Sustainably superior –
ductile iron pipe systems

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Ductile iron pipe systems

Pipes, fittings and valves of ductile iron

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Foreword

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Each chapter is a unit on its own, comparable to a folder on a computer. This means that each chapter can be amended, updated or added to by the publisher independently of the other chapters. It is equally easy for new chapters to be added.

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Griesheim, October 2015

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1 Introduction

1 Introduction

Around 150 years ago, urban infrastructures for supplying the townsfolk with drinking water were constructed almost exclusively with cast iron pipes. A major part of the supply network in operation today still dates back to that time. Since then the ductile iron pipe system has made enormous progress: the manufacturing processes have adapted to the increasing requirements regarding dimensional accuracy, weight reduction and efficiency. Pipe joint technology has become both more secure and simpler. The use of spheroidal graphite cast iron means that higher mechanical loads are possible while simultaneously reducing weight. Protection against chemical attack both inside and outside has been perfected and, with pipes, fittings, valves and accessories, a complete system has been produced for all tasks. Nowadays the system of ductile iron pipes, fittings, valves and accessories ensures the problem-free and cost-effective transport of predominantly liquid media (water and wastewater).

1.1 General

Essential piping networks serve for the transport of

- water (drinking water, process and industrial water) and
- wastewater (domestic, commercial and industrial wastewater).

The pipelines are predominantly laid underground and thus are not able to be inspected and monitored on any ongoing basis. Therefore they have to be constructed in a material with high resistance levels and a long working life. Their joints, too, must be durably tight against all influences from both inside and outside. Pipelines laid in the soil are exposed to many and varied stresses. Firstly there is the internal pressure necessary to convey the medium being transported. And secondly there are the external loads exerted on the pipelines above all by the soil itself and by traffic in the form of ground motion and vibrations. In addition to these internal and external loads, which usually occur in combination and may be both static and dynamic in nature, there are also chemical stresses from the surrounding soil and in some cases from the medium being carried; sometimes the influence of temperature fluctuations has to be taken into account as well.

In the main, the costs of transporting water and wastewater are determined by the costs of the pipeline, i.e. by the costs of the pipes, fittings and valves themselves, for their installation and for the operation and maintenance of the piping network.

If damage occurs to pipelines buried underground, not only is it very difficult to detect and locate this but usually it is also very expensive to remedy it. In case of damage then, in addition to the actual repair costs, the costs which have to be met for digging up and repairing modern urban road surfaces and for diverting traffic are considerably higher. Therefore sustainable piping networks must have high safety margins. Ductile iron pipe systems are characterised by the highest safety margins and meet all requirements for sustainable piping networks.

1.2 Cast iron as material for pipes

There is no reliable information about when and where the casting of iron was first discovered. However it is known that the art of iron casting was practised in China, for example, much earlier than it was in Europe.

The first iron suspension bridge was constructed there in around 300 AD. The first cast iron gun barrels were used in Europe in the 12th century.

In the first half of the 15th century remarkable achievements were already being made in the casting of gun barrels. It is probable that the first conduit pipes were also cast by gun founders on the orders of local noblemen. Obviously they very soon recognised the value of a long-lasting and pressure-resistant material for the construction of high-pressure water pipelines for their castles and fortresses. And thus cast iron set out on its path through the centuries as a piping material.

1.2.1 Old pipelines in grey cast iron

Cast iron pipes have been in use for more than 500 years, initially as grey cast iron pipes. Their long working life is legendary. At the start they were used above all for the transport of drinking and industrial water. By way of examples of the construction of old cast iron water pipelines, the following facts are known:

1455 the oldest cast iron pipeline was built; this was the pipeline supplying water for Dillenburg Castle **(Fig. 1.1)**.

1562 a water pipeline was laid in Langensalza to supply the Jacobi and Rathaus fountains.

Fig. 1.1 :
Cast iron pipe from the water supply pipeline for Dillenburg Castle (1455)

Fig. 1.2:
Flanged pipe from the park at the Palace of Versailles

1661	a water pipeline was laid for the castle in Braunfels. The cast iron pipes were in operation until 1875 and were dug up during the course of sewer laying work in 1932.
1664 – 1668	the pipeline was laid in the grounds of the Palace of Versailles to feed the water fountains there **(Fig. 1.2)**.
1710 – 1717	the construction of the cascades in the Kassel-Wilhelmshöhe castle park with the Hercules monument. Cast iron pipeline to supply the water features with water **(Fig. 1.3)**. Since June 2013 the Hercules monument along with the cascades has been a UNESCO World Heritage Site.

Since the middle of the 19th century, as a result of increasing industrialisation and the considerable growth in population with constant improvements in the standard of living, the consumption of water has been steadily rising.

Fig. 1.3:
Cast iron pipeline to supply the cascades of the Hercules monument in the Kassel-Wilhelmshöhe castle park with water (UNESCO World Heritage site since June 2013)

With the necessity of conveying ever larger volumes of water to consumers, the operating pressures in the supply lines increase.

Increasingly advanced processes for melting, casting and testing have led to improvements in the material properties of cast iron and hence also in the quality of cast iron pipes.

For the urban supply networks (drinking water) constructed since the middle of the 19th century, grey cast iron was the available material almost without exception. Later, steel came along as an additional material. The German gas and water industry statistics (Bundesverband der Deutschen Gas- und Wasserwirtschaft e. V. – BGW) for water indicate a proportion of cast iron pipes in the existing network in the Federal Republic in the 20th century, up to the nineteen fifties, of 85 %.

In this area of municipal water distribution, the main area of application for cast iron pipes since about 1960 was pipes and fitting in ductile cast iron and valves in spheroidal graphite cast iron*). The length of cast iron pipelines worldwide is estimated at several 10^7 km, of which about one third are pipes in ductile cast iron; each year several 10^5 km are added to this. The reasons for this high prevalence are, among other things

- the robustness of the pipe,
- high safety margins, even with respect to unplanned load cases,
- uncomplicated installation,

- hygienically safe for drinking water,
- the long working life of the system as a whole,
- the lowest damage rate of all piping materials,
- the lowest leakage rate,
- the lowest operating and maintenance costs,
- the fact that they can be used anywhere, from the simplest to the most difficult ambient conditions.

***) Note:**
"spheroidal graphite cast iron" and "ductile cast iron" are synonyms for a type of cast iron in which the graphite is predominantly present in spheroidal form. The expression "ductile cast iron" is normally used for pipes and fittings while the official material designation according to standard EN 1563 [1.1] for valves reads "spheroidal graphite cast iron". Where pipes, fittings and valves are mentioned in the same breath in the sections and chapters which follow, for the sake of simplicity and for easier reading, the material designation "ductile cast iron" is used.

These days, pipes, fittings and valves in ductile cast iron are the most important elements in the construction of drinking water and sewage pipelines across the world. With the more recent technological developments such as trenchless pipe laying and replacement processes and areas of application with significantly higher internal pressures or other stresses, piping systems in ductile cast iron have proved to be excellent. Ductile iron pipe systems are all-rounders for everything to do with water, whether we are talking about simple municipal water supply pipelines installed in the traditional way or the most complex of pipeline constructions with a whole range of special structures and particularly sophisticated construction processes.

1.2.2 Improvements in the production process and material properties

In order to meet increased demands, the cast iron pipe industry has developed new and more efficient production processes. In the early days, pipes were cast one by one in horizontal sand moulds and then, in 1885, the process changed to one where the pipes were cast in vertical sand moulds arranged on a series of frames, meaning that the production process could be continuous. However, the really significant innovation in cast iron pipe production was the introduction of the centrifugal casting process **(Chapter 3.3)**.

In Germany, the centrifugal casting of iron pipes has been practised since 1926. This process, which is ideally suited to mechanised mass production, enabled the pipe foundries to meet the constantly increasing demand for cast iron pipes without difficulty.

Over the course of time, cast iron has also undergone further developments as a material to adapt it to the increasing loads placed on piping networks.

For example, in around 1900 a tensile strength of at least 120 N/mm² was being demanded for sand-cast pipes, while by the thirties the minimum tensile strength had already reached 200 N/mm² for centrifugally cast pipes.

The beginning of production of pipes, fittings and valves in ductile cast iron is to be seen as the most recent and also the most significant stage in the development of foundry technology. Further details about "ductile cast iron" can be found in **Chapter 2** of this handbook.

The production of pipes, fittings and valves from ductile cast iron is described extensively in **Chapter 3**.

1.2.3 Piping systems in ductile cast iron for water supply and sewage disposal

Ductile, or malleable, cast iron pipes have been produced in Europe since 1951 and in the Federal Republic of Germany since 1956. It is the spheroidal graphite formation which makes malleability and stretching ability possible with ductile cast iron. These days the tensile strength of the material for ductile iron pipes is at least 420 N/mm^2. In addition to this high tensile strength, which already very clearly shows the improvement in performance, it is above all the remarkable malleability which is characteristic of ductile iron pipes.

With the improvement in the metallurgy of cast iron, the conditions are met for the use of ductile iron pipe systems in nearly all areas of the urban piping infrastructure (water and sewage).

In the water supply industry, i.e. for the transport of drinking water and industrial and process water, iron pipes and fittings in ductile cast iron have been used since the middle of the nineteen sixties. In accordance with standard EN 545 [1.2], which applies to water pipelines, the nominal sizes of pressure pipes in ductile cast iron range from DN 40 to DN 2000 in pressure classes C 20 to C 100. DIN 28603 [1.3] defines push-in joints from DN 80.

For external loads produced by the ground itself and by traffic, attention has to be paid to observing permissible ovalisation limits for the pipe of up to 4 %.

The application ranges with respect to permissible pressures are summarised in **Table 1.1** (excerpt from Table 17 of EN 545 [1.2]).

The introduction of spheroidal graphite cast iron has proved to be an advantage for valves. Because the tensile strength has been doubled, the wall thicknesses of valve bodies have been able to be dramatically reduced, thus halving the weight. There are more details about the material in **Chapter 7.1**.

In the sewage disposal industry, i.e. the transport of domestic, commercial and industrial wastewater, pipes and fittings in ductile cast iron were first of all used mainly for wastewater pressure lines in difficult terrain, e.g. in areas where there is a risk of subsidence or landslides and on steep slopes, for water crossings (culverts) and where installation conditions present static problems. According to standard EN 598 [1.4], which applies to sewers and sewage pipelines, the use of piping systems in ductile cast iron is not restricted to the construction of buried gravity pipelines.

Pressure class (C classes) = PFA [bar]							
DN	20	25	30	40	50	64	100
e_{min} [mm]							
80				**3,0**	3,5	4,0	4,7
100				**3,0**	3,5	4,0	4,7
125				**3,0**	3,5	4,0	5,0
150				**3,0**	3,5	4,0	5,9
200				**3,1**	3,9	5,0	7,7
250				**3,9**	4,8	6,1	9,5
300				**4,6**	5,7	7,3	11,2
350			**4,7**	5,3	6,6	8,5	13,0
400			**4,8**	6,0	7,5	9,6	14,8
450			**5,1**	6,8	8,4	10,7	16,6
500			**5,6**	7,5	9,3	11,9	18,3
600			**6,7**	8,9	11,1	14,2	21,9
700		**6,8**	7,8	10,4	13,0	16,5	
800		**7,5**	8,9	11,9	14,8	18,8	
900		**8,4**	10,0	13,3	16,6		
1000		**9,3**	11,1	14,8	18,4		
1100	8,2	**10,2**	12,2	16,2	20,2		
1200	8,9	**11,1**	13,3	17,7	22,0		
1400	10,4	**12,9**	15,5				
1500	11,1	**13,9**	16,6				
1600	11,9	**14,8**	17,7				
1800	13,3	**16,6**	19,9				
2000	14,8	**18,4**	22,1				

Note: The figures in bold indicate the standard range

Table 1.1:
Pressure classes (C classes) and minimum wall thicknesses e_{min} for ductile iron pipes in the area of drinking water supply in accordance with EN 545 [1.2];
PFA [bar] is the allowable operating pressure

They can also be used for the construction of pressure pipelines from DN 80 to DN 2000. In EN 598 [1.4] certain external stresses from soil and traffic loads are taken into account. These are applicable for a permissible deformation of the pipe of up to 4 % and for covering depths from 0.3 to 8.5 m.

More details on the design of pipes, fittings, valves and accessories in ductile cast iron can be found in **Chapters 5 to 10 as well as 14 and 15**, and on static calculations in **Chapter 16**.

1.3 Joint technology

In addition to the further development of cast iron and the production process, in order to adapt to increasing operating pressures in the piping networks improvements have also been made to the joint technology. Essentially, two types of joints are used for cast iron piping systems:

- push-in joints,
- flanged joints.

Push-in joints are generally used for underground cast iron pipelines (pipes, fittings, valves). These are flexible, rubber-sealed joints which offer both technical and economic advantages for installation.

Flanged joints tend to be favoured for pipelines above ground, as are used for example in pumping houses, waterworks or elevated tanks. As regards shut-off valves in urban water supply networks, for decades the flanged joint was also commonly used in underground pipelines for reasons of maintenance and repair. Flanged joints are restrained ones, but not moveable joints, and they transfer longitudinal and bending stresses from pipe to pipe.

The individual advantages of push-in joints and flanged joints can be combined by installing flanged sockets and flanged spigots on the flanges of fittings.

We shall look at the different types of joints in greater detail below, according to the chronological sequence of their development or their introduction onto the market.

1.3.1 Flanged joints

One of the oldest types of joints for cast iron pipes is the flanged joint **(Fig. 1.2)**. These were standardised for the first time in 1882, in the so-called “Standard components of the year 1882” produced by the German Association of specialists in gas and water (DVGW) together with the Association of German Engineers (VDI). Notwithstanding these first standards and regardless of the material being used, by 1926 the arrangement of the bolt holes had already been determined in such a way that the bolt holes lie symmetrical to both principal axes and their number is divisible by four in all nominal sizes.

The joint dimensions of cast iron flanges (external diameter, bolt hole circle diameter, raised face diameter, number and diameter of bolts, bolt hole diameter) are determined in EN 1092-2 [1.5]. Additional construction dimensions for PN 10 to PN 40 flanges are also given in this EN standard. A flanged joint consists of two flanges, a sealing element and a certain number of hexagon head bolts with nuts and washers. The material of the sealing element depends on the purpose of use in each case. The flanges of ductile iron pipes, fittings and valves are provided with raised sealing faces. **Fig. 1.4** shows a flanged joint of this kind (nuts to EN ISO 4034 [1.6] and hexagon head bolts to EN ISO 4016 [1.7]).

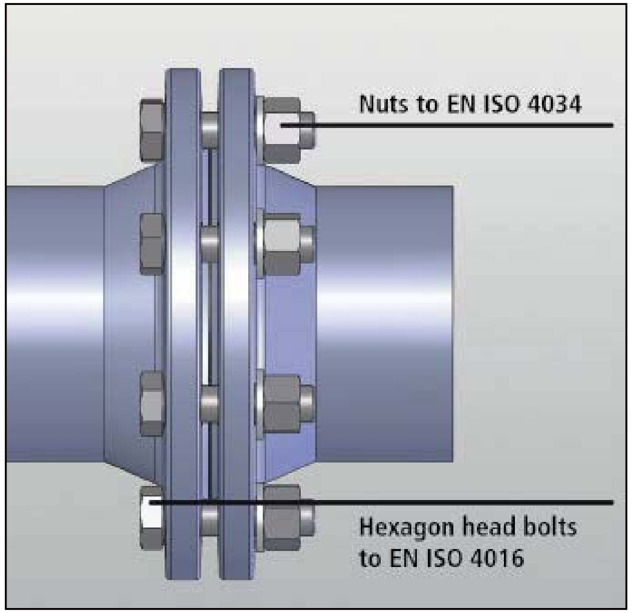

Fig. 1.4:
Flanged joint

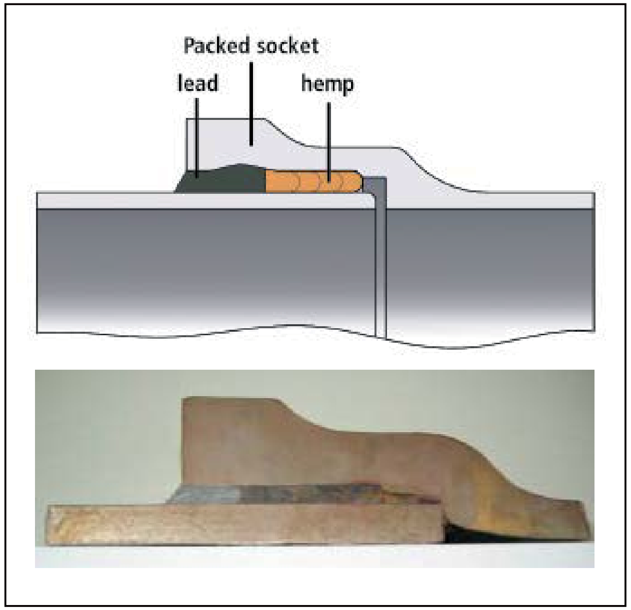

Fig. 1.5:
Packed socket joint

Fig. 1.6:
Cut section of a packed socket joint from an approximately 300 year old cast iron pipe – water supply pipeline for the cascades at the Kassel-Wilhelmhöhe castle park with the Hercules monument; UNESCO World Heritage site since June 2013
Source: mhk, Museumslandschaft Hessen Kassel

1.3.2 Packed socket joint

Until the introduction of rubber-sealed socket joints (around 1930) pipes and fittings in grey cast iron were mainly joined by means of packed sockets. These were not restrained joints. The packed socket joint **(Figs. 1.5 and 1.6)** is rigid and is not tight in case of movement.

The pipe joint is of immense importance for the reliability of a pipeline. In the area of cast iron pipes, the advantages of rubber-sealed socket joints were recognized very early on. After all, the rubber seal gives the pipeline flexibility which allows it to adapt to the stresses produced by traffic vibrations and ground movements as well as strain and compression forces in the pipe run without any adverse effects on tightness at the connection points.

Chapter 13 contains more details about the different types of sealing elements.

1.3.3 Screwed socket joints

The screwed socket joint has been used in Germany since 1931. Structural design and dimensioning are determined in detail in DIN 28601 [1.8]. **Fig. 1.7** shows the joint in cross-section.

The inside of the socket and the outside of the screw ring are buttress-threaded according to the direction of load. A screw ring axially compresses the elastic sealing element, which has hard rubber protective edges at the front and back, into its seating via a sliding ring. This produces the seal between the socket and the spigot end. The protective edges prevent the soft rubber part under compression in the middle from being forced out into the sealing gap.

The necessary angular deflections – the joint allows deflections of up to 3° from straightness – are only produced during installation after tightening the screw ring. These days the screwed socket joint is only used for fittings in the range from DN 40 to DN 400. A restrained joint can be produced by using additional elements. More on this in **Chapter 9**.

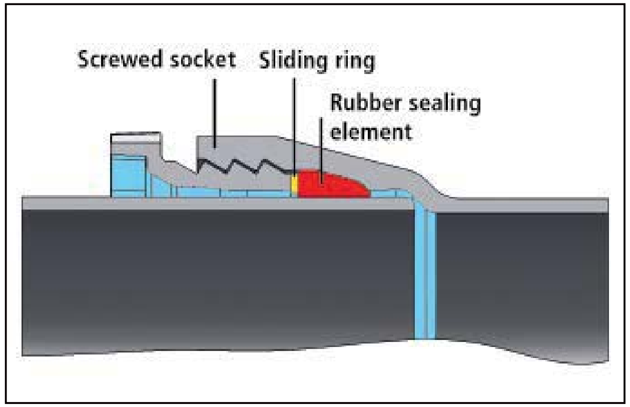

Fig. 1.7:
Screwed socket joint

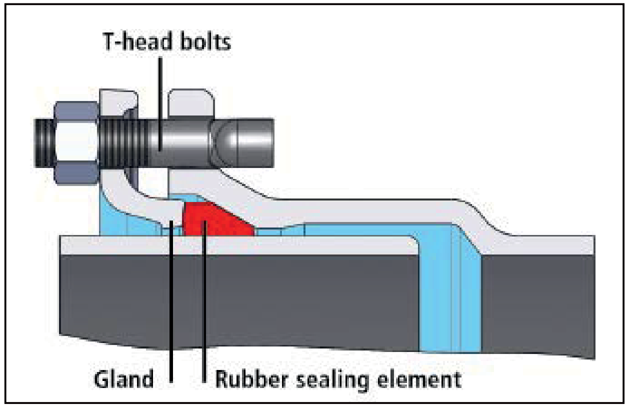

Fig. 1.8:
Bolted gland joint

1.3.4 Bolted gland joints

The bolted gland joint has been in use in Germany since 1936. Its dimensional construction is covered in DIN 28602 [1.9]; **Fig. 1.8** shows a cross-section.

