use of the inlet pressure is limited
- Therefore, upstream pressure reducers are frequently required
- Adverse hydraulic impact on the mains supply network is relatively high

3.1.1 Calculating the required pressure downstream of the PBS ($p_{discharge}$)

(assumed values)

$$p_{discharge} = \Delta p_{geo} + \Sigma(\Delta p_{frict}+\Delta p_{indiv}) + p_{min,flow} \ \text{[bar]} \qquad (12)$$

$p_{discharge} \ = 3.3 \ + 1.1 \ + \ 1.0$
$p_{discharge} \ = \ 5.4$ bar

The discharge pressure ($p_{discharge}$) required of a PBS with cascade control is the cut-in pressure (p_{ci}).
Depending on the design, the discharge pressure can rise up to the value
$p_0 = p_{inl} + H_0 / 10$.
This increase in pressure always depends on the type of pumps selected (flat/steep characteristic curve).
According to the local water provider, the supply pressure at the hand-over point may vary between a minimum value of $p_{min,V} = 2.2$ bar and a maximum value of $p_{max,V} = 3.5$ bar. As the inlet pressure fluctuations are too high for cascade control, it is necessary to install a pressure reducer. Due to the pressure reduction of approx. 0.7 bar achieved by the pressure reducer, the available inlet pressure is lowered to $p_{inl} = 1.5$ bar.

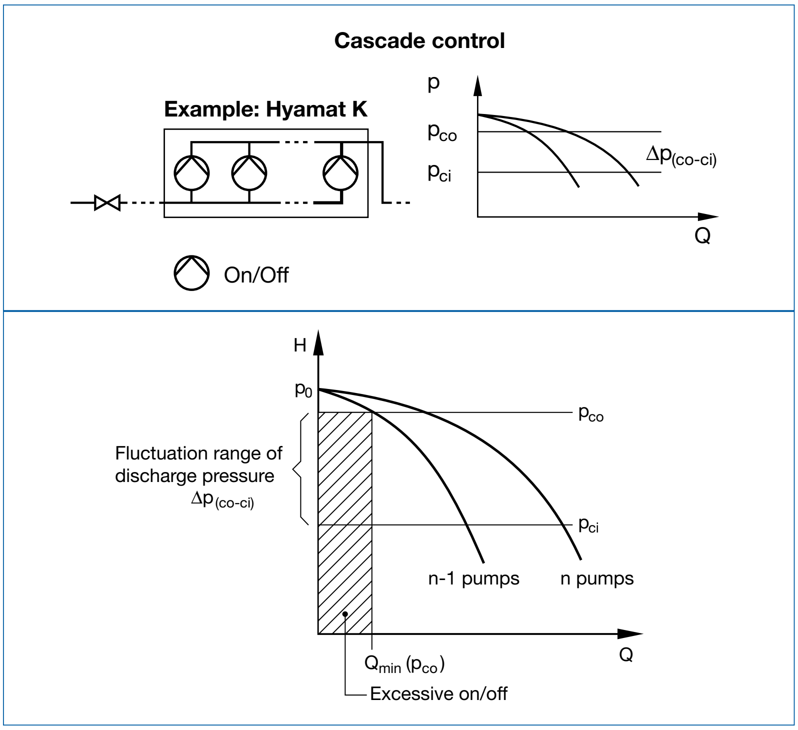


Fig. 4: Performance chart of a PBS with cascade control (type series: Hyamat K)

The pump's discharge head is therefore established as follows:

$$H = (p_{discharge} - p_{inl}) \cdot 10 \text{ [m]} \quad (13)$$

$H = (5{,}4 - 1{,}5) \cdot 10$

$H = 39$ m (Bild 5)

Key:

$p_{discharge}$ = Required pressure downstream of the PBS

Δp_{geo} = Static pressure loss

$\Sigma(\Delta p_{frict}+\Delta p_{indiv})$ = Pipe friction and other individual losses

$p_{min,flow}$ = Minimum flow pressure at consumer

H = Pump discharge head

p_{inl} = Available pressure upstream of the PBS

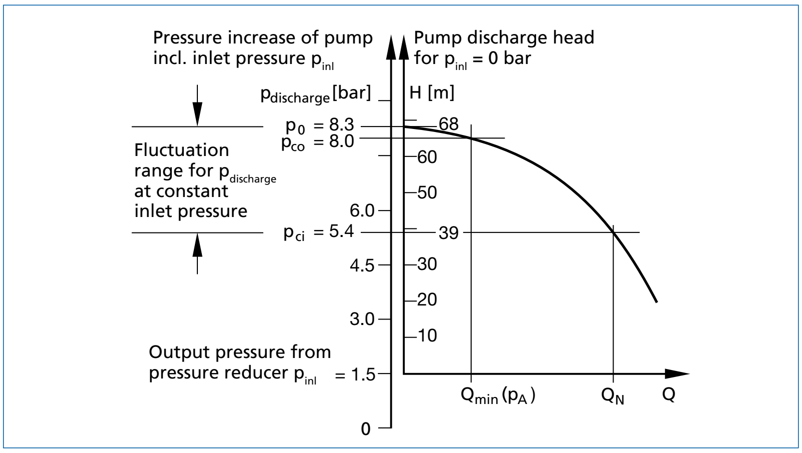


Fig. 5: Performance chart of a PBS with cascade control including pressure values for a specifically chosen pump with inlet pressure (p_{inl})

3.1.2 Selecting the appropriate PBS size

$\dot{V}_{peak} = Q_D = 24$ m³/h (assumed)

$H = 39$ m

The PBS selected is a Hyamat K 4/0607B with stand-by pump

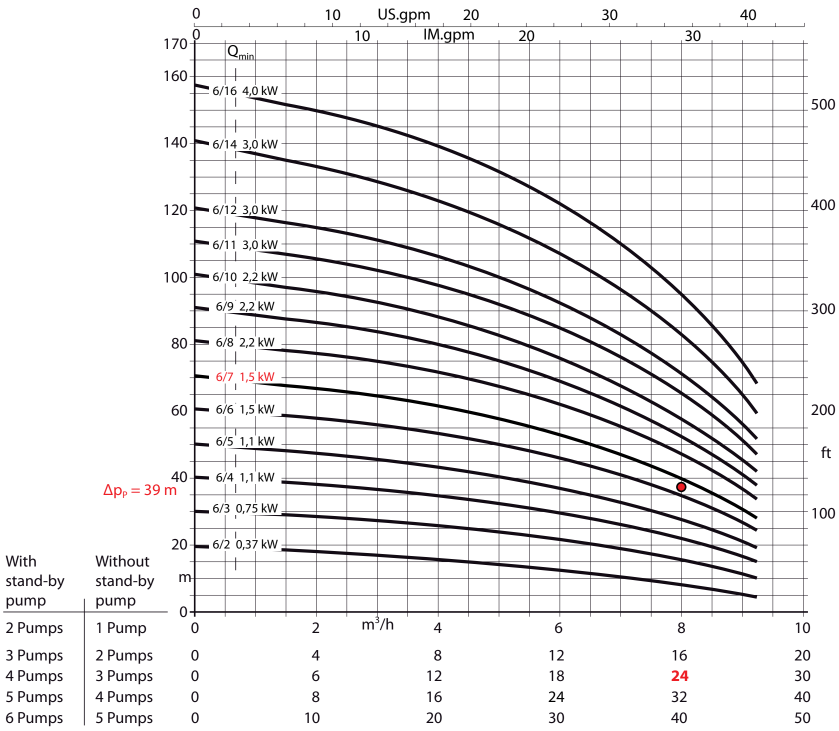


Fig. 6: Hyamat VP with Movitec 6B

3.1.3 Determining the pressure zones

Calculating p_{min} and p_{max} per floor: (Refer to Fig. 7).
The max. discharge pressure $p_{discharge} = p_0 = p_{inl} + H_0 / 10$ is assumed for the PBS' discharge pressure ($p_{discharge}$).
We assume that the installation of an upstream pressure reducer for a PBS in cascade operation is always compulsory. The available pressure upstream of the PBS (p_{inl}) is to be understood as the pressure reducer's output pressure. If a pressure reducer has not been installed, the max. possible supply pressure ($p_{max,V}$) is to be used for p_{inl}.

$$N_{flpr} = \frac{p_{discharge} - p_{max}}{\Delta p_{fl}} \qquad (14)$$

$$N_{flpr} = \frac{8.0 - 5.0}{0.3} = 10$$

Key:

N_{flpr} = Number of floors which have to be protected against inadmissible pressures by means of pressure reducers

$p_{discharge}$ = Required pressure downstream of the PBS

p_{max} = Maximum permissible flow pressure at consumer

Δp_{fl} = Pressure loss per floor (h_{fl} = 3m)

3.1.4 Calculating the maximum floor pressure $p_{max,fl}$

Assumption:

- Water consumption is zero or very low. Therefore, the head loss is $H_L \approx 0$
- 11 floors

Calculation:

The max. floor pressure ($p_{max,fl}$) is calculated by deducting the static pressure loss Δp_{geo} (floor X) of the respective floor from the PBS discharge pressure ($p_{discharge}$). The static pressure loss of a building N = 11 floors, meaning ground floor + 10 floors, amounts to:

$$\Delta p_{geo} = N \cdot \Delta p_{geo,fl} \ \text{[bar]} \qquad (15)$$

with $\Delta p_{geo,fl}$ = 0.3 bar

Δp_{geo} = 11 · 0.3 bar = 3.3 bar

$$p_{max} = p_{discharge} - \Delta p_{geo\ (floor\ X)} = p_0 - \Delta p_{geo\ (floor\ X)} \ \text{[bar]} \qquad (16)$$

For example for the 10th floor
p_{max} = 8.0 bar – 3.3 bar = 4.7 bar

In general, the following calculation applies to the max. floor pressure:

$$p_{discharge} = p_0 \ \text{[bar]} \qquad (17)$$

$$p_{max} = p_0 - \Delta p_{fl} \cdot N \ \text{[bar]} \qquad (18)$$

Key:

Δp_{geo} = Pressure loss from static head difference

$\Delta p_{geo,fl}$ = Pressure loss from static head difference per floor

$p_{discharge}$ = Required pressure downstream of the PBS

p_0 = Maximum pump pressure at zero flow rate = 0

p_{max} = Maximum pressure

Δp_{fl} = Pressure loss per floor

N = Number of floors

$\Delta p_{geo\ (floor\ X)}$ = Static pressure loss for floor X

3.1.5 Determining the minimum floor pressure $p_{min,fl}$

Assumption:

1. The PBS discharge pressure ($p_{discharge}$) corresponds to the cut-in pressure p_{ci}.
2. Water consumption is max. $Q_N = \dot{V}_{peak}$.
3. The dynamic pressure losses $\Sigma(\Delta p_{frict}+\Delta p_{indiv})$ correspond to the maximum value.
4. For simplification we assume a linear distribution of the pressure loss across the individual floors. This applies both to the static and dynamic pressure loss.

Calculation:

The following applies to a building with 11 floors (N = 11):

$\Delta p_{geo,fl}$ = 0.3 bar per floor

A dynamic pressure loss of

$\Sigma(R \cdot l+Z)$ = 1.1 bar

gives a dynamic pressure loss per floor of

$$\Delta p_{dyn,fl} = \frac{\Sigma(R \cdot l+Z)}{N} \text{ [bar]} \quad (19)$$

$$\Delta p_{dyn,fl} = \frac{1.1}{11} = 0.1 \text{ [bar]}$$

The calculated total pressure loss per floor is:

$$\Delta p_{fl,tot} = \Delta p_{geo,fl} + \Delta p_{dyn,fl} \text{ [bar]} \quad (20)$$

Δp_{fl} = 0.3 bar + 0.1 bar

Δp_{fl} = 0.4 bar

In general, the following applies to the flow pressure at a floor:

$$p_{min,(N)} = p_{discharge} - \Delta p_{fl} \cdot N \text{ [bar]} \quad (21)$$

Key:

$\Delta p_{dyn,fl}$ = Dynamic pressure loss per floor

$\Sigma(\Delta p_{frict}+\Delta p_{indiv})$ = Pipe friction and other individual losses

N = Number of floors

$\Delta p_{fl,tot}$ = Total pressure loss per floor

$\Delta p_{geo,fl}$ = Static pressure loss per floor

$p_{min,(6)}$ = Minimum flow pressure at the consumer in floor N

$p_{discharge}$ = Required pressure downstream of the PBS

Example:

Determining the available flow pressure for the 5th floor:

N = 6 (ground floor + 5 floors) using the values as per Fig. 7:

$p_{min,flow(6)}$ = 5.4 bar – 0.4 bar · 6

$p_{min,flow(6)}$ = 3.0 bar

3.1.6 Pressure zone calculation for a building equipped with a PBS using cascade control (Hyamat K)

Conclusion:

In the event of pump failure, consumers are not affected since appropriate measures (installation of pressure reducers on the inlet side, establishing pressure zones on the consumer side) have been taken.

- Inlet pressure reducer: Required as the inlet side pressure fluctuations are too high for cascade operation. As a result of the pressure loss inherent in the reducer (here = Δp 0.7 bar) the minimum available inlet pressure p_{inl} drops to 1.5 bar. The nominal discharge head required of the pump is thereby increased by 7 m.

- Consumer-side pressure reducer: On floors 3 to 8, the max. permissible pressure p_{max} = 5 bar would be exceeded (Fig. 7). For this reason, these floors require protection by pressure reducers. The available pressures are then set to a uniform pressure of 1.3 bar.

Summary

The cascade-controlled PBS is favourably priced. However, addressing this system's drawbacks (pressure fluctuations, excessive on/off, hydraulic impact on the water supply network...) requires the installation of various additional components (pressure controller, membrane-type accumulator, etc.), rendering it much more expensive.

