7 Valves

7 Valves

Valves are components in piping systems which, in addition to the function of "conducting the medium" (directing, changing the nominal width), also have the functions of blocking or regulating the rate of flow and the pressure. Depending on use, different materials are commonly used. The following chapter looks at valves in which the main material is spheroidal graphite cast iron.

7.1 Valves in spheroidal graphite cast iron

7.1 Valves in spheroidal graphite cast iron

The following section contains general information on function, construction, connection and material. This information is obligatory for all valves. For valves in the drinking water area, the requirements for materials in contact with drinking water also apply.

7.1.1 Classification of valves

In general, valves can be distinguished according to their

- functional features,
- basic design and
- type of connection.

The functional features of valves are defined in EN 736-1 [7.1-01]. **Table 7.1.1-01** contains a classification of valves according to their functional features.

Isolating valves are basically intended for shutting off lines. Because of their construction they are not suitable for flow regulation, or only to a limited extent.

For the isolation function only the "fully open" or "closed" valve positions are permissible. With regulating valves on the other hand, all intermediary positions are also admissible.

Table 7.1.1-02 contains a classification of valves according to basic design.

Table 7.1.1-03 gives a comparison of designs, connection possibilities and functional features.

Table 7.1.1-01:
Classification of valves according to functional features

Valve design	Type of action on the fluid	Examples
Isolating valve	Blocking or releasing the flow of substance	Shutoff valve, gate valve, butterfly valve
Regulating valve	Reducing the working pressure	Pressure reducing valve, throttle valve
	Tapping the flow substance	Sampling valve
Control device	Separate or combined control of pressure, temperature and volume	Control valve, control butterfly valve, regulating cock, servo valve
	Controlling a fluid level	Level control valve
Safety valve [1)]	Preventing excess pressures and subsequent shutoff	Outlet valve, safety valve, safety shutoff valve
Bursting disc safety device	Preventing excess pressures without subsequent shutoff	Bursting disc safety device
Return flow inhibitor	Preventing a reversal of flow	Non-return valve, check valve
[1)] [German designation differs] in DIN EN 736-1 [7.1-02]		

Source of Table 7.1.1-01 and Table 7.1.1-02:
Manual of pipeline construction, Vol. 1: planning, production, facilities
3rd edition, Günter Wossog, Vulkan Verlag, ISBN 978-3-8027-2745-0

Table 7.1.1-02: Classification of valves according to basic design

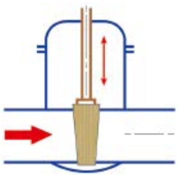
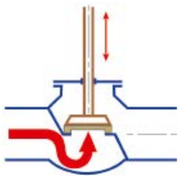
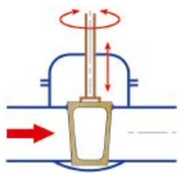
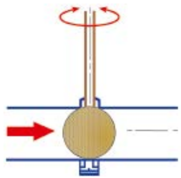
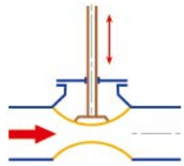
Working mechanism of the closure device				
Linear		Turning around the axis perpendicular to the direction of flow		Deformation of a flexible component
Direction of flow in the connection area				
Perpendicular to the movement of the closure device	In the direction of movement of the closure device	Through the closure device	Around the closure device	Different depending on design
				
Designation of basic designs				
Gate valve	Control valve	Cock	Flap valve [1)]	Diaphragm valve
Type of connection				
Wedge, plate, piston, diaphragm, disc	Cup, cone, Teller, cylinder (piston), ball, needle	Ball, cone (tap), cylinder	Disc, plate, rotary plug	Diaphragm, tube
Design examples				
Gate valve, slide valve, dam gate	Shutoff valve, throttle valve, safety valve, non-return valve, hydrant	Ball cock, cylinder cock, one-way stopcock	Butterfly valve, check valve, eccentric rotary plug valve	Diaphragm shutoff valve, diaphragm return flow inhibitor
[1)] This also includes the eccentric rotary plug valve				

Table 7.1.1-03: A comparison of valve designs

Criterion	Design				
	Gate valve	Control valve	Cock	Flap valve	Diaphragm valve
Flow resistance	Low	High	Low	Medium	Medium
Connection possibilities	Flanged, threaded, push-in socket, weld-on end	Flanged, push-in socket, threaded	Flanged, threaded	Flanged, push-in socket, weld-on end	Flanged, screwed socket
Piggable	Yes	No	Yes	No	No

The classification of valves according to connection type is covered in **Chapter 7.9** (in preparation).

7.1.2 Spheroidal graphite cast iron as valve material

Because of their diverse functions, valves are more cost-intensive and more complex to produce than pipes or fittings and they consist of a number of individual parts. When it comes to producing the complicated contours of their body, the "casting" production process is the most suitable.

"Cast iron", a material which was already being used at a very early stage, not only offers a high degree of freedom in its shaping but it also has great strength and ageing resistance. Experience shows it to be just as good as regards corrosion protection. For centuries a form of cast iron has been used which contains graphite in the form of flakes (lamellar graphite cast iron). These days spheroidal graphite cast ironis used almost without exception for the production of valve bodies in accordance with EN 1563 [7.1-03].

As well as the properties mentioned above, this material additionally offers outstanding toughness, which is particularly important for valves with their diverse range of load situations.

A summary of the types of spheroidal graphite cast iron normally used today for the production of valves and fittings can be found in **Table 7.1.2-01**.

Table 7.1.2-01:
A comparison of the properties of different types of spheroidal graphite cast iron for valves as per EN 1563 [7.1-03] and ductile cast iron for fittings as per EN 545 [7.1-04]

Material	Use	Standard	Tensile strength Rm [MPa]	Yield strength $R_{P0,2}$ [MPa]	Elongation at break A5 [%]	Brinell-Hardness [HB]	Modulus of elasticity [N/mm²]	Structure
EN-GJS-500-7 (GGG 50)	Valves and hydrants	EN 1563 [7.1-03]	500	320	7	170–230	169.000	pearlitic – ferritic
EN-GJS-400-15 (GGG 40)			400	250	15	135–180	170.000	pre-dominantly ferritic
EN-GJS-400-18LT (GGG 40.3)	Valves for use at low tem-peratures		400	240	18	130–175	169.000	purely ferritic
EN 545 [7.1-04]	Fittings	EN 545 [7.1-04]	420	270	≥5	< 250	170.000	pre-dominantly ferritic

Although spheroidal graphite cast iron is a material which has been very broadly perfected, further development potentials can nevertheless be identified for the future:

- new moulding processes guaranteeing castings of the highest precision and the most complex configuration,
- 3D development of valves – construction with FEM simulation, construction of pattern equipment, solidification simulation, rapid prototyping,
- development of ADI materials (ADI = Austempered Ductile Iron) with tensile strength > 1,000 MPa and acceptable elongation at break,
- development of materials with wall thicknesses up to 2 mm and high fatigue strength (3.8 % C; 2.9 % Si; 0.04 % Mn; 0.040 % Mg) and wall thickness reductions by means of micro-alloys,
- silicon doped ferritic cast iron with improved mechanical properties (up to 3.2 % Si), EN-GJS-500-12,
- development of new welding filler materials with 58 % Ni for the reliable production of a pearlitic structure.

The modern types of corrosion protection for components in spheroidal graphite cast iron provide reliable cover for all areas of use as regards soil type and medium carried **(Chapter 14 and Chapter 15)**.

Stainless steel is used among other things for drive shafts and other uncoated parts. Bolts are produced in A2 quality as a minimum (material no. 1.4301). Stem nuts and other components subject to tribological stress are usually in copperalloys.

NBR and EPDM as per EN 681-1 [7.1-05] are usually used for the seals **(Chapter 13)**.

7.1.3 Materials in contact with drinking water

The 2nd amendment to the drinking water regulation which came into effect on 13 December 2012 and in particular its article 17, Requirements for materials, means that in future the German Federal Environmental Agency will determine legally binding evaluations. These contain test specifications, test parameters and guidelines for methods. This also includes positive lists of basic and working materials and substances which come into contact with drinking water. The former Federal Environmental Agency guidelines, which had a voluntary character, will be replaced by these evaluation regulations.

Valve bodies in spheroidal graphite cast iron are always coated with epoxy or enamel. The drinking water has no contact with the spheroidal graphite cast iron.

The epoxy resins used as corrosion protection meet the requirements of the guidelines for the hygienic assessment of organic coatings in contact with drinking water of the German Federal Environmental Agency (UBA) [7.1-06]. Annex 5 of the coating guideline [7.1-07] contains a list of approved products.

In addition, all components and all coatings of an organic nature which come into contact with drinking water are to be tested for their potential to enhance microbial growth in accordance with DVGW worksheetW 270 [7.1-08].

For enamelled valve bodies which come into contact with drinking water, a draft enamel guideline is under preparation at the Federal Environment Agency. It is planned that the draft will be published in 2013 and the evaluation regulations will be established one year later.

In Germany DIN 50930-6 [7.1-09] is to be observed as regards metallic materials coming into contact with drinking water. This concerns components in stainless steel and copper alloys. They are included in the Federal Environment Agency list “Metal materials suitable for hygienic drinking water” [7.1-10].

Other functional parts such as gate valve wedges as well as flaps and gaskets are counted as elastomer materials in contact with drinking water. DVGW worksheet W 270 [7.1-08], Enhancement of microbial growth on materials in contact with drinking water is to be observed for this. In addition, the Federal Environment Agency elastomer guideline applies [7.1-11].

Furthermore the requirements and test methods of the Federal Environment Agency lubricants guideline [7.1-12] are to be observed for the lubricants which are used on the moving functional elements in valves.

7.1.4 References Chapter 7.1

[7.1-01] EN 736-1
Valves – Terminology –
Part 1: Definition of types of valves
[Armaturen - Terminologie – Teil 1: Definition der Grundbauarten]
1995

[7.1-02] DIN EN 736-1
Armaturen – Terminologie –
Teil 1: Definition der Grundbauarten;
Deutsche Fassung EN 736-1:1995
[Valves – Terminology –
Part 1: Definition of types of valves;
German version EN 736-1:1995]
1995-04

[7.1-03] EN 1563
Founding – Spheroidal graphite cast irons
[Gießereiwesen – Gusseisen mit Kugelgraphit]
2011

[7.1-04] EN 545
Ductile iron pipes, fittings, accessories and their joints for water pipelines –
Requirements and test methods
[Rohre, Formstücke, Zubehörteile aus duktilem Gusseisen und ihre Verbindungen für Wasserleitungen –
Anforderungen und Prüfverfahren]
2010

[7.1-05] EN 681-1
Elastomeric seals – Material requirements for pipe joint seals used in water and drainage applications –
Part 1: Vulcanized rubber
[Elastomer-Dichtungen – Werkstoff-Anforderungen für Rohrleitungs-Dichtungen für Anwendungen in der Wasserversorgung und Entwässerung –
Teil 1: Vulkanisierter Gummi]
1996 + A1:1998 + A2:2002 + AC:2002 + A3:2005

[7.1-06] Umweltbundesamt, Deutschland
UBA-Beschichtungsleitlinie –
Leitlinie zur hygienischen Beurteilung von organischen Beschichtungen im Kontakt mit Trinkwasser
[UBA-Coatings Guideline –
Guideline for the hygienic assessment of organic coatings in contact with drinking water]
2010-11

[7.1-07] Umweltbundesamt, Deutschland
Anlage 5 der Leitlinie zur hygienischen Beurteilung von organischen Beschichtungen im Kontakt mit Trinkwasser,
Organische Beschichtungen mit bestandener Prüfung entsprechend dieser Leitlinie,
Beschichtungen auf Epoxidharzbasis
[Coatings Guideline –
Annex 5 (list of products) PDF / 60 KB, in German]
2011-11-15

[7.1-08] DVGW-Arbeitsblatt W 270
Vermehrung von Mikroorganismen auf Werkstoffen für den Trinkwasserbereich –
Prüfung und Bewertung
[DVGW worksheet W 270
Enhancement of microbial growth on materials in contact with drinking water –
Test methods and assessment]
2007-11

[7.1-09] DIN 50930-6
Korrosion der Metalle –
Korrosion metallener Werkstoffe im Innern von Rohrleitungen, Behältern und Apparaten bei Korrosionsbelastung durch Wässer –
Teil 6: Bewertungsverfahren und Anforderungen hinsichtlich der hygienischen Eignung in Kontakt mit Trinkwasser
[Corrosion of metals –
Corrosion of metallic materials under corrosion load by water inside of pipes, tanks and apparatus –
Part 6: Evaluation process and requirements regarding the hygienic suitability in contact with drinking water]
2013-01

[7.1-10] Umweltbundesamt, Deutschland
Empfehlung –
Trinkwasserhygienisch geeignete metallene Werkstoffe
[Recommendation –
List of metallic materials suitable for contact with drinking water]
2012-12

[7.1-11] Umweltbundesamt, Deutschland
UBA-Elastomerleitlinie –
Leitlinie zur hygienischen Beurteilung von Elastomermaterialien im Kontakt mit Trinkwasser (Elastomerleitlinie)
[UBA-Rubber Guideline –
Guideline for the hygienic assessment of elastomer materials in contact with drinking water (Elastomer Guideline)]
2012-05

[7.1-12] Umweltbundesamt, Deutschland
UBA-Schmierstoffleitlinie –
Leitlinie zur hygienischen Beurteilung von Schmierstoffen im Kontakt mit Trinkwasser (Sanitärschmierstoffe)
[UBA- Lubricant Guideline –
Guideline for the hygienic assessment of lubricants in contact with drinking water (sanitary lubricants)]
2010-11

7.2 Corrosion protection of valves in spheroidal graphite cast iron

7.2 Corrosion protection of valves in spheroidal graphite cast iron

7.2.1 Epoxy coating

The epoxy coating of valves has meanwhile become the standard coating method for all valves in the areas of raw water, drinking water and wastewater.

Alongside the use of high-quality epoxy paints, epoxy powder coating, also known as EP coating, has become particularly popular for valves, being environmentally friendly and free of solvents. In the fusion bonding process the coating powder melts and becomes chemically bonded to the previously blasted metallic surface.

The overall, pore-free and complete protection provided by epoxy powder coating with a minimum coating thickness of 250 µm durably protects the fitting in all soil classes. The smooth internal surface also prevents incrustation.

Epoxy powder coating guarantees a seamless and homogenous all-over coating (inside and outside). Because corrosion primarily tends to start at the transition between different types of coating, a pore-free and flawless coating is the best protection against corrosion. Smooth internal surfaces ensure a high degree of protection against abrasion and incrustation.

Because of its good adhesion, hardness and dimensional stability under thermosetting, epoxy powder coating can also be used on the contact surfaces of sealing elements in valves.

Epoxy powder coating requires little energy for the coating process.

According to the epoxy powder coating of fittings described in EN 14901 [7.2-01], external and internal epoxy coatings for valves **(Figs. 7.2.1-01, 7.2.1-02 and 7.2.1-03)** are standardised in standards DIN 30677-1 [7.2-02], DIN 30677-2 [7.2-03] and DIN 3476 [7.2-04]. In particular RAL GZ 662 [7.2-05], the standard issued by the Quality Association for the Heavy Duty Corrosion Protection of Powder Coated Valves and Fittings (GSK), sets high requirements for epoxy powder coating. It possesses the following characteristics:

- hygienic and bacteriological safety,
- chemical resistance,
- smooth surface, low tendency for incrustation,
- absence of pores both inside and outside (test voltage 3 kV),
- high impact and pressure resistance,
- suitable for all soil classes as per DIN 50929-3 [7.2-06], OENORM B 5013-1 [7.2-07] and DVGW worksheet GW 9 [7.2-08],
- coating thickness ≥ 250 µm,
- full protection (continuous),
- high adhesive strength of at least 12 N/mm² after 7 days immersion in hot water,
- no emissions of solvents during the coating process,
- resistance to gases in accordance with DVGW worksheet G 260 [7.2-09].

Fig. 7.2.1-01:
Butterfly valve – coated inside and outside with epoxy powder in accordance with RAL GZ 662 [7.2-05]

Fig. 7.2.1-02:
Gate valve with flanges – epoxy powder coating inside and outside in accordance with RAL GZ 662 [7.2-05]

Fig. 7.2.1-03:
Check valve – external and internal coating with epoxy powder in accordance with RAL GZ 662 [7.2-05]

Application is by means of electrostatic powder coating with a spray gun **(Fig. 7.2.1-04)** or using the fluidised bed technique **(Figs. 7.2.1-05., 7.2.1-06 and 7.2.1-07)**; if the corresponding process parameters are observed, a consistently high coating quality is achieved with both processes.