Here it is the gland which applies pressure via T-head bolts onto the wedge-shaped sealing element, which has a hard rubber protective edge on the front. The sealing principle is practically the same as with the screwed socket joint. The necessary angular deflections – the joint also allows deflections of up to 3° from straightness – are only produced after the joint has been assembled. These days the bolted gland joint is only used in combination with certain types of fittings in the range from DN 500 to DN 1000.

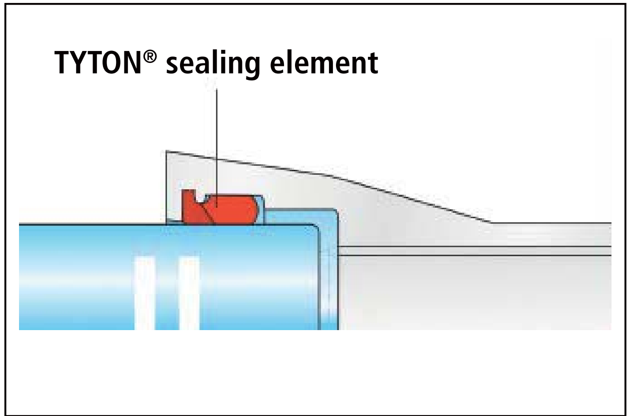

Fig. 1.9:
TYTON® push-in joint

1.3.5 Push-in joints

Nowadays, rubber-sealed push-in joints according to DIN 28603 [1.3] are predominantly used for ductile iron pipelines: the TYTON® push-in joint system has applications for the range between DN 80 and DN 1400, while the STANDARD push-in joint system is used in the range from DN 80 to DN 2000.

The TYTON® joint **(Fig. 1.9)** has been used in Germany since 1957. The profiled sealing element is produced from a mixture of hard and soft rubber.

Detailed information about push-in joints and their area of use can be found in **Chapter 8**.

1.3.6 Fields of use

The fields of use according to pressure classes (C classes) and minimum wall thicknesses e_{min} for ductile iron pipes in the field of water supply are shown in **Table 1.1**. In the field of sewage transport, ductile sewers as per EN 598 [1.4] are standardised for gravity pipelines up to 6 bar operating pressure. For higher pressures, pipes of pressure classes (C classes) according to EN 545 [1.2] are to be selected.

Special cases, such as the construction of a culvert pipeline or where there is a low cover depth, higher internal pressure loads or special linings and coatings can be dealt with by additional measures, either during production or during installation.

1.4 Modern ductile iron pipe techniques

The ductile iron pipe systems used today meet the requirements which are to be demanded of new piping networks for the transport of water and wastewater to a particularly high degree; there are additional fields of application in the field of industrial pipelines, e.g. for

- turbine pipelines for power production,
- snow-making equipment,
- fire extinguishing pipelines,
- cooling water pipelines.

But, because of their high loading capacity, ductile iron pipes have also opened up new fields of activity in construction technology, e.g. for

- trenchless laying techniques,
- foundation piles.

Corresponding details are covered in **Chapters 22 and 23**.

Ductile iron pipe systems owe their excellent properties above all to the following features:

- the modern jointing technology in the form of push-in joints including the flexible restrained push-in joints,
- the remarkable strength and stability of the material,
- the highly developed types of corrosion protection in the form of linings and coatings suited to specific tasks.

They offer high degrees of security against the stresses produced by the highest internal pressures. In addition, the material means that they resist practically all ground and traffic related loads.

Quite particular emphasis should be placed here on their ability to resist the resulting crushing and bending stresses, as it is precisely these types of stress which are considerably reduced by the flexible, rubber-sealed push-in joints.

The possibility of also providing such ductile iron pipes, fittings and valves with adequate external protection depending on the aggressive nature of the soil takes account of the practical realities during the installation of pipelines.

A comprehensive description of the various types of coatings can be found in **Chapter 14**.

All system components for the transport of drinking water, operating and process water or sewage are basically provided with appropriate linings in accordance with EN 545 [1.2] and/or EN 598 [1.4]. In particular this includes cement mortar and polyurethane linings for pipes. Fittings and valves are mainly coated all around with epoxy resin or enamel. **Chapter 15** contains details about linings.

1.5 Sustainability

In recent times, the term "sustainability" has gained increasing importance when assessing infrastructure investments. In such a consideration, economic, environmental and technical aspects are examined and evaluated, and this applies to the entire working life of the product.

The key points of sustainability criteria for ductile iron pipe systems with respect to an economic, environmental and technical assessment are shown in **Tables 1.2, 1.3 and 1.4** [1.10].

Table 1.2:
Economic sustainability criteria for ductile iron pipe systems

Sustainably superior –
ductile iron pipe systems

Economically superior

– push-in joints make for highly productive installation	▶ reduces labour costs
– no welding needed	▶ reduces labour costs
– installation in all weathers	▶ reduces labour costs
– sand bedding often not required	▶ reduces materials and logistics costs
– concrete thrust blocks not needed when joints are restrained	▶ reduces materials and logistics costs
– joints can be deflected angularly	▶ saves on fittings
– wide range of fittings and valves available so no need for specials	▶ reduces materials and labour costs
– extremely low damage rates	▶ reduces operating, energy, repair and maintenance costs
– operating life of up to 100 years or more	▶ keeps renovation budgets to a minimum

Investing in ductile iron pipe system pays for itself in low installation and operating costs with, at the same time, an extremely long operating life!

Table 1.3:
Environmental sustainability criteria for ductile iron pipe systems

Sustainably superior – ductile iron pipe systems

Environmentally superior

– impermeability to diffusion	▶ safeguards drinking water in all soil and installation conditions against environmentally damaging hydrocarbons and the groundwater when sewage is being transported
– linings approved to food hygiene standards	▶ ensure hygienic and environmentally safe transport of drinking water
– scrap as the raw material	▶ minimises the consumption of primary and fossil raw materials and reduces CO_2 emissions
– ductile iron can be recycled	▶ saves resources for present and future generations
– low expenditure on maintenance and repair costs over a long operating life	▶ avoids waste, minimises the consumption of resources and reduces CO_2 emissions

Ductile iron pipe systems can be shown to produce true sustainability!

Table 1.4:
Technical sustainability criteria for ductile iron pipe systems

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Technically superior

– the material is strong	▶ allows operating pressures up to 100 bars
– effective external protection	▶ shields against mechanical and chemical attack
– static load-bearing capacity	▶ allows very high stresses in the transverse and longitudinal directions
– joints	▶ allow operating pressures up to 100 bars; are resistant to root penetration
– ductile iron	▶ is non-combustible
– installation	▶ is possible with no special equipment
– restrained joints	▶ allow very high tractive forces and are therefore ideal for trenchless installation
– the material has superior properties	▶ which allow special applications in mountainous regions and for fire-fighting pipelines, snow-making systems and hydroelectric power stations

The technical performance of ductile iron pipe systems ensures the highest safety and reliability in all areas of the water industry!

1.6 Summary

Ductile iron pipe systems with their highly developed technology offer many advantages. With the push-in joint they are simple, safe and fast to install and are durably tight. They also stand up to diverse loads from both inside and outside. Installation, maintenance and follow-up costs are particularly low.

Consequently the ductile iron pipe system has an extremely long useful life.

With a multitude of technical advantages and practical operational properties, ductile iron pipe systems are seen as an economic and therefore sustainable solution for water supply and sewage disposal over the long term.

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[1.9] DIN 28602
Rohre und Formstücke aus
duktilem Gusseisen –
Stopfbuchsenmuffen-
Verbindungen –
Zusammenstellung, Muffen,
Stopfbuchsenring, Dichtung,
Hammerschrauben und Muttern
[Ductile iron pipes and fittings –
Bolted gland joints –
Assembly, sockets, counter ring,
sealing ring, bolts and nuts]
2000-05

[1.10] Sustainably superior –
ductile iron pipe systems
DUCTILE IRON PIPE SYSTEMS 47
(2013), p. 8/9
[Nachhaltig überlegen –
duktile Guss-Rohrsysteme
GUSS-ROHRSYSTEME 47
(2013), S. 10/11]

2 Ductile cast iron as a material

2 Ductile cast iron as a material

In contrast to grey cast iron, where the free graphite is present in lamellar form, the free graphite in ductile (malleable) cast iron is spherical in shape (spheroidal graphite). This form of graphite favours the elasticity of the cast iron and increases its inherent strength. It was only in the 1950's that the industrial production of cast iron pipes with spheroidal graphite (ductile iron pipes) began.

2.1 General

Ductile cast iron is a plastically malleable, tough iron-carbon material in which the carbon fraction is predominantly present as elementary spheroidal graphite. The main way in which it differs from grey cast iron is in the shape of the graphite particles. The word ductile comes from the Latin "ducere" = pliable (from ductus = to lead) and means malleable. In static calculations, pipes in ductile cast iron are therefore considered as having pliable properties or being flexible pipes.

When it is used for pipes, fittings and accessories, the material is referred to as ductile cast iron. Its mechanical and technological properties are described in standard EN 545 [2.1]. When used in bodies for valves it is called spheroidal graphite cast iron, as is usual in mechanical engineering generally, and its properties are determined in standard EN 1563 [2.2]. The two standards are the work of different technical standardisation committees.

With grey cast iron **(Fig. 2.1)**, because of their notching effect the graphite lamellae reduce the relatively high stability of the basic structure, whereby they cause its elongation after fracture to fall below 1 %.

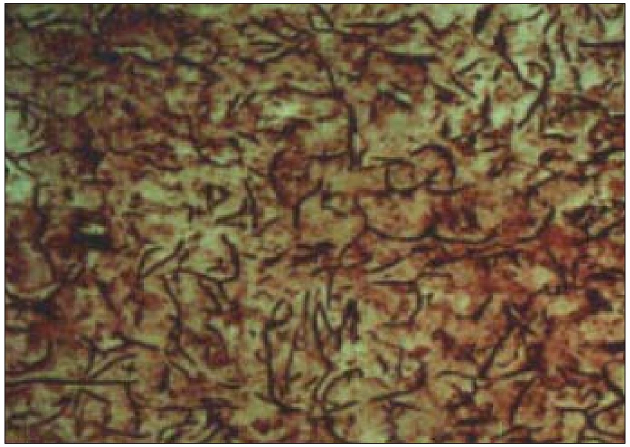

Fig. 2.1:
Cast iron with lamellar graphite (grey cast iron)

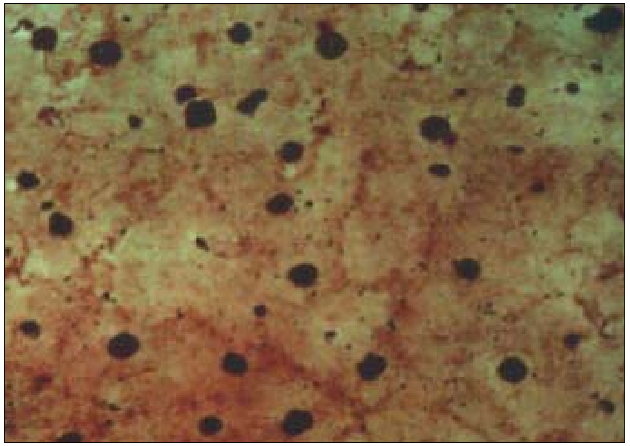

Fig. 2.2:
Cast iron with spheroidal graphite (ductile cast iron)

In ductile cast iron or spheroidal graphite cast iron the graphite is formed spherically **(Fig. 2.2)**. Spheroids (spherical mineral structures) affect the properties of the basic metallic structure to a considerably lesser extent than lamellae. While with cast iron with lamellar graphite **(Fig. 2.3)** the lines of tension are highly concentrated at the tips of the graphite lamellae, they flow around the graphite precipitated in spheroidal form almost undisturbed **(Fig. 2.4)**. For this reason, ductile cast iron is able to deform under load.

So that, during the solidification phase, the carbon crystallises in a broadly spheroidal shape, the molten iron has to be treated with magnesium. The result is a considerable increase in strength and malleability as compared with grey cast iron.

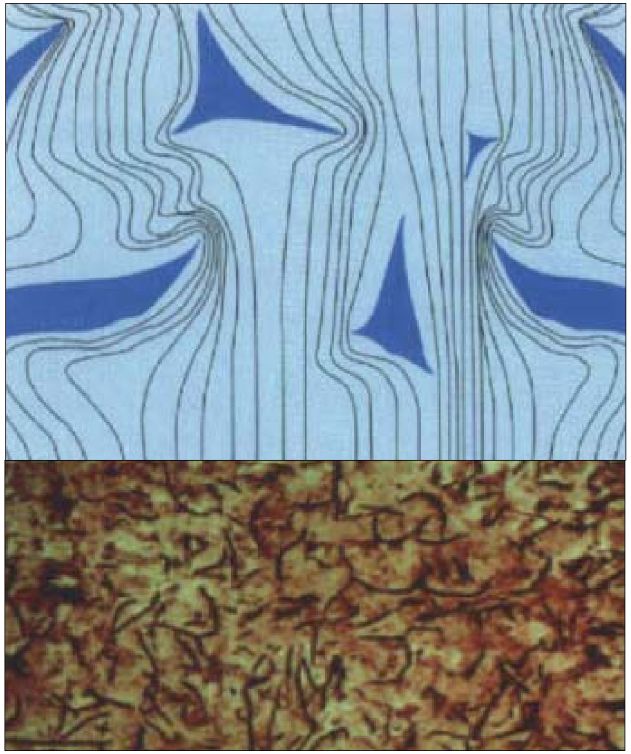

Fig. 2.3:
The flow of lines of tension in cast iron with lamellar graphite

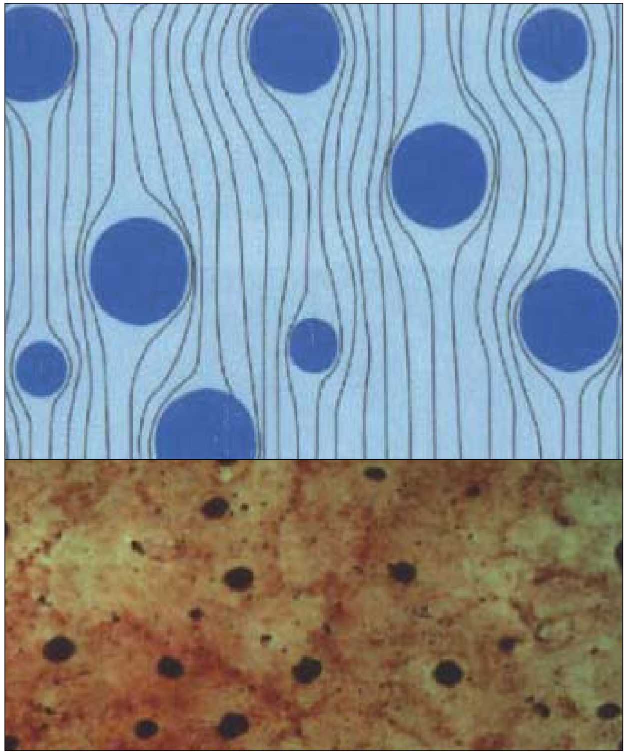

Fig. 2.4:
The flow of lines of tension in cast iron with spheroidal graphite

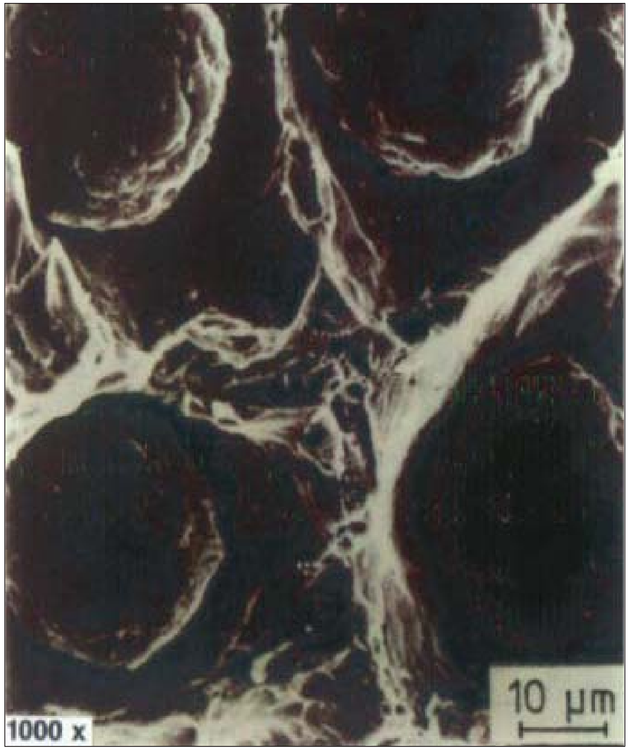

Fig. 2.5:
Scanning electron micrograph of graphite nodules

Fig. 2.5 shows spheroidal graphite nodules on the fracture surface of a ductile cast iron specimen. The size of the graphite nodules is in a range between 0.01 mm and 0.5 mm.

2.2 Structure

According to the applicable standards EN 545 [2.1] and EN 598 [2.3] the carbon fraction present as graphite must be predominantly spheroidal in form so that the workpiece has the required properties.

The matrix of the pipes should be predominantly ferritic **(Fig. 2.6)**, as ferrite produces the highest elongation values at the lowest hardness levels. Fittings, valve bodies and accessories are produced in sand moulds and have a ferritic-pearlitic structure. They do not need any additional heat treatment **(Fig. 2.7)**.

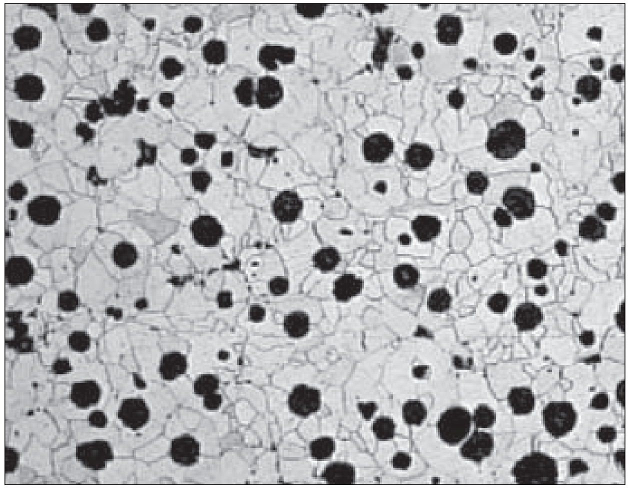

Fig. 2.6:
Ferritic structure

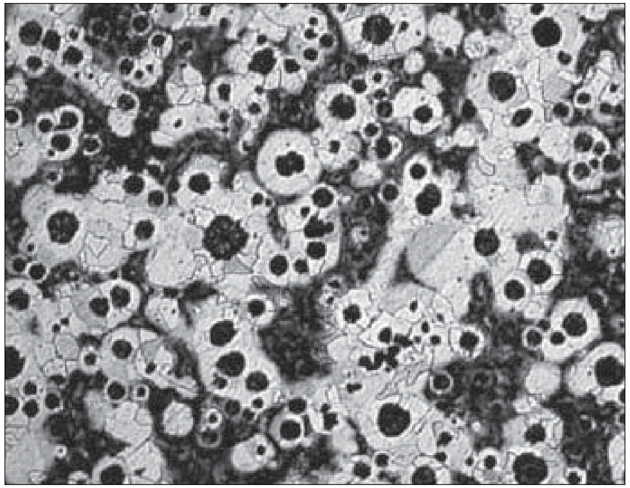

Fig. 2.7:
Ferritic-pearlitic structure

2.3 Technological properties

2.3.1 Material properties

According to standards EN 545 [2.1] and EN 598 [2.3], tensile strength and elongation after fracture are to be tested using round test bars. In addition, hardness of the material is to be determined. This is subject to an upper limit in order to enable machining, e.g. for flanges. Higher hardness levels are permissible in the area of the heat affected zone of weld seams **(Chapter 18)**.