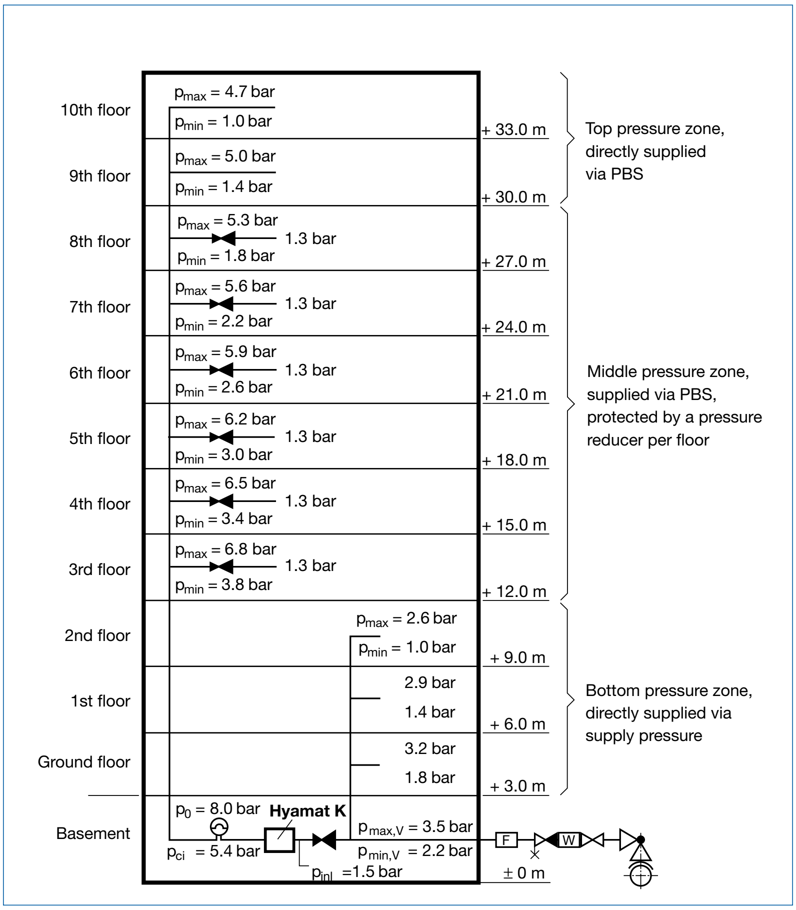


Fig. 7: Schematic drawing of a PBS operating with cascade control incl. pressure values and pressure zones

3.2 PBS with one variable speed pump (Hyamat V)

Features:

- One variable speed base load pump
- Peak load pumps cut in depending on the pressure (Δp range)
- Peak load pumps run at full speed
- Pump change-over of variable speed base load pumps is possible
- Discharge pressure is largely constant
- Inlet pressure fluctuations can be compensated
- In the event of a speed control malfunction, system operates like a cascade
- Under low-flow conditions, the base load pump is stopped irrespective of the inlet pressure
- Hydraulic impact on the water supply network is low
- Inlet-side pressure reducer is normally not required

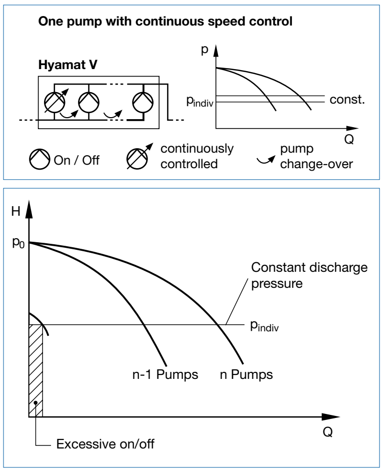


Fig. 8: Performance chart of a PBS with one variable speed pump (type series: Hyamat V)

3.2.1 Calculating the required pressure downstream of the PBS ($p_{discharge}$)

The discharge pressure $p_{discharge}$ is calculated as follows

$$p_{discharge} = \Delta p_{geo} + \Sigma(\Delta p_{frict} + \Delta p_{indiv}) + p_{min,flow} \quad [bar] \qquad (22)$$

$$p_{discharge} = 3.3 \text{ bar} + 1.1 \text{ bar} + 1.0 \text{ bar} = 5.4 \text{ bar}$$

Key:

$p_{discharge}$ = Required pressure downstream of the PBS

Δp_{geo} = Static pressure loss

$\Sigma(\Delta p_{frict} + \Delta p_{indiv})$ = Pipe friction and other individual losses

$p_{min,flow}$ = Minimum flow pressure at consumer

The required discharge pressure ($p_{discharge}$) on pressure booster systems with one variable speed pump is also referred to as the cut-in pressure (p_{ci}).
Under normal operating conditions, the discharge pressure is almost constant. When peak load pumps are started or stopped, the discharge pressure may slightly deviate from p_{ci} (e. g. ± 0.5 bar) for a short period of time.

Note:
In the event of a malfunction (speed control failure) the system automatically changes over to cascade operation. As a pressure reducer is not normally installed in the case of a PBS with one variable speed pump, the discharge pressure can rise to a maximum value of $p_{discharge} = p_0 = p_{inl,max} + H_0 / 10$.

Possible remedial measures:

Option 1

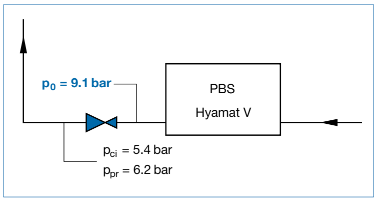


Fig. 9: Central pressure control (e.g. pressure reducer)

One central pressure reducer on the discharge side of the PBS

Setting the pressure reducer to the output pressure p_{pr} = 6.2 bar ensures that the pressure reducer is fully open under normal operating conditions. Only in the event of a fault is the pressure thus limited to the value set (p_{pr} = 6.2 bar).

The supply pressure at the hand-over point varies between the minimum $p_{min,V}$ = 2.2 bar and the maximum value $p_{max,V}$ = 3.5 bar.
PBSs with one variable speed pump are capable of handling supply pressure fluctuations (see Figs. 10 and 11) thus eliminating the need for pressure reducers.
The discharge head is determined on the basis of the minimum supply pressure $p_{min,V}$.

The pump head is calculated as follows:

$$H = (p_{discharge} - p_{inl,min}) \cdot 10 \text{ [m]} \quad (23)$$

H = (5.4 bar - 2.2 bar) · 10
H = 32 m
(i.e. 7 m less than cascade-controlled PBS)

Key:

H = Pump discharge head
$p_{discharge}$ = Required pressure downstream of the PBS
$p_{inl,min}$ = Minimum pressure available upstream of the PBS

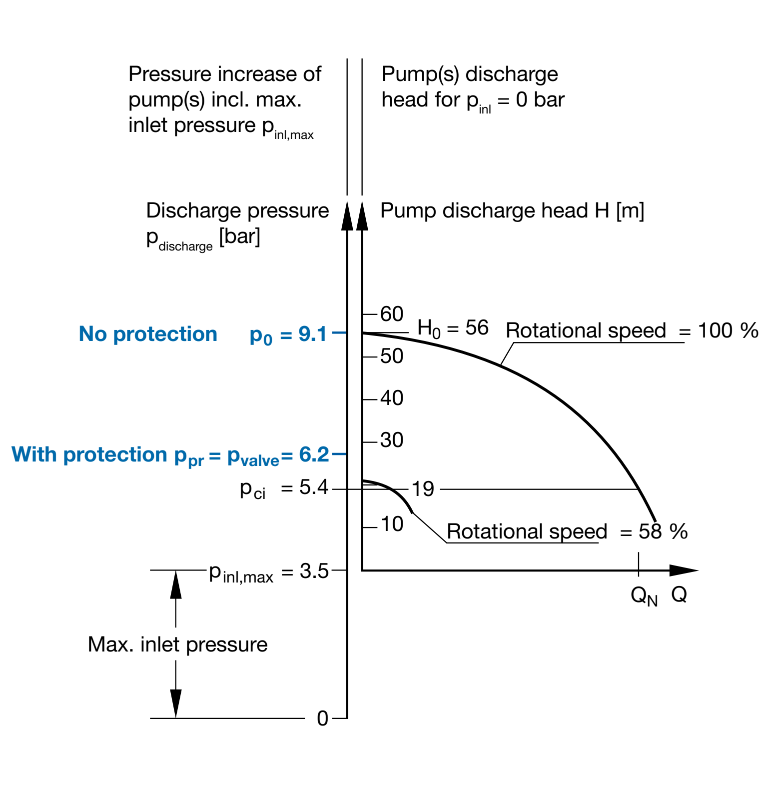


Fig. 10: Performance chart of a PBS with one variable speed pump, incl. pressure values for operation with max. inlet pressure $p_{inl,max}$. Inlet pressure reducers are not normally installed with this type of system! The max. inlet pressure $p_{inl,max}$, is critical for calculating the max. discharge pressure p_0. The max. discharge pressure p_0 can only occur in the case of a fault in the continuous speed control (change-over to cascade operation).

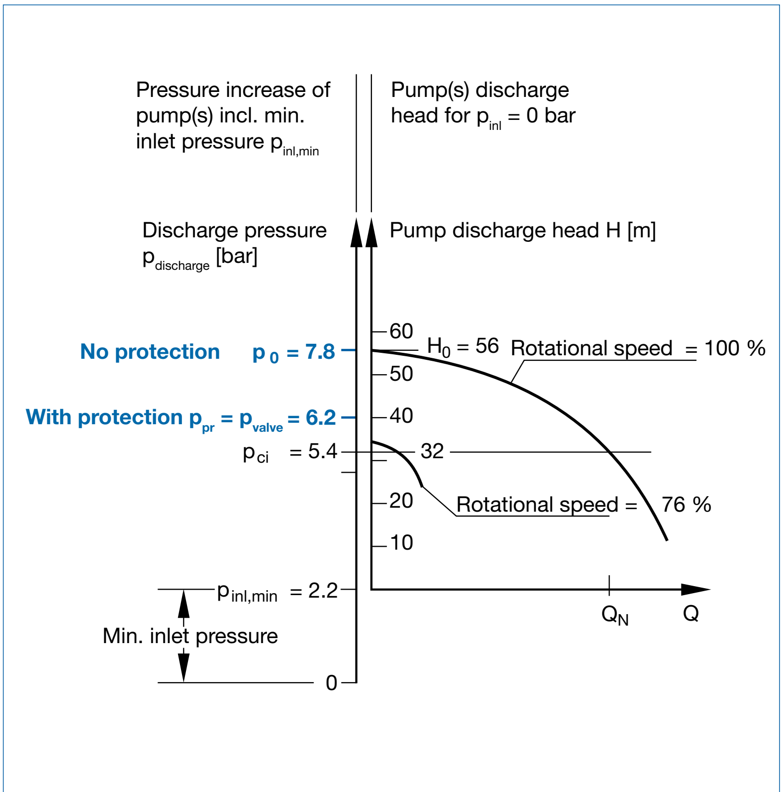


Fig. 11: Performance chart of a PBS with one variable speed pump, incl. pressure values for a specific pump with inlet pressure $p_{inl,min}$.

3.2.2 Selecting the appropriate PBS size:

$\dot{V}_{peak} = Q_D = 24\ m^3/h$ (assumed)
$H = 32\ m$
The PBS selected is a Hyamat K 4/0606B, 4 pumps (with stand-by pump).
In this case ($\Delta p_{inl,perm} = 0.6$ bar) the PBS operates without pressure reducer on the inlet pressure side.

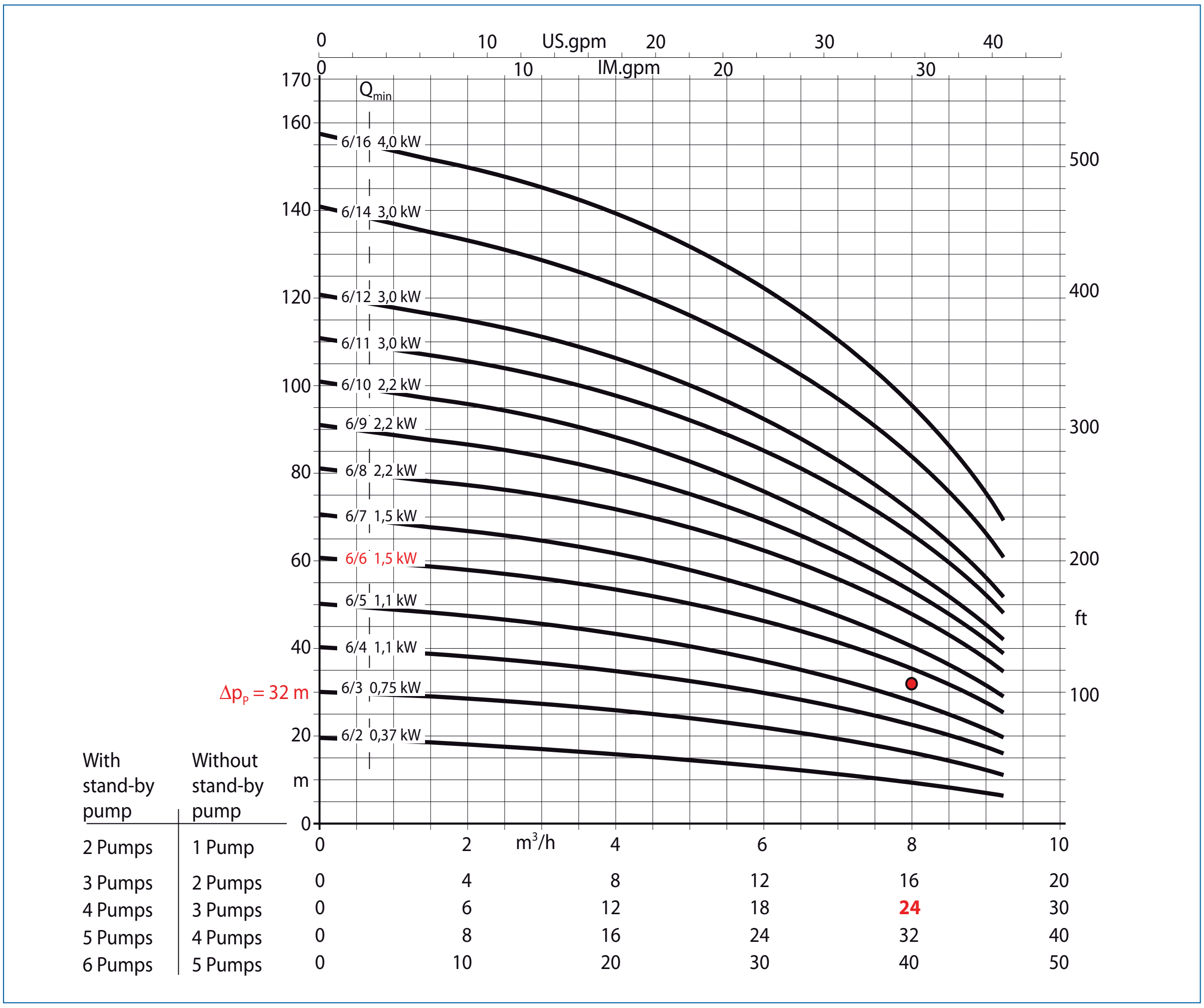


Fig.12: Selection chart Movitec 6B

3.2.3 Determining the pressure zones

Under normal operating conditions, a system using continuous speed control ensures an almost constant discharge pressure $p_{discharge}$ = 5.4 bar.
The following equation applies to the number of floors requiring protection (N_{flpr}):

$$N_{flpr} = \frac{p_{discharge} - p_{max}}{\Delta p_{fl}} \qquad (24)$$

$$N_{flpr} = \frac{5.4 \text{ bar} - 5.0 \text{ bar}}{0.3 \text{ bar}}$$

$$N_{flpr} = 1.3 \approx 2$$

From this equation can be deduced that the lowest two floors, namely the basement and the ground floor, would require protection.
However, the basement, ground floor as well as 1st and 2nd floors are not connected to the PBS. Floors 3 to 10 do not, in principle, require any protection.