A precondition for high-quality powder coating is the surface preparation of the parts. To achieve this, the parts of valves to be coated are blasted directly before the coating process. Blasting removes dirt, rust, grease and humidity from the parts producing a degree of purity of SA 2½ in accordance with EN ISO 12944-4 [7.2-10]. Constant cleaning of the blasting agent to remove impurities from circulation, as described in the GSK guidelines, is one of the essential conditions for the very good adhesion characteristics.

After that, depending on the epoxy powder used, the valve parts are heated in the oven to about 190 °C to 200 °C. In the subsequent coating process the heated parts are sprayed with epoxy powder or else dipped into a fluidised bed of powder.

Fig. 7.2.1-04:
Electrostatic application of epoxy powder with a spray gun

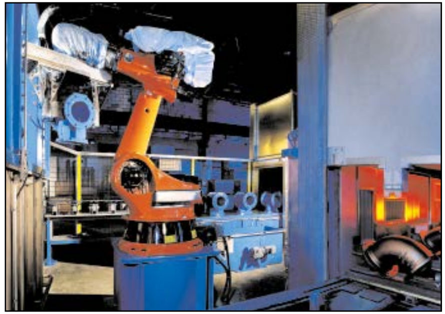


Fig. 7.2.1-05:
Application of epoxy powder by robot using the fluidised bed technique

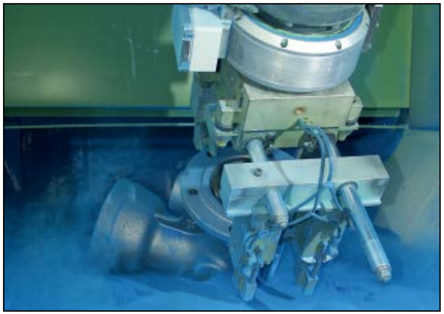


Fig. 7.2.1-06:
Dipping a valve body into the fluidised bed of powder

Fig. 7.2.1-07:
Gate valve body coated in the fluidised bed of powder

Because of the fast cross-linking of the resin the parts coated e.g. by the fluidised bed process can be taken out after only approximately 30 seconds without the coating being damaged by pressure marks. After the end of the coating process the parts are slowly cooled down to room temperature.

There then follows comprehensive quality testing which includes monitoring the coating thicknesses and impact resistance on original parts. This testing is also accompanied by inspection for disbonding of the coating, adhesive strength after 7 days immersion in hot water and cross-linking.

For valves to be installed outdoors, for example pillar hydrants, there is a need to protect the epoxy powder coating against long periods of UV exposure. To do this it has proved effective to apply an additional polyester coating, approx. 100 µm thick, to the outside surface while the epoxy film is still hot at about 170 °C. This duplex coating is then hardened at approx. 200 °C. The inseparable composite layer which this produces not only provides very good corrosion protection but it also gives the valve a very long-lasting protection against the light.

7.2.2 Enamel coating

As an outstanding and durable corrosion protection, enamel has been established in the area of water supply for more than 50 years.

Since the end of the nineties enamel has started to be applied on top of the external coating in order to produce an integral, continuous coating. As regards the material, the production technique and the testing technique, a proven and self-contained "complete enamel" coating system **(Fig. 7.2.2-01)** has been available for several years and it has now found its way into practical applications in the area of transporting raw water, drinking water and wastewater.

Fig. 7.2.2-01:
Valve with complete enamel coating

7.2.2.1 Requirements and characteristics of enamel coating

The requirements for enamel coating are determined in DIN 51178 [7.2-11] and in the DEV guideline "Quality and testing requirements for enamelled cast iron valves and pressure pipe fittings for the raw and drinking water supply sector" [7.2-12]. Testing according to DVGW worksheet W 270 [7.2-13] is not necessary as this is directed at the tendency to enhance microbial growth in organic materials. As a purely inorganic material, enamelling does not supply any nutrients for microorganisms and thus does not promote the formation of biofilms.

7.2.2.2 Complete enamelling

The "complete enamel" coating system has to meet two further requirements, which are irrelevant for the internal area:

- high impact resistance of the enamel bond,
- resistance against the corrosion environments of soil class III (highly aggressive soils) according to the specifications of DIN 50929-3 [7.2-06], OENORM B 5013-1 [7.2-07] and DVGW worksheet GW 9 [7.2-08].

The finely dispersed deposits of extremely small particles suppress the development and proliferation of cracks at points of excess stress, e.g. impact or thrust stress.

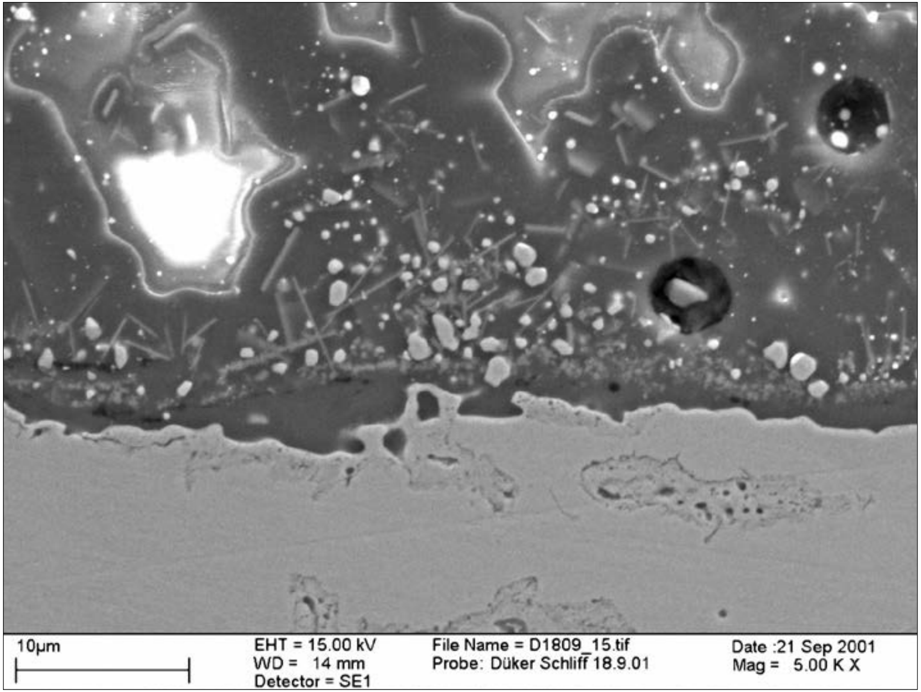


Fig. 7.2.2-02:
Detailed image of an enamel composite layer with spheroidal graphite cast iron; scanning electron microscope image, Fraunhofer Institute ISC, Würzburg

With complete enamelling of this standard of quality the specific material advantages of the enamel are united as follows:

- integral protection (continuous),
- hygienic and bacteriological safety,
- suitable for all soil types,
- high impact and pressure resistance,
- diffusion-proof,
- resistance to disbonding even where there is local surface damage,
- ageing resistance.

Enamelling is characterised by an intensive physical and chemical bonding with the substrate material (DIN 51178 [7.2-11]). This takes the form of a diffusion process from the substrate material towards the enamel and vice versa during firing. This causes a true composite layer to be formed with a thickness from a few to, depending on the material system, a few tens of micrometres **(Fig. 7.2.2-02)**.

In the image, the micro-roughness of the surface of the cast iron part (light, bottom) is clearly visible. The fine cracks discernible in this are the indentations between iron and enamel. Then moving upwards, a seam of approx. 2 µm which seems to be homogenously mixed can be detected. Above that there is then the actual composite layer, clearly over 10 µm thick, with different precipitations and deposits.

When enamelling valves in spheroidal graphite cast iron,a series of essential production parameters and restrictions determines the quality of the enamelling. The chemical composition of the cast iron substrate material, its microstructure, its pre-treatment and its surface condition are of decisive importance.

A clean ferritic structure in the surface layer makes the enamelling easier. Thermal/mechanical pre-treatment is the second essential condition. Clean blasting material with an abrasive effect cleans the surface of the cast iron part, activates it and increases the specific surface.

Fig. 7.2.2-03:
Gate valve body after blasting

Fig. 7.2.2-04:
Slip application on the outside of gate valve bodies by spraying

This means that it is necessary to have a rapid production process

- pre-treatment **(Fig. 7.2.2-03)**,
- application of the enamel slip **(Fig. 7.2.2-04)**,
- drying **(Fig. 7.2.2-05)**,
- enamel curing **(Figs. 7.2.2-06 and 7.2.2-07)**.

Fig. 7.2.2-05:
Internally coated gate valve bodies in the drying line

The basis for the testing and evaluation of enamelled components is DIN 51178 [7.2-11]. It describes test methods which simulate typical and realistic loads on the components.

Fig. 7.2.2-06:
A view inside the curing oven

Fig. 7.2.2-07:
Enamelled gate valve bodies and fittings after curing

7.2.3 References Chapter 7.2

[7.2-01] EN 14901
Ductile iron pipes, fittings and accessories –
Epoxy coating (heavy duty) of ductile iron fittings and accessories –
Requirements and test methods
[Rohre, Formstücke und Zubehör aus duktilem Gusseisen –
Epoxidharzbeschichtung (für erhöhte Beanspruchung) von Formstücken und Zubehörteilen aus duktilem Gusseisen –
Anforderungen und Prüfverfahren]
2006

[7.2-02] DIN 30677-1
Äußerer Korrosionsschutz von erdverlegten Armaturen;
Umhüllung (Außenbeschichtung) für normale Anforderungen
[Corrosion protection of burried valves;
coating for normal requirement]
1991-02

[7.2-03] DIN 30677-2
Äußerer Korrosionsschutz von erdverlegten Armaturen;
Umhüllung aus Duroplasten (Außenbeschichtung) für erhöhte Anforderungen
[External corrosion protection of buried valves;
heavy-duty thermoset plastics coatings]
1988-09

[7.2-04] DIN 3476
Armaturen und Formstücke für Roh- und Trinkwasser –
Korrosionsschutz durch EP-Innenbeschichtung aus Pulverlacken (P) bzw. Flüssiglacken (F) –
Anforderungen und Prüfungen
[Valves and fittings for untreated and potable water –
Protection against corrosion by internal epoxy coating of coating powders (P) or liquid varnishes (F) –
Requirements and tests]
1996-08

[7.2-05] RAL – GZ 662
Güte- und Prüfbestimmungen –
Schwerer Korrosionsschutz von Armaturen und Formstücken durch Pulverbeschichtung –
Gütesicherung
[Quality and test provisions –
Heavy duty corrosion protection of valves and fittings by powder coating –
Quality assurance]
2008

[7.2-06] DIN 50929-3
Korrosion der Metalle;
Korrosionswahrscheinlichkeit metallischer Werkstoffe bei äußerer Korrosionsbelastung;
Rohrleitungen und Bauteile in Böden und Wässern
[Corrosion of metals;
probability of corrosion of metallic materials when subject to corrosion from the outside;
buried and underwater pipelines and structural components]
1985-09

[7.2-07] OENORM B 5013-1
Oberflächenschutz mit organischen Schutzmaterialien im Siedlungswasserbau –
Teil 1: Abschätzung der Korrosionswahrscheinlichkeit und Schutz von unlegierten und niedriglegierten Eisenwerkstoffen
[Corrosion protection by organic coatings for water and wastewater engineering in residential areas –
Part 1: Assessment of corrosion probability and protection of unalloyed and low-alloyed ferrous materials]
2013-12-1

[7.2-08] DVGW-Arbeitsblatt GW 9
Beurteilung der Korrosionsbelastungen von erdüberdeckten Rohrleitungen und Behältern aus unlegierten und niedrig legierten Eisenwerkstoffen in Böden
[DVGW worksheet GW 9
Assessment of the corrosion level of buried pipes and tanks in unalloyed and low-alloyed ferrous materials in soils]
2011-05

[7.2-09] DVGW-Arbeitsblatt G 260
Gasbeschaffenheit
[DVGW worksheet G 260
Gas quality]
2013-03

[7.2-10] EN ISO 12944-4
Paints and varnishes –
Corrosion protection of steel structures by protective paint systems –
Part 4: Types of surface and surface preparation
[Beschichtungsstoffe –
Korrosionsschutz von Stahlbauten durch Beschichtungssysteme –
Teil 4: Arten von Oberflächen und Oberflächenvorbereitung]
1998

[7.2-11] DIN 51178
Emails und Emaillierungen –
Innen- und außenemaillierte Armaturen und Druckrohr formstücke für die Roh- und Trinkwasserversorgung –
Qualitätsanforderungen und Prüfung
[Vitreous and porcelain enamels-
Inside and outside enamelled valves and pressure pipe fittings for untreated and potable water supply –
Quality requirements and testing]
2009-10

[7.2-12] DEV-Richtlinie
Qualitätsanforderungen und Prüfvorschriften für emaillierte Gussarmaturen und Druckrohrformstücke für die Roh- und Trinkwasserversorgung
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2006-09-27

[7.2-13] DVGW-Arbeitsblatt W 270
Vermehrung von Mikroorganismen auf Werkstoffen für den Trinkwasserbereich –
Prüfung und Bewertung
[DVGW worksheet W 270
Enhancement of microbial growth on materials in contact with drinking water –
Test methods and assessment]
2007-11

7.3 Principles of hydraulics and the design of valves

7.3 Principles of hydraulics and the design of valves

Valves need to be designed for specific applications so that they can fulfil their desired functions correctly. Below you will find some explanations on the basic design of valves.

The terms used have been taken from EN 736-1 [7.3-01], EN 736-2 [7.3-02] and EN 736-3 [7.3-03].

When designing valves, the difference between isolation valves and control valves is an important aspect. While, as a rule, isolation valves are selected according to the nominal size and pressure rating of the pipeline, the choice of control valve is made on the basis of the hydraulic requirements of the control task to be performed.

In order to assist the user in selecting the correct valve for his purposes, manufacturers publish specific technical data on their valves.

7.3.1 Hydraulic principles

Physical laws influence the basic construction, nominal size and equipment of control valves. Therefore it is also important to consider these laws when selecting a control valve.

7.3.1.1 Flow resistance coefficient

If solid bodies on top of each other are moved against each other, there is a resistance to be overcome. This resistance is determined by the roughness of the surfaces in contact, among other things. The same also applies in a combination of a solid body and a liquid such as water. The roughness of the surface of the solid body determines the level of the resistance. The rougher the surface, the greater the resistance. However, the geometry of the solid body guiding the flow also affects the resistance; changes of direction increase it. Bearing this in mind, components along the line of flow can be considered and the resistance determined for each point. Finally the individual resistance values can be added together to produce an overall resistance.

The resistance of a component can be determined mathematically or by hydraulic measurements. The result is the flow resistance coefficient, referred to as zeta. As a rule the Greek letter ζ (zeta) is used as the symbol in formulas.

7.3.1.2 Pressure

Bernoulli's equation describes the changes in pressure across a pipeline through which a medium is flowing. This equation is also referred to as the law of conservation of energy. Bernoulli assumes that, when a medium is flowing through a pipeline, energy is not lost but is simply converted. The energy contained in a medium flowing through a pipe can be described as follows.

It contains:

- Pressure energy p [N/m²]
- Potential (stored) energy
  $$E_{pot} = g \cdot \rho \cdot z \quad [N/m^2] \qquad (7.3.1)$$

- Kinetic energy through speed

  $E_{Kin} = \frac{\rho}{2} \cdot c^2$ [N/m²] (7.3.2)

- Friction

  $W_R = \frac{\rho}{2} \cdot c^2 \cdot \sum\zeta$ [N/m²] (7.3.3)

Key:
ρ = density of the flow medium [kg/m³]
g = acceleration due to gravity
= 9.8 [m/s²]
z = height [m]
c = speed of flow of the medium with reference to nominal size [m/s]
ξ = zeta value [-]

Between the inlet (point 1) and the outlet (point 2) these energy proportions change **(Fig. 7.3.1)**.

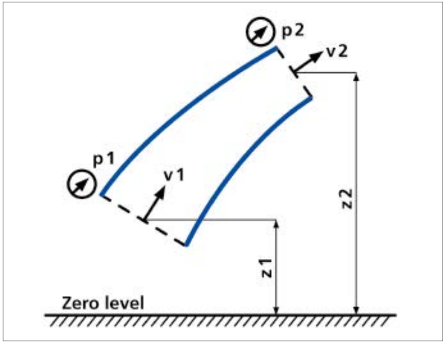

Fig. 7.3.1:
Change in the energy proportions between point 1 and point 2 of a line

Simply the fact that that friction has to be overcome on the way through the pipeline results in a change in the energy proportions. This means that the energy state can be described as follows:

If the application is reduced to the control valve, simplifications can be achieved. So potential energy no longer applies as the height difference between the inlet and outlet of the valve has no influence worth mentioning.