The standardised values for the mechanical properties of ductile cast iron and spheroidal graphite cast iron are given in **Tables 2.1 a and 2.1 b**.

Table 2.1 a:
Properties of ductile cast iron

<table>
<tr><th>Material</th><th>Application</th><th>Standard</th><th>Minimum tensile strength R_m
[MPa]</th><th>0.2 % elongation limit[1] $R_{p0,2}$
[MPa]</th><th>Minimum elongation after fracture[2] A
[%]</th><th>Hardness
[HB]</th><th>Notched bar impact work
[J]</th><th>Structure</th></tr>
<tr><td>Ductile cast iron</td><td>Pipes DN 80 to DN 1000</td><td rowspan="3">EN 545 [2.1]

EN 598 [2.3]</td><td>420</td><td>300</td><td>10</td><td>< 230</td><td>[3]</td><td>[3]</td></tr>
<tr><td>Ductile cast iron</td><td>Pipes DN >1000</td><td>420</td><td>300</td><td>7</td><td>< 230</td><td>[3]</td><td>[3]</td></tr>
<tr><td>Ductile cast iron</td><td>Non-centrifuged pipes, fittings DN 80 to DN 2000</td><td>420</td><td>300</td><td>5</td><td>< 250</td><td>[3]</td><td>[3]</td></tr>
</table>

[1] The 0.2 % elongation limit ($R_{p0.2}$) can be determined. It should not be less than:
- 270 MPa if A ≥ 12 % for DN 80 to DN 1000 or A ≥ 10 % for DN > 1000
- 300 MPa in other cases

[2] For centrifuged pipes from DN 80 to DN 1000 and a minimum wall thickness of ≥ 10 mm the elongation after fracture must be at least 7 %

[3] No requirement

Table 2.1 b:
Properties of spheroidal graphite ductile cast iron

Material	Application	Standard	Minimum tensile strength R_m [MPa]	0.2 % elongation limit [1] $R_{p0,2}$ [MPa]	Minimum elongation after fracture[2] A [%]	Hardness [HB]	Notched bar impact work [J]	Structure
EN-GJS-500-7 (GGG 50)	Valves and hydrants	EN 1563 [2.2]	500	320	7	180 – 220	6 – 8	perlitic-ferritic
EN-GJS-400-15 (GGG 40)			400	250	15	140 – 180	8–12	predominantly ferritic
EN-GJS-400-18LT (GGG 40.3)	Valves for use at low temperatures		400	250	18	140 – 150	>12	purely ferritic

With centrifugally cast pipes, in addition to the standard, routine ductility tests can also be carried out in-works with the help of ring flattening specimens or ball pressure specimens.

The strength properties mentioned so far, which are mainly to be tested on prepared specimens, relate to the material.

A summary of additional material properties of ductile cast iron and spheroidal graphite cast iron, which in some cases come from other standards and sources, is given in the following **Table 2.2**.

Other characteristic values which relate to components have been determined in the context of a DVGW study [2.4] on drinking water pipelines on the basis of tests.

Pressure pipes in ductile cast iron have strength values according to **Table 2.3**.

Because of the high bursting pressures which ductile iron pipes resist, they offer high safety margins.

Table 2.2:
Mechanical and physical values of ductile cast iron and spheroidal graphite cast iron

Property	Dimension	Value
Compression strength	MPa	550
Modulus of elasticity	MPa	160,000 – 170,000
Mean coefficient of linear thermal expansion	m/m · K	$10 \cdot 10^{-6}$
Heat conductivity	W/cm · K	0.42
Specific heat	J/g · K	0.55

Table 2.3:
Component strength of ductile iron pipes

Property	Dimension	Value
Compression strength	MPa	550
Longitudinal bending strength	MPa	420
Bursting strength	MPa	300
Stress range	MPa	135

2.3.2 Material testing

In order to test centrifugally cast pipes, specimen rings are separated from the spigot end of the pipe. With fittings, accessories and valve bodies (sand casting) separately cast specimens are tested.

The material properties
- tensile strength,
- 0.2 % proof stress and
- elongation after fracture

are determined on machined cylindrical test bars exclusively according to Equation (2.1).

$$L_o = 5 \cdot d_o \qquad (2.1)$$

L_o Length of the machined cylindrical bar in mm
d_o Diameter of the machined cylindrical bar in mm

Hardness is determined using the Brinell test as per ISO 6506-1 [2.5] and EN ISO 6506-1 [2.6] on the casting itself or on a specimen separated from the casting. To do this, the surface to be tested is prepared by means of light local grinding. After that a hardened steel ball with a defined diameter and a defined test force is pushed vertically into the specimen. The precise indentation diameter measured is inversely proportional to the Brinell hardness.

For pipes, the flattening tests on 30 mm wide rings supplement the determination of mechanical properties on a specimen bar **(Fig. 2.8)**.

Fig. 2.8:
Ring flattening test

2.4 References

[2.1] 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]
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[2.2] EN 1563
Founding – Spheroidal graphite cast irons
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[2.3] EN 598
Ductile iron pipes, fittings, accessories and their joints for sewerage applications – Requirements and test methods
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[2.4] Deutscher Verein des Gas- und Wasserfaches e. V.:
„Studie über erdverlegte Trinkwasserleitungen aus verschiedenen Werkstoffen“, Bericht II, Eschborn
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Metallic materials – Brinell hardness test – Part 1: Test method
[Metallische Werkstoffe – Härteprüfung nach Brinell – Teil 1: Prüfverfahren]
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[2.6] EN ISO 6506-1
Metallic materials – Brinell hardness test – Part 1: Test method (ISO 6506-1:2005)
[Metallische Werkstoffe – Härteprüfung nach Brinell – Teil 1: Prüfverfahren (ISO 6506-1:2005)]
2005

3 Production of pipes, fittings and valves

3 Production of pipes, fittings and valves

The raw material for iron casting is pig iron; it is reduced from iron ore in the blast furnace with the help of coke (iron from the first smelting). In most cases this iron undergoes further processing in the iron foundry in solid form (pig iron ingots). Occasionally, the molten pig iron is also directly processed to produce pipes and fittings.

Iron foundries usually melt their iron in cupola or electric furnaces from recycled material and pig iron. Coke, oil or natural gas is the fuel used here; no reduction takes place. The crystallisation of the carbon dissolved in the liquid iron in the form of graphite nodules is achieved by the addition of magnesium into the molten metal.

These days pipes are manufactured exclusively by means of the centrifugal casting process, where the centrifugal forces produce the pipe wall. The rapid cooling applied here means that heat treatment of the pipes is necessary in order to give them a malleable microstructure.

Fittings, valve bodies and accessories are cast in sand moulds; the speed of cooling here is low enough to mean that no subsequent heat treatment is necessary.

As a rule, the application of linings and protective coatings is part of the production process. After casting, pipes and fittings with flanges, as well as most of the components of valves, first undergo mechanical processing. They are only coated once this is done. Throughout the entire production process there is a defined system of controls and tests to guarantee the specified properties of the product, including marking. **Fig. 3.1** shows an example of the flow through the production process.

3.1 Melting the iron

In most cases iron for the production of pipes, fittings, valves and accessories is produced as recycled material from steel scrap, cast iron scrap and foundry pig iron in the cupola furnace or in the electric furnace.

3.1.1 Melting in the cupola furnace

The cupola furnace **(Fig. 3.2)** is the typical melting plant of an iron foundry; it is an upright shaft furnace which is charged from the top with the raw materials (steel scrap, cast iron scrap, recycled material and coke as the fuel).

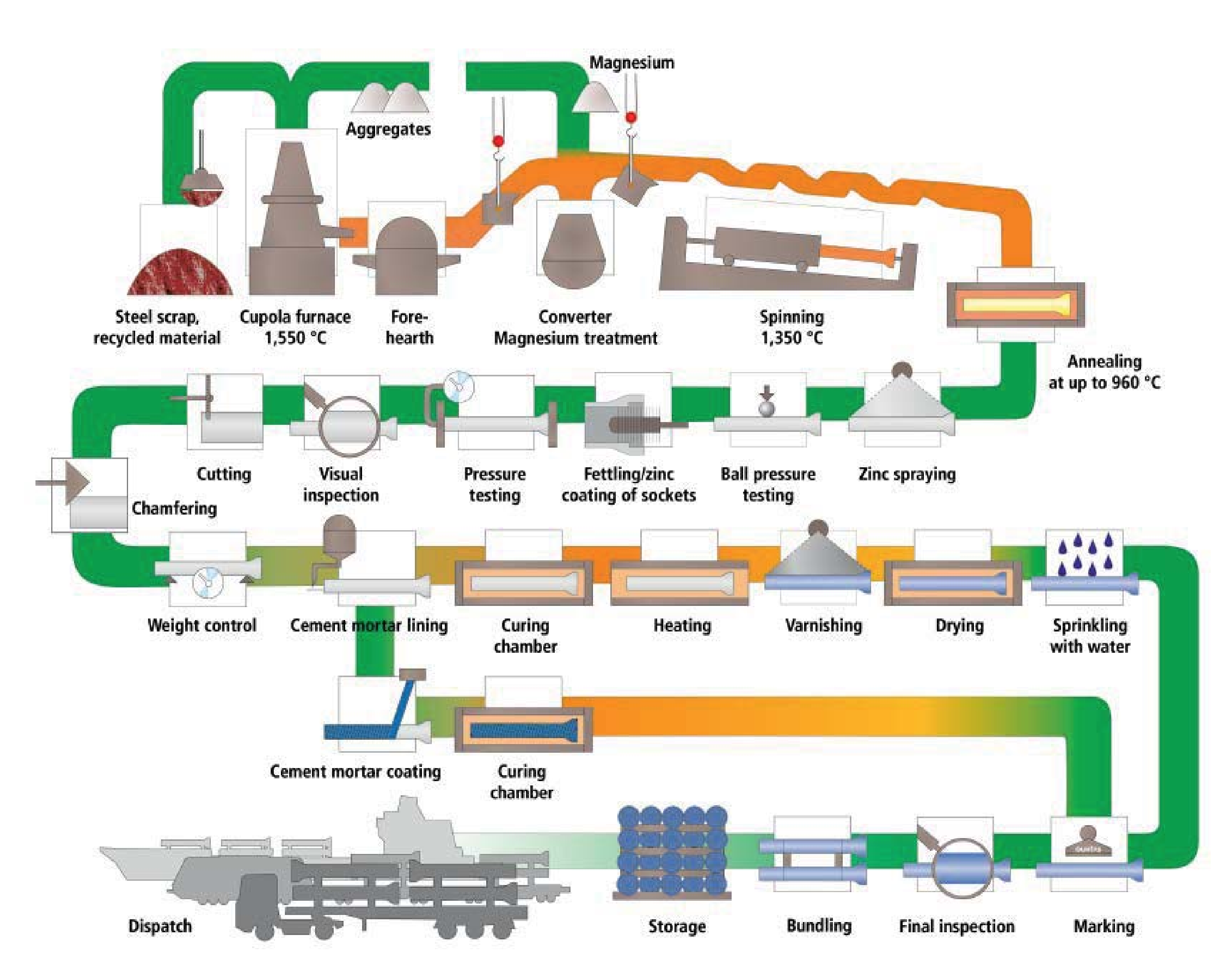


Fig. 3.1:
Production of a ductile iron pipe

Video 03.01:
Iron pipe foundry

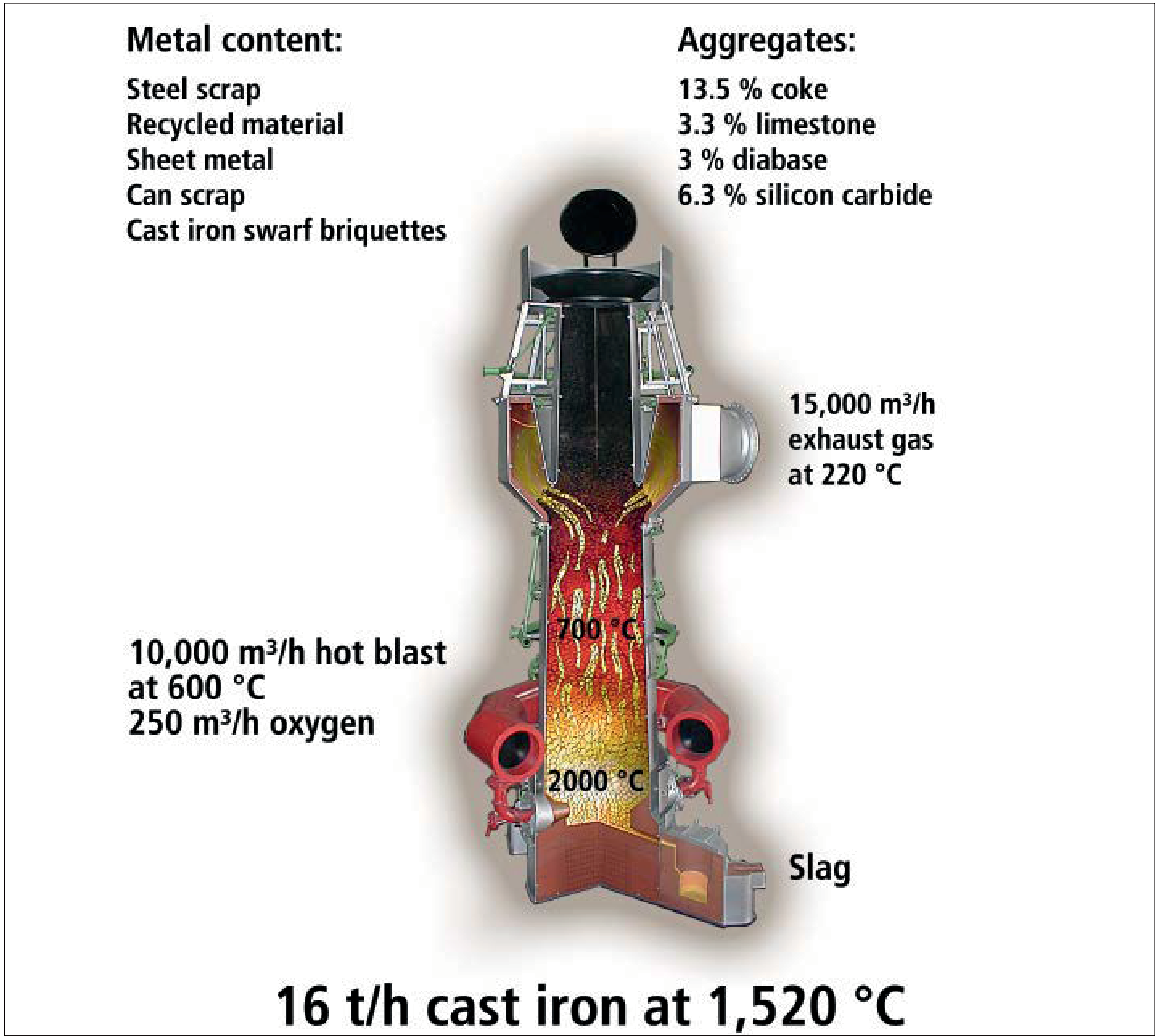


Fig. 3.2:
Sectional view and operation of a cupola furnace

Fig. 3.3:
Discharge of molten iron from the mixer

Heated air is blasted in from below causing the coke to burn. The heat thus produced melts the metallic content of the furnace which drops into the lower part of the shaft as molten iron. This flows continuously at about 1,450 °C through a channel into a collection vessel, the mixer, from which the iron is taken out in batches and desulphurised **(Fig. 3.3)**.

The cupola process has the advantage of a very good ecological balance because the metal content can consist of up to 100 % scrap

The cupola furnace is omnivorous – even bundles of vehicle scrap, rusted steel girders or excavated grey iron pipes can be recycled without problem, as organic impurities are burned off and so help the energy balance. Zinc, evaporated from the zinc-coated panels which are more and more often used in car manufacturing these days, burns to form zinc oxide which is filtered out of the flow of exhaust gas from the furnace along with other types of dust and is sent to recycling.

The coke used in the cupola furnace always contains a small proportion of sulphur, which dissolves in the liquid iron and can have a negative effect on the mechanical properties of the iron. This means that a stage has to be added after the production of the molten iron in which the sulphur is removed. This is done by using appropriate raw materials, such as calcium carbide, to which the sulphur becomes chemically bound. The reaction products float on the iron melt as slag and can thus be separated off.

3.1.2 The electric furnace

An equally common melting plant in iron foundries is the electric induction furnace **(Fig. 3.4)**. Its cylindrical vessel, lined with refractory materials, is surrounded by a coil through which an alternating current flows, thereby inducing a secondary current in the core of the metallic charge. In this way the metal content is heated and molten. No other energy sources, such as coke, are needed. Energy supply and temperature can be controlled more easily and quickly than in the cupola furnace.

3.2 Magnesium treatment

Without additional treatment, the iron molten in the cupola or electric furnace would have a predominantly lamellar graphite formation. However, what is wanted is the typical spheroidal graphite formation of ductile cast iron. This is achieved mainly by the addition of magnesium. A decisive factor here is the high affinity of magnesium to oxygen and sulphur.

Fig. 3.4:
Electrical induction furnace

The magnesium reduces almost all the oxides present in the melt and binds the sulphur as magnesium sulphide.

Because of their very low specific weight, the magnesium oxides and considerable volumes of magnesium sulphide rise to the surface of the liquid iron from where they are taken off as slag.

Despite extensive research, the mechanism by which magnesium treatment finally results in the formation of graphite spheroids has still not yet been clearly explained. The favoured model representation is that, by removing the sulphur to a few ppm, the interfacial tension between the surface of the graphite crystal seeds which are forming and the liquid iron is increased, which forces the graphite crystals into a spheroidal growth with the smallest boundary surface.

Various processes exist, e.g. pure or alloyed magnesium in ceramic bell chambers is pressed onto the bottom of a ladle filled with liquid iron, or, in a so-called converter, magnesium is put into a chamber and, when the covered converter is tipped, the magnesium is brought into a position underneath the liquid iron **(Fig. 3.5)**.