In the event of a fault: speed control failure

In this case, the following applies due to change-over to cascade operation:

$$p_{discharge} = p_0 = p_{max,v} + \frac{H_0}{10} \text{ [bar]} \qquad (25)$$

$$p_{discharge} = p_0 = 3.5 \text{ bar} + 6.1 \text{ bar} = 9.6 \text{ bar}$$

Result of (25) inserted into equation No. (24):

$$N_{flpr} = \frac{p_{discharge} - p_{max}}{\Delta p_{fl}}$$

$$N_{flpr} = \frac{9.6 \text{ bar} - 5.0 \text{ bar}}{0.3 \text{ bar}}$$

$$N_{flpr} = 15.3$$

This means that while in principle no floors require protection, in the event of a malfunction, all floors connected to the PBS must be protected.

Key:

N_{flpr} = Number of floors which have to be protected against inadmissible pressures by means of pressure reducers
$p_{discharge}$ = Required pressure downstream of the PBS
$p_{max,flow}$ = Max. permissible flow pressure
Δp_{fl} = Pressure loss per floor
p_0 = Maximum pump pressure at zero flow rate (Q= 0)
$p_{max,v}$ = Maximum pressure available upstream of the PBS
H_0 = Maximum pump discharge head at zero flow rate (Q= 0)

3.2.4 Determining the max. floor pressure ($p_{max,fl}$)

We take a static approach meaning we do not assume any flow losses $\Sigma(\Delta p_{frict} + \Delta p_{indiv})$.

Normal conditions:
$p_{discharge} = p_{ci}$

In the event of a fault:

$p_{discharge} = p_0$

$$p_{max,fl} = p_{discharge} - \Delta H_{geo\ (floor\ X)} \text{ [bar]} \qquad (26)$$

Key:

$p_{max,fl}$ = Maximum pressure per floor
$p_{discharge}$ = Required pressure downstream of the PBS
$\Delta H_{geo(floor\ X)}$ = Static pressure loss for floor X

Example:

Floor 10 requires:

$N = 11$ (ground floor + 10 floors)

$\Delta p_{geo,fl} = 0.3$ bar

$\Delta p_{geo\ (10th\ floor)} = N \cdot \Delta p_{geo,fl} = 11 \cdot 0.3 = 3.3$ bar

Normal conditions:

$p_{max,10th\ floor} = 5.4$ bar - 3.3 bar

$p_{max,\ 10th\ floor} = 2.1$ bar

In the event of a fault:

$p_{max,10th\ floor} = 9.6$ bar - 3.3 bar

$p_{max,\ 10th\ floor} = 6.3$ bar

The other floor pressures can be calculated using the respective Δp_{geo} values.

3.2.5 Determining the minimum floor pressure $p_{min,fl}$

By analogy, the following applies to floor 5:

$p_{min} = 3.0$ bar (cf. calculation example)

Summary

In the event of a fault (breakdown of the variable speed control), the pressure rises on those floors not provided with additional safety equipment, i.e. the max. static pressure on floors 4-10 considerably exceeds the maximum set pressure of 5 bar.

Possible effects:

- Considerably increased flow velocity
- Float valves of cisterns cease to close
- At a pressure p = 6 bar, the safety valves of the water heaters open.
  As a result of possible fluctuations, increased frequency of pump starts and even pressure surges are to be expected.

Possible remedial measures:

- Installation of a central pressure reducer downstream of the PBS (the value set for this downstream pressure must be > p_{ci})

The disadvantages of cascade operation are avoided. Generally, pressure reducers and large membrane-type accumulators are not necessary. Making full use of the inlet pressure saves electrical drive energy.

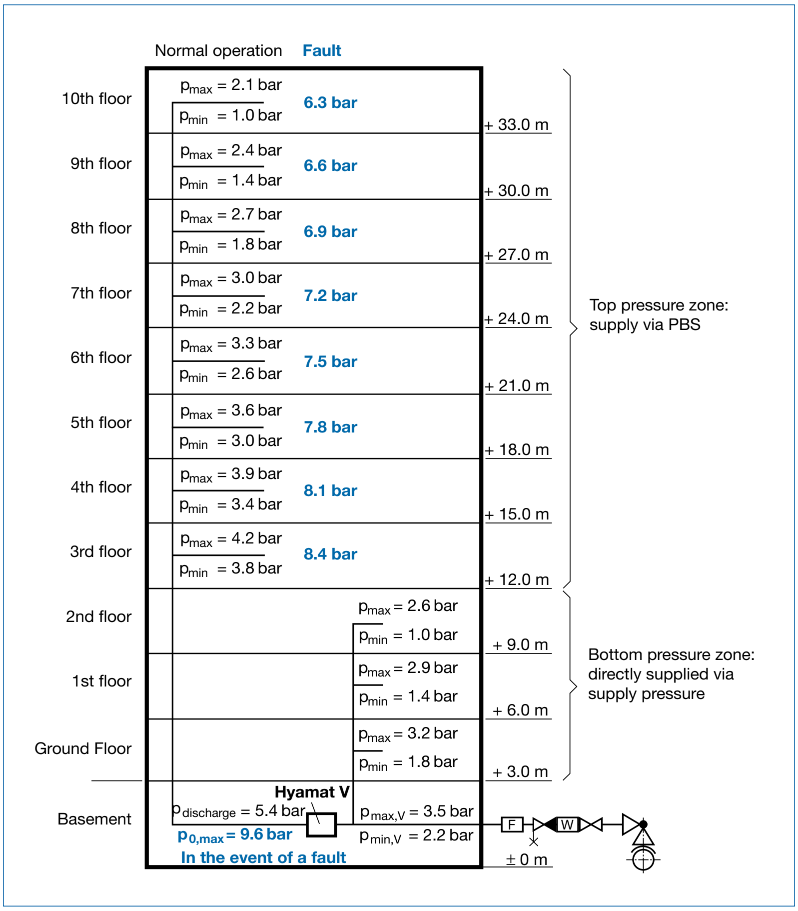


Fig. 13: Schematic drawing of a PBS with one variable speed pump incl. pressure values and pressure zones

3.3
PBS with speed control on all pumps (Hyamat VP)

- All pumps are variable speed
- Number of operating pumps depends on flow rate
- No pressure rise in the event of a fault/variable speed pump breakdown
- Broad regulating range, optimum conditions when all pumps are running
- Constant discharge pressure
- Compensation for very high inlet pressure fluctuations possible
- Fluctuations during operation have a very low hydraulic impact on the public water network

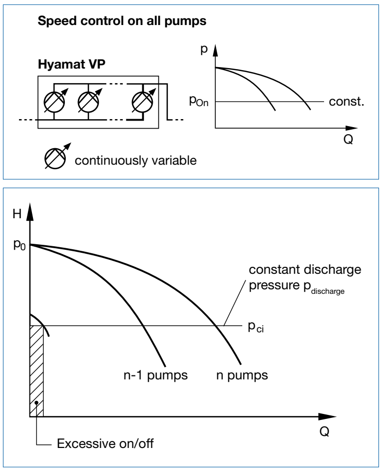


Fig. 14: Performance chart of a PBS with speed control on all pumps (type series: Hyamat VP)

3.3.1
Calculating the required pressure

The required pressure has been calculated as indicated in the above example

$p_{discharge} = p_{ci} = 5.4$ bar

Even in the event of a fault, inadmissible pressure rises cannot occur with this type of PBS concept.
Therefore, floors 3 to 10 can be directly connected to the PBS without any protective measures. A constant discharge pressure $p_{discharge}$ is guaranteed at all times.

3.3.2
Selecting the appropriate PBS size

Hyamat VP 4/0606B (Selection chart, see Fig. 12, p. 22)

3.3.3
Determining the pressure zones

$N_{flpr} = 1.3 \approx 2$

Refer to page 23, section 3.2.3 for the equation and the calculation.

From this equation can be deduced that the lowest two floors, namely the basement and the ground floor, would require protection.
As, however, the basement, ground floor as well as 1st and 2nd floors are not connected to the PBS anyway, this can be disregarded.
A special feature of this PBS concept is that even in the event of a fault (e.g. breakdown of one variable speed pump) a pressure rise is not to be expected. All other variable speed pumps continue operating. If required, the stand-by pump (also equipped with variable speed control) can be started up.
Hence, floors 3 to 10 are supplied with water without needing additional protective equipment.

3.3.4
Determining the max. floor pressure ($p_{max,fl}$)

We take a static approach, meaning we do not take into account any flow losses $\Sigma(\Delta p_{frict}+\Delta p_{indiv})$.
The following equation is therefore applied:

$$p_{discharge} = p_{ci} = \text{constant} \quad [\text{bar}] \qquad (27)$$

$$p_{max,fl} = p_{discharge} - \Delta p_{geo\ (floor\ X)} \quad [\text{bar}] \qquad (28)$$

Key:

$p_{discharge}$ = Required pressure downstream of the PBS

$p_{max,fl}$ = Maximum pressure per floor

p_{ci} = Cut-in pressure/ setpoint

$\Delta p_{geo\ (floor\ X)}$ = Static pressure loss for floor X

Example:

The following is applicable for floor 5:

$N = 6;$

$\Delta p_{geo,fl} = 0.3$ bar;

$p_{discharge} = 5.4$ bar

$\Delta p_{geo\ (5th\ floor)} = N \cdot \Delta p_{geo,fl}$

$= 6 \cdot 0.3$ bar

$\Delta p_{geo\ (5th\ floor)} = 1.8$ bar

therefore

$p_{max\ (5th\ floor)} = 5.4$ bar - 1.8 bar

$p_{max\ (5th\ floor)} = 3.6$ bar

3.3.5 Determining the minimum floor pressure $p_{min,fl}$

The minimum pressure has been calculated as described in section 3.2.5.

By analogy, the following is applicable for floor 5:

$p_{min\ (fl5)} = 3.0$ bar

Summary

All pumps are variable speed. In the event of a fault (breakdown of one variable speed pump), the Hyamat VP system continues operating with the available variable speed pumps. The discharge pressure is not subject to any fluctuations. Additional measures are not required. In buildings with more than 10 floors, pressure zones usually need to be defined.

Even if one frequency inverter unit breaks down, the discharge pressure remains constant (in the Hyamat V concept, by contrast, the PBS would automatically change over to cascade operation). Any hydraulic equipment limiting the pressure is not required.

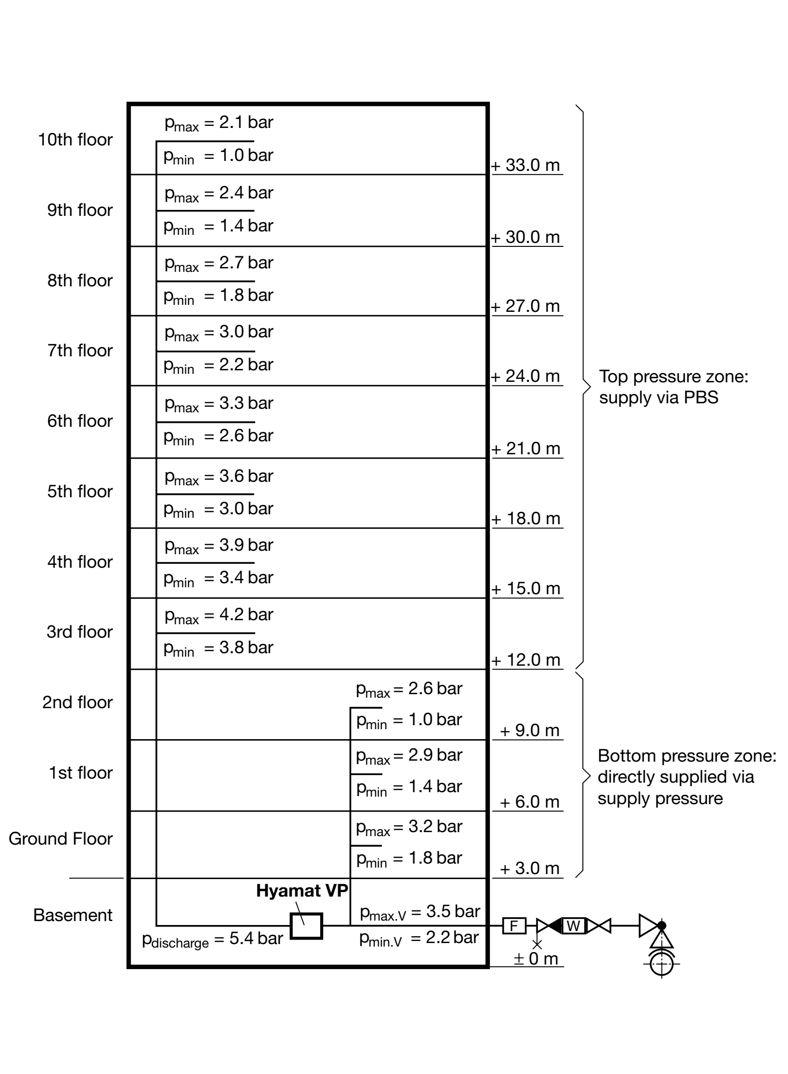
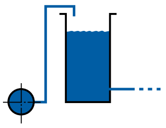
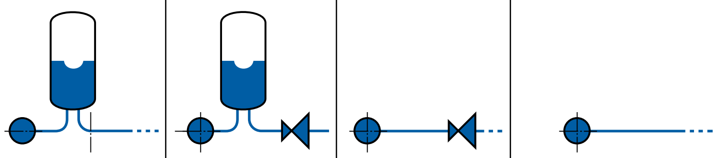


Fig. 15: Schematic drawing of a PBS, all pumps are variable speed controlled (Hyamat VP), incl. pressure values and pressure zones

4. Connection types

4.1 Overview - Connection types for drinking water (inlet side)

<table>
<tr><th colspan="6">Inlet side</th></tr>
<tr><th>Indirect connection</th><th colspan="5">Direct connection</th></tr>
<tr><td>Unpressurised tank for volume balancing
</td><td colspan="5"></td></tr>
<tr><td rowspan="5">⊕ No adverse effects on supply network
⊕ Demand peaks are covered
⊕ Constant inlet pressure
⊖ Risk of contamination</td><td colspan="3">⊕ Dampened impact on supply network</td><td rowspan="2"></td><td rowspan="3">⊕ Exploitation of design inlet pressure
⊖ Inlet pressure fluctuation must be limited
(max. +0.3/-0.2 bar)</td></tr>
<tr><td rowspan="2"></td><td colspan="2">⊕ No risk of contamination
⊖ Additional pressure loss</td></tr>
<tr><td></td><td colspan="2">⊕ Constant inlet pressure
⊖ Wasted energy</td></tr>
<tr><td colspan="3" rowspan="2">Tank is not required</td><td rowspan="2">Normally not required</td><td>⊕ Inlet pressure may fluctuate slightly
⊕ Full exploitation of inlet pressure
Observe pump curve profile</td></tr>
<tr><td>⊕ Greater inlet pressure fluctuation permitted
⊕ Full exploitation of inlet pressure
Observe pump curve profile</td></tr>
</table>