Equally the kinetic energy can be ignored as the speed, with reference to the nominal size of the line, is and remains the same before and after the valve.

$$p_1 + \rho \cdot g \cdot z_1 + \frac{\rho}{2} \cdot c_1^2 = p_2 + \rho \cdot g \cdot z_2 + \frac{\rho}{2} \cdot c_2^2 + \frac{\rho}{2} \cdot c_2^2 \cdot \sum\zeta = const.$$

[N/m²] (7.3.4)

Thus we arrive at:

$$p_1 = p_2 + \frac{\rho}{2} \cdot c^2 \cdot \sum\zeta \qquad [N/m^2] \quad (7.3.5)$$

or transposed

$$p_1 - p_2 = \Delta p = \frac{\rho}{2} \cdot c^2 \cdot \sum\zeta \qquad [N/m^2] \quad (7.3.6)$$

7.3.1.3 Flow velocity

Flow velocity describes the speed at which a medium is transported through a piping system. As a rule the nominal sizes of pipelines are designed with energy-saving aspects in mind, meaning that different nominal sizes may be present in the same pipeline system. Using the equation of continuity, the optimum nominal size for the control valve can be determined.

The equation of continuity states that the same volume of flow is present at every point in the pipeline, regardless of its local diameter.

It follows that:

$$A \cdot c = A_1 \cdot c_1 = A_2 \cdot c_2 = const. \qquad [m^3/s] \quad (7.3.7)$$

with $A = \frac{\pi}{4} \cdot D^2$ [m²] (7.3.8)

it then follows

$$D_2 = \sqrt{D_1^2 \cdot \frac{c_1}{c_2}} \qquad [m] \quad (7.3.9)$$

Key:
A = cross-sectional area of the nominal pipe size [m²]
c = flow velocity [m/s]
D = internal diameter of the nominal size [m]

7.3.1.4 K_v-value

For the selection and dimensioning of control valves, a characteristic value is usually used – the K_v-value or flow coefficient.

The K_v-value is a parameter for the achievable throughput of a medium – liquid or gas – through a component. The K_v-value is expressed either as [m³/h] or as [L/min]. Where water is the medium, the K_v-value indicates the volume of flow with a pressure difference of 1 bar over the length of the component. It is applicable for a water temperature of between 5 °C and 30 °C. When a control valve is fully open it is referred to as the K_{vs}-value.

The K_v-value is calculated as follows:

$$K_v = \dot{V} \cdot \sqrt{\frac{1\,bar}{\Delta p}} \qquad [m^3/h] \quad (7.3.10)$$

Key:
K_v flow coefficient [m³/h]
$\dot{V}$ volume flow = throughput volume [m³/h]
Δp actual pressure difference present [bar]

7.3.1.5 Cavitation

The deductions using the Bernoulli equation at the end of **Chapter 7.3.1.2** show that control actions change the physical parameters of pressure and speed of flow. Control valves only work at their best with higher speeds. This means that very high flow velocities can occur at throttling points. At the throttling points only, considerable energy conversion occurs from pressure energy to kinetic energy and lost energy **(Fig. 7.3.2)**.

After the water has passed through the throttling point it undergoes another energy conversion. Because the flow cross-section is now larger again, the speed of flow reduces. This means that kinetic energy is converted back to pressure energy. However, this process is not without loss, so that even higher pressure losses are experienced in addition.

Depending on the conditions of operating parameters this may mean that the pressure of the water in the throttling point is lower than the vapour pressure of the water. This then leads to the formation of vapour bubbles in the flow of water.

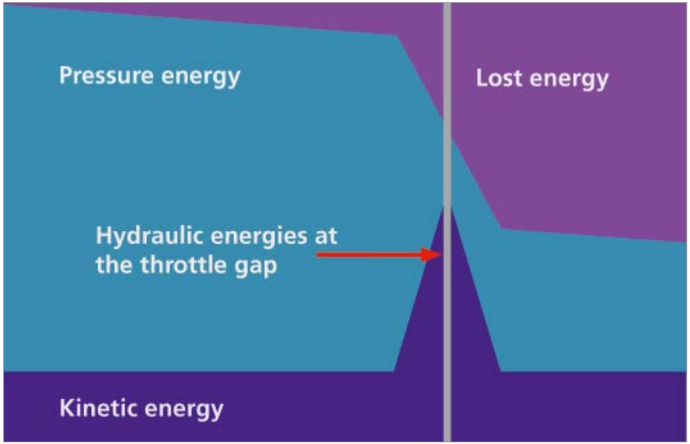

Fig. 7.3.2:
Hydraulic energies in the area of the throttle gap

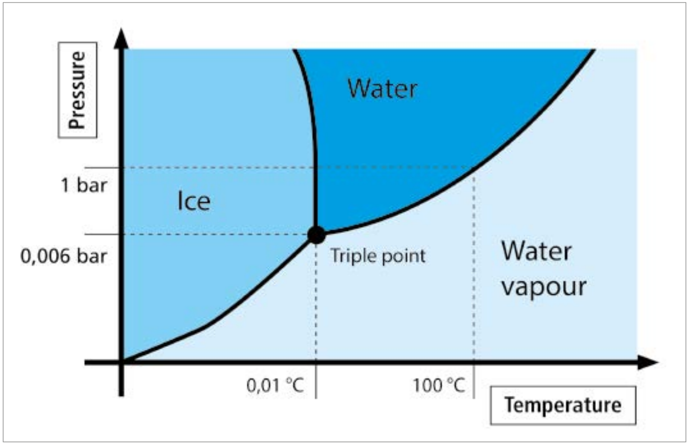

Fig. 7.3.3:
Phase diagram of water

The probability of this gets higher as the pressure after the throttling point approaches the level of atmospheric pressure. Depending on the pressure and temperature of the water, it changes its physical state. With an air pressure of 1 bar and a temperature of 100 °C vapour bubbles begin to form: the water boils **(Fig. 7.3.3)**.

The water in drinking water pipelines usually has a temperature of between 5 °C and 20 °C in our latitudes. The associated vapour pressure is then at around 0.015 bar absolute, or about 0.9 bar below atmospheric pressure.

Once the pressure in the throttling point reaches vapour pressure or below, the formation of vapour bubbles begins. The intensity of the vapour bubble formation depends on the degree to which the pressure is below vapour pressure **(Fig. 7.3.4)**.

After the throttling point a further energy conversion takes place. The increased pressure in the medium which this causes then has an effect on the vapour bubbles. The vapour bubbles are "dented" under the increased pressure and they implode, forming a micro water jet, which shoots through the vapour bubble. This process is summarised by the term "cavitation" **(Fig. 7.3.5)**.

Pressures of up to 10,000 bar have been able to be determined in micro water jets, regardless of the pressure in the pipe cross-section. These are the kind of energies which are used for waterjet cutting, of steel for example. A similar effect is also produced by cavitation in valves used for control purposes.

In order to keep the consequences of cavitation as slight as possible, there are the following possibilities:

- Directing the imploding vapour bubbles to the centre of the component so that they do not actually come into contact with it **(Fig. 7.3.6)**.
- Use of a material with a higher resistance to cavitation.
- Selection of an appropriate valve to avoid cavitation.

In order to evaluate cavitation in pipeline systems with control valves, the sigma cavitation index is applied.

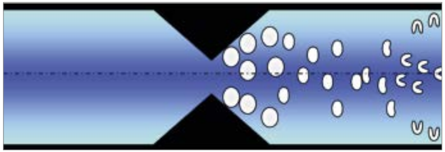

Fig. 7.3.4:
Vapour bubble formation in a throttling point

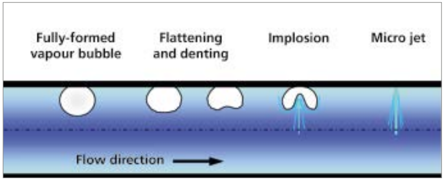

Fig. 7.3.5:
Schematic diagram of cavitation

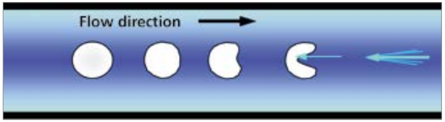

Fig. 7.3.6:
Directing vapour bubbles to the centre of the pipe

7.3.2 Valve design

7.3.2.1 Design of isolation valves

The design of isolation valves is essentially limited to determining nominal sizes and pressure ratings. As long as the flow velocity is within the range of the specifications in EN 1074-1 [7.3-04] and EN 1074-2 [7.3-05], the isolation valve is determined in much the same way as the pipeline itself.

7.3.2.2 Design of control valves

For control valves the hydraulic properties required of the control function need to be taken into account. This may mean that the different design stages have to be repeated a number of times.

As regards nominal pressure, the design of control valves is based on that of the pipeline.

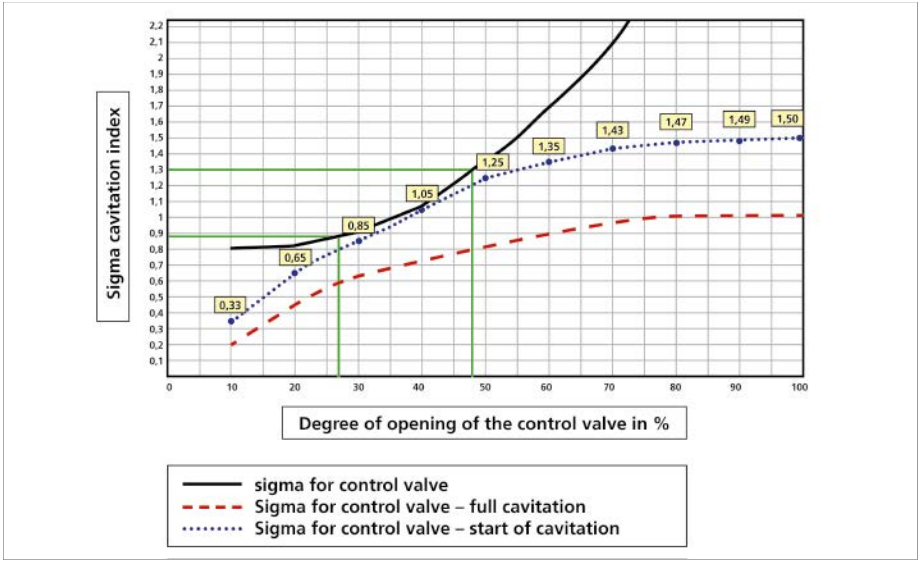

Fig. 7.3.2:
Cavitation assessment for an operating point

The nominal size of the control valve is determined for the maximum volume of water required. When doing this, the maximum allowable flow velocity according to the manufacturer's specification must also be taken into account.

Example:
- Nominal size of pipeline DN 150,
- maximum flow rate 96 m³/h (usual rate for extinguishing water in the municipal sector),
- maximum flow velocity according to manufacturer's specification, e.g. 4 m/s.

This results in a minimum diameter of 81.6 mm for the control valve. Allowing a tolerance for the flow velocity to be less than specified, this suggests a nominal size of DN 80 for the control valve.

7.3.2.3 Checking for the absence of cavitation

Once the nominal size and pressure rating have been established, a specific valve is selected. Each valve has a specific characteristic for the sigma cavitation index. A valve is said to be cavitation-free if its cavitation lines (······ and - - - -) are below the "valve in operating situation" line (——) **(Fig. 7.3.7)**.

7.3.3 References Chapter 7.3

[7.3-01] EN 736-1
Valves – Terminology –
Part 1: Definition of types of valves
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[7.3-02] EN 736-2
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Part 2: Definition of components of valves
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[7.3-03] EN 736-3
Valves – Terminology –
Part 3: Definition of terms
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[7.3-04] EN 1074-1
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Fitness for purpose requirements and appropriate verification tests –
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[Armaturen für die Wasserversorgung –
Anforderungen an die Gebrauchstauglichkeit und deren Prüfung –
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[7.3-05] EN 1074-2
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Teil 2: Absperrarmaturen]
2000 + A1:2004

7.4 Isolation valves

7.4 Isolation valves

7.4.1 Gate valves

7.4.1.1 Field of application

The gate valve is the most frequently installed valve in the water supply industry and can therefore be described as a standard valve. These days it is practically only resilient seated gate valves (rubber coated valve wedges) which are used in drinking water applications and they are subject to national approval regulations. Resilient seated and metal seated gate valves are used in the wastewater sector. The flow through a gate valve can be in both directions.

7.4.1.2 Resilient seated wedge gate valves

A resilient seated wedge gate valve essentially consists of the valve body, the valve wedge and the bonnet with integrated stem seal **(Fig. 7.4.1-01)**. The valve wedge is moved by the stem drive in the passage. In the open position these gate valves have a clear passage, in other words the whole of the pipe cross-section is open. This means that there are only very slight pressure losses. In addition, this makes pigging possible. Also in wastewater applications, the open cross-section is a great advantage because it prevents clogging with floating particles and solids. The classic construction connects the bonnet to the valve body with bolts. More recent constructions have non-bolted connections. To date, the necessarily complex geometry of a wedge gate valve can only be produced cost-effectively by the casting process. In case of overhaul, its design allows moving parts to be replaced without removing the entire valve.

Resilient seated wedge gate valves are characterised by the fact that there is a vulcanised rubber coating on the wedge of the valve which comes into contact with the corresponding sealing surfaces in the valve body, thereby sealing the valve **(Figs. 7.4.1-02, 7.4.1-03, 7.4.1-04, 7.4.1-05, 7.4.1-06, 7.4.1-07 and 7.4.1-08)**. The elastic rubber coating of the wedge compensates for any slight irregularities in the cast body and forms an optimum seal even when dirt is present. This means that resilient seated gate valves are also suitable for communal sewage systems where there is a certain degree of solids content.

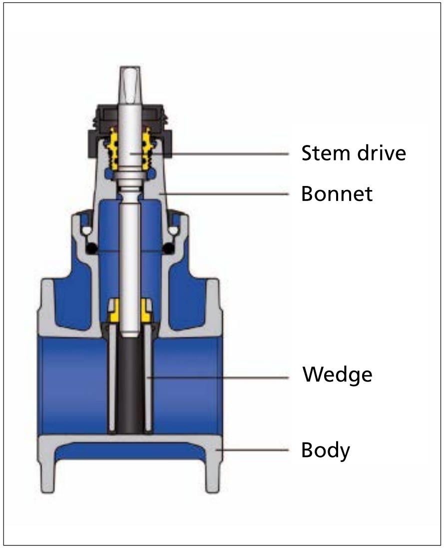

Fig. 7.4.1-01:
Design of a wedge gate valve:
Body, bonnet, stem drive and wedge

Fig. 7.4.1-02:
Sectional image of a resilient seated flanged gate valve with a non-bolted connection between bonnet and body

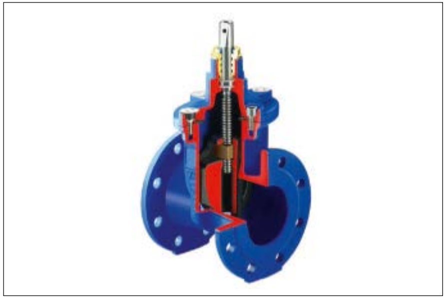

Fig. 7.4.1-03:
Sectional image of a resilient seated flanged gate valve with a bolted connection between bonnet and body

Fig. 7.4.1-04:
Resilient seated flanged gate valve with threadless stem mounting

Fig. 7.4.1-05:
Resilient seated TYTON® push-in gate valve DN 150

Fig. 7.4.1-06:
Resilient seated Novo SIT® push-in gate valve

Fig. 7.4.1-07:
Resilient seated TYTON® push-in gate valve with spigot end and socket end, BAIO® system

Fig. 7.4.1-08:
Resilient seated wedge gate valve with spigot end and socket end

Fig. 7.4.1-09:
Metal seated wedge gate valve

Smooth and homogeneous coatings, such as the epoxy resin powder coating according to GSK guidelines for heavy-duty corrosion protection RAL GZ 662 [7.4-01] or enamelling to DIN 51178 [7.4-02] and DEV guideline [7.4-03], prevent incrustations from forming in the valve body. Because of the free and smooth passage, the resilient seated gate valve has broadly replaced the metal seated valve as the standard gate valve. It is available in nominal pressure stages PN 10, PN 16 and PN 25.

Resilient seated gate valves are not suitable as flow control and regulation devices – they are simple ON/OFF valves. The reason for this lies in the geometry of the wedge guiding. When the wedge moves into the cross-sectional area of flow, high forces occur in the intermediate positions which put stress on one side of the opening; if it stays in this intermediary position for long, this can cause damage. Where the flow is restricted to a high degree there is also the risk of cavitation damage to the valve body. In addition, the resilient seated wedge gate valve also has poor control characteristics.