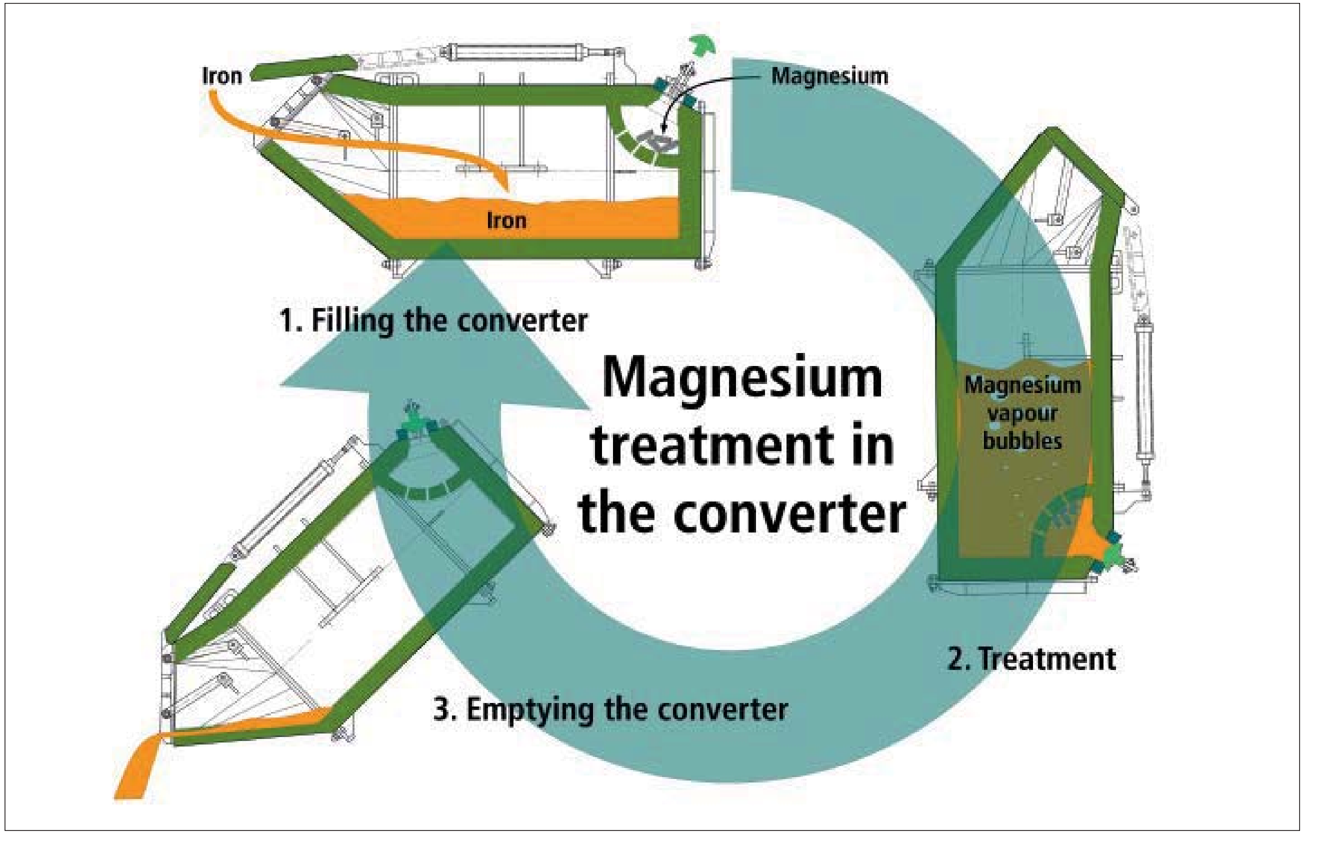


Fig. 3.5:
Magnesium treatment in the converter

Another possibility is the use of a wire filled with magnesium. For the production of fittings and valve bodies using the sand moulding process, magnesium treatment in the casting mould (in-mould process) has proved effective **(Fig. 3.6)**.

With all processes, the magnesium evaporates in the molten iron bath, produces turbulence in this and so reacts favourably with oxygen and sulphur so that small volumes of it are dissolved into the iron.

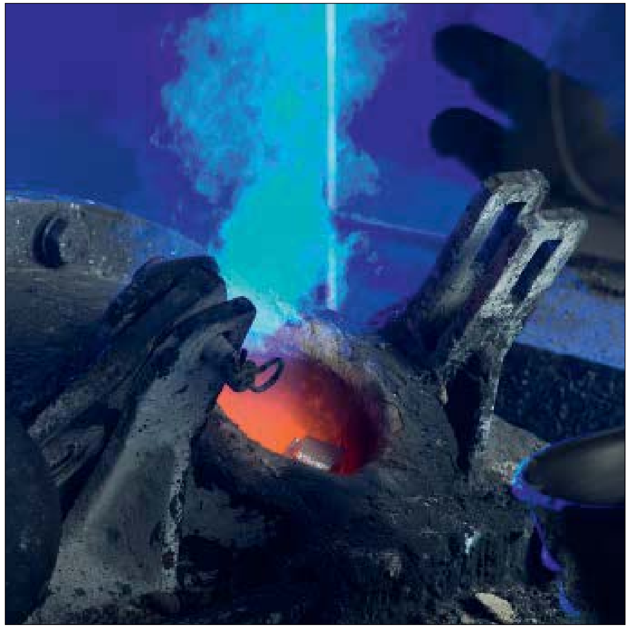


Fig. 3.6:
Reaction of the liquid iron during magnesium treatment

3.3 Casting process

3.3.1 Pipe production using the centrifugal casting process

The notion of producing pipes by centrifuging cast iron in metal moulds dated back to a patent by an engineer called Eckhardt in the year 1809. However, because there was little need for it and because of insufficient technical conditions, this invention was not able to be implemented. A particular difficulty lay in the distribution of the liquid iron in the casting mould rotating about its horizontal axis.

In 1910 Otto Briede from Benrath invented the moving casting machine. His idea was put into practice by the Brazilian, de Lavaud, after whom the "De Lavaud process" for the centrifugal casting of pipes used right across the world today is named. Centrifuged iron pipes were produced in Germany for the first time in 1926.

Essentially, two working methods are used:

1) Centrifuging in metal moulds (mould-spinning moulds) according to the De Lavaud process **(Fig. 3.7)** and
2) Centrifuging in metal moulds with linings according to the wet-spray process.

With both processes, the outside contour of the pipe is produced by a metal mould (spinning mould). The mould is located in a machine housing which can move longitudinally. At a number of points it rests on rollers and is held in place by pressure rollers on the top. Water is used for cooling from the outside. Driven by an electric motor, the mould rotates around its longitudinal axis. The internal profile of the mould determines the external shape of the pipe. In the widening of the mould on the socket side, a core formed according to the internal profile of the pipe socket, produced from sand and a binder, is inserted. At the same time this core closes off the mould.

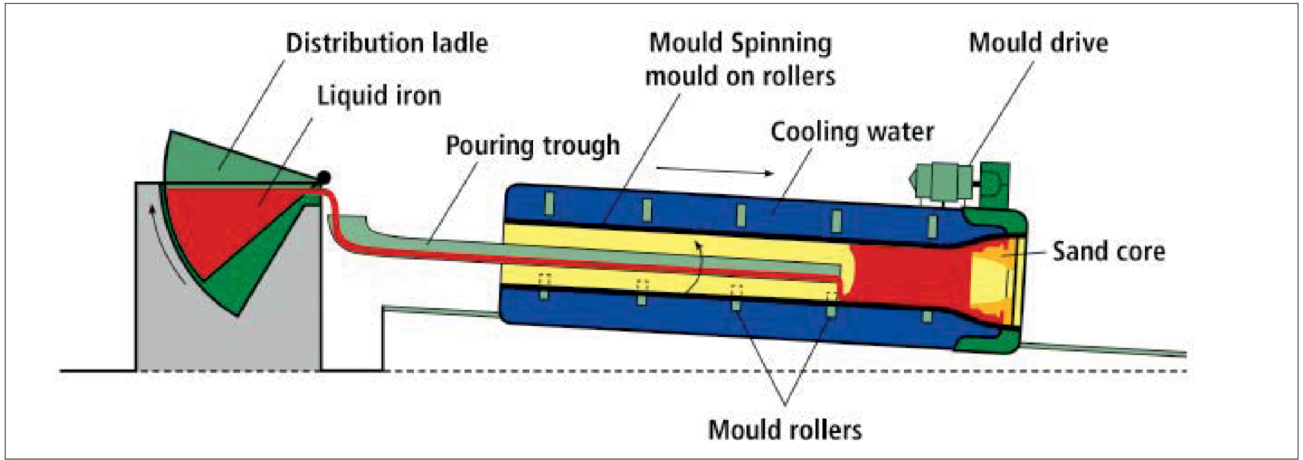


Fig. 3.7:
Centrifugal casting machine – pipe centrifuging process in metal moulds according to de Lavaud

Fig. 3.8:
Pouring trough retracted from the mould

Video 03.02: Centrifugal casting machine – animation

On the spigot-end side of the mould a collar is applied which corresponds approximately to the wall thickness of the pipe. The casting machine equipped in this way is tilted towards the socket side and is arranged on rails so that it can be moved longitudinally. At the upper end of the frame is the casting device with the distribution ladle which can take the volume of liquid iron for one or more pipes. A controlled, even speed of tilting means that during the casting process a constant volume of iron per unit of time flows over the pouring lip of the distribution ladle into the pouring nozzle and from there out into the pouring trough. At the beginning of casting the trough projects into the mould almost to the end of the socket. Before the iron starts to flow, the mould is put into rotation. The iron flowing out at the tip of the pouring trough is captured by the rotating mould, first filling the space between the socket core and the mould and then forming the barrel of the pipe as a result of centrifugal force as the casting machine moves longitudinally **(Fig. 3.8)**.

Because of the interaction of movements, the iron is laid down on the wall of the mould in a helix which, in the liquid state, merges into a homogenous pipe. A thicker or thinner pipe wall is produced by changing the volume of iron for the casting process.

The speed of rotation of the mould is selected so that a centrifugal force of 15 g to 30 g is exerted on the liquid iron. Because of the centrifugal force and because of the directional solidification of the pipe wall from the mould side to the inside of the pipe, a particularly dense structure is produced. The centrifugal force has a further effect in that the oxidation products produced during the casting process and any slag carried away with them will, because of their weight, be forced inwards and are easy to remove during later cleaning. Because of the speed of cooling and the reduction in volume of the liquid iron occurring on solidification, the pipe comes away from the wall of the mould and can be pulled out mould on the socket side **(Fig. 3.9)**.

Fig. 3.9:
Iron pipe is pulled out of the casting machine socket-end first

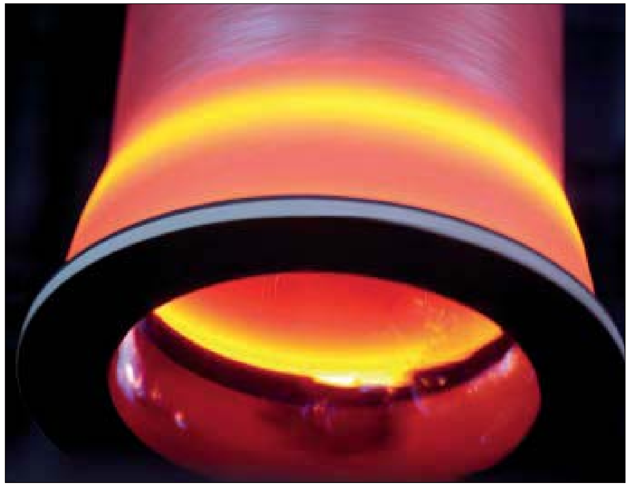


Fig. 3.10:
Solidified pipe is pulled out of the mould

3.3.2 De Lavaud process

With this process, the mould is cooled from outside with water. Its inside surface is peened to produce ball-shaped depressions. This cold-peening increases the strength of the surface and helps the liquid iron to be taken up with the rotation movement of the mould. In this way, the iron pipes spun in metal moulds take on the surface typical of them. During or shortly before the pouring process, an inoculation powder is scattered into the mould. The process allows for extremely short cycle times because the pipe solidifies very quickly and can be removed within a few seconds; the next pipe can be cast immediately afterwards **(Fig. 3.10)**.

In the non-lined moulds of the de Lavaud process, the surface of the mould is subjected to considerable thermal stresses due to temperature changes:

- outside which, in comparison to the inside surface, is only subject to a slightly fluctuating water temperature,
- inside, with the casting temperature of the molten iron, around 1,300 °C.

Between two casting operations, the inside temperature can drop to 200 °C and below. The stress on the mould caused by this unabsorbed temperature change is accordingly high, which explains its limited working life.

3.3.3 Wet-spray process

With the wet-spray process the mould is given an approximately 0.5 mm thick layer of lining. This layer (quartz powder bonded with bentonite) is wet-sprayed onto the mould before each casting process. The process comes from an English-speaking area and bears the widely used name wet-spray.

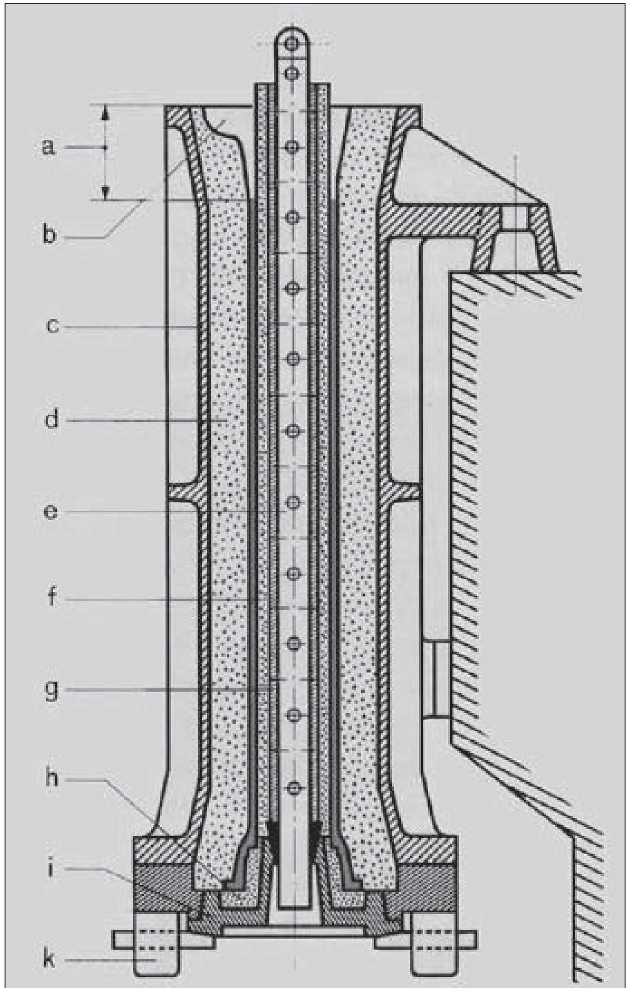
The thin lining reduces the amplitudes of the temperature change in the wall of the mould, which favours the working life of the mould. However, the lining has to be renewed after each casting; this extends the cycle time accordingly.

3.3.4 Older pipe production methods no longer in general use

Sand moulding is the oldest method of producing cast iron pipes and fittings. For the production of pipes, two-part horizontal sand moulds were originally used. Because of the high degree of buoyancy during casting the process resulted in a restriction of pipe length. A further development was the moulding and casting in upright, seamless sand moulds **(Fig. 3.11)**.

The pattern consists of a socket and a barrel part. The socket pattern is inserted into the vertically standing moulding box from underneath and fixed. The barrel pattern is inserted from above and centred in the socket pattern with a conical stud.

The moulding sand is put into the cavity between pattern and moulding box and compacted.



a) Lost head
b) Pouring funnel
c) Moulding box
d) Moulding sand
e) Core clamping tube
f) Core
g) Straw rope or wood wool wrapping
h) Socket core
i) Socket flap
k) Locking ring

Fig. 3.11: Principle of the vertical static casting of pipes

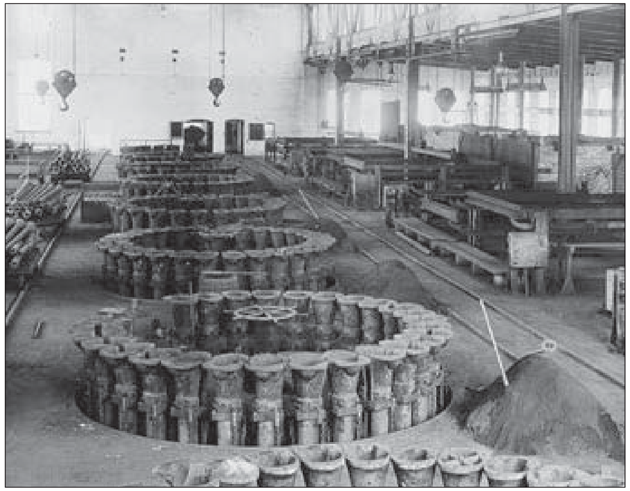


Fig. 3.12:
A view inside the foundry hall with a pipe casting carousel

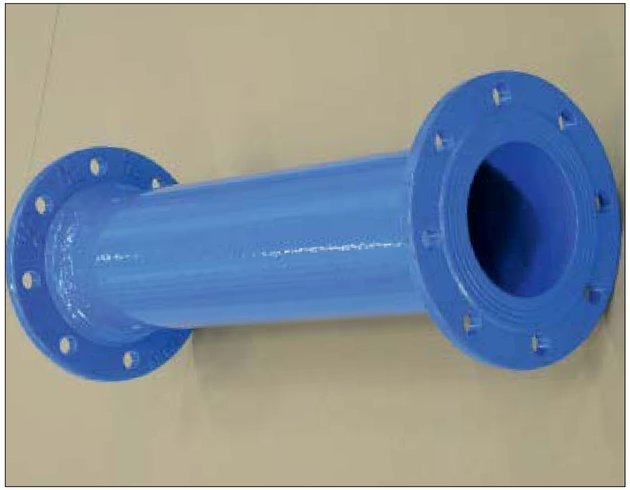


Fig. 3.13:
Double flanged pipe DN 150/500 with integral cast-on flanges

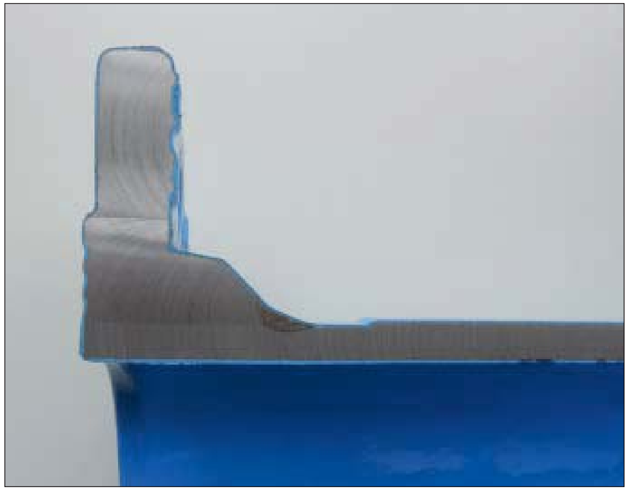


Fig. 3.14:
Detailed view of the shrink fit after cutting open

In order to increase productivity, these standing moulds were arranged in carousels **(Fig. 3.12)**. Depending on the design of the moulds and cores, straight pipes or pipes with up to two sockets or flanges could be produced.

3.3.5 Production of flanged pipes

Flanged pipes **(Fig. 3.13)** with shorter overall lengths are mainly produced in two-part horizontal moulds (double flanged pipe). In addition there are flanged pipes which are produced by pre-welding or screwing cast iron flanges onto spun cast iron pipes. Also shrink-fitting and welding is common practice **(Fig. 3.14)**.

3.3.6 Production of fittings and valve bodies using the sand casting process

Using the centrifugal casting process it is only possible to produce rotationally symmetrical articles with cylindrical to conical external contours. Components with curves, branches or a number of connections (sockets or flanges) as well as valve bodies require a different forming process.

For this purpose, patterns in metal, plastic or wood are used which completely map the external contour of the component. With these patterns, moulds are produced from pure quartz sand mixed with a binder as the negative for the external contour of the component. This sand mould withstands the pressure and the temperature of the liquid iron until it has solidified. After that the sand mould is crushed and the sand is used again in the cycle. The mould is “lost” with each casting.

The internal contour of the casting is also mapped in this process, whereby the quartz sand for the “core” required here usually gets its strength from an organic binder. The cores must also resist the casting temperature of more than 1,300 °C. Nevertheless they must yield to the shrinkage pressure during solidification so that the hollow part does not tear on the core during shrinking. Finally, they should also be easy to remove after the casting has cooled. As the cast metal solidifies, it burns the binder, the core loses its cohesion and the loose sand can be removed from the cooled casting.

Figure 3.15 shows a production line for fittings with lost cores. **Figures 3.16, 3.17 and 3.18** show examples of the preparatory work for the production of fittings with lost cores.