Key:

- Optimum
- Good
- Possible
- Unfavourable

Supply network

Break tank

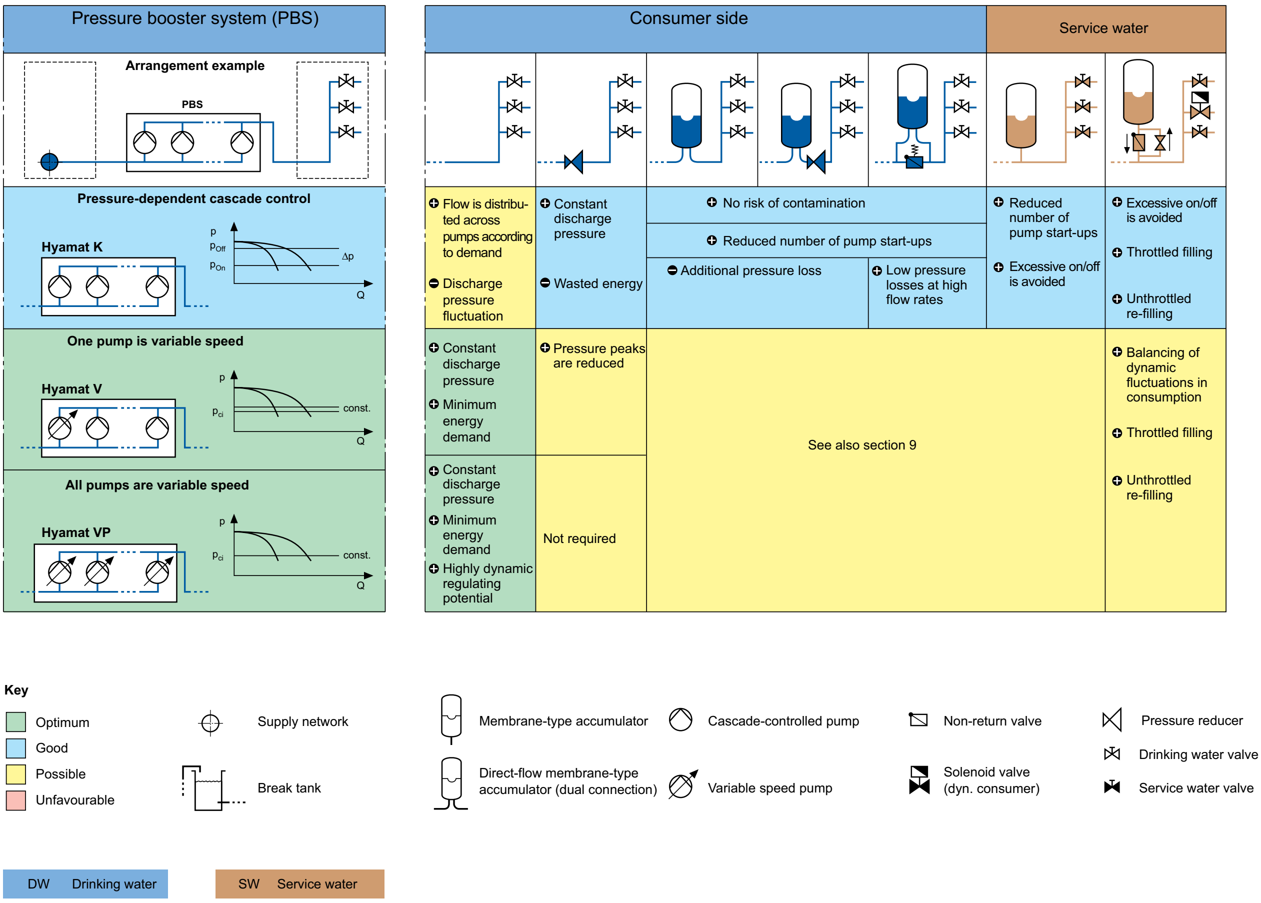
Membrane-type accumulator

Direct-flow membrane-type accumulator (dual connection)

DW Drinking water

SW Service water

4.2
Overview - Connection types for drinking water (consumer side)



4.3
Dry running protection

"Dry running protection" is the protection of the pump system against inadmissible operation (e.g. under lack-of-water conditions) and the timely stopping of the PBS to protect the supply network.
The following presents an overview of the various dry-running protection concepts.

4.3.1
Protection of the supply network

By stipulating minimum pressures, the General Water Supply Terms Ordinance (AVB Wasser V), the DIN 1988 and DIN EN 806 standards endeavour to prevent consumers directly supplied via the service pipe being inadmissibly compromised as a result of PBS operation.
Possible causes for an inadmissible pressure drop at the service pipe are for example:

- Insufficient supply network. The pressure of the mains water pipe drops when considerable quantities of water are extracted.
- If the service pipe's diameter is insufficient, the supply pressure drops at the hand-over point when considerable quantities of water are consumed.
- Pressures drop at the hand-over point if considerable quantities of water are pumped via the PBS (e. g. due to large pumps and/or a large membrane-type accumulator downstream of the PBS). An inlet pressure monitoring device is installed on the PBS inlet side in order to monitor and observe the required minimum pressure of $p_{min,V}$ = 1 bar.
  Depending on the system, this monitoring equipment can either be a pressure switch or an analog pressure transmitter. Whenever the minimum pressure is reached the PBS should reduce the number of operating pumps.
- The PBS must be equipped with switching and control equipment that ensures the pressure does not drop below the minimum inlet pressure by more than 50 % (lack-of-water control to protect upstream consumers).

Simultaneous stopping of all operating pumps must be avoided.
Alternatively, the possibility of an indirect connection of the PBS providing sufficient protection should be examined.

4.3.2
Protection of pressure booster system

High-pressure centrifugal pumps are mainly employed for PBSs and, apart from a few exceptions, these are non-self-priming pump types. This means that the inlet/suction pipe must be constantly filled with water.
In essence, all protection concepts aim to prevent inadmissible rises in temperature or, in the worst case, the dry running of the pumps. A distinction is made between direct and indirect protection methods.

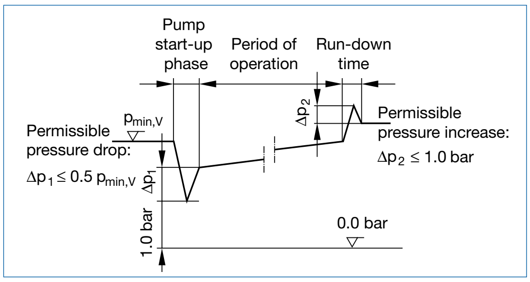


Fig.16: Pressure development at the consumer end of the service pipe, i. e. upstream of the PBS, as pumps start and stop

Direct protection:

- Flow monitoring on the PBS inlet side

Indirect protection:

- Inlet pressure control upstream of the PBS – particularly in the case of cascade control (Hyamat K) – by making sure that the pumps can exceed the cut-out pressure p_{co}.
- Water level control in the inlet tank
- Pump performance monitoring (electrically)
- Temperature monitors on each pump (alternatively)

Conclusion:
Generally, PBSs must be protected against operating with a lack of water.
As a whole host of connection types for PBSs and different operating conditions exists, there is no such thing as a standard solution.
The protection concept chosen must always suit the individual operating conditions (see Fig. 17).

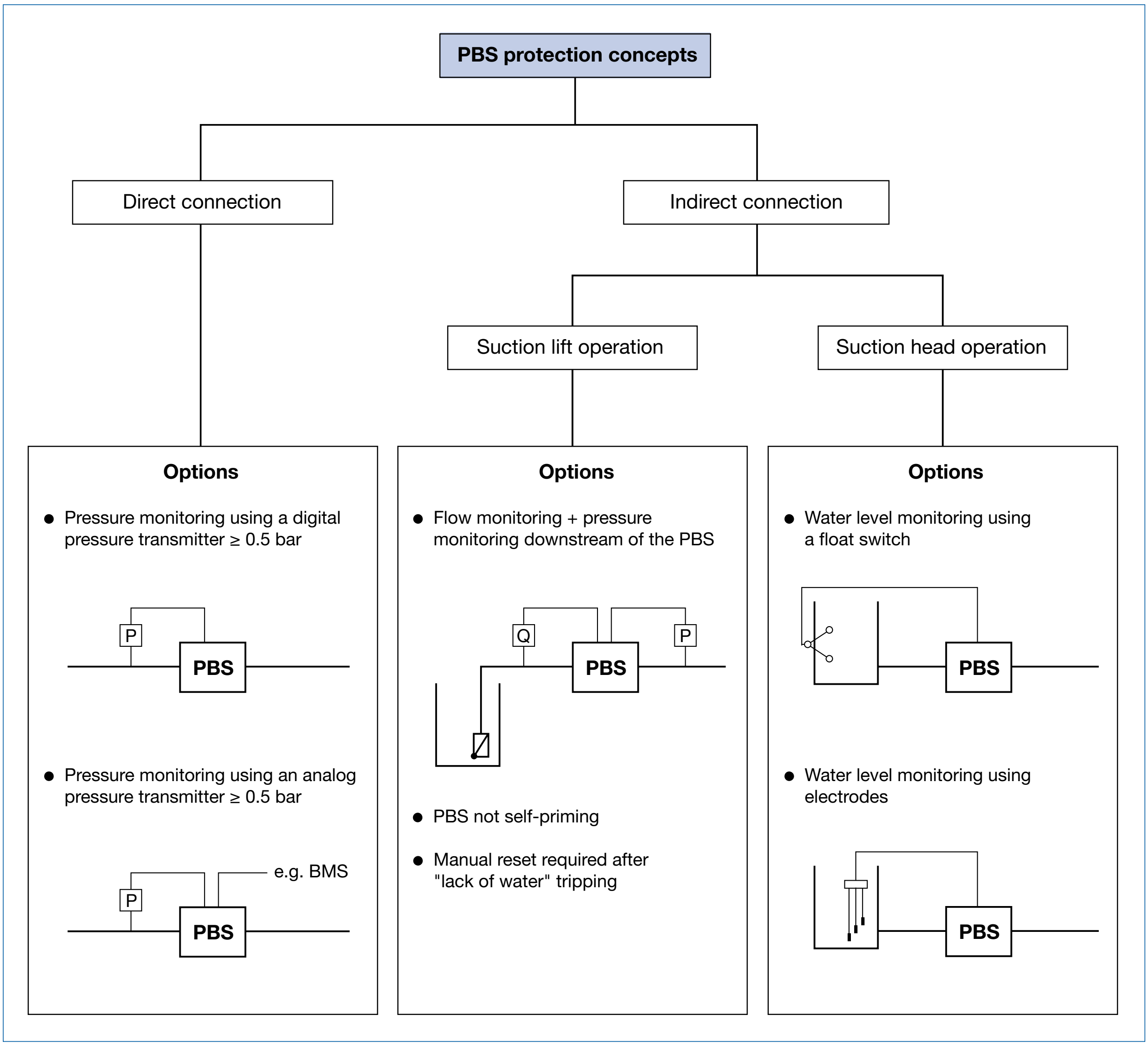


Fig. 17: PBS protection concepts

4.4
Effects of inlet pressure fluctuations

4.4.1
Indirect connection

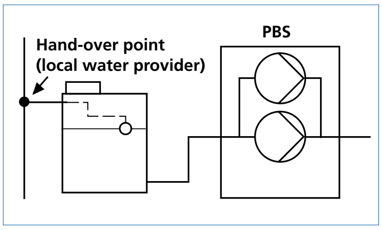


Fig. 18: Indirect connection

The PBS takes the required quantity of water from a break tank situated upstream. (Break tank to DIN EN 1717)
The effective volume of the break tank is established using the following equation:

$$V_{BT} \geq 0.03 \cdot Q_{peak} \qquad (29)$$

Key :
Q_{peak} = Peak flow rate
V_{BT} = Effective volume of break tank

The tank filling device is usually sized such that the PBS's nominal flow rate Q_D is reached under normal inlet pressure (p_{inl}) conditions. If the inlet pressure drops to the minimum inlet pressure $p_{inl,min}$ this may lead to a significant reduction of the filling volume.

Example:
$p_{inl,min}$ = 1.0 bar
$p_{inl,max}$ = 3.1 bar
p_{inl} = 2 bar (assumed)
Q_D = 20 m³/h

Selection of float valve
for p_{inl} = 2 bar, Fig. 19
Q_D = 20 m³/h → 1 1/2"
at $p_{inl,min}$ = 1 bar → Q = 14 m³/h

This results in a filling volume reduction of 30%.
It should be noted that the stored volume will be used up under minimum inlet pressure conditions and a water consumption of more than 14 m³/h over a prolonged period of time (risking a lack-of-water condition).

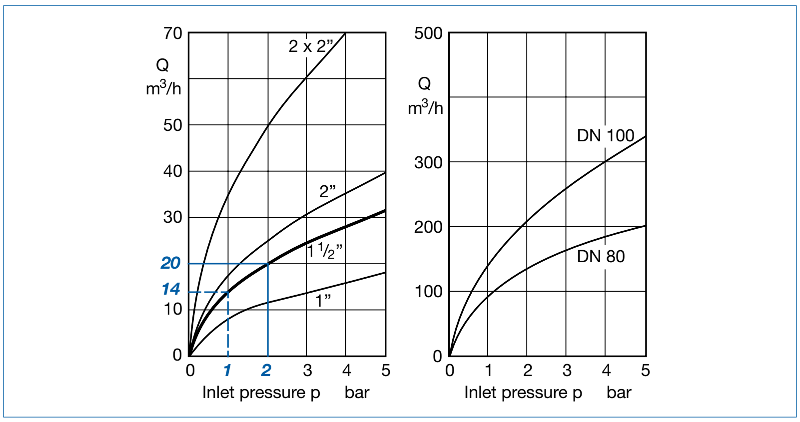


Fig. 19: Selection diagram for filling devices

The PBS's function is not impaired as long as water is available.