The gate valves meet the requirements of both EN 1074-2 [7.4-04] and EN 1171 [7.4-05]. Also to be considered are DVGW Worksheets GW 336-1 "Stem extensions for underground installation – Part 1: Standardisation of interfaces between buried valves and spindle extensions" [7.4-06] and W 363 "Isolating valves, check valves, air valves and control valves made from metal for drinking water distribution systems – Requirements and testing" [7.4-07].

Other standards to be considered are: EN 558 [7.4-08], EN 736-1 [7.4-09], EN 1503-3 [7.4-10], EN 12516-2 [7.4-11] and EN 12516-4 [7.4-12].

7.4.1.3 Metal seated wedge gate valves

The metal seated wedge gate valve **(Fig. 7.4.1-09)** is characterised by a metal shut-off device which moves into a so-called valve bag in the lower part of the body when the valve closes.

Table 7.4.1-01:
Field of application of resilient seated knife gate valves

Field of application	Type of application (examples)
Wastewater	Digested sludge, wastewater, raw sludge, air
Chemical industry	Chemically contaminated wastewater
Biogas plant	Sludge, waste water

The drawback with this type of construction lies with the sealing principle, in terms of the valve bag and the high breakaway torque when the valve opens. In the open position, flow resistances occur with a deadwater area, favouring the formation of deposits and incrustations. This can result in high actuating torques on opening and closing. Metal seated gate valves are normally used in the area of water and wastewater, in industrial applications and in district heating systems up to a nominal pressure of PN 40.

7.4.1.4 Resilient seated knife gate valves

Resilient seated knife gate valves are used above all in wastewater and industrial applications for the widest range of media. As pressures in these areas of use are normally lower than with drinking water applications, it is usually the simpler and cheaper design of knife gate valve which is selected. **Fig. 7.4.1-10** shows the construction of a resilient seated knife gate valve. They are produced in nominal sizes DN 50 to DN 1400 for operating pressures of up to 16 bar. **Table 7.4.1-01** gives some examples of the fields of use of resilient seated knife gate valves.

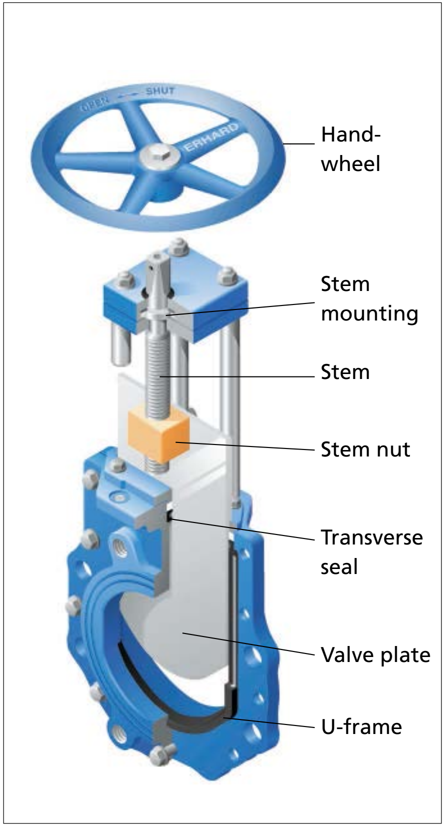

Fig. 7.4.1-10:
Construction of a knife gate valve

Fig. 7.4.1-11:
Resilient seated knife gate valve PN 10 with hand-wheel

Fig. 7.4.1-12:
Resilient seated knife gate valve PN 10 with pneumatic drive

Fig. 7.4.1-13:
Resilient seated knife gate valve with electric drive

Fig. 7.4.1-14:
Resilient seated knife gate valve for installation underground

Resilient seated knife gate valves **(Figs. 7.4.1-11, 7.4.1-12 and 7.4.1-13)** essentially consist of a cast valve body, a stainless steel valve plate and a stem drive, often with integral position display. Depending on the application, various sealing materials and operating methods are possible.

Resilient seated knife gate valves are used above all in wastewater applications, but they are also used for controlling other liquid media. They are not suitable for use with drinking water. Resilient seated knife gate valves are primarily installed in shafts and structures, but constructions are also available for installation underground **(Fig. 7.4.1-14)**.

A major advantage of the gate valve construction is the completely free passage when the valve is open and the valve plate which is impervious to dirt. Because of the free passage through the valve body, no solids can get stuck in the valve.

Knife gate valves with a fully developed flange (through bolt holes and blind threaded holes) can be used both for installation between flanges and for end-of-line applications without a counter-flange. The short K1 face-to-face length meets standard EN 558 [7.4-08].

Modular systems make other configurations possible, such as:

- electrical display of limit positions,
- scraper for cleaning the valve plate,
- triangular or pentagonal orifices for regulation purposes,
- numerous actuator and actuator extension possibilities.

Depending on the medium carried, suitable materials are available for the valve plate and the seals.

7.4.2 Butterfly valves

7.4.2.1 General

After the gate valve, the second most frequently installed type of valve for water supply applications is the butterfly valve **(Figs. 7.4.2-01, 7.4.2-02, 7.4.2-03, 7.4.2-04, 7.4.2-05, 7.4.2-06 and 7.4.2-07)**. They have a shut-off element located in the cross-section of the line which is referred to as the butterfly disc. Just like gate valves, butterfly valves are purely shut-off devices (ON/OFF function).

The designs most commonly used today are resilient seated centric or double-eccentric butterfly valves.

Butterfly valves essentially consist of a valve body, which is installed in the pipeline with flanged joints, and a shut-off element, referred to as the butterfly disc. The butterfly disc is usually adjusted by means of a gear mechanism and, in the open position, lies parallel to the direction of flow **(Fig. 7.4.2-03)**. The standard range of nominal sizes goes from DN 50 to DN 4000 and the normal pressure stages range from PN 6 to PN 40.

Fig. 7.4.2-01:
Examples of butterfly valves with hand-wheel – butterfly valve coated with epoxy resin powder (left) and fully enamelled butterfly valve (right)

Fig. 7.4.2-02:
Centric butterfly valve with worm-gear and hand-wheel

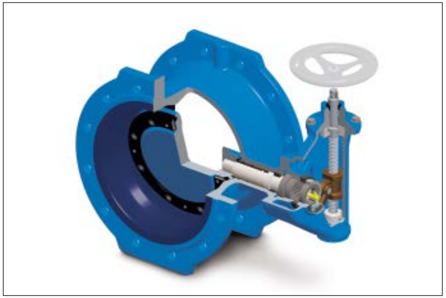

Fig. 7.4.2-04:
Double-eccentric butterfly valve with slider crank mechanism and hand-wheel

Fig. 7.4.2-06:
Double-eccentric butterfly valve with spindle gear and electric drive for large nominal sizes, e.g. DN 1800

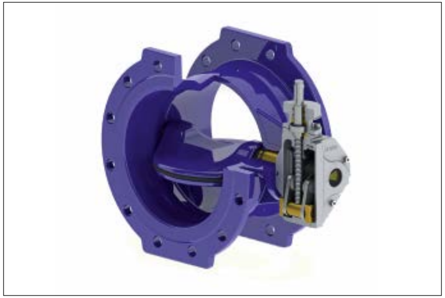

Fig. 7.4.2-03:
DN 250 double-eccentric butterfly valve with slider crank mechanism

Fig. 7.4.2-05:
Double-eccentric butterfly valve with loose flange

Fig. 7.4.2-07:
Double-eccentric butterfly valve with hydraulic drive for very large nominal sizes, high pressure stages and as a safety valve

Advantages of butterfly valves as compared with gate valves:

- Less space required – butterfly valves can be made to be very compact even for large diameters. No deadwater space as the shut-off device is integrated directly in the cross-section of the pipeline and does not need any installation space.
- Lighter weight – because of their compact construction, butterfly valves are lighter in large diameters.
- Low actuating moment – because of the friction in the wedge-guide, particularly with high nominal sizes, gate valves have high actuating moments. By contrast, double eccentric butterfly valves are also easier to actuate because of the gearing mechanisms used.
- When installed underground, because of the low overall height (the same as the pipeline) and especially with higher nominal sizes, no conduits are necessary for frost protection.

Disadvantages of butterfly valves as compared with gate valves:

- Greater flow resistance – while gate valves present practically no flow resistance in the fully open position (pressure loss coefficient $\xi = 0.1 - 0.2$),
- butterfly valves have relatively high flow resistance values in the open position, depending on the design and dimensions (pressure loss coefficient $\xi = 0.2 - 0.9$).
- Expensive construction – as compared with gate valves, the construction is somewhat more expensive and only becomes worthwhile with larger nominal sizes.
- Pigging is not possible in pipelines with butterfly valves.

Selection criteria:

When deciding between gate valves and butterfly valves, the following examples represent factors which are of particular importance:

- actuation torque,
- weight of the valve,
- flow rates,
- operating pressure,
- operating medium,
- installation situation,
- pigging possibilities.

For reasons of price, the gate valve is generally used up to DN 300.

7.4.2.2 Types of butterfly valves

With butterfly valves, a distinction is made between the following types of construction:

- Centric mounting of the butterfly disc **(Fig. 7.4.2-08)** – the shaft of the butterfly disc is arranged both in the centre of the valve body and in the centre of the disc. Because of its short overall length (EN 558, overall length K1 [7.4-08]), this construction with tight-closing, resilient seated elastomer body seating is very suitable for fittings between two pipeline flanges or for flange-mounting as an end-of-line device. Actuation is often by means of a ratch lever (to DN 300), electric drive or pneumatic drive. The arrangement of the elastomer sealing seat in the body opens up the possibility of producing the butterfly disc in the widest range of materials. This offers the advantage that the valve can be used for the widest range of mediums.

- Simple eccentric mounting of the butterfly disc – the shaft is arranged on the pipe axis of the valve body outside the seating surface of the butterfly disc **(Fig. 7.4.2-09)**. With this, as well as the centric mounting of the shaft, the butterfly disc performs a purely rotary movement.
- Double eccentric mounting of the butterfly disc – the shaft is arranged both outside the pipe axis of the valve body and outside the seating surface of the butterfly disc **(Fig. 7.4.2-10)**. This means that the butterfly disc performs a relative movement resulting from a linear and rotary movement of the butterfly disc. In this movement, when it leaves the seating surface, the seal applied to the butterfly disc is completely separated from the seating surface in the valve body after a short rotation movement, thereby making opening and closing easier. The double eccentric butterfly valve can react to pressure from both sides.

7.4.2.3 Types of body construction

In the construction of water supply pipelines, it is mainly butterfly valves with flanges and face-to-face lengths in accordance with EN 558 [7.4-08] series R14 which are installed **(Fig. 7.4.2-11)**. Alternatively, butterfly valves with push-in joints can also be supplied **(Fig. 7.4.2-12)**.

In pipelines as from DN 500, butterfly valves of length R15 with integral bypasses are also used. For pipelines in waterworks, and above all with smaller nominal sizes, short sandwich-type butterfly valves in length R20 are also used **(Fig. 7.4.2-13)**.

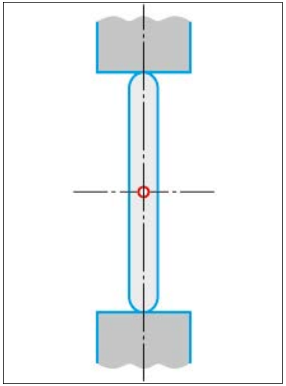

Fig. 7.4.2-08:
Centric design

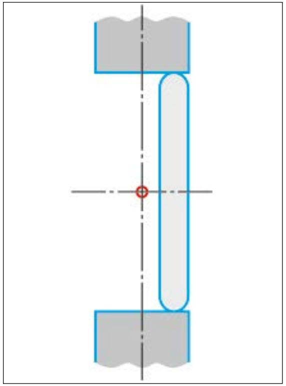

Fig. 7.4.2-09:
Simple eccentric design

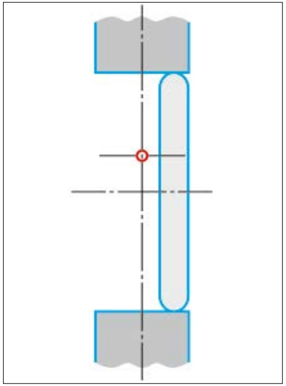

Fig. 7.4.2-10:
Double eccentric design

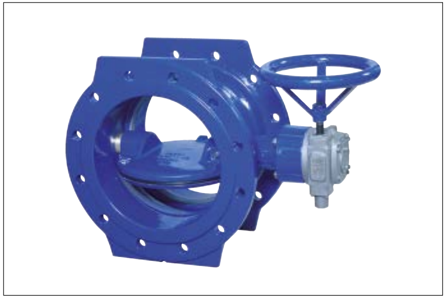

Fig. 7.4.2-11:
Butterfly flange valve with gearing and hand-wheel

Fig. 7.4.2-12:
Butterfly valve with push-in joints

Fig. 7.4.2-13:
Flange-mount butterfly valve with gearing and hand-wheel

Fig. 7.4.2-14:
Centric wafer-type butterfly valve with lever

Fig. 7.4.2-15:
Lug-type butterfly valve with lever

Fig. 7.4.2-16:
U-type design with gearing and hand-wheel

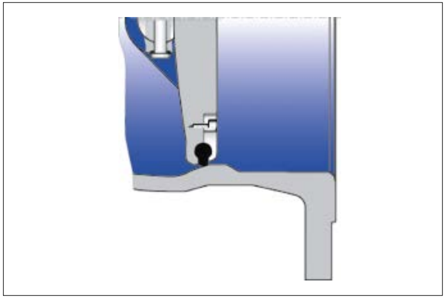

Fig. 7.4.2-17:
Sealing ring seated directly on the cast iron body

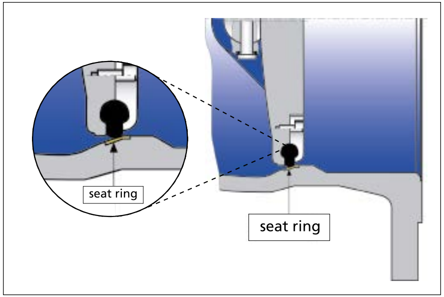

Fig. 7.4.2-18:
Sealing ring seated on the seat ring

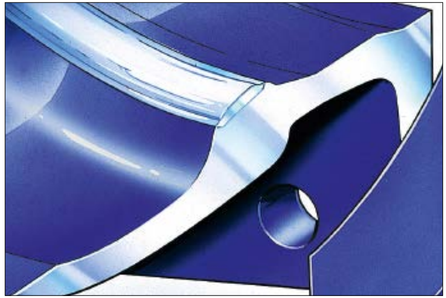

Fig. 7.4.2-19:
Sealing ring seated on a seating area produced by overlay welding

With flange-mount butterfly valves, a distinction is made between the following designs:

- Wafer-type: designed for clamping **(Fig. 7.4.2-14)**,
  Lug-type: designed with threaded blind holes **(Fig. 7.4.2-15)**,
  U-type: designed for U-form clamping **(Fig. 7.4.2-16)**.

7.4.2.4 Sealing principles

Depending on the type of construction, different sealing principles and body designs are used:

- With centrically mounted butterfly discs, the valve body is designed with a rubber sleeve. This sealing principle also allows the use of a body in the form of a flange-mount butterfly valve.
- As a rule, eccentrically mounted butterfly discs are designed with resilient seating. The main seal, in the form of a profile-ring seal, is clamped and fixed to the butterfly disc. The body belonging to this type comes in two different designs of seating surface. In one version the profile sealing ring seals onto a corrosion-protected seating surface prefabricated directly into the body **(Fig. 7.4.2-17)**.

In the other version the body has a stainless steel ring in the seating area of the body **(Fig. 7.4.2-18)** or a seating area produced by overlay welding **(Fig. 7.4.2-19)**. This sealing principle requires on the one hand a mounting of the butterfly disc which is at least eccentric and on the other hand a body in different face-to-face lengths.

Practical tip:
With butterfly valves for flanged connections it must be borne in mind that, in the open position, the butterfly disc projects beyond the end of the body. Particularly with flange-mount butterfly valves, it is important to check that there is no danger of collision with adjacent components.

7.4.3 Ball valves

Ball valves have robust forms of shell. Ball valves are generally used as shut-off elements. They mainly consist of balls which present a through-hole in the open position. **Figs. 7.4.3-01 and 7.4.3-02** are schematic diagrams of the functions of a ball valve.