Fig. 3.15:
Production of fittings with lost cores

Fig. 3.16:
Pattern for the production of the sand mould

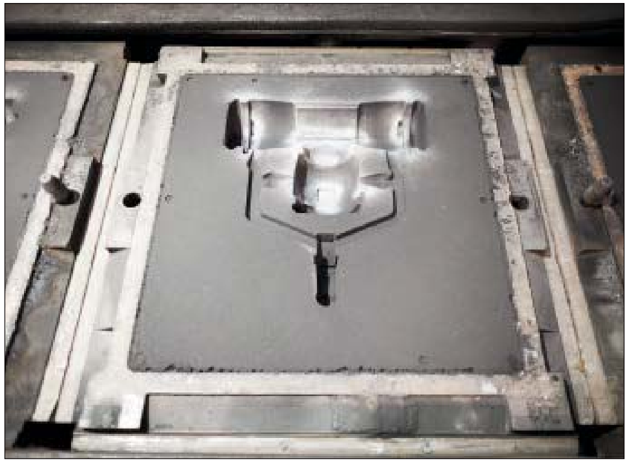


Fig. 3.17:
Sand mould prepared for the insertion of the lost core

Fig. 3.18:
Lost core inserted in the sand mould

Castings produced in high volumes are cast using moulding machines. The patterns are made of plastic or metal. The preferred mould material is clay-bonded quartz sand with additives, usually carbon dust. The mould material is compacted by shaking, pressing or shooting. Another method uses boxless moulds. In this case a hardening sand-synthetic resin mixture forms the mould material.

Also there is the vacuum moulding process. Here the strength of the mould sand, without binder, is achieved by negative pressure.

Smaller series and larger castings are produced in individual mould boxes, where a so-called sand slinger is used for compacting the moulding sand. It centrifuges the moulding material at high speed onto the pattern and the sand with which it is already filled. This solidifies the sand-clay mixture. The patterns are made of wood or plastic.

Cores for fittings and valves are mainly produced from quartz sand with cold or hot hardening binders. They must be stable enough to resist the casting pressure which, because of the density of the iron, reaches around 1 bar even with a static casting height of 1.40 m. In general it is the case that the sand moulding process allows an almost unrestricted freedom of design for components.

3.4 Post-treatment

Post-treatment refers to all processes on pipes, fittings and valve bodies which are performed after casting.

3.4.1 Subsequent heat treatment

Some of the production processes described for pipeline components make subsequent heat treatment necessary.

The reason for this is that the solid-state carbon dissolved in the liquid iron is either separated as elementary graphite or remains dissolved in the iron.

The higher the speed of cooling, the higher is the proportion of dissolved carbon in the iron (cementite). This structure has a high degree of hardness and a low elongation after fracture. A subsequent annealing process breaks down the cementite into ferrite and graphite, whereby the form of the graphite in ductile cast iron is spheroidal.

With sand moulding, as a rule the speed of cooling is so low that after solidification a broadly ferritic-graphitic structure with low proportions of pearlite is present and the required mechanical values are reached without annealing.

By contrast, fast cooling is characteristic for the casting of pipes in water-cooled moulds. Pipes produced in this way must be annealed, according to the necessary level of workability and ductility. This is usually done in gas-fired continuous furnaces. At temperatures of around 920 °C to 950 °C, the pipes rollthrough the furnace at a controlled speed **(Fig. 3.19)**. Carriages are used to keep them moving which are fixed onto a transport chain. The annealing time and the temperature are established in a time-temperature diagram for the furnace and these are automatically controlled. Large-diameter pipes can also be annealed standing on the socket in batch furnaces. This enables ovalisation of the pipes to be avoided.

Fig. 19:
Pipes in the continuous annealing furnace

Fig. 3.20:
Castings after blasting

3.4.2 Fettling and mechanical processing

Mould and core sand is blasted from cast parts using cut wire (blasting) **(Fig. 3.20)**. Casting seams, gates and riser attachments are separated and ground.

Fittings are checked for tightness in accordance with EN 545 [3.1] before applying the coating. Then, if necessary, the flange and spigot end are machined. Components for valves are generally subjected to machining after fettling. Then they are blasted and taken to the surface coating process directly after this. After coating the components are assembled as complete valves. In the final process the valves undergo tightness and function testing.

3.5 Application of coatings and linings

3.5.1 Pipes

Zinc or zinc-aluminium coating with protective finishing layer

The zinc or zinc-aluminium coating is applied to the pipes after they have been heat-treated. With metallic zinc spraying, zinc wire (minimum purity 99.99 %) or zinc-aluminium wire (Zn85Al15) is molten in a flame or in an electric arc. The fine metallic drops are blasted at high speed onto the surface to be coated. This happens in automatically operating equipment; for example the spray gun moves along the rotating pipe. In this way the zinc or zinc-aluminium coating is applied in a helix shape **(Fig. 3.21)**.

Fig. 3.21:
Applying the zinc-aluminium coating

Straight after zinc or zinc-aluminium coating, the pipes are checked for dimensional accuracy and tightness tested on fully automated testing and fettling lines. Also included in this type of protection of the pipes is a finishing layer which is applied to the rotating pipe. The inside of the socket is given separate treatment here.

The zinc or zinc-aluminium coating for pipes in ductile cast iron is standardised in EN 545 [3.1] and EN 598 [3.2].

Cement mortar coating

Cement mortar coating is a multi-layer coating for pipes with the following layer structure **(Fig. 3.22)**:

- zinc coating,
- with or without primer layer (two-component synthetic resin coating),
- cement mortar layer.

The cement mortar layer is a layer of fibrous cement mortar based on blast-furnace cement, which can be polymer-modified, pigmented and wrapped with a bandage material. The primer layer may be omitted if a polymer-modified cement mortar is used. The fibres mixed with the mortar may be glass or plastic fibres. For the application of the cement mortar coating, there are two processes in use. What the two processes have in common is that a certain amount of fibres cut to length are mixed into the polymer-modified mortar which comes out of the compulsory mixer. The mortar is then pumped to a circular spray nozzle (spraying process) or a flat die (extrusion process).

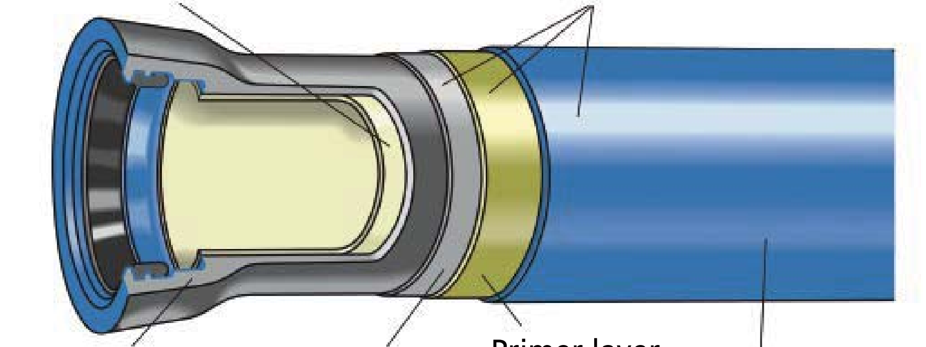


Fig. 3.22:
Layer structure of a pipe with cement mortar coating and cement mortar lining

Fig. 3.23:
Spraying process

Fig. 3.24:
Cement mortar coating – extrusion process

With the spraying process the mortar is sprayed onto the rotating pipe using compressed air **(Fig. 3.23)**. The spray nozzle is mounted on a support and travels slowly along the pipe. A smoothing mechanism then reduces the cement mortar coating to the specified layer thickness.

With the extrusion process, the cement mortar comes out of a stationary flat die and winds an even layer thickness in bands around the rotating pipe as it slowly travels past the nozzle. Synchronous with the application of the mortar, this also receives a bandage of PE net tissue. At almost the same time as the bandaging, a smoothing mechanism which is also set up to be stationary then smoothes the surface of the mortar. After this stage, the PE net tissue is completely covered with a thin layer of mortar **(Fig. 3.24)**.

With both processes, mortar flow rate, pipe rotation speed and speed of travel are to be coordinated in such a way that the nominal coating thickness for the cement mortar coating keeps to a value of 5 mm over the entire length of the pipe barrel. The end face of the socket and the spigot end of the pipe remain free of cement mortar. These parts also have a zinc coating and, after the cement mortar coating has set, they are provided with a finishing layer.

The cement mortar coating of ductile cast iron pipes is standardised in EN 15542 [3.3]. According to EN 545 [3.1] these pipes can be installed in soils of any level of corrosiveness.

Polyurethane coating

The polyurethane (PUR) used is a solvent-free two-component system with resin and hardening agent. Polyurethane, mineral fillers, pigments and additives are selected in such a way that the end product meets the functional requirements set and the drinking water regulations. Before applying the PUR coating, the surface of the pipe is cleaned so that it is technically clean, free of rust, loose particles of material, dirt, oil, grease and moisture. In order to meet these requirements, the surface of the pipes is blasted to preparation grade SA 2 ½ as per EN ISO 8501-1 [3.4]. The pipes are first heated to about 50 °C in order to ensure an acceleration of the polymerisation of the components to a mechanically resilient coating. The polyurethane is then sprayed onto the rotating pipe **(Fig. 3.25)**. The pore-free PUR coating is applied to the entire pipe barrel continuously from the end face of the socket up to and including the spigot end. After the coating process the coating is also checked to ensure that it is free of pores.

The PUR coating has a uniform and even appearance in terms of colour, smoothness and structure. Adhesive strength, freedom from porosity, hardness and coating thickness are checked daily in production **(Fig. 3.26)**.

Fig. 3.25:
Applying the black PUR coating

Fig. 3.26:
Ductile iron pipe with polyurethane coating and polyurethane lining

The PUR coating of ductile iron pipes is standardised in EN 15189 [3.5]. According to EN 545 [3.1] these pipes can be installed in soils of any level of corrosiveness.

Polyethylene coating

The polyethylene coating consists of LDPE (low density polyethylene). It is applied to the pipe using a soft adhesive; up to and including DN 500 this is done using the tubular extrusion process, as from and including DN 400 using the flat die wrapping extrusion process.

The PE coating of ductile iron pipes is standardised in EN 14628 [3.6]. According to EN 545 [3.1] these pipes can be installed in soils of any level of corrosiveness.

Cement mortar lining

In the centrifugal rotation process, after the application of the fresh mortar (sand-cement-water mixture) the pipe is brought to a sufficiently high speed of rotation so that the centrifugal acceleration is at least twenty times gravitational acceleration. With this acceleration and with additional vibration forces, the fresh mortar undergoes compaction and smoothing **(Fig. 3.27)**.

With centrifugal rotation, part of the mixing water is driven out. A concentration of fine grains and fine elements occurs towards the surface of the cement mortar lining. The cement mortar lining hardens in curing chambers at a defined air humidity and temperature. The cement mortar lining of ductile iron pipes is standardised in EN 545 [3.1] and EN 598 [3.2].

Polyurethane lining

The polyurethane used is a solvent-free two-component system with resin and hardening agent. Mineral fillers, pigments and additives are selected in such a way that the end product meets the functional requirements set and the drinking water regulations (e.g. DVGW). Before applying the PUR lining, the inside surface of the pipe is cleaned so that it is technically clean, free of rust, loose particles of material, dirt, oil, grease and moisture. In order to meet these requirements the inside surface of the pipe is ground and double-blasted to preparation grade SA 2 ½ as per EN ISO 8501-1 [3.4]. The pipes are first heated to about 50 °C in order to ensure an acceleration of the polymerisation of the components. This means that short cycle times can be achieved in the coating process.

Fig. 3.27:
Centrifugal rotation – applying a cement mortar lining

The polyurethane is then sprayed onto the rotating pipe using a lance with a rotating nozzle **(Fig. 3.28)**. The centrifugal force produced by the rotation of the pipe itself results in a very smooth surface which has good hydraulic properties. The pore-free polyurethane lining is applied continuously to the whole of the pipe surface.

Fig. 3.28:
Applying the PUR lining using a lance with rotating nozzle

The inside of the socket is also lined with polyurethane. In combination with the PUR lining, an iron pipe is also provided with integral corrosion protection.

After the coating process the lining is checked to ensure that it is free of pores. The PUR lining has a uniform and even appearance in terms of colour, smoothness and structure. Adhesive strength, freedom from porosity, hardness and coating thickness are checked daily in production.

The polyurethane lining of ductile iron pipes is standardised in EN 15655 [3.7].

3.5.2 Fittings and valves

Epoxy resin coating

As is the case with valves, the powder coating of fittings with epoxy resin is becoming increasingly important. According to EN 545 [3.1], fittings coated in this way are suitable for soils of all classes of aggressiveness. The same also applies to valves coated with fusion bonded epoxy.

To achieve this, the castings first of all undergo surface treatment in the form of blasting (preparation grade SA 2 ½). The castings are then heated to an object temperature of approximately 200 °C and dipped into a fluidised bed with epoxy resin powder **(Fig. 3.29)** or coated electrostatically using a spray gun **(Fig. 3.30)**.

This produces pore-free coatings with layer thicknesses of more than 250 µm. Depending on the type of equipment used, the coating process may be automated. Continuous monitoring of the coating as regards cross-linking, mechanical properties, disbonding and coating thickness ensures constant quality.

Fig. 3.29:
Epoxy powder applied by robots in the fluidised bed process

Fig. 3.30:
Electrostatic application of epoxy powder with a spray gun

The epoxy powder coating of ductile iron fittings is standardised in EN 14901 [3.8] and RAL GZ 662 [3.9]. The epoxy coating of valve bodies is standardised in DIN 30677-1 [3.10], DIN 30677-2 [3.11], DIN 3476 [3.12] and RAL GZ 662 [3.9].

Cement mortar lining

Fittings are lined with cement mortar using the projection process in accordance with EN 545 [3.1] and EN 598 [3.2]. In this process a worm pump is used to pump the cement mortar through a tube and then through a rotating projection head driven by compressed air onto the wall of the pipe, thereby compacting it. After curing at defined conditions the fittings then undergo further processing.

Depending on the particular case, blast furnace cement is generally used here. With this type of mortar application it is not possible for excess water to be driven out; the preparation of the mortar using the necessarily low water-cement ratio is made possible by the addition of a synthetic resin emulsion.

Depending on the nominal size, the total coating thickness is 2.5 mm to 9 mm.

As an external coating, fittings lined with cement mortar are usually provided with a 70 µm bitumen coating. In individual cases a two-component zinc rich paint and a bitumen finishing layer are also used.

The cement mortar lining of ductile iron fittings is standardised in EN 545 [3.1] and EN 598 [3.2].

Technical enamelling

Vitreous enamel as a coating material tends to be used in places where vessels, pipes, fittings and valves need to be protected against chemical exposure and in some cases also extreme conditions **(Fig. 3.31)**.

With ductile cast iron as the base material, vitreous enamel produces a combination which offers a range of significant properties, for example:

- a smooth, anti-adhesive surface,
- a high degree of hardness,
- a glass-like, fully inorganic structure,
- a high chemical resistance.

The castings are often annealed before enamelling in order to improve conditions for enamelling.

After the annealing process the surface is blasted (EN ISO 12944-4 [3.13]; SA 2 ½). Blasting cleans and activates the surface and produces a certain degree of surface roughness. In addition the specific surface is increased. This means that it meets the conditions for material bonding in the following enamelling process.

The basic material consists of so-called enamel frits. These are produced by smelting (at over 1,200 °C) and then quenching and breaking up natural inorganic materials including quartz, feldspar, borax, soda, potash, aluminium oxide and other metal oxides. The enamel frits are milled with additives and water to produce an enamel slip.

Fig. 3.31:
Fitting coated outside and inside with enamel

The slip is applied to the casting by dipping, pouring **(Fig. 3.32)** or spraying **(Fig. 3.33)** and then dried at ≤ 110 °C. This is then followed by the actual firing process, in a temperature range of between 750 °C and 900 °C depending on the quality of the enamel.

Fig. 3.32:
Applying enamel by pouring

Fig. 3.33:
Applying enamel by spraying

Fig. 3.34:
Examples of the labelling of ductile fittings

The enamelling of ductile cast iron fittings and valves is standardised in DIN 51178 [3.14]. A detailed description of the enamelling technique can be found in **Chapter 7.2**.

3.6 Marking

3.6.1 Marking of pipes and fittings in ductile cast iron

The marking of pipes and fittings **(Fig.3.34)** is defined in product standards EN 545 [3.1] and EN 598 [3.2] and also in EADIPS®/FGR® - Standard 33 [3.15]. The marking of allowable operating pressures (PFA) for the restrained flexible push-in joints of pipes is covered in EADIPS®/FGR® - Standard 75 [3.16] **(Figs. 3.35 and 3.36)**.

The marking of material, production date and nominal size is cast into or onto the product.

The marking of the material as "ductile cast iron", which must also be visible after installation, consists of three raised or recessed points arranged in a triangle or three parallel, notch-shaped depressions on the end face of the socket.

For socket pipes produced by means of the centrifugal casting process, the marking is basically applied to the socket.

Fig. 3.35:
Marking of a ductile iron pipe with restrained flexible push-in joint in accordance with [3.16]

Fig. 3.36:
Marking of allowable operating pressure (PFA) in accordance with [3.16]

In this case nominal size, manufacturer identification and year are to be cast into the inside of the socket where they will not interfere with the function of the joint.

Coloured markings for the wall thickness class and for the type of lining and coating, but also additional markings, will be applied to the end face of the socket or directly behind the socket.

Fittings will be marked as following in accordance with product standards:

- Marking of the manufacturer,
- Marking of the year of manufacture,
- Marking for ductile cast iron,
- Nominal size DN,
- Nominal pressure PN for flanges,
- The degree mark for bends.

The markings are cast onto the outside of the body of the fitting.

The following markings can also be cast, applied with paint or enclosed with the packaging:

- Reference to the relevant standard (e.g. EN 545 [3.1]),
- Indication of the certification authority (e.g. DVGW).

For flanged pipes with welded, shrink-fit or screwed flanges the marking is cast into the back of the flange and for cast flange pipes it is applied to the pipe barrel.

FGR® marking with a number (the number is allocated to a manufacturer), e.g. FGR® 2, indicates that this manufacturer is a member of the European Association for Ductile Iron Pipe Systems · EADIPS® / Fachgemeinschaft Guss-Rohrsysteme (FGR®) e. V.

3.6.2 Marking of valves in spheroidal graphite cast iron

The marking of valves **(Figures 3.37, 3.38, 3.39 and 3.40)** is done according to the specifications of EN 19 [3.17] and EN 1074-1 [3.18].

Fig. 3.38:
Marking of a gate valve, DN 100, GR 14

Fig. 3.39:
Marking of a plunger valve, DN 800, PN 10/16

Fig. 3.37:
Marking of a nozzle check valve

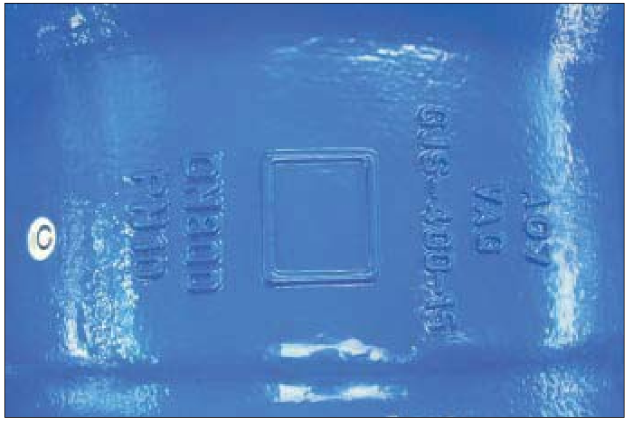


Fig. 3.40:
Marking of a butterfly valve, DN 800, PN 10

3.7 Testing

3.7.1 Testing the pipe

After the annealing process and after tightness testing, ductile iron pipes with or without zinc coating undergo dimensional checking on combined fettling and testing lines. In addition, they are checked for any flaws outside and inside by means of visual inspection. For example, wall thickness measurements are taken with quick-test gauges. The sockets and spigot ends are checked with limit gauges. Hardness testing is carried out for a subsequent assessment of the annealing process. An evaluation of ferrite levels and ductility (elongation after fracture) is provided by the ring flattening test (deformation of a ring cut from the pipe) on the fettling and testing line; compact-ability is a reference value for ductility.