4.4.2
Direct connection, inlet pressure fluctuations in the form of pressure increases

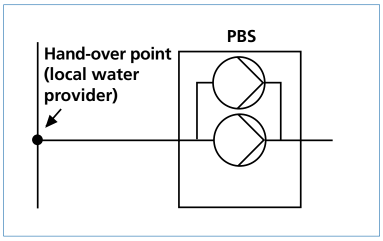


Fig. 20: Direct PBS connection

When PBSs with cascade control (Hya-Eco, Hya-Solo D, Hyamat K) are used, inlet pressure fluctuations (in this case in the form of pressure increases) will directly influence the PBSs' discharge pressure. Since cascade-controlled PBSs have an inherent discharge pressure fluctuation of $\Delta p_{(co-ci)}$ + 0.3 bar (Fig. 21), the sum of discharge pressure fluctuation and inlet pressure fluctuation must be examined to ensure that it is acceptable for the consumers downstream. The maximum fluctuation range recommended by DIN 1988 is 2.5 bar.

$$\Delta p_{PBS,max} = \Delta p_{(co-ci)} + 0{,}3 + \Delta p_{max,v} \text{ [bar]} \quad (30)$$

Key:

$\Delta p_{PBS,max}$ = Maximum pressure difference downstream of the PBS

$\Delta p_{(co-ci)}$ = Difference between cut-in/cut-out pressures

$\Delta p_{max,V}$ = Maximum pressure available upstream of the PBS

If this is not the case, it is important to use an inlet-side or discharge-side pressure controller/reducer.

A negative effect of inlet pressure increase is the shifting of the minimum flow rate for continuous operation (Q_{co} at p_{co}) and the minimum inlet pressure $p_{inl,min}$ to considerably larger cut-out flow rates at increased inlet pressure, especially in the case of PBSs with a low number of stages. The consequences are as follows (Fig. 21):

- Low flow rates (> Q_{co} for $p_{max,V}$) involve the risk of the system switching on and off with excessive frequency (very high number of start-ups of the PBS pumps).
- As a result of the cut-out of the last pump in operation at flow rates > Q_{co} audible pressure surges in the pipes are to be expected.

Example:
Impact of inlet pressure increase on a real pump curve (Fig. 23), Hyamat K series with Movitec 4B.

Q_{co} = 1.5 m³/h at $p_{min,V}$

After an inlet pressure increase of 0.5 bar

$p_{inl} = p_{min,v} + 0.5$ bar

the cut-out flow rate Q_{co} is 3.5 m³/h.

Cascade-controlled PBSs have fixed pressure-dependent switching points for pump cut-in and cut-out.
In the case of direct PBS connection, the respective inlet pressure is added to the discharge head of the pump(s).
The factory-set value for the cut-out pressure p_{co} is normally 0.3 bar lower than the maximum discharge pressure of the pump (at Q = 0 m³/h).

Point 1 on the pump curve (Fig. 22) characterises the cut-out flow rate of the pump for the design inlet pressure $p_{min,V}$ (not considering possible stop delays).
As a pump is always stopped whenever the cut-out pressure p_{co} is exceeded, the conclusion in the case of increased inlet pressure is that the pump stops with a lower discharge pressure.

Point 2 demonstrates the increased cut-out flow rate at the lower pump discharge pressure.
The characteristic curves used as an example clearly show that especially with flat pump curves (fewer stages) one can expect an excessive flow rate increase at the cut-out point.

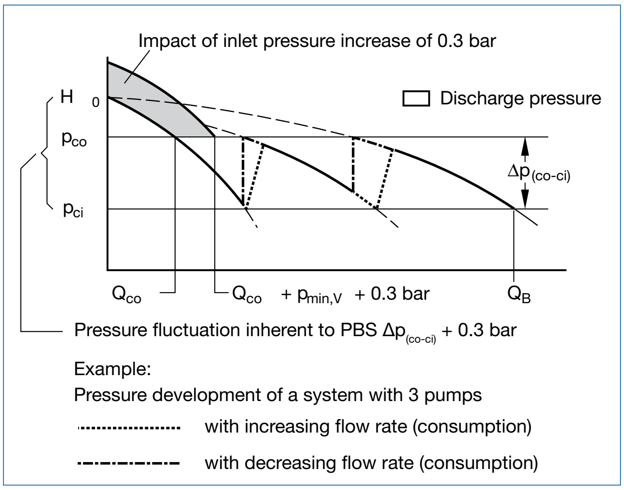


Fig. 21: The operating characteristics of a pressure booster system with cascade control, i. e. without speed control.

Inlet pressure fluctuations in the form of pressure decrease

Inlet pressure fluctuations (in this case in the form of pressure decreases) which fall below the minimum inlet pressure are particularly dangerous for pressure booster systems. Cascade-controlled PBSs have a nominal cut-out pressure margin of 0.3 bar.

This means that the maximum pump discharge head is 0.3 bar above the cut-out pressure p_{co}. As soon as the minimum inlet pressure drops by more than 0.3 bar, the PBS pumps in operation can no longer reach the cut-out pressure.

Example: Hyamat 0405

Shut-off head H_0 = 47 m

Cut-out point p_{co1} = 44 m

In the event of a minimum inlet pressure increase $p_{min,V}$ of 0.5 bar, the cut-out point shifts to p_{co2} = 39 m

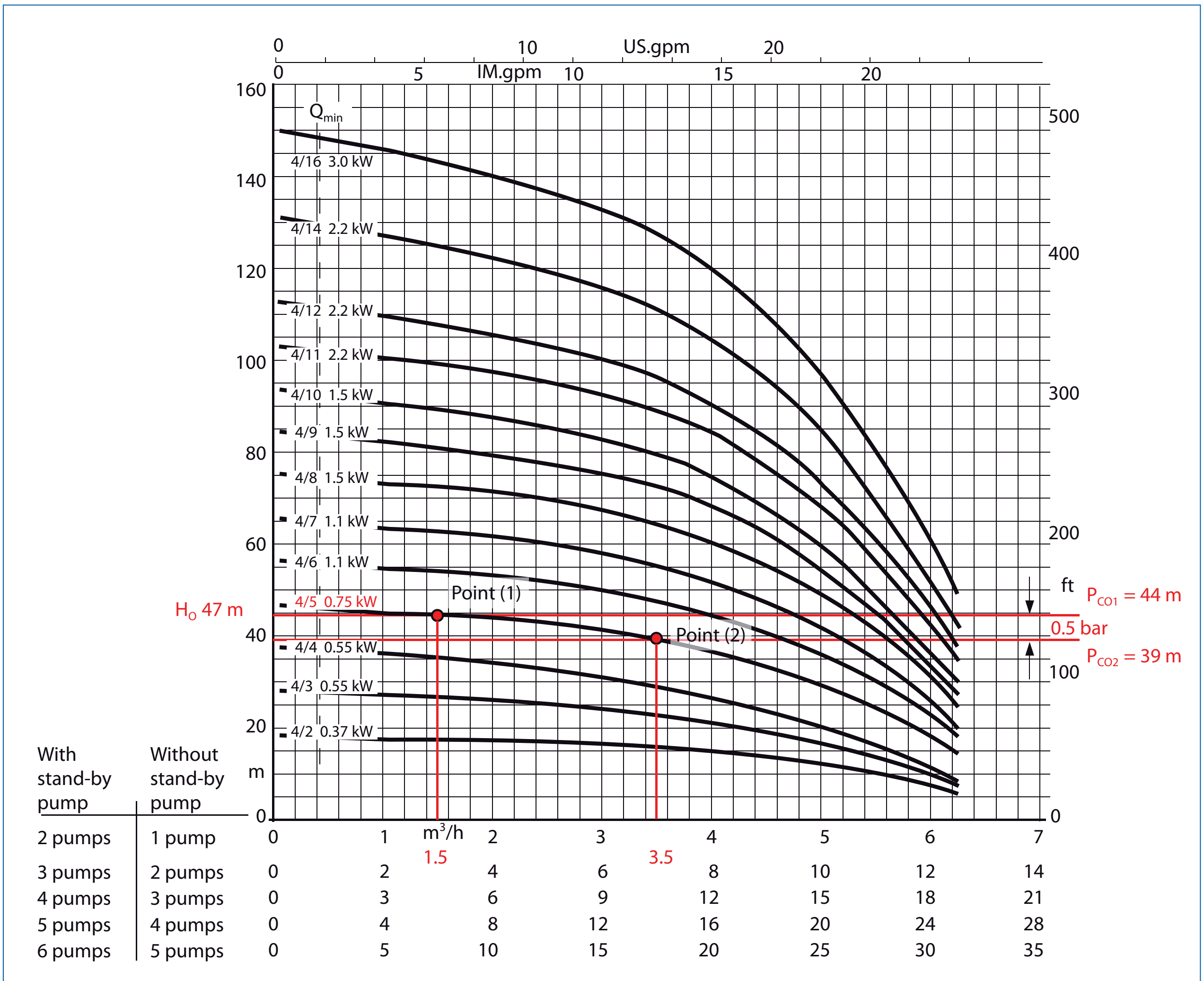


Fig.12: Selection chart Movitec 4B

4.5 Causes of pressure surges

4.5.1 Pressure surges caused by valves

All kinds of valves can, when they close quickly, lead to pressure surges.
The theoretic basis for calculating this phenomenon is described in the formula by Joukowsky:

$$\Delta H = \frac{a}{g} \cdot \Delta_V \quad [m] \qquad (31)$$

Key:
ΔH = Pressure increase
a = Propagation of a pressure wave at approx. 1000 - 1200 m/s
g = Acceleration due to gravity, approx. 10 m/s²
Δv = Velocity difference

The full impact of the pressure surge can be mathematically expressed by the following formula:

$$T_C \leq T_R = \frac{2 \cdot l}{a} \quad [s] \qquad (32)$$

Key:
T_C = Valve closing time
T_R = Reflection time in the pipe
l = Length of piping up to the location of disturbance

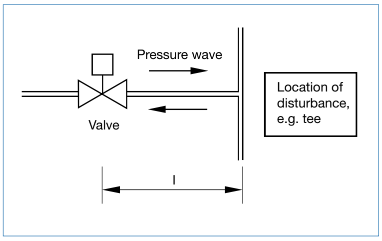


Fig. 23: Pressure surge caused by valves

This means when the pressure wave returns and the valve is closed, the pressure surge according to Joukowsky fully develops:

Remedy:
T_C must be markedly longer than T_R.

e.g.: $T_C \geq 2 \cdot T_R$

4.5.2 Pressure surges as a result of inlet pressure fluctuations in the case of PBSs with cascade control

If the inlet pressure increases, the pump curves shift upwards and the base load pump is stopped at a higher volume flow (Fig. 24).
This results in an increased flow velocity change as the pump stops, thus generating pressure surges!

Remedy:
A pressure reducer/controller has to be installed upstream of the pressure booster system to prevent detrimental effects.

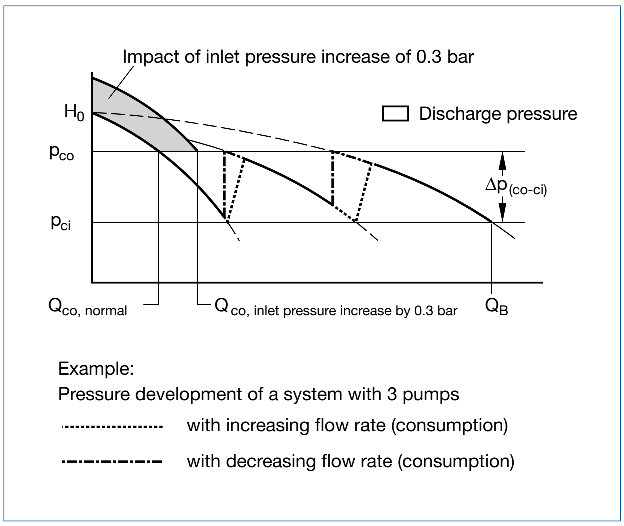


Fig. 24: Operating characteristics of a pressure booster system with cascade control, i. e. without speed control.

5. Pressure reducer

5.1 General

The criteria for using pressure reducers have been described in DIN 1988-200.
Pressure reducers must be compliant with DIN EN 1567 and DVGW W 570-1.

A pressure reducer protects systems against excessively high supply pressure.
It can be used for residential buildings, industrial and commercial purposes depending on its specifications.
With a view to energy efficiency, the use of pressure reducers should however be avoided with variable speed systems.

5.2 Application:

Pressure reducers are required

- if according to DIN 4109 Part 5 (draft status) the static pressure at the extraction points exceeds 5 bar.
- to limit the operating pressure in the consumer pipes in the event that the highest possible static pressure at any given point in the drinking water system may reach or exceed the pipes' highest permissible operating pressure, or if appliances and installations allowing lower pressures only are connected.
- if the static pressure upstream of a safety valve may reach 80 % of its response pressure. With a safety valve response pressure of 10 bar, for example, it is necessary to install a pressure reducer if the static pressure exceeds 8 bar.
- if high-rise buildings are supplied via one pressure booster system only and several pressure zones are required. In such cases pressure reducers are installed either into the pressure zones' risers or into the floor service pipes.

5.3 Determining the nominal diameter:

To determine the pressure reducer's nominal diameter, it is necessary to establish the maximum peak flow V_{peak} at the point of use.
(to DIN 1988-300)

Pressure reducers must be sized on the basis of the required flow rate, not the nominal pipe diameter.
For pressure reducer sizing refer to the relevant table in DIN 1988-200; ensure that the actual maximum flow is as close as possible to the values specified in the table but does not exceed them.
A differentiation is made between installations which comply with the sound insulation requirements of DIN 4109, Part 5 (e.g. residential buildings), and those (e.g. commercial installations) which do not comply with these requirements.

Marking:
Pressure reducers are marked in accordance with DVGW Worksheet 375.