Resilient seated ball valves are mostly used in the water industry. There are basically two different construction principles available:

- Firstly there are ball valves constructed with the ball plug mounted and run directly in the valve body. The drive shaft is not used for mounting but only for actuation. With this type of construction the seals required for making the valve tight are housed in the body. The ball plug constantly presses the seal into the body **(Fig. 7.4.3-03)**.
- With the other construction principle, the ball plug is double-eccentrically mounted in the body with the use of shafts on both sides. In a similar way to butterfly valves, the ball plug pivots in its seat.

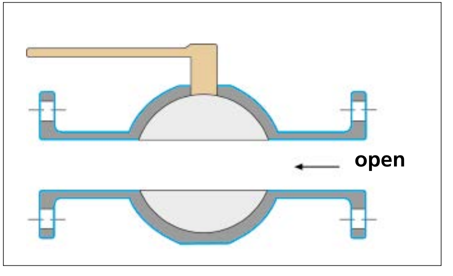

Fig. 7.4.3-01:
Ball valve position:
fully "open"

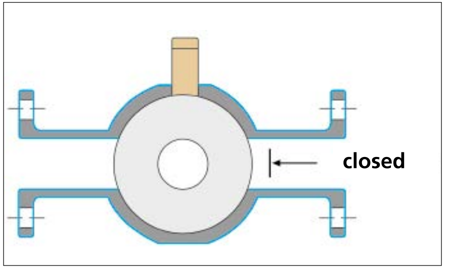

Bild 7.4.3-02:
Ball valve position:
fully "closed"

With this system, the sealing element is applied to the ball plug. It is only in contact with the body and/or the body seating for about the last 10° of the rotary movement. In all other positions of the ball plug there is a gap between body and ball plug.

In practice the construction with double eccentrically mounted ball plug **(Fig. 7.4.3-04)** has proved to be very well suited in the field of water supply but also in pressure pipelines for conveying wastewater **(Fig. 7.4.3-05)** and is low-maintenance.

To date, ball valves have found their use above all in pipelines carrying water at higher pressure stages of up to 100 bar and higher flow rates of up to 15 m/s. The undisrupted flow at the outlet of the ball valve also means that they are predestined for installation in the intake before turbines and pumps. In the double eccentric construction, the ball valve can be used for control functions because of the behaviour of the pressure loss coefficient ξ.

Fig. 7.4.3-03:
Cross-section of a ball valve – valve shell with ball plug

Fig. 7.4.3-04:
Ball valve with slider crank mechanism and hand-wheel

Fig. 7.4.3-05:
DN 1000 ball valve for a wastewater pressure pipeline

7.4.3.1 Double eccentric ball valve

The basic construction of ball valves used in the water supply industry is based on the positive experiences with double eccentric butterfly valves. With just a 3° pivoting movement, the ball plug moves free of the seating on opening. This means that the working life of the profile seal is considerably increased.

Advantages and construction features of a double eccentric ball valve:

- In the open position **(Figs. 7.4.3-06 and 7.4.3-07)** the profile ring is outside the area of flow. The sealing part, which is not sensitive to deposits, retains its sealing properties in both directions of flow.
- There is a clearance between the outside diameter of the ball plug and the valve body which produces a very smooth flow behaviour in the intermediary position **(Fig. 7.4.3-08)**. This means that oscillations and vibrations at high flow speeds and high pressures are avoided.
- The ball plug, with equalised pressure and the current flowing round it **(Fig. 7.4.3-08)**, can thus be used for a flow speed of up to 15 m/s without problem.

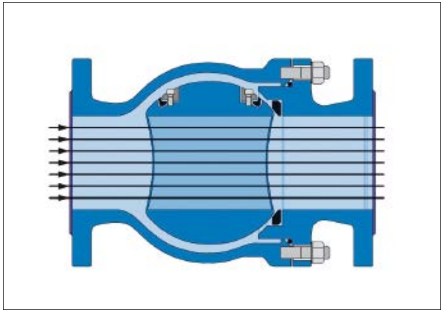

Fig. 7.4.3-06:
Ball valve fully open

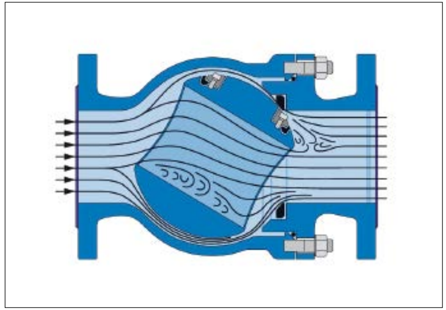

Fig. 7.4.3-08:
Ball valve half open

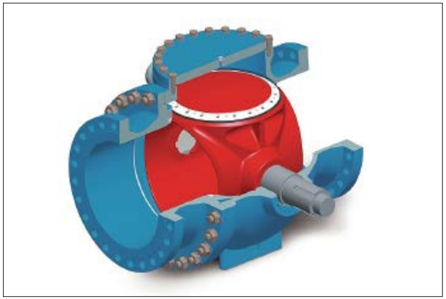

Fig. 7.4.3-07:
Cross-section of a ball valve – fully open position

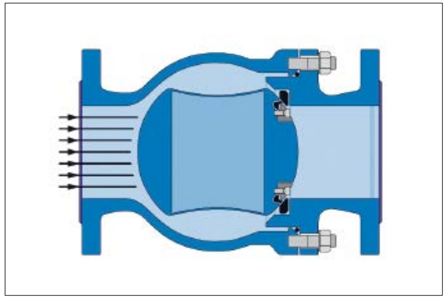

Fig. 7.4.3-09:
Ball valve closed

With these construction features, although the ball valve is not suitable for flow control and regulation operations, it is the ideal isolating valve for higher pressure stages and flow rates **(Fig. 7.4.3-09)**.

The entirely free and undisturbed passage through the valve **(Fig. 7.4.3-04)** means that only very slight pressure losses occur. For this reason this valve is not only used for the flushing and draining of main lines but it is also very often installed before turbines or as a start-up valve after pumps **(Fig. 7.4.3-05)**.

Ball valves are either mechanically, electrically, pneumatically or hydraulically actuated.

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7.5 Tapping valves

7.5 Tapping valves

Tapping valves have a large field of application in the public water supply system. They are used as connections and branches in pipelines as from DN 80. DIN 3543-2 [7.5-01] as well as DVGW worksheets GW 336-1 [7.5-02], GW 336-2 [7.5-03], W 332 [7.5-04], W 333 [7.5-05], W 336 [7.5-06] and W 365 [7.5-07] are to be observed.

Tapping valves are most frequently used for the connection of service pipelines or branch pipelines. The major advantage of tapping valves is the possibility of producing a later connection with the supply pipeline system without having to take the whole system out of operation.

Additional fields of application:

- The production of venting points,
- The production of drainage points,
- The production of measurement and injection points.

In the water supply industry, tapping valves are usually connected by means of clamps or straps.

7.5.1 Sealing for supply lines

A seal is required for tapping valves which are not welded to the pipeline. The following types of seals can be used:

- Profile seals (these directly surround the area of the tapped opening),
- Flat sealing mats (these are pressed onto a large area between the tapping valve and the line).

7.5.2 Tapping valves without operational shut-off

Tapping valves without operational shut-off **(Figs. 7.5.2-01 and 7.5.2-02)** are only suitable if there is no need for a possibility of shutting off the flow directly from the valve.

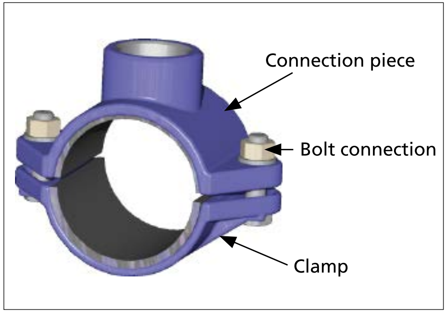


Fig. 7.5.2-01:
Tapping valve without operational shut-off, with clamp

Fig. 7.5.2-02:
Tapping valve without operational shut-off, with steel strap

Basically, tapping valves without operational shut-off usually consist of the following two components:

- Connection piece without operational shut-off,
- Clamp (this serves to attach the connection piece to the supply pipeline).

The connection piece may be threaded, for example, to enable it to be connected to other supply pipelines.

7.5.3 Tapping valves with operational shut-off

The purpose of the operational shut-off device is to allow the flow of water in the branch pipeline to be interrupted and, in case of underground piping systems, it is usually actuated by means of a stem extension with an operating key.

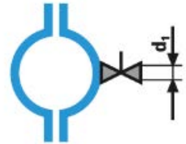
Tapping valves with operational shut-off can be equipped with an auxiliary shut-off device. Auxiliary shut-off devices are used while the pipeline is being tapped.

The purpose of auxiliary shut-off devices is to prevent the medium being carried from escaping when the tapping equipment is being assembled or taken down. There are different designs of auxiliary shut-off devices:

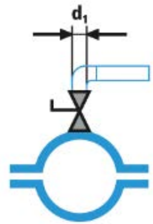
- as an additional shut-off integrated into the tapping valve for operational shut-off,
- an auxiliary and operational shut-off device in one unit,
- as a separate and reusable tool (is installed during the assembly of the tapping valve).

The different types of operational shut-off devices **(Fig. 7.5.3-01)** are covered in DIN 3543-2 [7.5-01].

Female thread – outlet in the direction of tapping (for lateral tapping)



Female thread – outlet in the direction of tapping (for upward tapping)



Female thread – outlet vertical to the direction of tapping (for upward tapping)

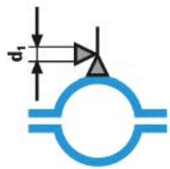


Fig. 7.5.3-01:
Different types of operational shut-off device according to DIN 3543-2 [7.5-01] – d_1 is equivalent to diameter of connection

In addition, and depending on the field of application and the diameter of the pipe, there are numerous types of tapping valves **(Figs. 7.5.3-02 and 7.5.3-03)**

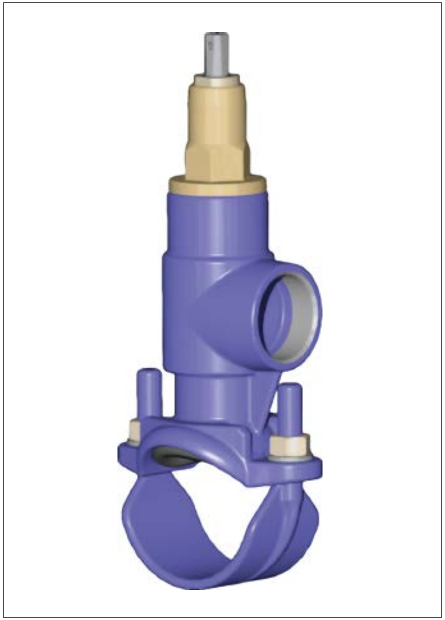


Fig. 7.5.3-02:
Tapping valve for cast iron pipelines with cast iron bracket

Fig. 7.5.3-03:
Tapping valve for cast iron pipelines with steel strap

More tapping valves with different house connections are shown in **Figs. 7.5.3-04, 7.5.3-05, 7.5.3-06, 7.5.3-07 and 7.5.3-08**.

Fig. 7.5.3-05:
Tapping sleeve with steel strap – house connection via male thread

Fig. 7.5.3-07:
Tapping sleeve – house connection via push-in joint and integral auxiliary shut-off device

Fig. 7.5.3-04:
Tapping sleeve with steel strap – house connection with female thread

Fig. 7.5.3-06:
Tapping sleeve with integral shut-off device – house connection via push-in joint

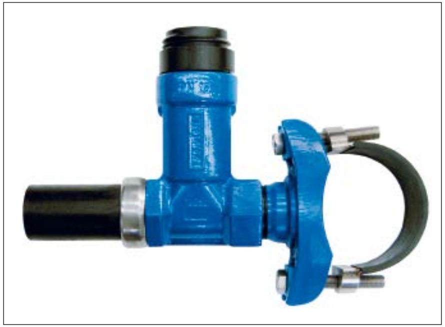


Fig. 7.5.3-08:
Tapping valve with steel strap and lateral outlet

7.5.4 Tapping process for tapping valves

There are different methods for tapping the main pipeline:

- Tapping by means of an integral milling tool or punch,
- Tapping using separate tapping equipment.

The geometry and the material for drills, milling tools and punches depend on the material of the supply pipeline to be tapped. For pipelines in ductile cast iron and grey cast iron, twist drills are used as well as bore-type cutters. When using hole cutters it is important to make sure that the disk of pipe wall cut out remains in the cutter after completion.

7.5.4.1 Tapping by means of an integral milling tool or punch

With this type of tapping valve the milling tool or punch is directly integrated into the tapping valve and stays there after the tapping process **(Fig. 7.5.4-01)**.

7.5.4.2 Tapping using separate tapping equipment

For tapping purposes, the tapping device is fixed to the tapping valve by means of a threaded or flanged connection. Universal tapping devices which can be mounted on different, commercially available tapping valves using an adapter are to be preferred. Tapping can be done manually or with motor-driven equipment (e.g. compressed air or electric drive) **(Fig.7.5.4-02)**.

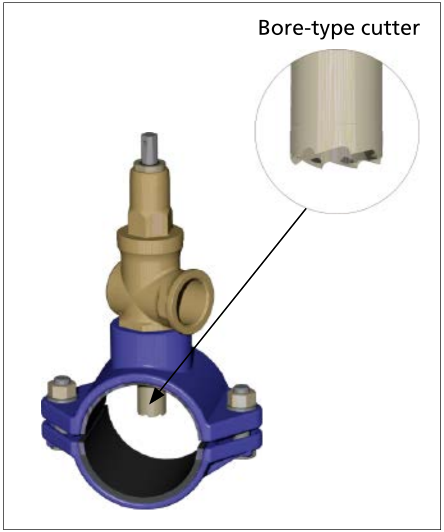


Fig. 7.5.4-01:
Tapping valve with integrated Bore-type cutter

Fig. 7.5.4-02:
Example of tapping equipment – manual or motor-driven

7.5.5 References Chapter 7.5

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7.6 Control valves

7.6 Control valves

7.6.1 General

Control valves are special valves constructed specifically for performing control functions in the water supply industry. In contrast to gate valves and butterfly valves, which are mainly used as shut-off devices in pipeline systems, control valves meet the particular requirements of controlled operations. Control valves are predominantly used for applications where volume flow rates need to be accurately metered or water pressure has to be precisely regulated or reduced. To achieve this, control valves can be operated in any position between fully open and closed.

7.6.2 Areas of application

Control valves are suitable both for purified and drinking water and for cooling water at temperatures which are customarily as high as 50° C.

The main areas of use of control valves are:

- Water pumping for reservoirs and dams,
- Bypass pipelines for hydropower plants,
- Long-distance pipelines,
- Water treatment in waterworks,
- Water supply to pumping stations,
- Controlling the intake of elevated tanks,
- Drinking water networks,
- Cooling water circuits for industrial and power station applications.

Another example of use is controlling the air supply to aeration basins in sewage treatment plants. In this case control valves are also used with air as the medium because their control characteristics allow for better metering than knife gate valves or waver-type butterfly valves **(Chapter 7.6.3.5)**.

7.6.3 Designs

Control valves are basically divided into two different groups. One group requires an external power source and the other is by own-medium controlled.

<u>Valves using an external power source</u>

Valves which are operated by an external power source are moved to the required regulating position by drive mechanisms such as a hand wheel, electric actuators and pneumatic or hydraulic drives. With smaller dimensions the usual construction is a seating surface arranged vertically to the pipe axis **(Fig. 7.6.1)**. With this type of design the valve is referred to as a piston valve.

Fig. 7.6.1:
Piston valve

A particular form of this is the plunger valve in which the hydraulic cylinder in the pipe axis moves towards the seating surface **(Fig. 7.6.2)**. Plunger valves are used e.g. for the control of very high volumes of water in the bottom outlet of reservoirs **(Fig. 7.6.3)**.

Own-medium controlled valves

Own-medium controlled valves draw the energy for their movement from the pressure in the pipeline. These valves include both pilot-operated control valves **(Fig. 7.6.4)** and direct operated valves **(Fig. 7.6.5)**.

7.6.3.1 Piston valves

With piston-type control valves the flow inside the valve is diverted. The hydraulic piston moves perpendicular to the pipeline. This type of construction is mainly used in sizes up to DN 150. The valve consists of a valve body, a mounting flange, a top column, a protective cover and the interior parts with valve piston, control cylinder and stem.