Instead of the ring flattening test, a ball indentation test can also be carried out. The precise mechanical strength values (tensile strength, 0.2 % yield point, elongation after fracture and Brinell hardness) are determined in material testing laboratories. These values are to be tested on cylindrical test bars machined from the pipe wall.

The requirements for the lining and the tests which need to be carried out are defined in EN 545 [3.1] and EN 598 [3.2]. Regular testing in the context of certification ensures consistent quality, as in e.g. DVGW test specification GW 337 [3.19] and DVGW supplement GW 337-B1 [3.20].

3.7.2 Testing fittings and valves

For castings, fittings and valve bodies produced in sand moulds, similar testing criteria to those for pipes apply. However, unlike the procedure for pipes, with fittings the specimens cannot be taken from the casting itself without destroying it. Mechanical properties are tested on cylindrical test bars taken from separately cast U or Y specimens; hardness can be measured on the casting itself. For the quick-test for ductility, sound velocity measurement is carried out using ultrasound, either on a separately cast test bar or on the casting itself.

Tightness and function tests on fittings and valves are incorporated at an appropriate point in the overall course of their production. This also applies to all testing of material properties, dimensions and other criteria as required in the product and coating standards for process control.

Depending on the agreement reached, the results of the testing of pipes, fittings and valves are recorded in a works certificate or an acceptance certificate in accordance with EN 10204 [3.21].

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4 Quality management

4 Quality management

This chapter is being prepared.

5 Wall thickness calculation for ductile iron pipes

5 Wall thickness calculation for ductile iron pipes

When laying underground pipelines consisting of ductile iron pipes to standard EN 545 [5.1], for the most part the pipes are assembled using push-in joints as standardised in DIN 28603 [5.2]. For calculating the wall thickness of ductile iron pipes, a distinction is made between

- non-restrained flexible push-in joints and
- restrained flexible push-in joints.

5.1 Stresses in pressure pipelines

With a pressure pipeline consisting of pipes assembled with restrained joints, e.g. by welding, the internal pressure generates stresses in the pipe wall, which may be circumferential or tangential stresses σ_t and longitudinal or axial stresses σ_a, as shown in Fig. 5.1.

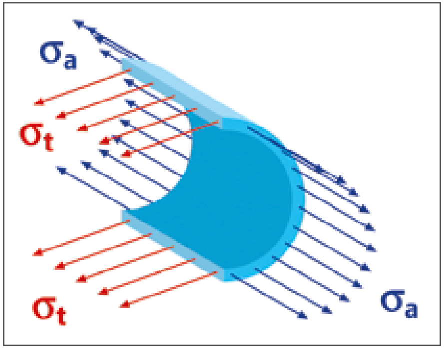

Fig. 5.1:
Stresses produced by internal pressure in a wall of pressure pipes assembled with restrained joints

The two types of stress are calculated as follows:

$$\sigma_t = \frac{p \cdot D}{2 \cdot e} \quad [\mathrm{N/mm^2}] \qquad (5.1)$$

$$\sigma_a = \frac{p \cdot D}{4 \cdot e} \quad [\mathrm{N/mm^2}] \qquad (5.2)$$

p	internal pressure [bar]
D	mean diameter (D = (DE + Di) / 2 = DE – e) [mm]
DE	external diameter [mm]
Di	internal diameter [mm]
e	wall thickness [mm]
σ_t	tangential stress in the pressure pipe wall [N/mm²]
σ_a	axial stress in the pressure pipe wall [N/mm²]

Conversion factor:
1 bar corresponds to 0.1 N/mm²

5.2 Calculating the wall thickness of pipes with non-restrained flexible push-in joints

5.2.1 Calculating the wall thickness of pipes according to pressure classes (C-classes)

For calculating the pipe wall thickness of ductile iron pipes with non-restrained flexible push-in joints, the simple Barlow's formula is used in which the tangential stresses produced by internal pressure, the tensile strength of the pipe material, the thickness of the pipe wall and the diameter of the pipe correlate with each other.

Non-restrained flexible push-in joints do not transmit any axial forces. If the pressure of the medium produces axial forces on dead ends, branches, reducers or changes of direction, these must be transferred into the ground by appropriate means, such as concrete thrust blocks.

Over the last six decades, non-restrained flexible push-in joints have had a considerable influence in shaping the image of the cast iron pipe; they are inexpensive and simple to assemble. Non-restrained push-in joints do not transmit any axial forces, meaning that the stresses shown in Fig. 5.1 in the axial direction σ_a are equal zero. As can be seen in Fig. 5.2, the stresses in the wall of such a socket pipe only run in the circumferential direction as tangential stress σ_t.

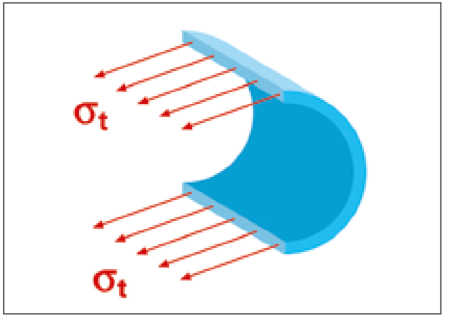

Fig. 5.2:
Tangential stress σ_t in the circumferential direction in a pipe with a non-restrained flexible push-in joint

In principle, they are calculated according to equation 5.1 (Barlow's formula):

$$\sigma_t = \frac{p \cdot D}{2 \cdot e} \quad [\text{N/mm}^2] \qquad (5.1)$$

σ_t tangential stress in the pressure pipe wall [N/mm²]
p internal pressure [bar]
D mean diameter (D = (DE + Di) / 2 = DE – e) [mm]
e wall thickness [mm]

This produces the following equation for internal pressure p:

$$p = \frac{2 \cdot E \cdot \sigma_t}{D} \quad [\text{N/mm}^2] \qquad (5.2)$$

Once the minimum pipe wall thickness and a safety factor have been introduced, we arrive at equation 5.3 incorporated in product standard EN 545 [5.2], with which the allowable operating pressure PFA is calculated for the component:

$$\text{PFA} = \frac{20 \cdot e_{min} \cdot R_m}{D \cdot S_F} \quad [\text{bar}] \qquad (5.3)$$

Where:

PFA = p = allowable operating pressure for the component

e_{min} = minimum pipe wall thickness

R_m = σ_t = minimum tensile strength = 420 MPa

S_F = safety factor

Conversion factors:

1 N/mm² = 1 MPa = 10 bar

With a minimum tensile strength R_m = 420 MPa for ductile cast iron and the safety factor S_F = 3 we arrive at the following constant 5.4:

$$\frac{20 \cdot R_m}{S_F} = 2.800 \qquad [\text{MPa}] \qquad (5.4)$$

The allowable operating pressure PFA for the component can be calculated with equation 5.5 from the external pipe wall diameter DE and pipe wall thickness e_{min} :

$$\text{PFA} = 2.800 \cdot \frac{e_{min}}{\text{DE} - e_{min}} \qquad [\text{MPa}] \qquad (5.5)$$

Minimum wall thicknesses e_{min} for ductile iron pipes								
		Pressure class (C-classes) = PFA [bar]						
		20	25	30	40	50	64	100
DN	DE [mm]	e_{min} [mm]						
40	56				**3.0**	**3.5**	4.0	**4.7**
50	66				**3.0**	**3.5**	4.0	**4.7**
60	77				**3.0**	**3.5**	4.0	**4.7**
65	82				**3.0**	**3.5**	4.0	**4.7**
80	98				**3.0**	**3.5**	4.0	**4.7**
100	118				**3.0**	**3.5**	4.0	**4.7**
125	144				**3.0**	**3.5**	4.0	**5.0**
150	170				**3.0**	**3.5**	4.0	**5.9**
200	222				**3.1**	**3.9**	5.0	**7.7**
250	274				**3.9**	**4.8**	6.1	**9.5**
300	326				**4.6**	**5.7**	7.3	**11.2**
350	378			**4.7**	5.3	**6.6**	8.5	**13.0**
400	429			**4.8**	6.0	**7.5**	9.6	**14.8**
450	480			**5.1**	6.8	**8.4**	10.7	**16.6**
500	532			**5.6**	7.5	**9.3**	11.9	**18.3**
600	635			**6.7**	8.9	**11.1**	14.2	**21.9**
700	738		**6.8**	7.8	10.4	**13.0**	16.5	
800	842		**7.5**	8.9	11.9	**14.8**	18.8	
900	945		**8.4**	10.0	13.3	**16.6**		
1000	1048		**9.3**	11.1	14.8	**18.4**		
1100	1152	8.2	**10.2**	12.2	16.2	**20.2**		
1200	1255	8.9	**11.1**	13.3	17.7	**22.0**		
1400	1462	10.4	**12.9**	15.5				
1500	1565	11.1	**13.9**	16.6				
1600	1668	11.8	**14.8**	17.7				
1800	1875	13.3	**16.6**	19.9				
2000	2082	14.8	**18.4**	22.1				
Note: the figures in bold represent the standard range								

Table 5.1: Minimum wall thicknesses e_{min} for ductile iron pipes as per EN 545 [5.1] depending on nominal size DN and pressure class (C-class)

Using equation 5.5 it is possible to calculate the minimum wall thickness e_{min} for an allowable operating pressure PFA with a given nominal size:

$$e_{min} = \frac{DE \cdot PFA}{2.800 + PFA} \quad [mm] \qquad (5.6)$$

Table 5.1 shows the minimum wall thicknesses e_{min} according to EN 545 [5.1] for the seven pressure classes (C-classes) which are assigned to operating pressures PFA 20; 25; 30; 40; 50; 64 and 100. The lower limit for the minimum wall thicknesses has been reduced to e_{min} = 3,0 mm.

5.2.2 Calculating wall thicknesses according K-classes

Since the introduction of ductile cast iron around 60 years ago, the minimum wall thickness e_{min} has undergone a considerable evolution which is due to the impressive development and optimisation of centrifugal casting production technology. The primary beneficiaries of this are the small nominal sizes from DN 80 to DN 250 which account for an extremely high proportion in urban distribution networks.

When the first ductile iron pipes were produced in the middle of the nineteen fifties, safety standards were initially still based on the characteristics of thick-walled grey cast iron pipes. At the time, casting machines were still being manually controlled, meaning that the minimum wall thickness was only observed with large “allowances”. For a coherent representation of wall thicknesses over the entire range of nominal sizes, these were divided into K-classes which were in existence for more than four decades. Nominal wall thicknesses e were determined taking account of the permissible circumferential stresses in the pipe wall using the formula

$$e = 5 + 0.01 \cdot DN \quad [mm] \qquad (5.7)$$

in wall thickness class K 10. Wall thicknesses which deviated from this could be represented in their own K-classes

$$e = K \cdot (5 + 0.001 \cdot DN) \quad [mm] \qquad (5.8)$$

whereby the proportionality factor K was part of a series of whole numbers … 8, 9, 10, 11, 12 …

For drinking water supply, type K values were 10 to begin with, then later on 8 and 9. In order for wall thicknesses of the smaller nominal sizes to remain practically feasible at all, the lower limit for nominal wall thicknesses was reduced to e = 6 mm. The following determination applies to the minimum wall thickness e_{min} for measurement purposes:

$$e_{min} = e - \Delta e \quad [mm] \qquad (5.9)$$

Δe permissible dimensional deviation (minus tolerance)

The following applies for e > 6 mm:

$$\Delta e = -(1.3 + 0.001 \cdot DN)\ [mm] \qquad (5.10)$$

The following applies for e ≤ 6 mm:

$$\Delta e = -1.3 \qquad [mm] \qquad (5.11)$$

Hence the lowest minimum pipe wall thickness was 4.7 mm.

5.3 Development of minimum pipe wall thicknesses

The accurate production of smaller pipe wall thicknesses in the centrifugal casting process has matured due to improved machine control and continuous process optimisation in the six decades since the emergence of ductile iron pipes. So it was only logical that the cast iron pipe industry would continue the trend by adapting water supply components to the prevailing pressures – a development which manifested itself in EN 14801 [5.3]. Back in 2002, in the edition current at the time, EN 545 introduced pressure class C 40 in addition to the wall thickness classes (K-classes) still in existence.

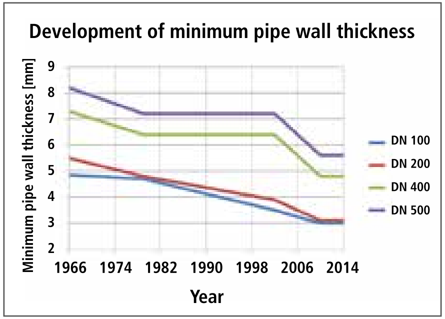

Fig. 5.3:
Development of minimum pipe wall thickness e_{min} from 1966 to 2014

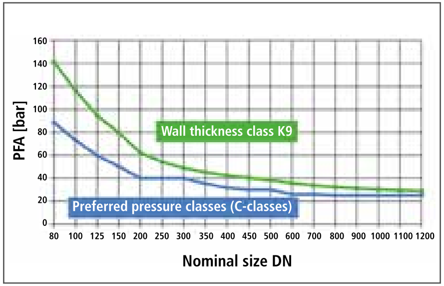

Fig. 5.4:
Comparison of wall thickness class K 9 with the preferred pressure classes (C-classes) as regards allowable operating pressure PFA

As from 2010, EN 545 [5.1] now only contains the pressure (C) classes.

The development of minimum pipe wall thicknesses over the last decades in Fig. 5.3 shows that, since the introduction of ductile iron pipes, in terms of production technology it has been possible to reduce minimum wall thicknesses by almost half.

5.4 Comparison of wall thickness classes (K-classes) and pressure classes (C-classes) for non-restrained flexible pipes

For non-restrained pipes up to nominal size DN 300, calculated according to internal pressure, the introduction of pressure classes (C-classes) has led to some very major changes as compared with the wall thickness classes (K-classes), as can be seen in the diagram alongside (Fig. 5.4). As from DN 400 the differences tend to be negligible.

Minimum wall thicknesses e_{min} for ductile iron pipes																		
DN	DE [mm]	Pressure classes (C-classes) = PFA							Wall thickness classes (K-classes)									
		20	25	30	40	50	64	100	7		8		9		10		11	
		e_{min} [mm]							e_{min} [mm]	PFA [bar]	e_{min} [mm]	PFA [bar]	e_{min} [mm]	PFA [bar]	e_{min} [mm]	PFA [bar]	e_{min} [mm]	PFA [bar]
40	56				3.0	3.5	4.0	4.7										
50	66				3.0	3.5	4.0	4.7										
60	77				3.0	3.5	4.0	4.7										
65	82				3.0	3.5	4.0	4.7										
80	98				3.0	3.5	4.0	4.7	4.7	141.1	4.7	141.1	4.7	141.1	4.7	141.1	5.0	150.5
100	118				3.0	3.5	4.0	4.7	4.7	116.2	4.7	116.2	4.7	116.2	4.7	116.2	5.2	129.1
125	144				3.0	3.5	4.0	5.0	4.7	94.5	4.7	94.5	4.7	94.5	4.8	97.1	5.5	110.1
150	170				3.0	3.5	4.0	5.9	4.7	79.6	4.7	79.6	4.7	79.6	5.1	85.7	5.7	97.1
200	222				3.1	3.9	5.0	7.7	4.7	60.6	4.7	60.6	4.8	61.9	5.5	71.1	6.2	80.4
250	274				3.9	4.8	6.1	9.5	4.7	48.9	4.7	48.9	5.2	54.2	6.0	62.2	6.7	70.2
300	326				4.6	5.7	7.3	11.2	4.7	41.0	4.8	41.8	5.6	48.9	6.4	56.1	7.2	63.2
350	378			4.7	5.3	6.6	8.5	13.0	4.7	34.9	5.2	38.7	6.0	45.2	6.9	51.7	7.7	58.2
400	429			4.8	6.0	7.5	9.6	14.8	4.7	31.0	5.5	36.4	6.4	42.4	7.3	48.5	8.2	54.6
450	480			5.1	6.8	8.4	10.7	16.6	4.9	28.9	5.9	34.5	6.8	40.2	7.8	46.0	8.7	51.7
500	532			5.6	7.5	9.3	11.9	18.3	5.2	27.6	6.2	33.0	7.2	38.4	8.2	43.8	9.2	49.3
600	635			6.7	8.9	11.1	14.2	21.9	5.8	25.8	6.9	30.8	8.0	35.7	9.1	40.7	10.2	45.7
700	738		6.8	7.8	10.4	13.0	16.5		6.4	24.5	7.6	29.1	8.8	33.8	10.0	38.5	11.2	43.1
800	842		7.5	8.9	11.9	14.8	18.8		7.0	23.5	8.3	27.9	9.6	32.3	10.9	36.7	12.2	41.2
900	945		8.4	10.0	13.3	16.6			7.6	22.7	9.0	26.9	10.4	31.2	11.8	35.4	13.2	39.7
1000	1048		9.3	11.1	14.8	18.4			8.2	22.1	9.7	26.2	11.2	30.2	12.7	34.3	14.2	38.5
1100	1152	8.2	10.2	12.2	16.2	20.2			8.8	21.6	10.4	25.5	12.0	29.5	13.6	33.5	15.2	37.4
1200	1255	8.9	11.1	13.3	17.7	22.0			9.4	21.1	11.1	25.0	12.8	28.9	14.5	32.7	16.2	36.6
1400	1462	10.4	12.9	15.5					10.6	20.4	12.5	24.1	14.4	27.9	16.3	31.6	18.2	35.3
1500	1565	11.1	13.9	16.6					11.2	20.2	13.2	23.8	15.2	27.5	17.2	31.1	19.2	34.8
1600	1668	11.8	14.8	17.7					11.8	19.9	13.9	23.5	16.0	27.1	18.1	30.7	20.2	34.3
1800	1875	13.3	16.6	19.9					13.0	19.5	15.3	23.0	17.6	26.5	19.9	30.0	22.2	33.5
2000	2082	14.8	18.4	22.1					14.2	19.2	16.7	22.6	19.2	26.1	21.7	29.5	24.2	32.9

Table 5.2: Comparison of pressure classes (C-classes according to EN 545:2011 [5.1] (left) with the wall thickness classes (K-classes) in EN 545:2007 [5.4] (right)

This effect is based solely on the fact that, with the introduction of pressure classes (C-classes), the limit value for minimum wall thickness has been reduced by roughly one third, from 4.7 mm to 3.0 mm. The equation applicable for calculating wall thicknesses (5.6) remains the same as before.

Table 5.2 illustrates the relationship between the previous K-classes and the new pressure classes (C-classes) for each nominal size. The wall thickness measured in millimetres represents the common comparison parameter for C-classes and for K-classes. The table shows the areas with similar wall thicknesses and the areas corresponding to pressure classes for the allowable operating pressure PFA in the same colours.

This table offers the possibility of comparing the earlier K-classes (wall thickness classes) with the new pressure classes (C-classes), because the actual minimum wall thickness e_{min} is the common reference parameter.

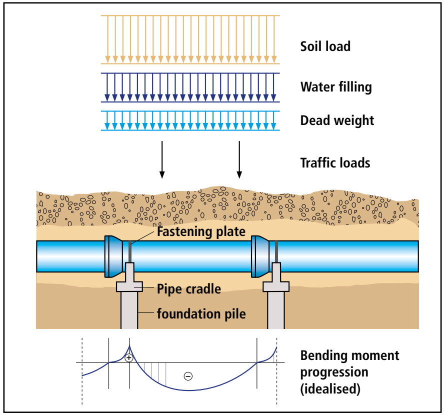

Fig. 5.5:
Bending moments for a buried pipeline on piles

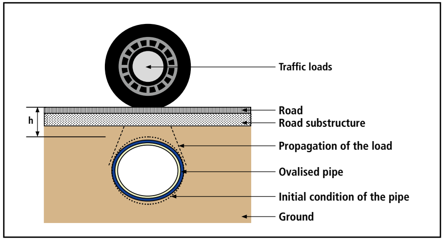

Fig. 5.6:
Ovalisation due to soil loads and traffic loads

5.5 The effect of longitudinal bending strength and ring stiffness on the calculation of pipe wall thickness dimensions

Classification according to pressure classes (C-classes) is only applicable for non-restrained systems in which only tangential stresses σ_t produced by internal pressure are decisive when it comes to calculating pipe wall thickness (Fig. 5.2).