6. Standards, directives and statutory regulations

DIN 1988-100
Codes of practice for drinking water installations (TRWI)
– Protection of drinking water, drinking water quality control; DVGW* code of practice (DVGW: German Technical and Scientific Association for Gas and Water)

DIN 1988-200
Codes of practice for drinking water installations (TRWI)
Installation Type A (closed system)
– Planning, components, apparatus, materials; DVGW code of practice

DIN 1988-300
Codes of practice for drinking water installations (TRWI)
– Pipe sizing; DVGW code of practice

DIN 1988-500
Pressure booster systems with variable speed pumps

DIN 1988-600
Drinking water installations in connection with fire-fighting and fire protection installations

DIN EN 805
Water supply - Requirements for systems and components outside buildings

DIN EN 806
Specifications for installations inside buildings conveying water for human consumption
Part 1: General
Part 2: Design
Part 3: Pipe sizing
Part 4: Installation
Part 5: Operation and maintenance

DIN EN 1717
Protection against pollution of potable water installations and general requirements of devices to prevent pollution by backflow

DIN 2000
Centralized drinking water supply; principles for drinking water requirements, planning, construction and operation of units

DIN 2001-1
Drinking water supply from small units and non-stationary plants – Part 1: Small units - Guidelines for drinking water, planning, construction, operation and maintenance of plants

DIN 2001-1 Supplement 1
Example of a checklist for the control of a water catchment plant

DIN 2001-2
Drinking water supply from small units and non-stationary plants – Part 2: Non-stationary units - Guidelines for drinking water requirements, planning, construction and operation of units

DIN 4109
Sound insulation in buildings; requirements and verifications

DIN 4807-5
Expansion vessels – Part 5: Closed expansion vessels with membrane for drinking water installations; Requirements, test, design and designation

DIN EN 15182
Part 1: Common requirements
Part 2: Combination branchpipes
Part 3: Smooth bore jet and/or one fixed spray jet angle branchpipes

IfSG – Protection Against Infection Act
Act regulating the prevention of and protection against communicable diseases in humans

LMBG – Foodstuffs and Commodities Act
Official food control law for food, tobacco, cosmetic products and other commodities to protect health and to safeguard consumers' rights

TrinkwV 2011 - Drinking Water Ordinance
Regulation for the quality of water for human use

VDI Directives
Directives issued by the Association of German Engineers

Regular testing of pressure vessels (§15 BetrSichV - German Industrial Safety Regulation)

If a system and its components require supervision, they must be tested by an authorised supervision/inspection body at defined, regular intervals to ensure they are in good working condition.

On the basis of a safety evaluation, the operator must determine the testing intervals of the overall system and the system components within six months following the commissioning of the system.

The tests must be performed in compliance with the information given in the table below:

Class	Product of max. pressure and vessel volume PS x V [bar x l]	Testing prior to commissioning or following a modification	Regular testing	
			Internal testing Person in charge/Interval	Strength test Person in charge/Interval
	PS x V ≤ 50	System does not require supervision/inspection		
3	50 < PS x V ≤ 200	Qualified person [Qp]	QP (Testing/inspection interval as per manufacturer's specifi-cations or based on experience with operating mode)	QP (Testing/inspection interval as per manufacturer's specifi-cations or based on experience with operating mode)
2	200 < PS x V ≤ 1000	Authorised inspection agency	QP (Testing/inspection interval as per manufacturer's specifi-cations or based on experience with operating mode)	QP (Testing/inspection interval as per manufacturer's specifi-cations or based on experience with operating mode)
	1000 < PS x V ≤ 3000	Authorised inspection agency	Authorised inspection agency (≤ 5 years)	Authorised inspection agency (≤ 5 years)
1	PS x V > 3000	Authorised inspection agency	Authorised inspection agency (≤ 5 years)	Authorised inspection agency (≤ 5 years)

Table 1: Pressure vessel classification and testing in accordance with §15 BetrSichV (Industrial Safety Regulation)

QP: Qualified person:
Persons who have the requisite technical knowledge to perform testing and inspection of work material due to their vocational training or recent professional duties (previous "expert" e.g. from manufacturer or depot).

Authorised inspection agency:
supervision and inspection body (officially accepted expert, e.g. TÜV) notified by the responsible regional authorities

Inspection, maintenance and repair to DIN EN 806-5

Inspection, maintenance and repair: According to the manufacturers' operating instructions

Carried out by: Installation contractor

Interval: Annually, unless otherwise specified by the manufacturer

7. Worksheets

Worksheet 1: Calculation flow rates and minimum flow pressures of common drinking water extraction points

Step 1:

Determining the calculation flow rates of all taps/fittings and apparatus to be connected according to manufacturer's specifications (Approximate evaluation on the basis of reference values according to DIN 1988-300, Table 2).

Step 2: Adding the calculation flow rates = ΣV_{cal}

Type of taps/fittings	DN	Minimum flow pressure $p_{min,flow}$ MPa	Calculation flow rate V_{cal} l/s
Water tap without aerator*	15	0.05	0.30
	20	0.05	0.50
	25	0.05	1.00
With aerator	10	0.10	0.15
	15	0.10	0.15
Mixer taps for shower**	15	0.10	0.15
Bathtub	15	0.10	0.15
Kitchen sink	15	0.10	0.07
Sink	15	0.10	0.07
Bidets	15	0.10	0.07
Household machines **Washing machine (to DIN EN 60456)**	15	0.05	0.15
Dishwasher (to DIN EN 50242)	15	0.05	0.07
Toilets and urinals			
Feed valve for cisterns (to DIN EN 14124)	15	0.05	0.13
(Manual) flush valve for urinal (to DIN EN 12541)	15	0.10	0.30
(Electronic) flush valve for urinal (to DIN EN 15091)	20	0.10	0.30
Flush valve for toilet	20	0.12	1.00

Important information:
Manufacturers have to specify the minimum flow pressure and the calculation flow rates on the cold and hot water side (in the case of mixer taps). Always observe the manufacturer's specifications when establishing the pipe diameter; these may deviate considerably from the data specified in this table. The following should be taken into account:
If the manufacturer's minimum flow pressure and calculation flow rate specifications are below the values given in the table, two options are available:
If the drinking water installation is sized on the basis of the lower values for hygienic and economic reasons, this must be agreed with the building owner/client and the requirements for sizing the taps/fittings (minimum flow pressure, calculation flow rate) taken into account in the drinking water installation design.
If the drinking water installation is not sized on the basis of the lower values, the tabulated values must be used. If the manufacturer's specifications are above the tabulated values, the drinking water installation must be sized on the basis of the manufacturer's values.

a Without connected apparatus (e. g. lawn sprinkler).
b The specified calculation flow rate must be applied both to the cold and to the hot water connection.
c Angle valves for sinks and S-shaped connections for shower and bathtub taps/fittings must be taken into account via their individual hydraulic losses or via the minimum flow pressure of the tap/fitting.

Table 2: Minimum flow pressures and calculation flow rates of common drinking water extraction points

Worksheet 2:
Calculating the peak flow

The simultaneity of water extraction depends on the usage (e.g. apartments, hotels etc.). Generally speaking, it is unlikely that all connected extraction points (taps/fittings) would be opened simultaneously.

The peak flow rate for the $0.2 \leq \Sigma V_{cal} \leq 500$ range is calculated using equation (33) for the building types specified in table 3.

$$V_{peak} = a(\Sigma V_{cal})^b - c \qquad (33)$$

Key:

V_{peak} = Peak flow rate
V_{cal} = Calculation flow rate (refer to table 2)
a, b, c = Constants (refer to table 3)

Building type \ Constant	a	b	c
Residential buildings	1.48	0.19	0.94
Hospital ward	0.75	0.44	0.18
Hotel	0.70	0.48	0.13
School	0.91	0.31	0.38
Administration building	0.91	0.31	0.38
Assisted-living facilities, senior citizens' residence	1.48	0.19	0.94
Nursing home	1.40	0.14	0.92

Table 3: Constants for peak flow rate

Exceptions:

- Living unit (LU)
Experience has shown that the flow rates established with equation (33) are too high towards the end of the supply line (viewed in flow direction) and with regard to distribution of the living units on the various floors, as no more than two extraction points (e.g. in a bathroom) are used simultaneously.
The peak flow rate in each supply line section of a living unit is therefore assumed to be the total flow of the largest extraction point (taps/fittings) installed in this line section (this also applies to those cases where the flow rate for the living unit is lower according to equation (33). If a second living unit is connected to a line section (e.g. in the riser), the peak flow rates of the two living units are added together as long as the resultant peak flow rate is lower than that calculated with equation (33). If this is not the case, the peak flow rate must be established using equation (33).

- Continuous consumer
The flow rate in the case of continuous consumption is added to the peak flow rate of the other extraction points. If water is extracted for more than 15 minutes, e.g. via a garden irrigation valve, then this extraction point is referred to as a continuous consumer.

- Multiple extraction point systems
The total flow rate is taken as a basis for the calculation. The extent of simultaneous water extraction must be determined with the operator. If they can occur simultaneously, the peak flow rates of a multiple extraction point system and other sections in the building must be added together.

- Special-purpose buildings, commercial and industrial plants
Particular consideration must be given to the simultaneity of water extraction in special-purpose buildings (i.e. other building types than those listed in table 3) and drinking water installations in commercial and industrial plants.
For industrial, agricultural and gardening facilities, slaughterhouses, dairies, laundries, canteen kitchens, public baths etc., the peak flow rate must be established on the basis of the total flow rates in consultation with the facilities' operator. This is also applicable for certain sections of the drinking water installation, e.g. commercial businesses in residential buildings. The peak flow rates of these drinking water installation sections must be added together if they occur at the same time.

Worksheet 3: Water meter

Standard values for pressure losses Δp_{wm} of water meters

Flow meter type	Nominal flow rate $\dot{V}_N(Q_n)$ m^3/h	Pressure loss Δp at $\dot{V}_{max}$ (Q_{max}) to DIN ISO 4064, Part 1
Turbine flow meter	< 15	1000
Woltman-type flow meter (vertical)	≥ 15	600
Woltman-type flow meter (parallel)	≥ 15	300

Table 4: Water meter pressure losses

As a rule, the water meter type, quantity and size are specified by the local water provider. If the local water provider specifies the size of the water meter, then the water meter pressure loss indicated by the provider must be applied.

The following applies according to DIN ISO 4064, Part 1:

$$\dot{V}_N(Q_n) = 0.5\ \dot{V}_{max}\,(Q_{max}) \tag{34}$$

$\dot{V}_N(Q_n)$ applies to continuous consumption

$\dot{V}_{max}\,(Q_{max})$ applies to short-term peak consumption

Connection, nominal and maximum flow rate of water meters to DIN ISO 4064, Part 1

Flow meter type	Connection: Thread size to DIN ISO 228, Part 1	Connection: Connection size (nominal flange size) DN	Nominal flow rate *) V·n (Qn) m^3/h	Maximum flow rate V·max (Qmax) m^3/h
Positive displacement and turbine flow meters	G 1/2 B	–	0.6	1.2
	G 1/2 B	–	1	2
	G 3/4 B	–	1.5	3
	G 1 B	–	2.5	5
	G 1 1/4 B	–	3.5	7
	G 1 1/2 B	–	6	12
	G 2 B	–	10	20
Woltman-type water meter	–	50	15	30
	–	65	25	50
	–	80	40	80
	–	100	60	120
	–	150	150	300
	–	200	250	500

Table 5: Water meter flow rates

*) *The nominal flow rate is a water meter specification. According to DIN ISO 4064, Part 1, thread sizes for a given nominal flow V·n (Q_n) can also be taken from the class directly above or below those indicated in the table for the respective values.*

Worksheet 4:

Worksheet 4: Approximate calculation of the consumer pipe downstream of the PBS

Filter-induced pressure losses

A reference value of **200 mbar** can be applied for filters with $\dot{V}_{max} = \dot{V}_{peak}$.

Pressure loss Δp_{DH} of drinking water heating systems

To calculate the pressure loss of further apparatus (e. g. water softening or dosing equipment) obtain relevant manufacturer's data, if required.

Device type	Pressure loss Δp_{DH}
Electric through-flow water heater, hydraulically controlled electronically controlled	 1000 800
Electric or gas water heater with storage tank, nom. volume up to 80 l	200
Gas through-flow water heater and combined gas heater for hot water and heating systems to DIN EN 297, DIN EN 625	800

Table 6: Reference values for pressure loss Δp_{DH} of drinking water heating systems

Pressure losses of consumer pipes downstream of the PBS

Approximate calculation

In the planning phase the system designer is required to perform a detailed calculation of the pressure losses to DIN 1988-300.

Pipe length from PBS to the least hydraulically favourable extraction point $\Sigma l_{downstream}$ m	Mean pressure drop in consumer pipes $\frac{\Delta p_{frict} + \Delta p_{indiv}}{l}$ mbar/m
≤ 30	20
> 30 ≤ 80	15
> 80	10

Table 7: Reference values for pressure loss evaluation of consumer pipes downstream of PBS

Worksheet 5: Overview of fundamental calculation parameters

Table 8 shows an example of the fundamental calculation parameters involved.

No. of flow path/branch				
No.	Description	Designation	Value	Unit
1	Minimum pressure downstream of the water meter	$p_{min,WZ}$		hPa
2	Pressure loss from static head difference	Δp_{geo}		hPa
3	Apparatus pressure loss Water meter	Δp_{wm}		hPa
	Apartment water meter	Δp_{wm}		hPa
	Filters	Δp_{fil}		hPa
	Water softening equipment	Δp_{soft}		hPa
	Dosing system	Δp_{dos}		hPa
	Drinking water heating systems	Δp_{dh}		hPa
	Further apparatus	Δp_{ap}		hPa
	Further apparatus	Δp_{ap}		hPa
	Further apparatus	Δp_{ap}		hPa
4	Minimum flow pressure Tap/fitting: _________________________	$p_{minflow}$		hPa
5	Sum total of pressure losses	$\Sigma \Delta p$		hPa
6	For balancing calculation: pipe friction and other individual losses in sections (TS) which have already been considered Section (TS) ________ to section (TS) __________	$\Sigma (I \cdot R+Z)$		hPa
7	Available for pipe friction and other individual losses Section (TS) _________ to section (TS) __________	$\Sigma (I \cdot R+Z)_V$		hPa
8	Estimated percentage for individual apparatus losses	α		%
9	Available for pressure loss due to pipe friction	Δp_{pf}		hPa
10	Pipe length	I_{total}		m
11	Available pipe friction pressure loss gradient	R_L		hPa/m

Table 8: Overview of fundamental calculation parameters

Worksheet 6:
Conversion of discharge head H into pressure increase Δp

$$\Delta p = \rho \cdot g \cdot H \tag{35}$$

Δp = Pressure increase in p_a
1 Pa = 1 N/m^2
1 bar = 100,000 Pa
ρ = Density in kg/m^3
g = Acceleration due to gravity = 9.81 m/s^2
H = Discharge head per pump in m

In practice, the value assumed for acceleration due to gravity (g) is 10 m/s^2 and for density δ 1000 kg/m.