Fig. 7.6.2:
Plunger valve

Fig. 7.6.4:
Pilot-operated control valve

Fig. 7.6.3:
Plunger valve DN 800, PN 10,
with aeration as a bottom outlet valve in the wall of a dam

Fig. 7.6.5:
Direct operated control valve

With the pressure-relieved valve piston the power required for operating the valve is largely independent of operating conditions. Pressure and flow rate are affected by the position of the interior parts and the control cylinder. The seal on the valve seat is produced by O-rings or securely fitted profile sealing rings.

Fig. 7.6.6:
Piston valve with electric drive

Fig. 7.6.7:
Piston valve with hand-wheel

Fig. 7.6.8:
Piston valve with float

Piston valves are mainly operated by electric drive mechanisms **(Fig. 7.6.6)**. However hand-wheels are also used **(Fig. 7.6.7)** as well as, for container inlets, levers with floats **(Fig. 7.6.8)**.

7.6.3.2 Plunger valves

The plunger valve **(Fig. 7.6.9)** is a straight form control valve with a flow cross-section which is annular in every position.

Fig. 7.6.9:
Plunger valve

Inside the valve body the plunger (also called the piston) is moved by a crank mechanism in the direction of flow axial to the seating surface of the valve.

Plunger valves are regulating devices which generate different pressure drops in piping systems by continuously constricting the flow at the valve seat according to the plunger setting. Depending on the application, the nominal size of the valve must be sufficiently dimensioned to be able to achieve the greatest rate of flow required with the lowest pressure difference and to relieve maximum pressure differences over the long term without damage. Additionally no damage whatsoever must be caused by vibrations or cavitation effects along the course of travel to the piping system downstream or to the structure as a whole.

In recent decades the reliable plunger valve has been further developed for control tasks in water supply systems. Current plunger valves are more or less universally available in nominal sizes DN 150 to DN 2000 in pressure ratings PN 10 to PN 63.

Large numbers of plunger valves are in use around the world, including some valves in pressure stage PN 160 **(Fig. 7.6.10)**. The compactly designed body is generally produced in high-quality ductile cast iron.

In some particular applications plunger valves have also been produced from special materials such as high-grade steel.

Fig. 7.6.10:
Plunger valve PN 160

Internal parts are usually entirely made of stainless steel. A major advantage of the plunger valve is the fact that the plunger runs through stainless longitudinal guides hard-faced or screwed to the valve body **(Fig. 7.6.11)**. This provides an optimum guide for the plunger and thus ensures free of play sliding with extremely low actuation forces at the same time.

The shape of the outlet of the plunger valve is variable **(Figs. 7.6.12 to 7.6.14)** and, like a kind of construction kit, it allows the valve characteristics to be changed. This is a very important advan-

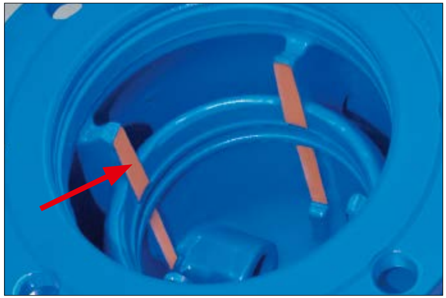

Fig. 7.6.11:
Longitudinal guides of the plunger valve

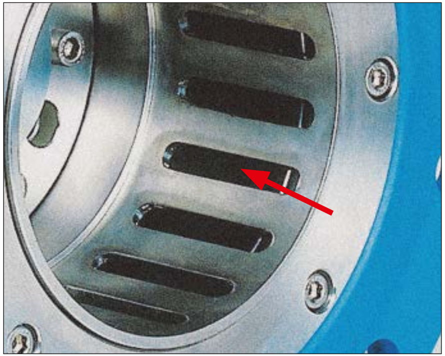

Fig. 7.6.12:
Slotted cylinder

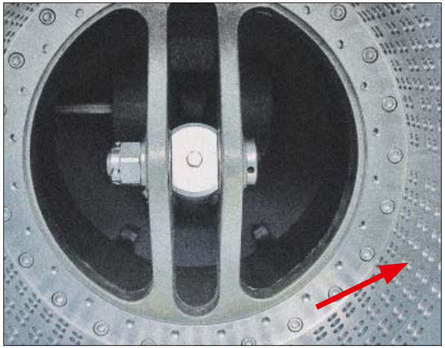

Fig. 7.6.13:
Perforated cylinder

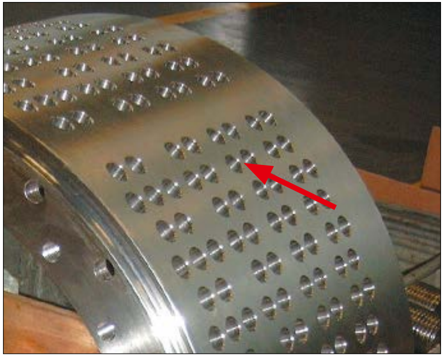

Fig. 7.6.14:
Special forms

tage of the plunger valve as it means that even after installation in the pipeline it can be adapted to altered operating conditions.

7.6.3.3 Pilot-operated valves

Pilot-operated control valves perform the widest variety of control functions; they work in almost all applications without an outside energy source. The most common type of design for pilot-operated control valves are the so-called diaphragm-operated valve in its function as a pressure reduction valve. These valves have a chamber separated by a diaphragm which forms the basis for the hydraulic control of the valve position. Because of the differences in surface at the valve seat and the diaphragm, at the same pressure a force is produced on these surfaces which closes the valve. This state exists if the pilot valve is completely closed **(Fig. 7.6.15)**.

When the pilot valve is open water flows through the control circuit. This causes a pressure drop at an orifice plate, the pressure in the diaphragm chamber and hence the closing force decrease and the main valve opens **(Fig. 7.6.16)**.

In the control mode the pilot valve opens according to its function (e.g.: pressure reduction valve or overflow valve). The main valve both opens and closes due to pressure differences in the diaphragm chamber. The valve regulates according to the demands of the pilot valve. Where there is a balance of forces between the seat and the diaphragm, the valve remains in its current position **(Fig. 7.6.17)**.

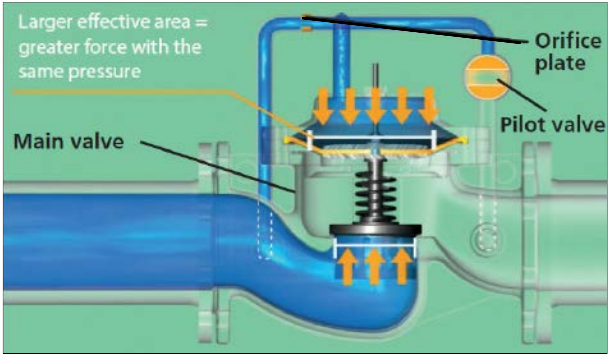

Fig. 7.6.15:
Main valve and pilot valve closed

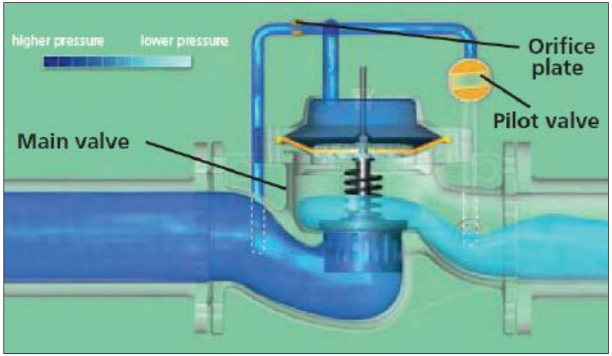

Fig. 7.6.17:
Main valve and pilot valve going into control mode

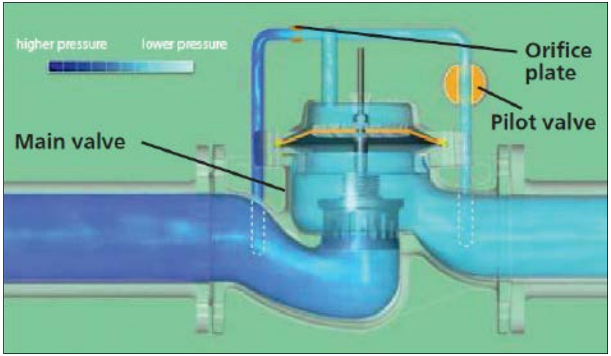

Fig. 7.6.16:
Main valve and pilot valve completely open

Fig. 7.6.18:
Pilot-operated plunger valve driven by its own medium

With pilot-operated control valves there are also applications in which plunger valves are used. In this case special drives are necessary for use in water **(Fig. 7.6.18)**.

7.6.3.4 Direct-operated control valves

Direct-operated control valves **(Fig. 7.6.5)** are predominantly used for pressure reduction. They must be capable of converting a fluctuating inlet pressure to a lower supply pressure regardless of flow rate. Direct-operated, spring-loaded pressure reduction valves are very suitable for this and offer an economically interesting solution if no high requirements are set for control accuracy. In contrast to pilot-operated pressure reduction valves, the back pressure set falls as the flow rate rises. With a pressure difference of more than 3 bar between forward pressure and back pressure the use of these valves is no longer worth recommending because of the possibility of cavitation occurring. The valves are equipped with adjustable compression springs for setting the back pressure (P2) **(Fig. 7.6.19)**. The moving parts of the valve are pressure-compensated as regards the forward pressure which means that this has no effect on the control function of the valve. By preloading the spring accordingly, the desired value for the back pressure can be set or changed.

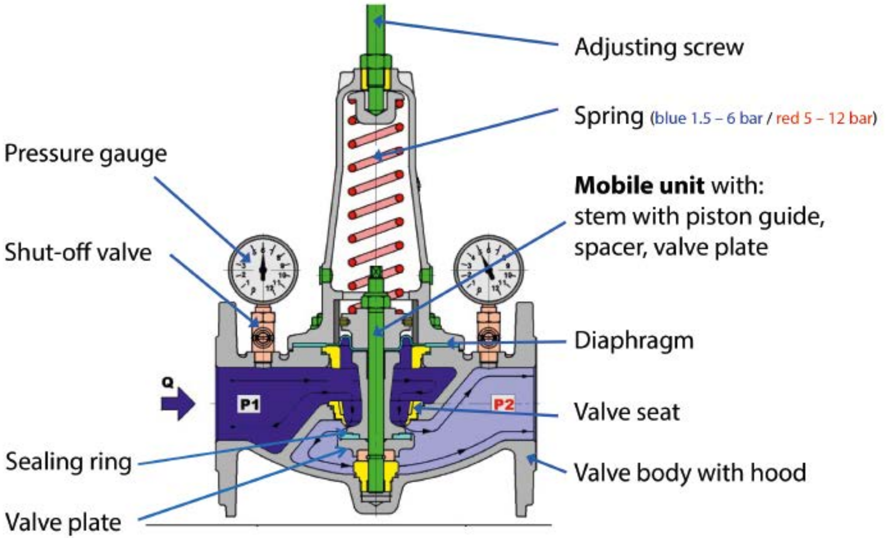

Fig. 7.6.19:
Construction of the valve

If the back pressure drops below the set value, the valve opens. When it increases again it then closes. If there is a balance between the force on the valve plate and the spring force, then the valve stays in an intermediate position.

7.6.3.5 Special applications

The use of valves for controlling compressed air is one possible application. Special gate valves can also be used for regulating the air supply to aeration tanks in sewage treatment plants, such as knife gate valves **(Figs. 7.6.20 and 7.6.21)** or butterfly valves, since the operating pressures to be governed are very low. With operating pressures above 0.5 bar the requirements of the pressure equipment directive [7.6-01] are to be observed.

Fig. 7.6.20:
Knife gate valve with perforated aperture

Fig. 7.6.21:
Knife gate valve with control orifice

7.6.4 Operating limits

The maximum operating temperatures and operating pressures specified in the manufacturer's technical documentation should not be exceeded. The closed valve should only be loaded up to the maximum allowable pressure $P_{s,max}$. This may be different from the PN. In common parlance, PN refers to the nominal pressure. However the definition according to EN 1333 [7.6-02] states that the PN is merely an alphanumerical parameter to ensure that pipeline parts can be connected with each other.

The maximal allowable flow velocity is based on EN 1074-1 [7.6-03]. Over and above this and regardless of the pressure stage, control valves should be operated with a flow speed of up to 5 m/s. These are considered as reference values at full operating pressure. If the flow speed is any higher, this can result in turbulence in the valve and even cavitation. Exceptions are use as the end valve in the bottom outlets of reservoirs and dams.

When it comes to selecting the correct nominal diameter (DN) there is a significant phrase in DVGW technical information sheet W 335 [7.6-04]: "With all control valves, correct dimensioning does not depend on the nominal diameter of the pipeline but on the flow rate and the operating pressures".

For this reason it is important to have the equipment data to hand when selecting a control valve so that suitability can be checked against the manufacturer's technical data.

Another important operating limit for control valves is cavitation. A cavitation study needs to be carried out for each application so that the control valve can perform sustainably and without damage **(Chapter 7.3)**.

7.6.5 References Chapter 7.6

[7.6-01] DIRECTIVE 97/23/EC
DIRECTIVE 97/23/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment
„Pressure Equipment Directive (PED)"
[Richtlinie 97/23/EG des europäischen Parlaments und des Rates vom 29. Mai 1997 zur Angleichung der Rechtsvorschriften der Mitgliedstaaten über Druckgeräte –
„Druckgeräterichtlinie (DGRL)"]
1997-05-29

[7.6-02] EN 1333
Flanges and their joints –
Pipework components –
Definition and selection of PN
[Flansche und ihre Verbindungen –
Rohrleitungsteile –
Definition und Auswahl von PN]
2006

[7.6-03] EN 1074-1
Valves for water supply –
Fitness for purpose requirements and appropriate verification tests –
Part 1: General requirements
[Armaturen für die Wasserversorgung –
Anforderungen an die Gebrauchstauglichkeit und deren Prüfung –
Teil 1: Allgemeine Anforderungen]
2000

[7.6-04] DVGW-Merkblatt W 335
Druck-, Durchfluss- und Niveauregelung in Wassertransport und -verteilung
[DVGW technical information sheet W 335
Pressure, flow and level control in water transport and water distribution]
2000-09

7.7 Air valves

7.7 Air valves

7.7.1 General

According to DVGW technical information sheet W 334 [7.7-01] the accumulation of air in drinking water pipelines can lead to considerable dynamic pressure changes on account of the different density of the two types of medium. It is therefore important that pipelines are kept as free of air as possible.

Air can get into pipelines in a number of ways, for example:

- dissolved in the water,
- present in empty or drained pipelines,
- sucked in at high points,
- sucked in from a sump pit,
- introduced via surge vessels.

To protect the pipeline against unacceptable pressure fluctuations and ensure that it functions without problem, air release or air admission is necessary for the equipment in the pipeline depending on operating status.

The gas bubbles trapped in pipelines (air, carbon dioxide etc.) reduce the free cross-section of flow, increase the pressure loss in the pipeline and in some cases cause unwanted pressure surges.

As a rule, air valves are installed in shafts or buildings. They can also be installed on pipelines running above ground. However there are also designs which are suitable for buried installation in the form of air valve sets.

7.7.2 Air release

Air release is not necessary in normal network operation as branches in the pipeline, hydrants and above all house connections automatically provide venting. Even with long-distance pipelines, no forced air release is required if the speed of flow is sufficient to carry the air bubbles away, even when the pipeline runs along a downward gradient. In cases where disruptive accumulations of air can form, automatically operating air release valves are used. Air is mainly to be expected in water pipelines in places where certain conditions are present, such as decreasing pressures and rising temperatures. This means that air bubbles **(Fig. 7.7.1)** tend to collect at

- static high points (L 1, L 3, L 6, L 7) and
- hydraulic high points (L 2, L 4).

Hydraulic high points sometimes occur in certain operating situations and are transitory in nature.

7.7.3 Aeration

Aeration by means of automatic air valves is necessary in the following cases:

- the draining of sections of pipeline,
- where negative pressures are produced, to protect the pipeline (for example behind pipe burst safety devices) **(Fig. 7.7.1)**.

7.7.4 Selection of air valves

Most air valve designs **(Fig. 7.7.2)** are based on the float principle with and without lever reinforcement.