However, such influencing factors should also be taken into account when calculating non-restrained systems as they cause a significant proportion of axial stresses σ_a in the system to be calculated. These may be axial stresses due to bending moments in the longitudinal direction (Fig. 5.5) or to uneven loads in the circumferential direction (Fig. 5.6).

		Permissible bending moments M(x) [kNm]									
		Class 40		Class 50		Class 64		K 9		K 10	
DN	DE [mm]	e_{min} [mm]	M (x)[kNm]	e_{min} [mm]	M (x)[kNm]	e_{min} [mm]	M (x)[kNm]	e_{min} [mm]	M (x)[kNm]	e_{min} [mm]	M (x)[kNm]
80	98	3.0	5.3	3.5	6.1	4.0	6.9	4.7	8.0	4.7	8.0
100	118	3.0	7.8	3.5	9.0	4.0	10.2	4.7	11.8	4.7	11.8
125	144	3.0	11.7	3.5	13.6	4.0	15.4	4.7	17.9	4.8	18.2
150	170	3.0	16.4	3.5	19.0	4.0	21.6	4.7	25.2	5.1	26.7
200	222	3.1	29.2	3.9	36.4	5.0	46.2	4.8	44.4	5.5	50.6
These bending moments, expressed in kilonewton metres [kNm], relate to a load with the same value, expressed in kilonewtons [kN], acting in the central point of a 4 m span.											
Key:		M(x) ≤ 9.9 kNm		10.0 kNm ≤ M(x) ≤ 19.9 kNm		20.0 kNm ≤ M(x) ≤ 29.9 kNm		M(x) ≥ 30.0 kNm			

Table 5.3: Permissible bending moments M(x) for DN 80 to DN 200 pipes for pressure classes (C-classes) and wall thickness classes (K-Classes)

		Minimum ring stiffness S [kN/m²]									
		Class 25		Class 30		Class 40		K 9		K 10	
DN	DE [mm]	e_{st} [mm]	S [kN/m²]	e_{st} [mm]	S [kN/m²]	e_{st} [mm]	S [kN/m²]	e_{st} [mm]	S [kN/m²]	e_{st} [mm]	S [kN/m²]
300	326					5.4	68	6.4	110	8	160
350	378			5.5	46	6.1	67	6.8	89	8.5	120
400	429			5.7	34	6.9	63	7.2	72	9.1	100
450	480			6	28			7.7	61	9.6	86
500	532			6.5	27			8.1	52	10.1	74
600	635			7.7	26			9	41	11.2	58
700	738	7.8	17					9.8	34	12.2	49
800	842	8.6	15					10.7	30	13.2	42
900	945	9.5	15					11.5	26	14.3	37
1000	1048	10.5	14.5					12.3	24	15.4	34
The values for calculated wall thickness e_{st} have been calculated as follows: $e_{st} = e_{min} + 0.5\ (1.3 + 0.001\ DN)$ [mm]											
Key:		S ≤ 29.9 kN/m²		30.0 kN/m² ≤ S ≤ 49.9 kN/m²		50.0 kN/m² ≤ S ≤ 99.9 kN/m²		M(x) ≥ 30.0 kNm			

Table 5.4: Summary of minimum ring stiffness values S for nominal sizes DN 300 to DN 1000 for pressure classes (C-classes) and wall thickness classes (K-classes)

5.5.1 Permissible bending moments

The bending moments recordable without damage for pressure classes (C-classes) and wall thickness classes (C-classes) are shown in Table 5.3. It can be seen that, in soils liable to subsidence or where trenchless pipe laying techniques are used, pipes with a higher permissible bending moment are required than those resulting from calculation by means of pressure classes.

5.5.2 Minimum ring stiffness

Stresses due to soil and traffic loads can cause ovalisation, which might be as high as 4%. The minimum ring stiffness values relating to this are stated in both versions of EN 545 and also, dependent on pressure class, in EN 545:2011 [5.1] plus, dependent on wall thickness class, in EN 545:2007 [5.4]. Table 5.4 gives a summary of the values. As is to be expected, the higher ring stiffness areas are once again to be found with the higher wall thicknesses. Here again, the wall thickness is often decisive as opposed to pressure class.

4.2 Pressure classes

According to 3.21, the pressure class of a component is determined by a combination of construction-related functional capability and the functional capability of the non-restrained flexible joint.

Restrained joints can lower the PFA; in this case the PFA is to be specified by the manufacturer.

Fig. 5.7:
Quote from EN 545 [5.1]

5.6 Ductile iron pipes with restrained flexible joints

5.6.1 Identification of the allowable operating pressure

Section 4.2 (Fig. 5.5) of EN 545 [5.1] states that, with restrained joints, the allowable operating pressure PFA may be reduced.

4.7.1 Pipes and fittings

All pipes and fittings must be legibly and durably marked and shall bear at least the following information:

- the manufacturer's name or mark
- an indication of the year of manufacture
- the identification as ductile cast iron
- the DN
- the PN rating of flanges for flange components
- the reference to this European standard, i.e. EN 545
- the pressure class designation of centrifugally cast pipes

The first five indications must be cast-on or cold-stamped. The other indications may be applied by any other process, e.g. painted onto the casting.

Fig. 5.8:
Quote from EN 545 [5.1]

As seen in Fig. 5.1, restrained pipe joints produce a multiaxial stress state in the pipe wall whereby, with the allowable operating pressure PFA being lower when compared with the non-restrained joint, the pressure class is therefore lower.

The multiaxial stress state in a pipe wall which, in addition to the tangential stress σ_t produced by internal pressure, must also take up axial stresses σ_a, results in a distinct reduction in the allowable operating pressure PFA as compared with the non-restrained design. Therefore the specification of pressure class C as a synonym for the allowable operating pressure PFA is no longer sufficient for restrained-joint pipelines. This has consequences for the identification of the pipes. Fig. 5.8 shows the identification requirements of EN 545 [5.1], Section 4.7.1.

According to EN 545 [5.1], Section 4.2, manufacturers must state the lower values for the PFA of their restrained push-in joints. However, there is no clear and unambiguous determination of the identification of pipes with restrained joints to be found in EN 545 [5.1]. EADIPS®/FGR® has responded to this situation by publishing its own identification standard, EADIPS®/FGR®-NORM 75 [5.5], (Chapter 3, Figs. 3.35 and 3.36).

5.6.2 Positive locking push-in joints

A further requirement has come more and more into the foreground in the last decade: the increasing frequency with which restrained push-in joints are being used with the trenchless laying techniques and the associated requirement for the maximum permissible tensile strength values in the Technical Rules of DVGW Worksheet GW 320-1 [5.6] etc. (see also Chapter 22 on trenchless pipe laying and replacement techniques). In these sets of rules, the permissible tensile strength of, above all, positive locking push-in joints with a welding bead on the spigot end (Fig. 9.5) plays a decisive role for the pulling-in length of a pipe string. Hence it is a determining factor for excavation distances and therefore for the efficiency of a pipe material for a specific trenchless technique. Trenchless pipe laying techniques are mainly performed with positive locking restrained push-in joints. These joints must have a welding bead on the spigot end. A minimum wall thickness of approximately 5 mm for a high-quality weld penetration is considered as a precondition for compliance with the required permissible tensile strength. Also, with trenchless pushing-in techniques, a minimum wall thickness is required for transferring the compressive forces, so that the permissible compression stresses in the connection joint are not exceeded.

Depending on the application case, a number of load types due to internal pressure, vertical load and bending stress, as well as those due to the maximum permissible tensile and compressive forces associated with trenchless laying techniques must therefore be calculated and the optimum pipe determined. The effects on practical planning are described in articles in EADIPS®/FGR® Annual Journals 45 [5.7] and 46 [5.8].

5.7 References

[5.1] EN 545:2011
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]
2011

[5.2] DIN 28603
Rohre und Formstücke aus duktilem Gusseisen –
Steckmuffen-Verbindungen –
Zusammenstellung, Muffen und Dichtungen
[Ductile iron pipes and fittings –
Push-in joints –
Survey, sockets and gaskets]
2002-05

[5.3] EN 14801
Conditions for pressure classification of products for water and wastewater pipelines
[Bedingungen für die Klassifizierung von Produkten für Rohrleitungssysteme für die Wasserversorgung und Abwasserentsorgung nach auftretenden Drücken]
2006

[5.4] EN 545:2007
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]
2006

[5.5] EADIPS®/FGR®-NORM 75
Rohre aus duktilem Gusseisen –
Kennzeichnung des zulässigen Bauteilbetriebsdrucks (PFA) längskraftschlüssiger beweglicher Steckmuffen-Verbindungen von Rohren –
Ergänzung zur EN 545:2010
[EADIPS®/FGR® STANDARD 75
Ductile iron pipes –
Marking of the allowable operating pressure PFA of restrained flexible push-in socket joins of pipes –
Supplement to EN 545:2010]
2013-06

[5.6] DVGW-Arbeitsblatt GW 320-1
Erneuerung von Gas- und Wasserrohrleitungen durch Rohreinzug oder Rohreinschub mit Ringraum
[DVGW worksheet GW 320-1
Replacement of gas and water pipelines by pipe pulling or pipe pushing with annular gap]
2009–02

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Wanddickenklassen und Druckklassen in der EN 545 –
Vergleich zwischen den Versionen von 2007 und 2010
GUSS-ROHRSYSTEME,
Heft 45 (2011), S. 23 ff
[Wall-thickness classes and pressure classes in EN 545 –
Comparison between the 2007 and 2010 versions
DUCTILE IRON PIPE SYSTEMS,
Issue 45 (2011), p. 19 ff]

[5.8] Rammelsberg, J.:
Auswirkungen der neuen EN 545 auf die Planungspraxis für Trinkwasserleitungen aus duktilem Gusseisen.
GUSS-ROHRSYSTEME,
Heft 46 (2012), S. 35 ff
[The impact of the new EN 545 on practical planning and design for ductile iron drinking water pipelines,
DUCTILE IRON PIPE SYSTEMS,
Issue 46 (2012, p. 33 ff]

[5.9] EN 1092-2
Flanges and their joints –
Circular flanges for pipes, valves, fittings and accessories, PN designated –
Part 2: Cast iron flanges
[Flansche und ihre Verbindungen –
Runde Flansche für Rohre, Armaturen, Formstücke und Zubehörteile, nach PN bezeichnet –
Teil 2: Gusseisenflansche]
1997

6 Design and marking of fittings

6 Design and marking of fittings

This chapter is being prepared.

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

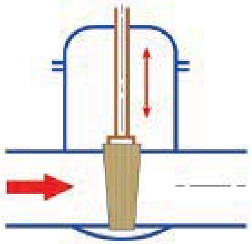
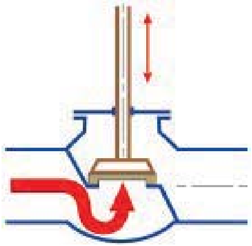
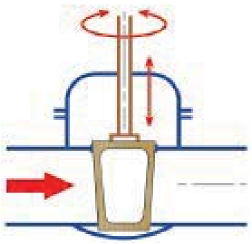
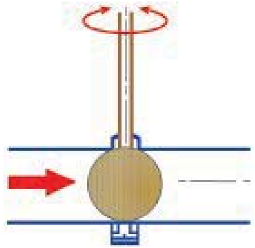
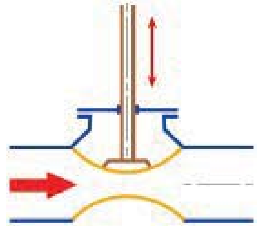
Working mechanism of the closure device				
Linear		Turning around the axis perpendicular to the direction of flow		Deformation of a flexible component
Direction of flow in the connection area				
Perpendicular to the movement of the closure device	In the direction of movement of the closure device	Through 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 microalloys,
- 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 Grund-
bauarten;
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 Wasser-
leitungen –
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 Wasser-
versorgung 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 Epoxidharz-
basis
[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/mm^2 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.

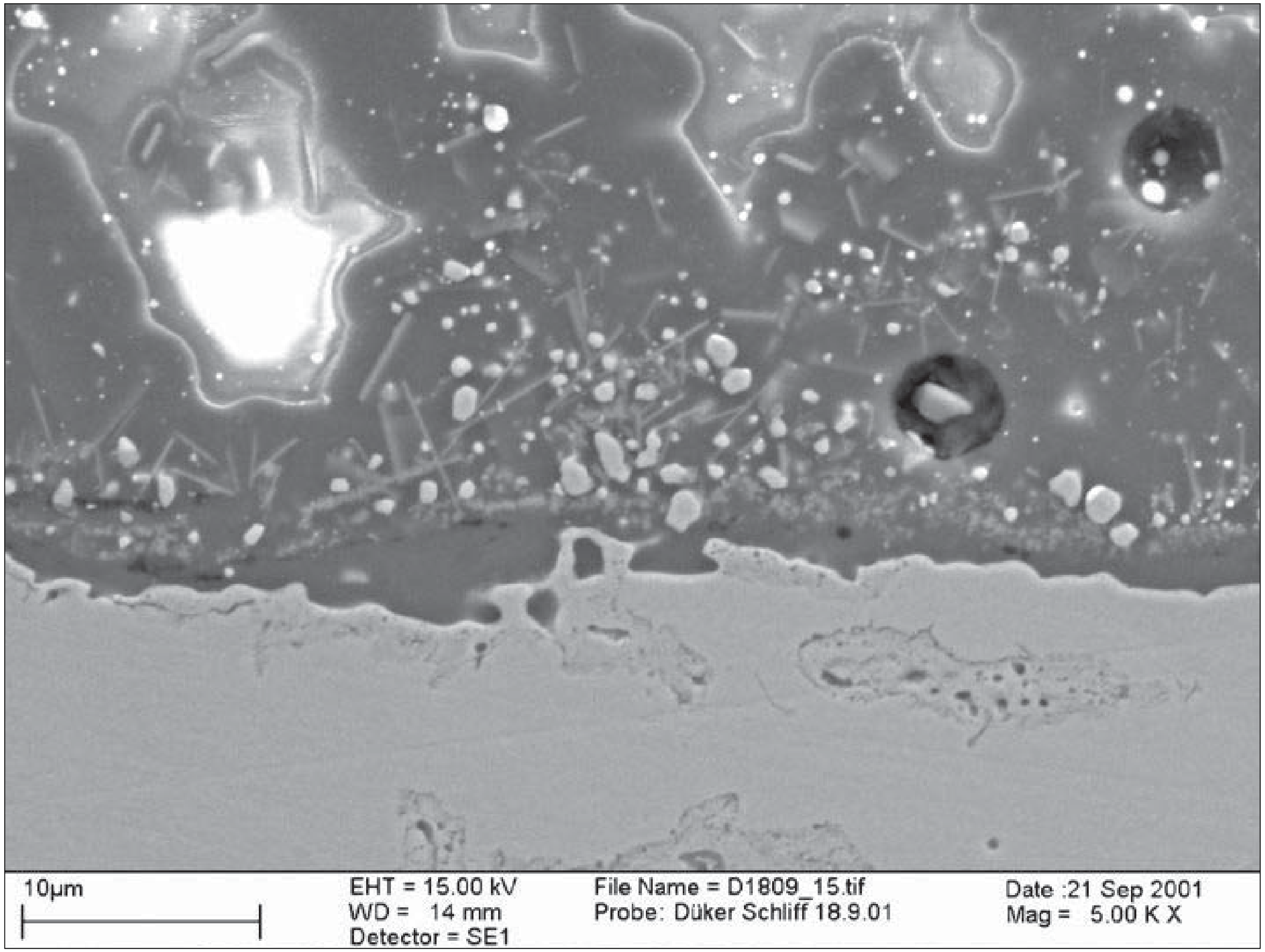


Fig. 7.2.2-02:
Detailed image of an enamel composite layer with spheroidal graphite cast iron; scanning electron microscope image, Fraunhofer Institute ISC, Würzburg

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

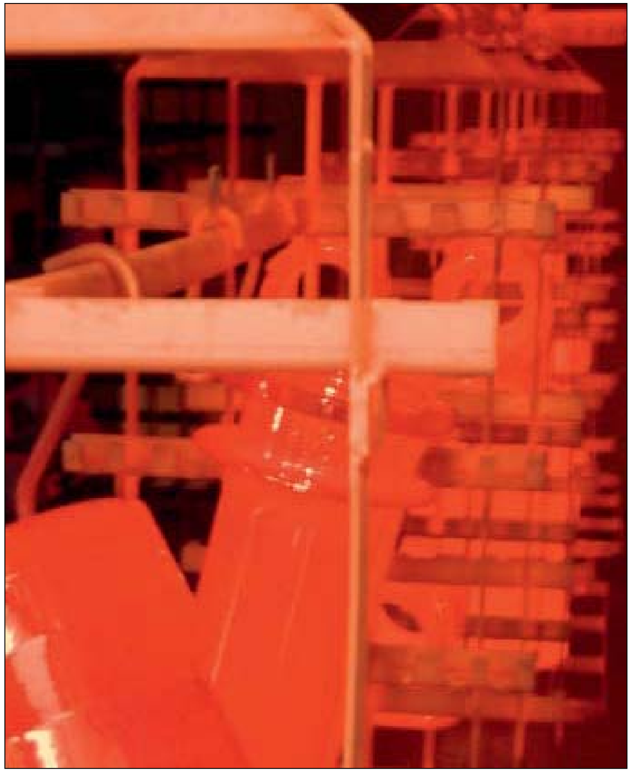


Fig. 7.2.2-06:
A view inside the curing oven

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

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.

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;
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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
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Requirements and tests]
1996-08

[7.2-05] RAL – GZ 662
Güte- und Prüfbestimmungen –
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Gütesicherung
[Quality and test provisions –
Heavy duty corrosion protection of valves and fittings by powder coating –
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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
[Quality requirements and test specifications for enamelled cast iron valves and ductile iron fittings for untreated and potable water supply]
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
  $E_{pot} = g \cdot \rho \cdot z$ [N/m²] (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]
ζ = zeta value [-]

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

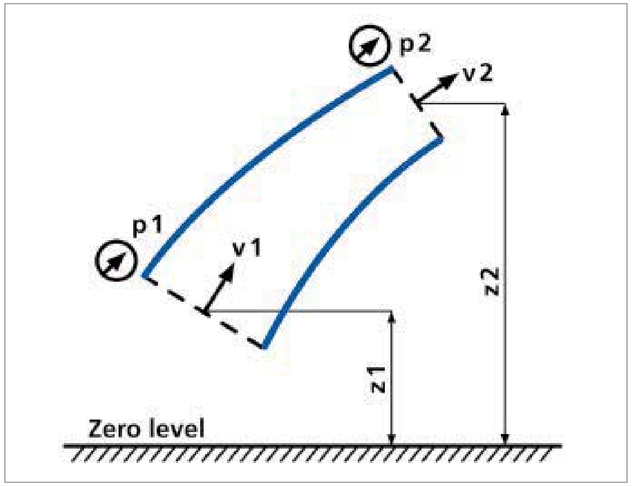

Fig. 7.3.1:
Change in the energy proportions between point 1 and point 2 of a line

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:

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

[N/m²] (7.3.4)

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.

Thus we arrive at:

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

or transposed

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

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:

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

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

it then follows

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

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:

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

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.