The above equation is therefore simplified:

$$\Delta p \approx \frac{H}{10} \text{ [bar]} \tag{36}$$

Δp = Pressure increase in bar
H = Discharge head in m

Both equations also apply to static pressure losses, e.g. Δp_{geo}, and the static head losses, e.g. H_{geo}

Therefore:

$$\Delta p_{geo} \approx \frac{H_{geo}}{10} \text{ [bar]} \tag{37}$$

Worksheet 7:
Head losses in steel pipes

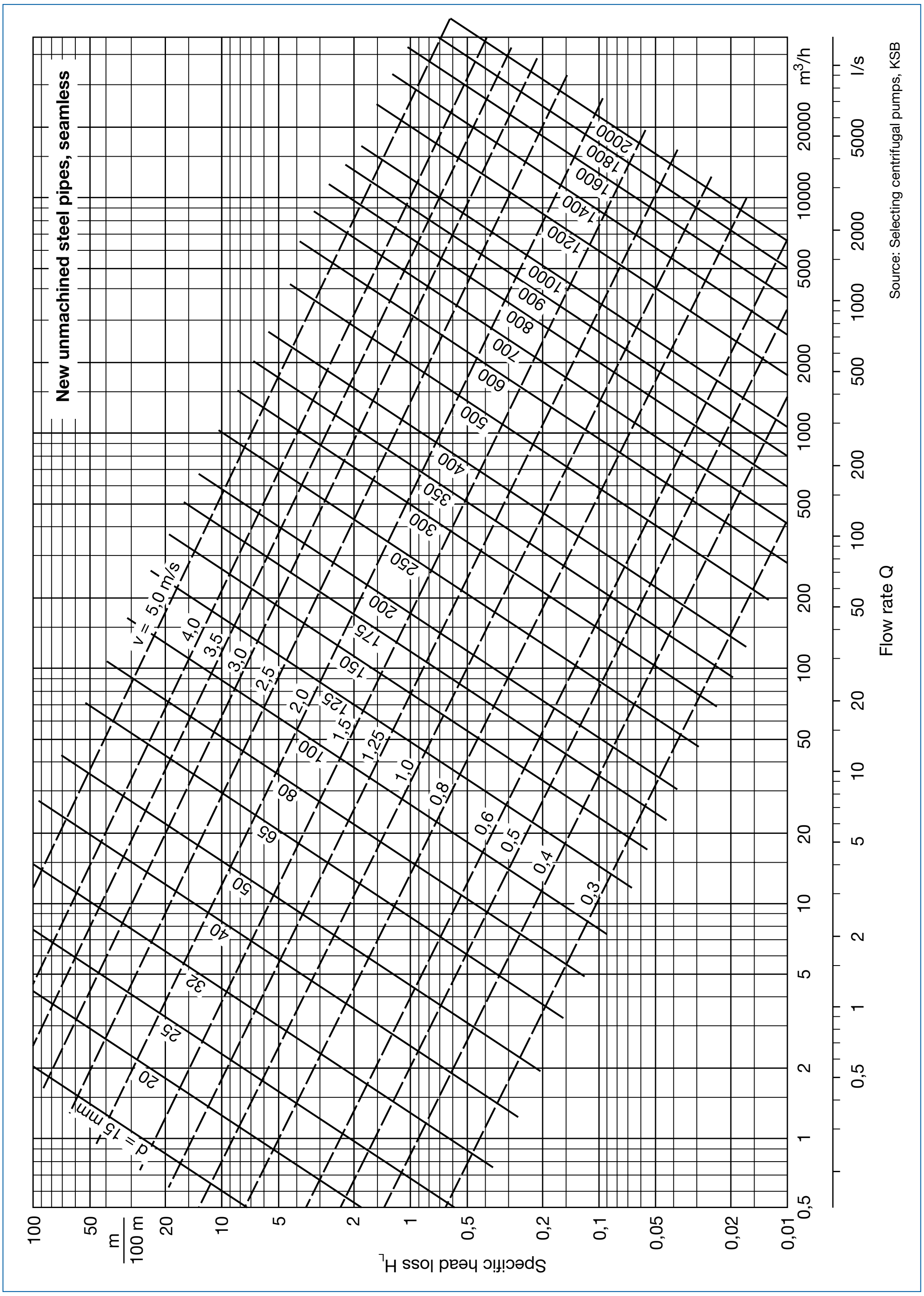


Fig. 25: Head losses H_L for new unmachined steel pipes, seamless (k= 0.05 mm)

Worksheet 8:
Head loss of low-friction pipes

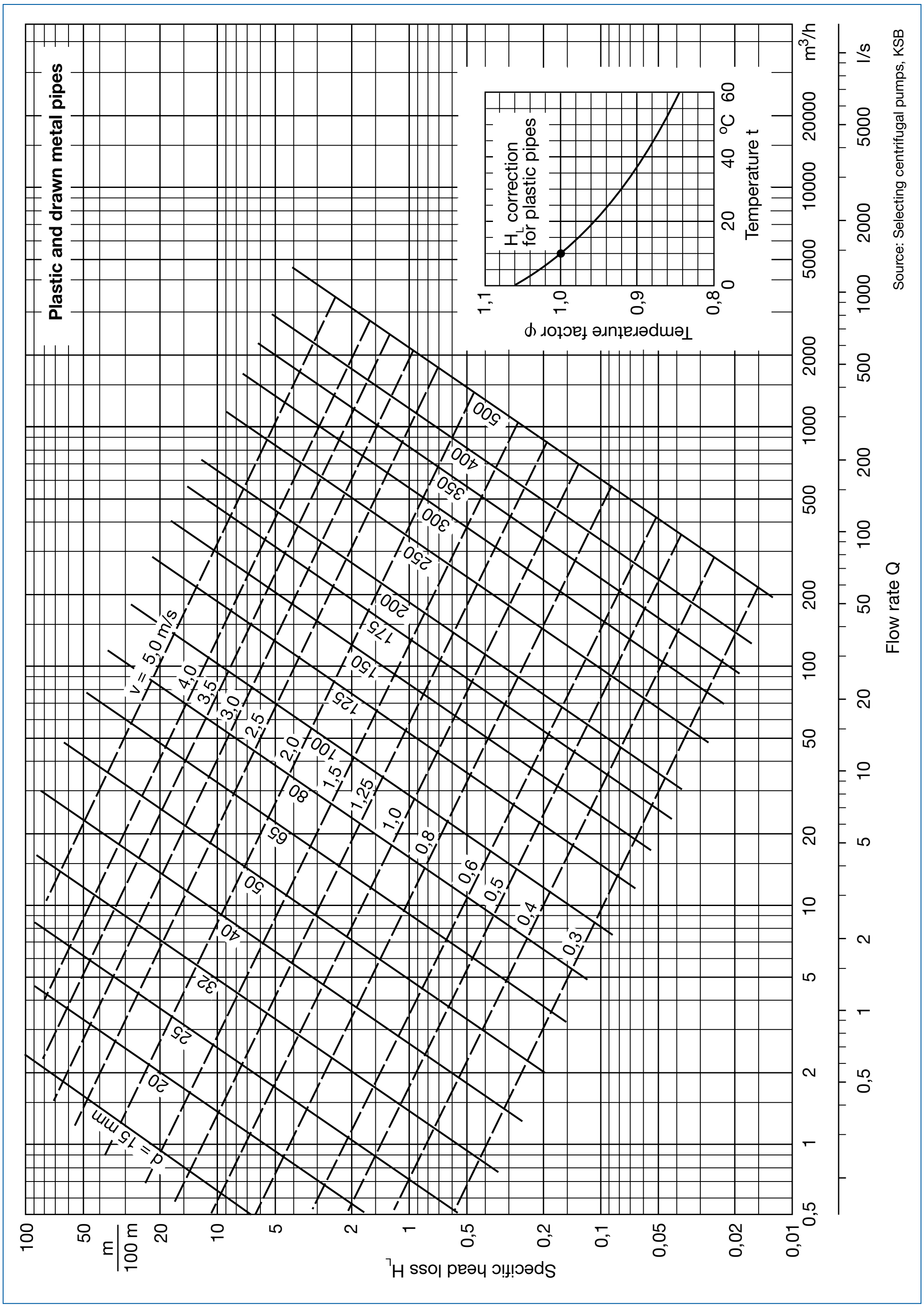


Fig. 26: Head losses H_L for low-friction pipes (k ≈ 0)
(For plastic pipes when t ≠ 10°C multiply by the temperature factor 'φ'.)

Worksheet 9:
Permissible flow rate criteria of a PBS

Nominal service pipe diameters	Max. total flow upstream of PBS and consumer pipes without PBS	Max. permissible flow rates for direct connection of a PBS without pressurised inlet tank	
DN	I Q_{max} at v < 2.0 m/s	IIa Q_{max} at v < 0.15 m/s	IIb Q_{max} PBS at v < 0.5 m/s
	m3/h		
25 / 1"	3.50	0.26	0.88
32 / 1 1⁄4"	5.80	0.43	1.45
40 / 1 1⁄2"	9.00	0.68	2.30
50 / 2"	14.00	1.06	3.50
65	24.00	1.80	6.00
80	36.00	2.70	9.00
100	57.00	4.20	14.00
125	88.00	6.60	22.00
150	127.00	9.50	32.00
200	226.00	17.00	57.00
250	353.00	26.50	88.00
300	509.00	38.00	127.00

Table 9: Permissible flow velocity in service pipe (to DIN 1988-300)

I:
The total flow velocity upstream of the PBS and upstream of the consumer pipes without PBS must not exceed 2.0 m/s.
For direct connection to a PBS without pressurised inlet tank the difference in flow velocity in the service pipe as a result of starting and stopping the PBS pumps must not exceed the following values:

IIa:
v < 0.15 m/s by one (the largest) single pump

IIb:
v < 0.5 m/s by simultaneously stopping all PBS duty pumps

The table provides information on flow rate criteria for the specified nominal service pipe diameters depending on the following:
– permissible flow velocity (IIa) and
– its change as a result of the number of pumps started / stopped (IIb) and
– total flow rate (I).

Worksheet 10:
Accumulator selection/calculation (KSB recommendation) / inlet side

Some of the following design information is taken from DIN 1988 and other parts are specific KSB information.

Inlet side

Break tank for indirect connection

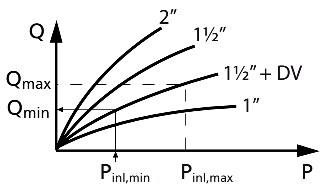
Standard i.e. the water supply network is capable of providing $\dot{V}_{max}$ at any time

Tank selection

$$V_{BT} = 0.03 \cdot \dot{V}_{max}\ (Q_D) \quad [m^3]$$

N.B.: The size of the tank is proportional to that of the re-fill valve.

Selection of re-fill valve by means of $P_{inl,min}$, Q_D



(3) This selection allows for a buffer volume sufficient for approx. 100 s in the case of maximum water consumption and if re-filling does not take place.

Determining the storage volume by the volume difference/time method

$$V_{BT} = (Q_D - Q_{min}) \cdot t \quad [m^3]$$

Membrane-type accumulator for direct connection

Total volume of accumulators on inlet pressure side of PBS

Maximum flow rate of a PBS pump	Total accumulator volume on inlet pressure side of pumps
$\dot{V}_{max,p}$	V_{tot}
m^3/h	m^3
≤ 7	0.3
> 7 ≤ 15	0.5
> 15	0.75

The minimum volume should not be less than 0.3 m³.

Key:

- $P_{inl,min}$ = Minimum available pressure on filling side
- $P_{inl,max}$ = Maximum inlet pressure on filling side·
- $\dot{V}_{max,p}$ = Maximum volume flow of a PBS pump
- V_{tot} = Total accumulator volume in m³
- Q_D = PBS design flow rate
- Q_{min} = Re-fill flow rate under minimum inlet pressure ($p_{inl,min}$) conditions
- Q_{max} = Maximum permissible re-fill flow rate (≙ network extraction)
- V_{BT} = Effective volume of break tank in m³
- t = Buffering period of break tank in h

Worksheet 11:
Accumulator selection/Consumer side

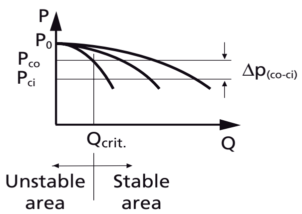
Consumer side

Cascade control

Pressure booster systems with pressure-dependent or cascade control (e. g. Hya-Solo, Hyamat K)

Sizing the accumulator

Selection on the basis of the $Q_{crit.}$ limit



Q_{crit} = Flow rate at cut-out point

$$V_{tot} = Q_{crit.} \cdot \frac{P_A + 1}{S \cdot n \cdot \Delta p_{(co-ci)}}$$

Pump size	Number of stages	Switching operations/h
2	2 to 10	23
2	11 to 25	14
4	2 to 10	23
4	11 to 25	14
6	2 to 9	20
6	10 to 26	12
10	2 to 7	17
10	8 to 21	9
15	2 to 7	17
15	8 to 16	9
25-45	2 to 6	14
25-45	7 to 10	9

Speed control

Pressure booster systems with infinitely variable speed control on one or all pumps (e.g. Hyamat V, Hyamat VP)

Membrane-type accumulators are normally not required in variable speed pump systems. (except for 8-litre accumulators / KSB standard)

In the case of consumers with very low demand, KSB recommends an 80-litre standard accumulator (dual connection).

Key:

- V_{tot} = Total accumulator volume
- $Q_{crit.}$ = Critical minimum flow rate of PBS
- P_{co} = PBS cut-out pressure
- P_{ci} = PBS cut-in pressure
- $\Delta p_{(co-ci)}$ = Difference between cut-in/cut-out pressures
- n = Number of pumps (incl. stand-by pump)
- s = Permissible number of start-ups

Worksheet 12:
Selection diagram for pressure reducers

The DVGW directives stipulate that, as a rule, a flow velocity of 2 m/sec. must not be exceeded in domestic water supply systems.
The common velocity range of between 1 and 2 m/s has been highlighted in dark grey in the diagram below. For pressure reducer sizing it is advisable to assume a velocity of approx. 1.5 m/s to ensure the pressure reducer is sufficiently dimensioned for higher loads at a later stage. This diagram (Fig. 27) allows the required nominal diameter (DN) for a specified flow rate V (m³/h or l/min) to be established.

For the pressure reducers' installation position refer to the manufacturer's specifications. The installation must not transmit stresses to the piping.