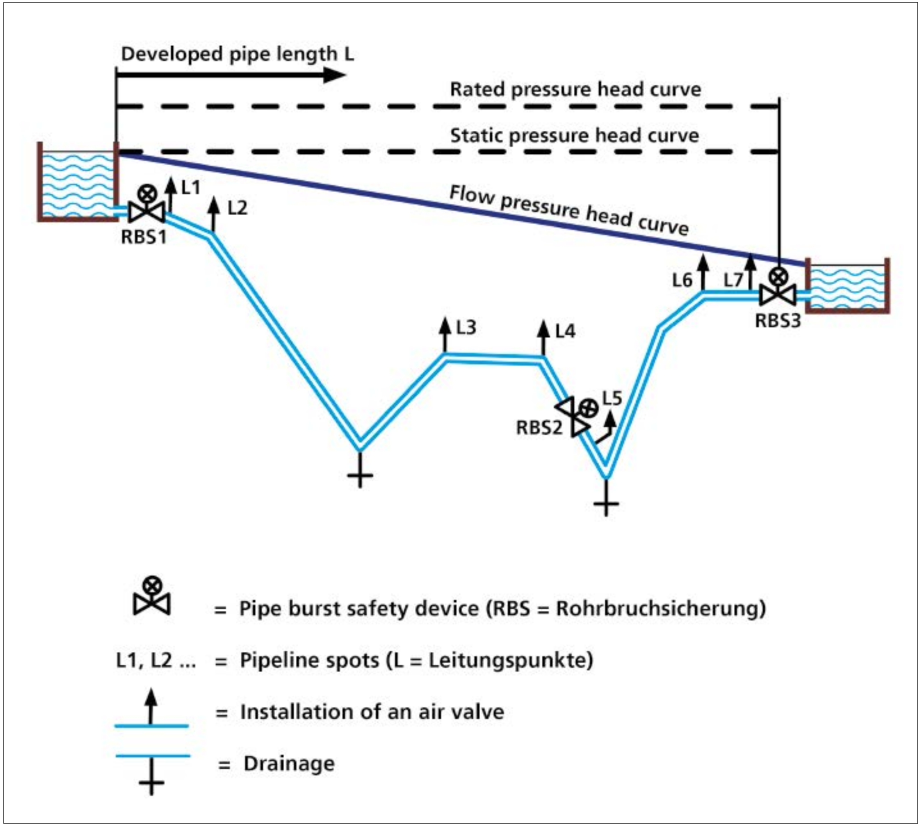

Fig. 7.7.1:
Installation locations of air valves in a pipeline

Fig. 7.7.2:
Air valves

7.7.4.1 Float principle

Large diameter float

The float is raised by the operating medium and always stays closed under pressure even when air accumulates during operation **(Figs. 7.7.3 and 7.7.4)**.

Small diameter float

The float is raised by the operating medium and closes the nozzle **(Fig. 7.7.3)**. It opens again if air bubbles accumulate in the body during operation **(Fig. 7.7.4)**.

The air valve can be effective for both main ventilation and operational air release. This state occurs for example when starting to fill a pipeline with water.

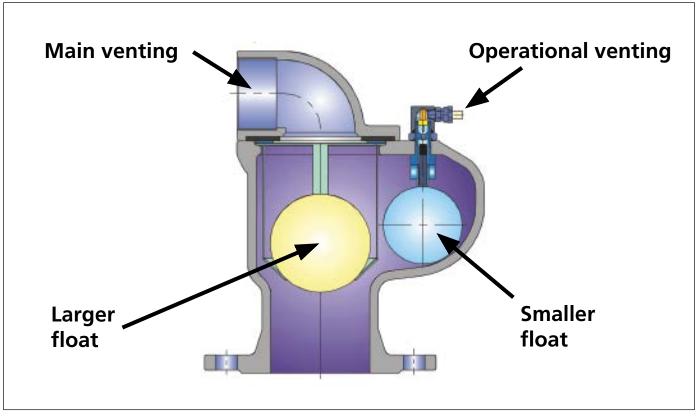

Fig. 7.7.3:
Air valve with large and small float in the open state

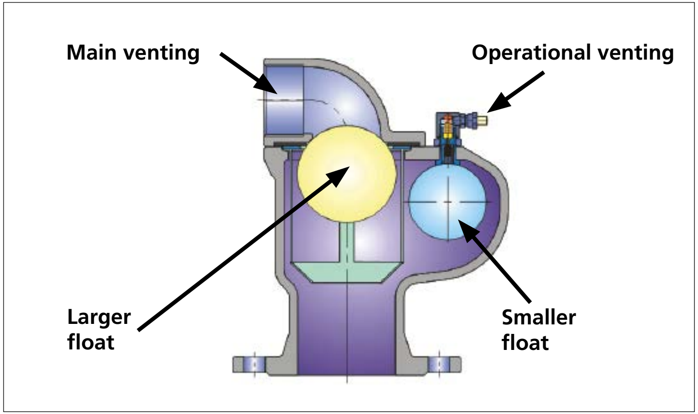

Fig. 7.7.4:
The valve is tightly closed.
Both main venting and operational venting are closed because there is no accumulation of air in the pipeline

7.7.4.2 Valve lever function

In the normal operating state the float is in its "up" position. The nozzle valves are closed **(Fig. 7.7.5, left)**. In case of a negative pressure wave the float drops and the nozzle valves open. Air in the pipeline is sucked out through the nozzles. The liquid level drops accordingly **(Fig. 7.7.5, centre)**. As soon as the pressure wave goes back to positive pressure, the central valve plate closes the large nozzle **(Fig. 7.7.5, right)**.

Fig. 7.7.6 shows a section through an air valve with valve lever function, which can be used in valves for water and sewage pipelines under pressure **(Fig. 7.7.7)**.

7.7.4.3 Lever principle

A float is attached to a lever which in turn is mounted on an articulated joint. The lever performs a pivoting movement **(Fig. 7.7.8)**.

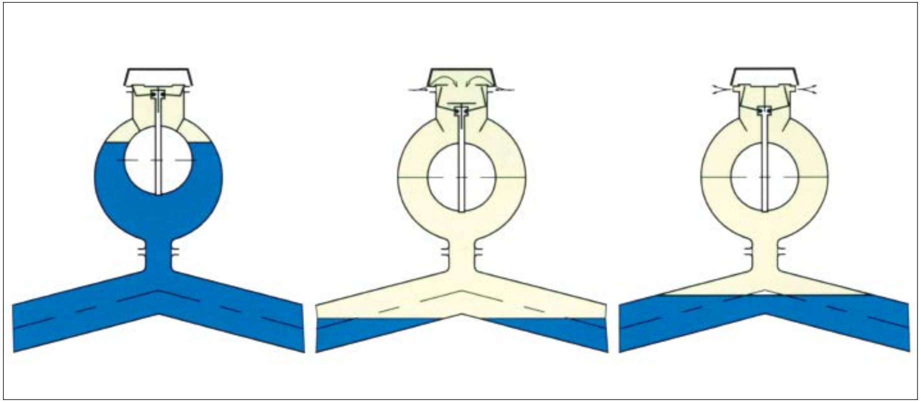

Fig. 7.7.5:
The float mechanism and valve lever function

Left: The valve is closed. The float is positioned at the top.

Middle: Under negative pressure the float drops down. The nozzle valves open and air is introduced into the pipeline. The liquid level falls accordingly.

Right: As soon as the pressure wave goes back to positive pressure, the central valve plate closes the large nozzle. In this process, the free-moving valve plate acts like a non-return valve. The air that is drawn in by this action can now only escape slowly and in a controlled way through the two small nozzles. The two columns of water are slowed down and slowly merge with each other. An abrupt collision is avoided along with the effects resulting from this.

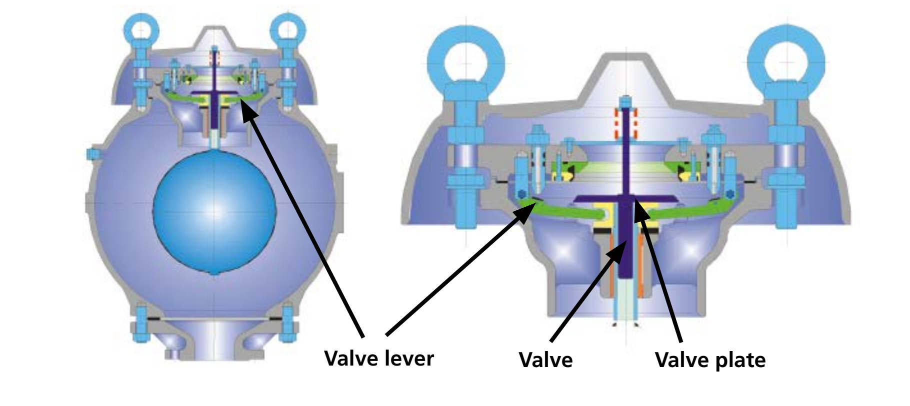

Fig. 7.7.6:
Sectional view of a single chamber valve with valve lever for small and large air volumes

Fig. 7.7.7:
Air valve with lever function for sewage pipelines under pressure

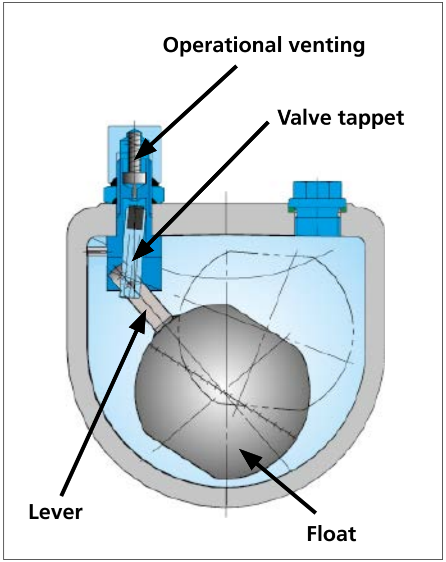

Fig. 7.7.8:
Different lever principles for air valves – the illustration shows the operational venting process. The float is attached to a lever. A valve tappet on the lever closes the venting hole under positive pressure. Under negative pressure the float drops and the hole is opened. Air can escape.

7.7.4.4 Dynamic pressure brake

A movable gate is mounted in the flow path of the valve body. When a certain flow velocity is exceeded the medium pushes the gate into the seat of the valve. This only leaves a reduced cross-section free. This dynamic pressure brake is used to protect the air valve from pressure surges **(Fig. 7.7.9)**.

7.7.4.5 Air valve with slide gate

So that the air valve can be isolated from the pipeline for overhaul work, a gate valve is often installed before the air valve. This means that the air valve can be dismantled or cleaned even while the main pipeline remains in operation **(Fig. 7.7.10)**. A soft-seated gate valve is best suited to this function as it allows free passage.

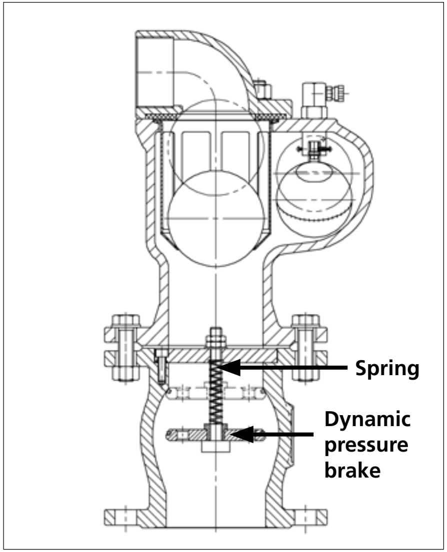

Fig. 7.7.9:
Air valve with dynamic pressure brake

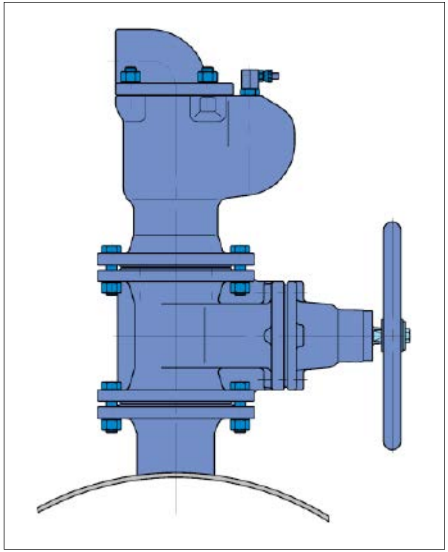

Fig. 7.7.10:
Air valve with gate valve

7.7.4.6 Air valve with air-intake stop

In order to prevent air inflow with small air valves and only ensure air release functions, air valves with a device to stop air-intake are often used **(Fig. 7.7.11)**. The main application for these valves is in suction pipelines for mechanically purified water or in the drinking water industry.

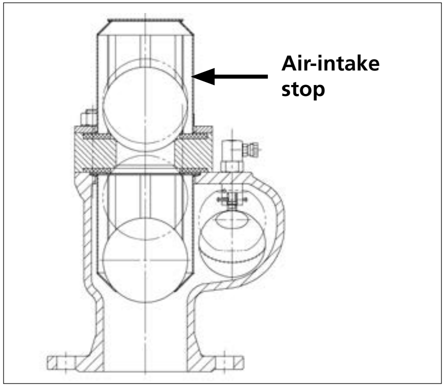

Fig. 7.7.11:
Air valve with air-intake stop

7.7.4.7 Air valve with air-release stop

In order to prevent air outflow with small air valves and only allow the admission of air, air valves with air-release stop are often used **(Fig. 7.7.12)**. The main application for these valves is in pressure pipelines for drinking water or mechanically purified water.

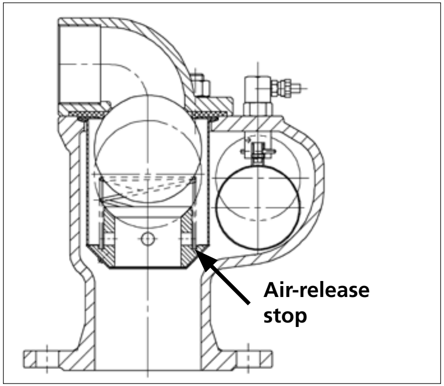

Fig. 7.7.12:
Air valve with air-release stop

7.7.4.8 Operating characteristics

If air is given off when filling pipelines via venting valves, the speed of filling must be kept as slow as possible. The dreaded pressure surge (Joukovsky surge), which occurs if the float of the venting valve slams the valve seat shut at the end of the filling process, must remain below the allowable maximum operating pressure (PMA = maximum hydrostatic pressure, including surge, that a component can withstand from time to time in service [7.6-02]). As a rule the allowable pressure surge is limited to 3 bar for safety reasons. According to DVGW technical information sheet W 334 [7.6-01] the filling speed is limited to 0.25 m/s.

The size and number of venting valves is to be determined according to the nominal size of the pipeline, the filling volume, the topography and the maximum allowable air speed in the narrowest cross-section of the venting valve (main venting).

As regards aeration parameters it is generally assumed that the pressure in the pipeline should not be below the absolute pressure of 0.8 bar (0.2 bar negative pressure). According to experience, the limits are met with sufficient certainty if the air inlet speed in the correctly dimensioned aerator is no more than 80 m/s. Also, the speed of 80 m/s should not be exceeded for reasons of noise prevention.

7.7.4.9 Air valves for buried installation

In general, air valves are installed in shafts. Their construction is described in DVGW worksheet W 358 [7.7-03]. In order to save on construction work for the shaft, air valve sets are used **(Figs. 7.7.13 and 7.7.14)**. On the left is an illustration of an air valve which releases air underground via a surface box. The figure on the right shows an above ground design.

7.7.4.10 Air valves for small volumes of air

Air valves are available for the admission and release of small volumes of air.

The valve is fitted with an internal thread and can be mounted directly on the pipeline **(Fig. 7.7.15)**. Valves of this kind are mainly used for installation in buildings.