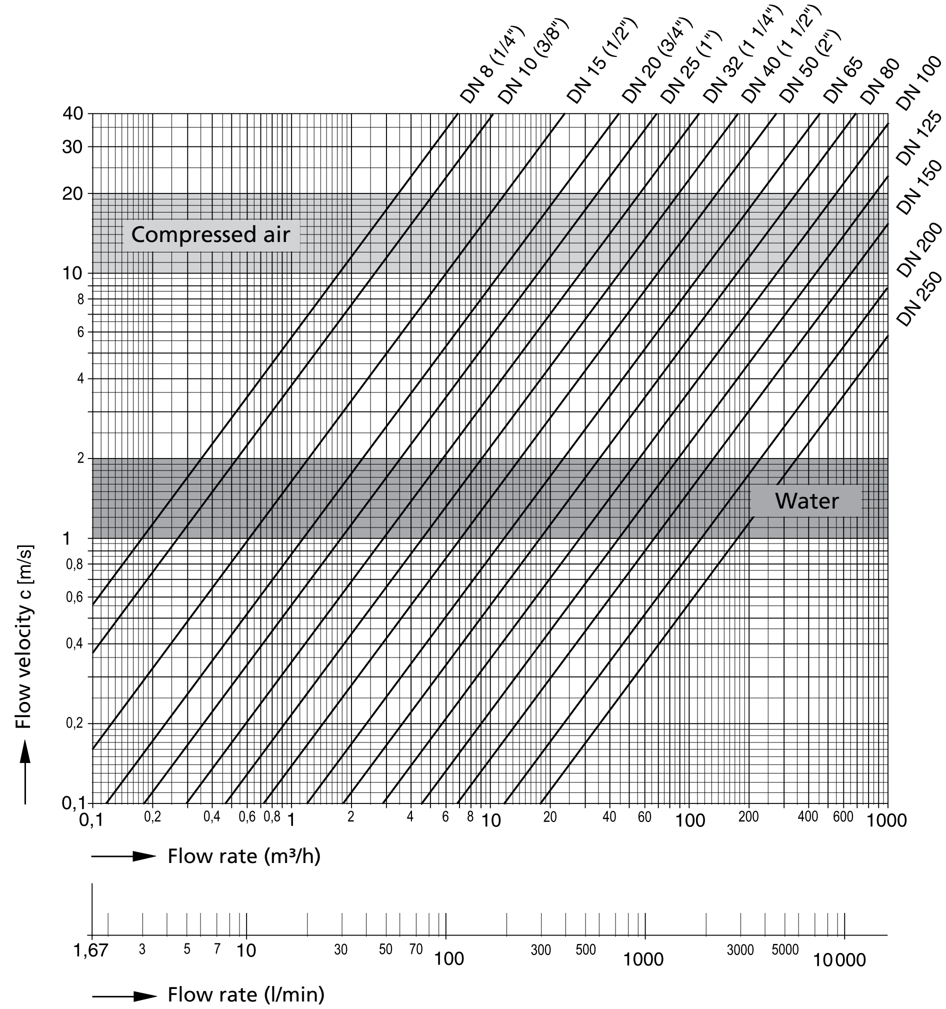


Fig. 27: Selection diagram for KSB pressure reducers

Determining the nominal diameter to DIN 1988-200

Pressure reducers must be sized on the basis of the required flow rate, not the nominal pipe diameter.

Pressure reducers should be selected in conjunction with the piping calculation. They should take into account the manufacturer's data and must comply with the data given in tables 10 and 11 as per DIN 1988-200 and the sound insulation requirements to the DIN 4109 series.

Nominal diameter	Peak flow rate V_{peak} at flow velocity 2 m/s	
DN	l/s	m^3/h
15	0.5	1.8
20	0.8	2.9
25	1.3	4.7
32	2	7.2
40[a]	2.3	8.3
50[a]	3.6	13
65[a]	6.5	23
80[a]	9	32
100[a]	12.5	45
125[a]	17.5	63
150[a]	25	90
200[a]	40	144
250[a]	75	270
[a)] No conformity mark regarding noise characteristics currently available		

Table 10: Nominal pressure reducer diameters for systems which have to comply with the sound insulation requirements to DIN 4109 (e.g. residential buildings)

Nominal diameter	Peak flow rate V_{peak} at flow velocity 3 m/s	
DN	l/s	m^3/h
15	0.5 (0,35[a])	1.8 (1.3[a])
20	0.9	3.3
25	1.5	5.4
32	2.4	8.6
40[a]	3.8	13.7
50[a]	5.9	21.2
65[a]	9.7	35
80[a]	15.3	55
100[a]	23.3	83
125[a]	34.7	125
150[a]	52.8	190
200[a]	92	330
250[a]	139	500
[a)] Safety valve group		

Table 11: Nominal pressure reducer diameters for systems which do not have to comply with the sound insulation requirements to DIN 4109 (e.g. commercial systems)

Worksheet 13:
Frequency of inspection and maintenance of components for drinking water installation to DIN EN 806-5

Information on how frequently inspection and maintenance should be performed on components for drinking water installations is specified in the table below.

Components not listed in this table may also require inspection and maintenance.

Inspection and maintenance requirements may differ between EU member states.

No.	System components and units	Applicable standards	Inspection	Routine maintenance
1	Air gap (unrestricted)	EN 13076	Every 6 months	
2	Air gap with non-circular overflow (unrestricted) (AB)	EN 13077	Every 6 months	
3	Air gap with submerged feed incorporating air inlet plus overflow (AC)	EN 13078	Annually	
4	Air gap with injector (AD)	EN 13079	Every 6 months	
5	Air gap with circular overflow (restricted) (AF)	EN 14622	Annually	
6	Air gaps with minimum circular overflow (verified by test or measurement) (AG)	EN 14623	Annually	
7	Controllable backflow preventer with reduced pressure zone (BA)	EN 12729	Every 6 months	Annually
8	Non-controllable backflow preventer with different pressure zones (CA)	EN 14367	Every 6 months	Annually
9	In-line anti-vacuum valves (DA)	EN 14451	Annually	Annually
10	Pipe interrupter with atmospheric vent and moving element (DB)	EN 14452	Annually	
11	Pipe interrupter with permanent atmospheric vent (DC)	EN 14453	Every 6 months	
12	Controllable (anti-pollution) check valve (EA)	EN 13959	Annually	Annually
13	Non-controllable (anti-pollution) check valve (EB)		Annually	Replace every 10 years
14	Controllable (anti-pollution) double check valve (EC)		Annually	Annually
15	Non-controllable (anti-pollution) double check valve (ED)		Annually	Replace every 10 years
16	Mechanical disconnector, direct actuation (GA)	EN 13433	Every 6 months	Annually
17	Mechanical disconnector, hydraulic actuation (GB)	EN 13434	Every 6 months	Annually
18	Hose union backflow preventer (HA)	EN 14454	Annually	Annually
19	Hose union anti-vacuum valves (HB)	EN 15096	Annually	Annually
20	Automatic diverter (HC)	EN 15506	Annually	

Continued on page 53

Continued on page 52

No.	System components and units	Applicable standards	Inspection	Routine maintenance
21	Hose union anti-vacuum valves, combined with check valve (HD)	EN 15096	Annually	Annually
22	Pressurised air inlet valves (LA)	EN 14455	Annually	Annually
23	Pressurised air inlet valves, combined with downstream check valve (LB)		Annually	Annually
24	Hydraulic safety group	EN 1487	Once a month	Annually
25	Expansion group	EN 1488	Once a month	Annually
26	Pressure safety valve	EN 1489	Once a month	
27	Combined temperature and pressure relief valve	EN 1490	Once a month	
28	Expansion valve	EN 1491	Once a month	
29	Pressure reducers	EN 1567	Annually	Annually
30	Inline hot water supply tempering valves	EN 15092	Every 6 months	Annually
31	Pressure booster pump	EN 806-2 prEN 806-4	Annually	
32	Backwashing filters, (80 µm to 150 µm)	EN 13443-1	At least every six months	
33	Non-backwashing filters, (80 µm to 150 µm)	EN 13443-1	At least every six months	
34	Filters (< 80 µm)	EN 13443-2	At least every six months	
35	Dosing system	EN 14812 prEN 15848	Every 2 months	At least every six months
36	Softeners	EN 14743	Every 2 months	At least every six months
37	Electrolytic treatment systems with aluminium anodes	EN 14095	Every 2 months	At least every six months
38	Active media filters	EN 14898	Every 2 months	At least every six months
39	Membrane separation devices	EN 14652	Every 2 months	At least every six months
40	Devices using mercury low-pressure ultraviolet radiators	EN 14897	Every 2 months	At least every six months
41	Nitrate removal device	EN 15219	Every 2 months	At least every six months
42	Water heaters	EN 12897	Every 2 months	Annually
43	Piping system	EN 806-2 prEN 806-4	Annually	
44	Water meter, cold	MID [1]	Annually	Every 6 years
45	Water meter, hot	MID [2]	Annually	Every 5 years
46	Fire-fighting systems	EN 806-2 prEN 806-4	National regulations	

Worksheet 12: Frequency of inspection and maintenance of components for drinking water installation to DIN EN 806-5

8.
Nomenclature

Description	Symbols	Units
Propagation velocity of a pressure wave	a	m/s
Simultaneous use factor	f	–
Acceleration due to gravity (9.81 m/s²)	g	m/s²
Pump discharge head	H	m
Max. pump discharge head at zero flow rate (Q = 0)	H_0	m
Static head loss	H_{geo}	m
Floor height	H_{fl}	m
Head loss	H_L	m
Head increase	ΔH	m
Static pressure loss for floor X	$\Delta H_{geo\ (floor\ X)}$	m
Number of pumps (incl. stand-by pump)	n	–
Number of floors which have to be protected against inadmissible pressures by means of pressure reducers	N_{flpr}	–
Number of floors which can be supplied without PBS	$N_{without\ PBS}$	–
Pressure	p	bar
Maximum pump pressure at zero flow rate (Q = 0)	p_0	bar
Cut-out pressure, pressure at which one pump of a pressure-controlled PBS cuts out	p_{co}	bar
Cut-in pressure, pressure at which one pump of a pressure-controlled PBS cuts in	p_{ci}	bar
Setpoint (of a speed controlled PBS)	p	bar
Flow pressure at consumer	p_{flow}	bar
Minimum flow pressure at consumer	$p_{min,flow}$	bar
Minimum flow pressure at consumer in floor	$p_{min,flow(N)}$	bar
Minimum pressure available at the local water provider’s hand-over point	SPLN	bar
Maximum pressure	p_{max}	bar
Maximum permissible flow pressure at consumer	$p_{max,flow}$	bar
Maximum pressure per floor	$p_{max,fl}$	bar
Maximum pressure at the local water provider’s hand-over point	$p_{max,V}$	bar
Required pressure downstream of the PBS	$p_{discharge}$	bar
Available pressure upstream of the PBS	p_{inl}	bar
Minimum pressure available upstream of the PBS	$p_{inl,min}$	bar
Maximum pressure upstream of the PBS	$p_{inl,max}$	bar
Opening pressure of a by-pass valve	p_{valve}	bar

Description	Symbols	Units
Pressure drop when pump is started	Δp_1	bar
Pressure increase when pump is stopped	Δp_2	bar
Apparatus pressure loss	Δp_{ap}	bar
Difference between cut-in/cut-out pressures	$\Delta p_{(co-ci)}$	bar
Maximum pressure difference downstream of the PBS	$\Delta p_{PBS,max}$	bar
Dynamic pressure difference	Δp_{dyn}	bar
Dynamic pressure loss per floor	$\Delta p_{dyn,fl}$	bar
Static pressure loss	Δp_{geo}	bar
Static pressure loss per floor	$\Delta p_{geo,fl}$	bar
Static pressure loss for floor X	$\Delta H_{geo(floor\ X)}$	bar
Pressure loss per floor	Δp_{fl}	bar
Total pressure loss per floor	$\Delta p_{fl,tot}$	bar
Pressure fluctuation upstream of the PBS	Δp_{inl}	bar
Water meter pressure loss	Δp_{wm}	bar
Permissible pressure loss	Δp_{perm}	bar
Mean pressure drop in consumer supply pipes	$\Delta p/l$	mbar/m
Cut-out flow rate of the last pump in operation (without after-run period)	Q_{co}	m^3/h
PBS design flow rate = nominal flow rate of a PBS ($\dot{V}_{max}$)	Q_D	m^3/h
Maximum volume flow of a PBS incl. stand-by pump	Q_{DS}	m^3/h
Fire-fighting water volume flow	Q_{Ffw}	m^3/h
Critical minimum flow rate of pressure-dependent cascade control	$Q_{crit.}$	m^3/h
Minimum flow rate	Q_{min}	m^3/h
Maximum permissible filling volume flow	Q_{max}	m^3/h
Maximum permissible volume flow from water supply network	$Q_{max,netw}$	m^3/h
Nominal flow rate of water meters	Q_n	m^3/h
Nominal flow rate of PBS	Q_N	m^3/h
Filling volume flow	Q_{fill}	m^3/h
Water supply network volume flow	Q_{netw}	m^3/h
Low or continuous consumption dependent on usage	$Q_{Consumer,small}$	m^3/h

Description	Symbols	Units
Volume flow difference	ΔQ	m^3/h
Volume flow change of a highly dynamic consumer	$\Delta Q_{max,dyn}$	m^3/h
Flow rate change per pump	ΔQ_{Pu}	m^3/h
Number of start-ups	S	–
Period of time required to fill a hydrant pipe up to the wall hydrant which is most unfavourably located	t	s
Break tank buffering period	t	h
Time difference	Δt	s
Closing time of valve	T_C	s
Reflection time in the pipe	T_R	s
Flow velocity	v	m/s
Flow velocity difference	Δ_v	m/s
Effective volume of the break tank	V_{BT}	m^3
Accumulator volume	V_{accum}	m^3
Gross accumulator volume	V_{gross}	m^3
Total accumulator volume	V_{tot}	m^3
Volumetric contents of network piping	V_{pipe}	m^3
Calculation flow rate of a tap/fitting	V_{cal}	l/s
Total inlet tank volume	V_{inl}	m^3
Volume difference	ΔV	m^3
Nominal flow rate of water meters	$\dot{V}_n$	m^3/h
Minimum flow rate	$\dot{V}_{min}$	m^3/h
Nominal flow rate of a PBS = design flow rate of a PBS (QD)	$\dot{V}_{max}$	m^3/h
Maximum flow rate of a PBS pump	$\dot{V}_{max,P}$	m^3/h
Calculation flow rate of a wall hydrant	$\dot{V}_{cal,Hydr}$	l/s
Peak flow rate of PBS	$\dot{V}_{peak}$	l/s
Sum of all calculation flow rates of all taps/fittings to be supplied	$\Sigma\dot{V}_{cal}$	l/s
Pipe friction and other individual losses	$\Sigma(\Delta p_{frict}+\Delta p_{indiv})$	bar
Pipe friction and other individual losses from supply pipe up to PBS	$\Sigma(R{\cdot}l+Z)_{inl}$	bar
Pipe friction and other individual losses downstream of PBS	$\Sigma(R{\cdot}l+Z)_{discharge}$	bar
Mean pressure drop in a pipe	R	bar/m
Individual friction losses	Z	bar
Pipe length	l	m
Sum of pipe length from PBS to the hydraulically least favourable extraction point	$\Sigma l_{discharge}$	m
Accumulator efficiency	e	–
Temperature factor	j	–

The information based on DIN standards has been given with the approval of DIN Deutsches Institut für Normung e. V. (German Institute for Standardisation, Berlin). Users must ensure that all DIN standards applied are up-to-date. Latest editions can be obtained from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin. Where available, the translation of this planning information brochure is based on the official standards translation(s).

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