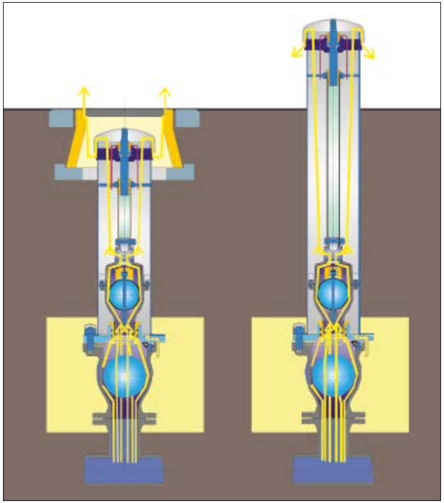

Fig. 7.7.13:
Air valve for buried installation

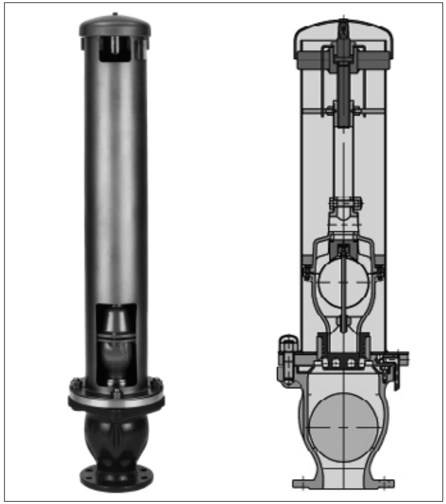

Fig. 7.7.14:
Air valve for buried installation – above ground design

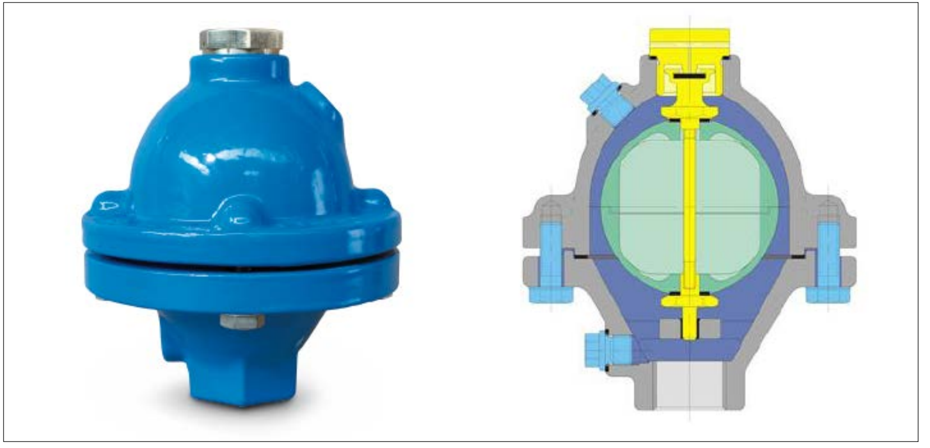

Fig. 7.7.15:
Air valve for small volumes of air with internal threaded connection

7.7.5 References Chapter 7.7

[7.7-01] DVGW-Merkblatt W 334
Be- und Entlüften von Trinkwasserleitungen
[DVGW technical information sheet W 334
Aeration and air release for drinking water pipelines]
2007-10

[7.7-02] EN 805
Water supply –
Requirements for systems and components outside buildings
[Wasserversorgung –
Anforderungen an Wasserversorgungssysteme und deren Bauteile außerhalb von Gebäuden]
2000

[7.7-03] DVGW-Arbeitsblatt W 358
Leitungsschächte und Auslaufbauwerke
[DVGW worksheet W 358
Manholes and outlet structures for piping systems]
2005-09

7.8 Hydrants

7.8 Hydrants

7.8.1 Field of use

A hydrant is part of the central extinguishing water supply for towns and communities. It makes firefighting possible but it also helps public users (e.g. road maintenance and urban departments) and private users (e.g. street cleaning companies and open-air festival organisers) to take water from the public water supply network (communal water supply). In addition, hydrants prove to be very helpful for operational measures such as the flushing and ventilation of piping networks. They are the only valves which allow drinking water to be taken directly from the supply network.

DVGW worksheet W 331 [7.8-01] covers the choice, installation and operation of hydrants and DVGW worksheet W 405 [7.8-02] deals with the provision of extinguishing water.

Possible fields of application for hydrants:

- Taking off extinguishing water,
- Ventilating pipelines,
- Flushing piping networks, particularly in end sections for reasons of hygiene,
- Producing temporary network connections,
- Emergency water take-off,
- Short-term water supply, e.g. for construction purposes, funfairs, etc.,
- Bridging for emergency supplies,
- Drainage of pipelines,
- Leak detection.

Depending on the position of the outlet opening, a distinction needs to be drawn between underground and pillar hydrants. Pillar hydrants are preferable for fire-fighting purposes; they are easy to find, easily accessible and ready for operation at all times. However, in densely built-up areas and in narrow streets with heavy traffic, underground hydrants have to be used and their location must be identified with indication plates.

More far-reaching regulations (specific to individual countries) can be found in standards EN 14384 [7.8-03] and EN 14339 [7.8-04].

As it must be assumed that the users of hydrants will have different qualifications, high requirements are set for construction, ease of operation, ease of maintenance and operational safety:

1. Low flow resistance:

- A hydrodynamically efficient construction of the shell and valve body,
- Minimum flow rate at 1 bar pressure difference (k_V value):
  pillar hydrants as per **Table 7.8.-01**,
  underground hydrants to EN 14339 [7.8-04]
  - 60 m³/h for DN 80 and
  - 75 m³/h for DN 100.

2. Pressurised water tightness:

- For hydrants with automatic drainage, the main shut-off device must be closed before the drainage device opens or the drainage device must be closed before the main shut-off device opens.

Table 7.8.-01:
Minimum flow rate values k_V for pillar hydrants as per Table 4 of EN 14384 [7.8-03]

Number and size of outlets to be tested										
Hydrant DN	1 x 37,5 mm	2 x 37,5 mm	1 x 50 mm	2 x 50 mm	1 x 65 mm	2 x 65 mm	1 x 100 mm	2 x 100 mm	1 x 150 mm	2 x 150 mm
80 und 100	30	60	40	60	80	140	160 [a)]	–	–	–
150	–	–	–	–	80	140	160	280	300	–

a) Does not apply to DN 80
– Combination of DN/size of outlet not permissible

Table 7.8.-02:
Maximum residual water volume after draining pillar and underground hydrants

Maximum residual water volume after draining as per EN 1074-6 [7.8-05]	
DN	Residual water max. ml
65	100
80	100
100	150
150	200

3. Low residual water volume:
- Permissible residual water volumes for automatic drainage devices in accordance with EN 14384 [7.8-03] and EN 14339 [7.8-04] with reference to EN 1074-6 [7.8-05] as per **Table 7.8-02** for pillar and underground hydrants,

4. Protection from roots:
- The drainage opening must be protected against root penetration, e.g. with a 50 mm dry section beneath the drainage point as per DVGW test specification VP 325 [7.8-06].

5. Actuating the main shut-off device:

- In accordance with EN 1074-6 [7.8-05] the following maximum actuation torque values apply:
  - DN 65: 85 Nm,
  - DN 80: 105 Nm,
  - DN 100: 130 Nm,
  - DN 150: 195 Nm.

6. Protection of the stem seal:

- Protection against the ingress of surface water and dirt above the seal (O-rings).

7. No deadwater spaces:

- All parts which come into contact with drinking water must be within the flow zone during opening or when in the open position.

8. Internal and external coating:

- Internal and external coating is covered in **Chapter 7.2**.

7.8.2 Materials

- Valve shell parts are generally constructed in spheroidal graphite cast iron to EN 1563 [7.8-07] and steel. In accordance with EN 14384 [7.8-03], other materials are also permissible. For example, upper sections in aluminium are also available **(Fig. 7.8.2-01)**.
- PUR (polyurethane) and EPDM (ethylene propylene diene monomer) are used as materials for shut-off elements.

Fig. 7.8.2-01:
Pillar hydrant – upper part in aluminium

7.8.3 Pillar hydrants

Pillar hydrants used in the public water supply system must meet the requirements of EN 14384 [7.8-03], EN 1074-1 [7.8-08], EN 1074-6 [7.8-05] and other national regulations where applicable such as DVGW worksheet W 386 (P) [7.8-09].

7.8.3.1 Construction

- Pillar hydrants project above ground level and have a main shut-off valve and one or more water take-off points.
- Pillar hydrants consist of two parts: the bottom section of the hydrant which contains the main valve and is installed underground plus the top part of the hydrant which is generally flanged onto the bottom part at ground level.

- Pillar hydrants are equipped with a predetermined breaking point which is normally located in the connection flange between the top and bottoms parts of the hydrant. This protects the bottom part of the hydrant and the pipeline to which it is connected.

- The majority of pillar hydrants are in nominal sizes DN 80 and DN 100, designed for a allowable operating pressure PFA = 16 bar. They have a vertical or horizontal inlet with a flanged, push-in or spigot end joint **(Figs. 7.8.3-01 and 7.8.3-02)**.

- The pipe covering usually varies between 1.25 m and 1.5 m. This ensures that, even with a minimum volume of residual water, the main valve cannot freeze up. Shallower pipe coverings down to a minimum of 0.2 m can be found in tunnels with restricted space **(Figs. 7.8.3-03 and 7.8.3-04)**.

Fig. 7.8.3-01:
DN 100 pillar hydrant – 2 B outlets

Fig. 7.8.3-02:
Design examples – DN 100 pillar hydrant – 2 B outlets, 1 A outlet with flanged joint

Fig. 7.8.3-03:
Tunnel hydrant with adjustable height, inlet bend and assembly base

Fig. 7.8.3-04:
Tunnel hydrant with a hand-wheel as the operating element

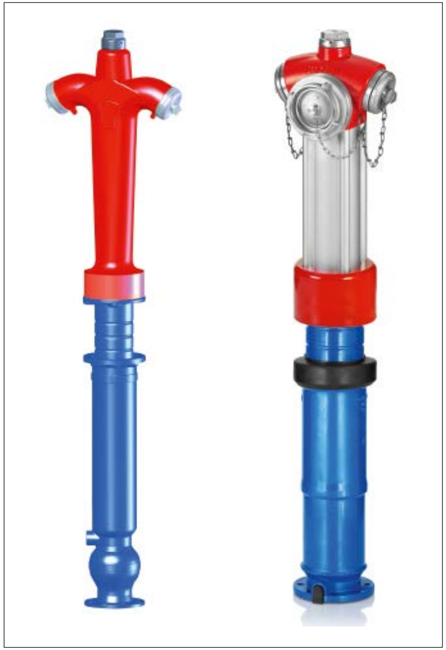

Fig. 7.8.3-05:
DN 100 pillar hydrants with flanged joint – height-adjustable bottom part

- The bottom part of hydrants is normally designed for a fixed depth of pipe cover.

In Switzerland, the majority of hydrants have height-adjustable bottom parts **(Fig. 7.8.3-05)**.

- Pillar hydrants differ in the type of protection of their B outlets – without drop jacket **(Fig. 7.8.3-06)** or with drop jacket **(Figs. 7.8.3-07 and 7.8.3-08)**.

Fig. 7.8.3-06:
Cross-section of a DN 100 pillar hydrant with 2 B outlets and 1 A outlet with stainless steel column

Fig. 7.8.3-07:
Examples of DN 100 pillar hydrants with 2 B outlets and 1 A outlet with closed drop jacket

Fig. 7.8.3-08:
Pillar hydrant with open drop jacket – 2 B outlets and 1 A outlet

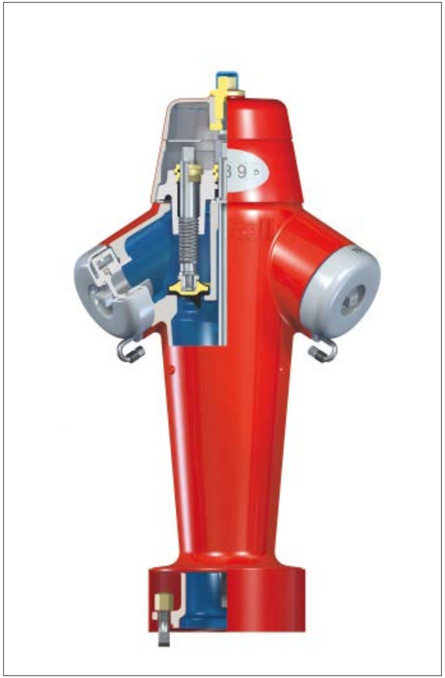

Fig. 7.8.3-09:
The upper part of a pillar hydrant without drop jacket and with B outlets which can be shut off

- **Fig. 7.8.3-09** shows a pillar hydrant without a drop jacket and with B outlets which can be shut off.
- Operation is by means of a hydrant key which is specific to each country.
- Pillar hydrants can have single or double shut-off devices. The double shut-off version is usually a ball or cone design.

7.8.3.2 Connection options

Pillar hydrants are used in different piping and pipe joint systems. Different joints are available for these:

- Hydrant with flanged joint,
- Hydrant with spigot ends and various restrained joint systems (Novo SIT®, TYTON SIT PLUS®, BLS®, VRS®-T, BAIO®, vonRoll HYDROTIGHT, threaded sockets or similar).

7.8.4 Underground hydrants

Underground hydrants used in public water supply systems must meet the requirements of EN 14339 [7.8-04], EN 1074-1 [7.8-08], EN 1074-6 [7.8-05] and other national regulations where applicable such as DVGW worksheet W 386 (P) [7.8-09].

7.8.4.1 Construction

The majority of underground hydrants are in nominal sizes DN 80 and DN 100. They are usually housed in surface boxes in the road as per DIN 4055 [7.8-10] and can be operated from there. A standpipe according to DIN 14375-1 [7.8-11] is always required in order to take off water and this is connected to the locking claw. In addition to the locking claw connection there are also different types of connection specific to the individual region; in Switzerland, for example, there are also round-thread connections.

The main shut-off device is actuated by applying a hydrant key. The design of the hydrant key varies from region to region, e.g. in accordance with DIN 3223 [7.8-12].

Underground hydrants consist of a one or two-part shell, also referred to as a jacket pipe or standpipe, the lower part of which houses the shut-off device. The opening movement may be against or with the direction of flow. Underground hydrants can have single or double shut-off devices. The double shut-off version is usually a ball or cone design **(Figs. 7.8.4-01 and 7.8.4-02)**.

The double shut-off version has the advantage that the shut-off device including its drive elements can be replaced in the surface box with the line under full pressure. When hydrants with a double shut-off system are used there is no need for an up-stream gate valve.

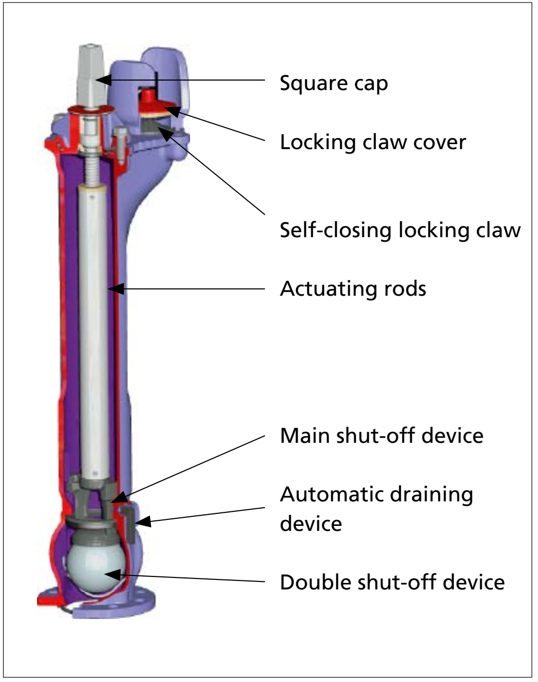

Fig. 7.8.4-01:
DN 80 underground hydrant – double shut-off, opening against the direction of flow – coating with epoxy resin powder

Fig. 7.8.4-02:
DN 80 underground hydrant – double shut-off, opening against the direction of flow – fully enamelled

As underground hydrants are usually located in surface boxes there is the risk that, with insufficient maintenance and in unfavourable locations (road subsidence) road grit, stones or other small objects may get into the shell and damage the shut-off device. In order to minimise this risk, two systems are used in the area of the locking claw: sealing flap and cover.

7.8.4.2 Connection options

Underground hydrants are used in different piping and pipe joint systems. Different joints are available for these:

- Hydrant with flanged joint,
- Hydrant with spigot ends and various restrained joint systems (Novo SIT®, TYTON SIT PLUS®, BLS®, VRS®-T, BAIO®, vonRoll HYDROTIGHT, threaded sockets or similar).

7.8.5 Industrial hydrants

The field of application for industrial hydrants, as the term suggests, in industrial plants, power stations, airports and any locations where large volumes of extinguishing water are required **(Figs. 7.8.5-01 and 7.8.5-02)**.

Fig. 7.8.5-01:
Industrial hydrant for the supply of extinguishing water in industrial plants

Fig. 7.8.5-02:
Industrial hydrant for the supply of extinguishing water in industrial plants

Industrial hydrants have a DN 150, PN 16 flanged joint, 2 upper B outlets and, characteristically for industrial hydrants, 2 lower A outlets. There are industrial hydrants with or without drop jackets **(Figs. 7.8.5-03 and 7.8.5-04)**.

Industrial hydrants are usually of the same construction as pillar hydrants. A particular design is the industrial hydrant with a ball valve **(Chapter 7.4.3)** as the shut-off device **(Fig. 7.8.5-05)**.

Fig. 7.8.5-03:
Industrial hydrant with DN 150 ball valve and without drop jacket

Fig. 7.8.5-04:
Industrial hydrant with DN 150 ball valve and drop jacket

Fig. 7.8.5-05:
A ball valve as the shut-off device for a DN 150 industrial hydrant

7.8.6 References Chapter 7.8

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