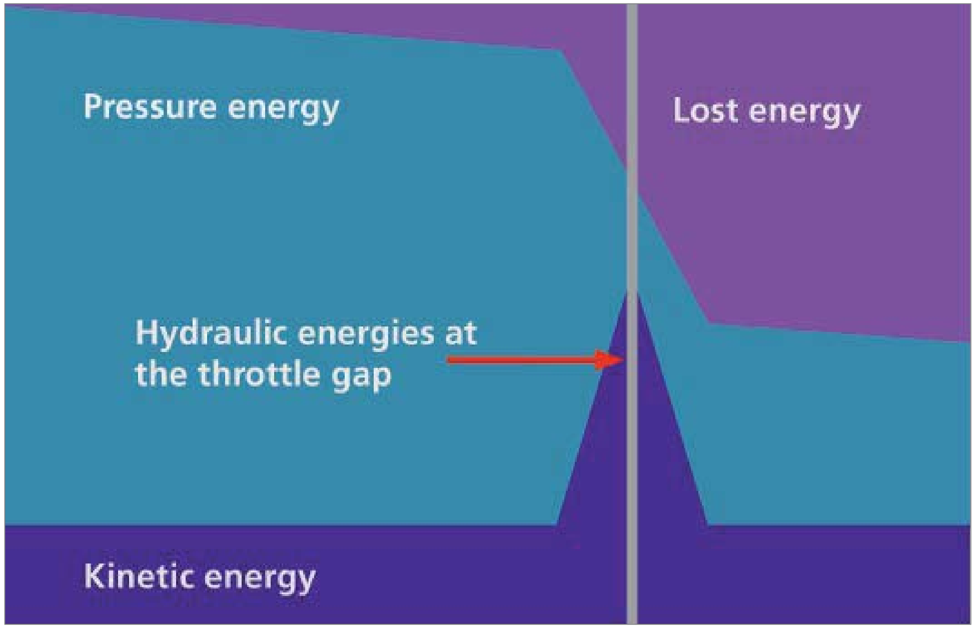

Fig. 7.3.2:
Hydraulic energies in the area of the throttle gap

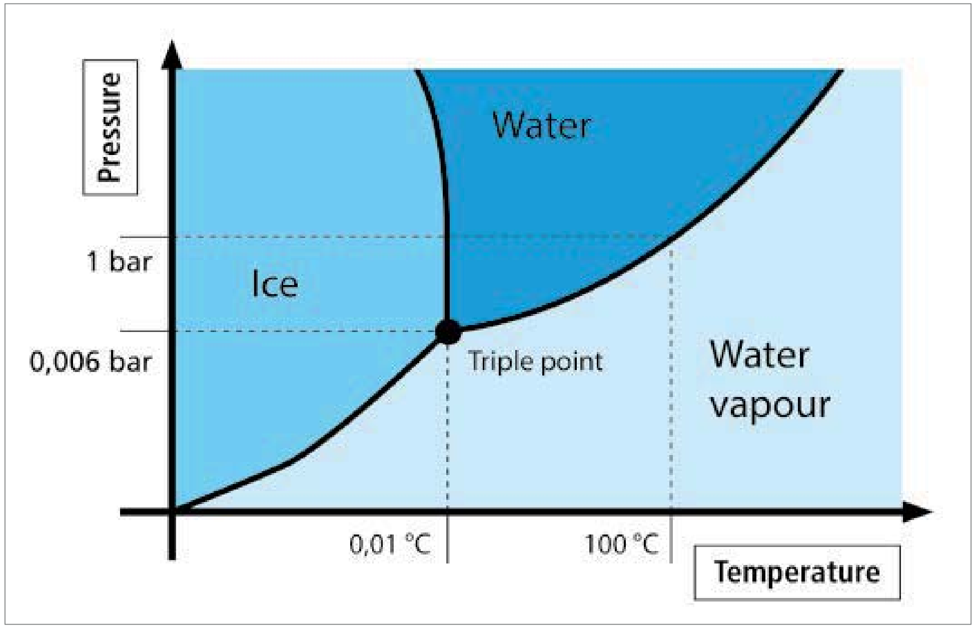

Fig. 7.3.3:
Phase diagram of water

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.

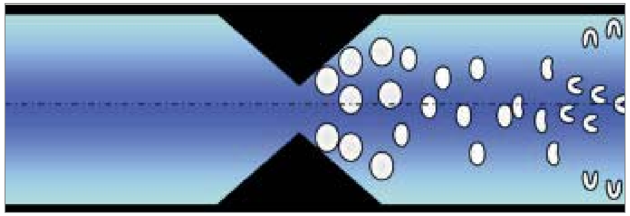

Fig. 7.3.4:
Vapour bubble formation in a throttling point

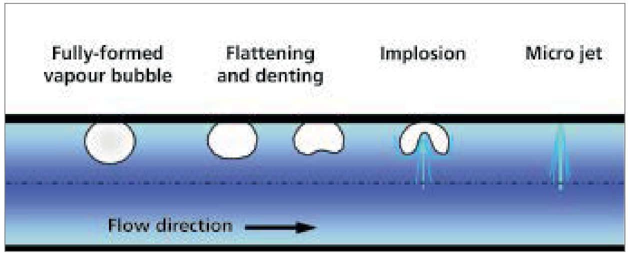

Fig. 7.3.5:
Schematic diagram of cavitation

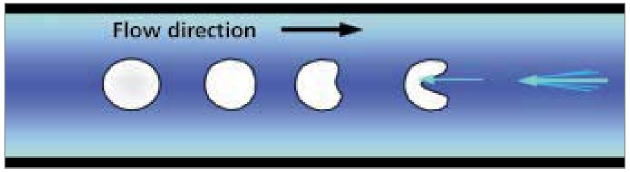

Fig. 7.3.6:
Directing vapour bubbles to the centre of the pipe

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.

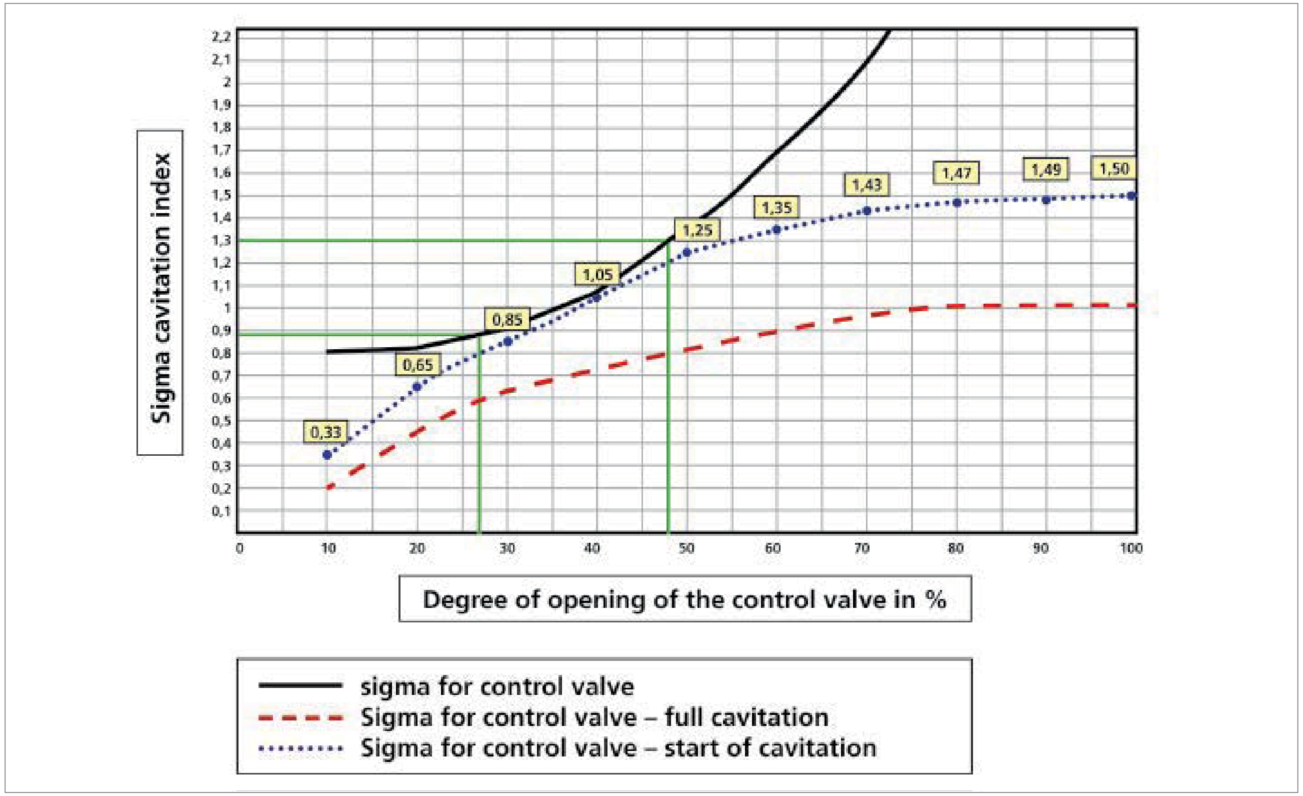

Fig. 7.3.2:
Cavitation assessment for an operating point

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
[Armaturen – Terminologie – Teil 1: Definition der Grundbauarten]
1995

[7.3-02] EN 736-2
Valves – Terminology –
Part 2: Definition of components of valves
[Armaturen – Terminologie – Teil 2: Definition der Armaturenteile]
1997

[7.3-03] EN 736-3
Valves – Terminology –
Part 3: Definition of terms
[Armaturen – Terminologie – Teil 3: Definition von Begriffen]
2008

[7.3-04] 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

[7.3-05] EN 1074-2
Valves for water supply –
Fitness for purpose requirements and appropriate verification tests –
Part 2: Isolating valves
[Armaturen für die Wasserversorgung –
Anforderungen an die Gebrauchstauglichkeit und deren Prüfung –
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.

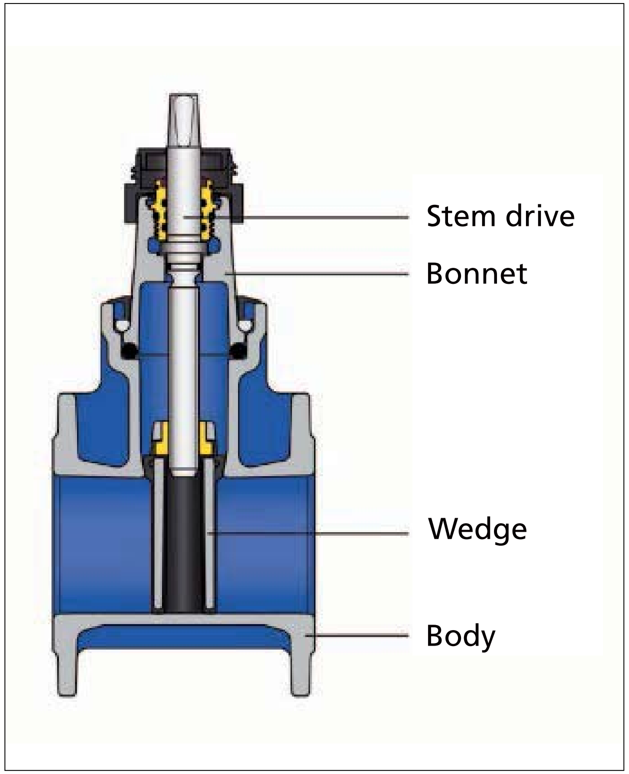

Fig. 7.4.1-01:
Design of a wedge gate valve:
Body, bonnet, stem drive and wedge

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

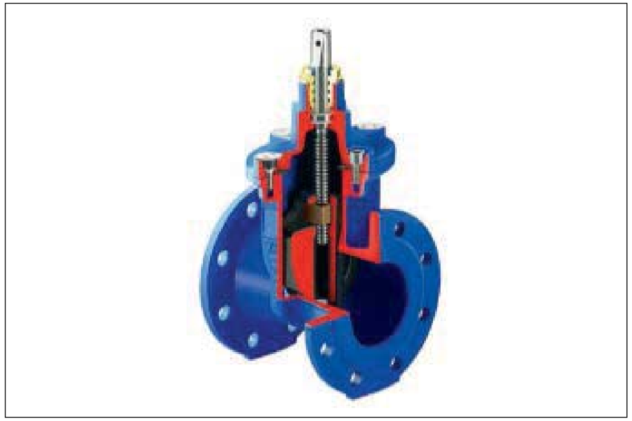

Fig. 7.4.1-03:
Sectional image of a resilient seated flanged gate valve with a bolted connection between bonnet and body

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.

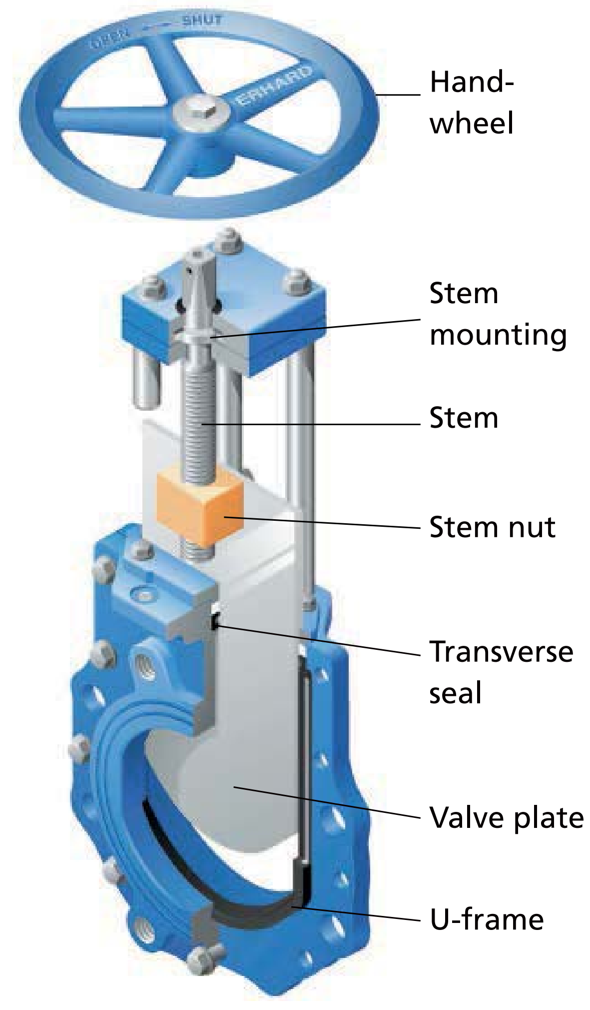

Fig. 7.4.1-10:
Construction of a knife gate valve

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

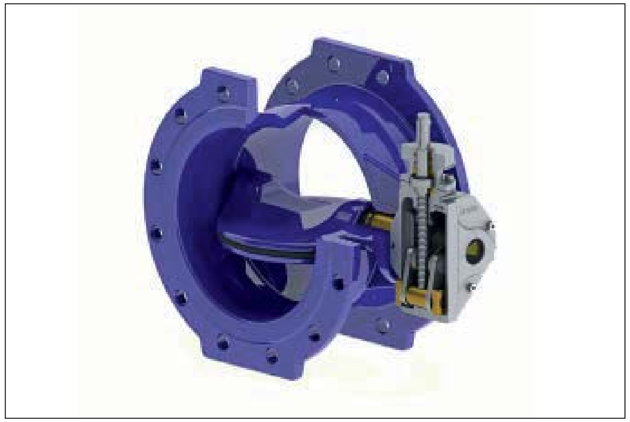

Fig. 7.4.2-03:
DN 250 double-eccentric butterfly valve with slider crank mechanism

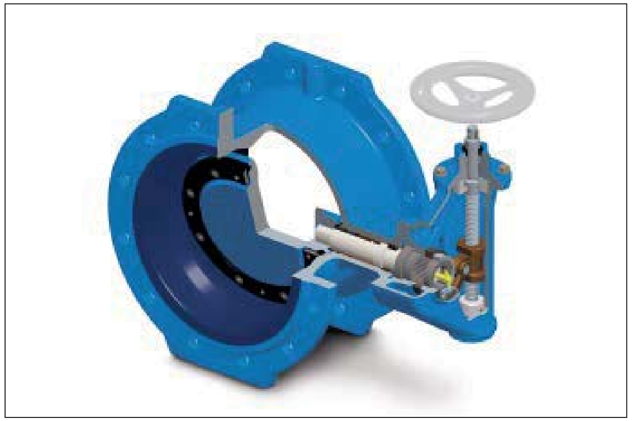

Fig. 7.4.2-04:
Double-eccentric butterfly valve with slider crank mechanism and hand-wheel

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

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

Fig. 7.4.2-07:
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)**.

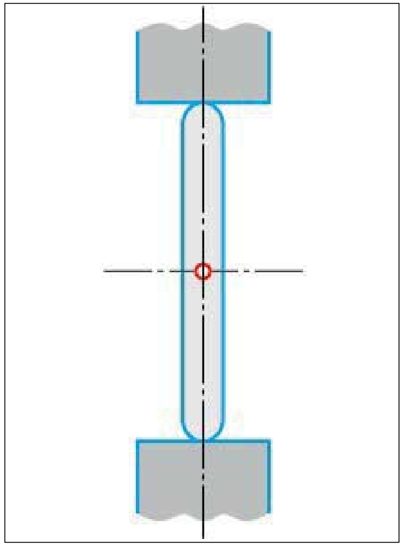

Fig. 7.4.2-08:
Centric design

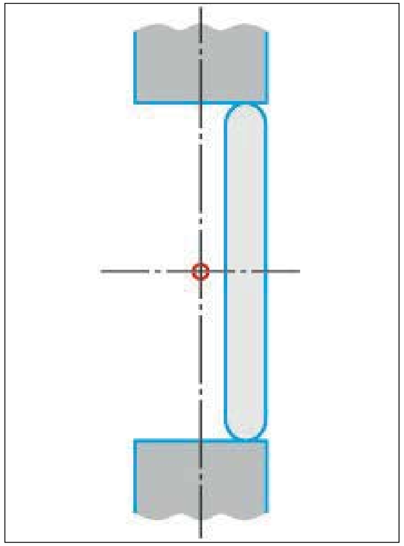

Fig. 7.4.2-09:
Simple eccentric design

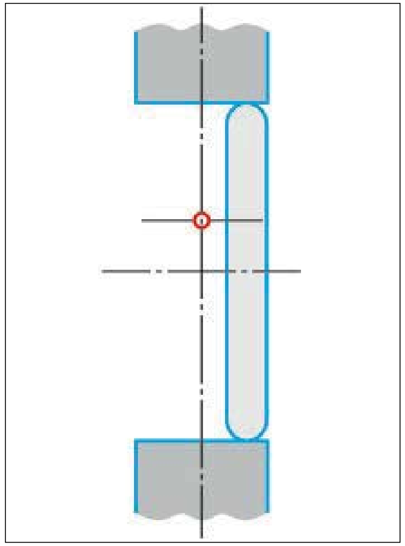

Fig. 7.4.2-10:
Double eccentric design

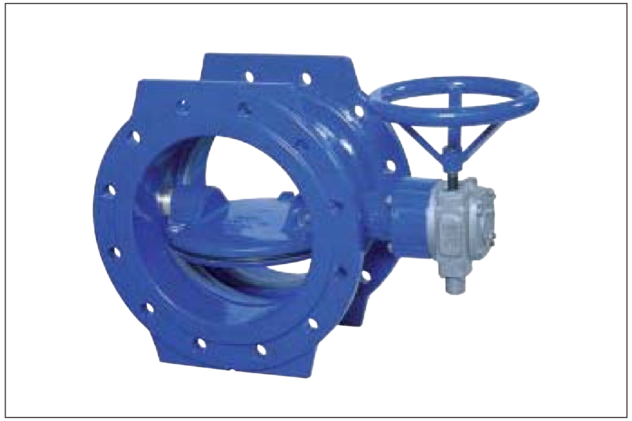

Fig. 7.4.2-11:
Butterfly flange valve with gearing and hand-wheel

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

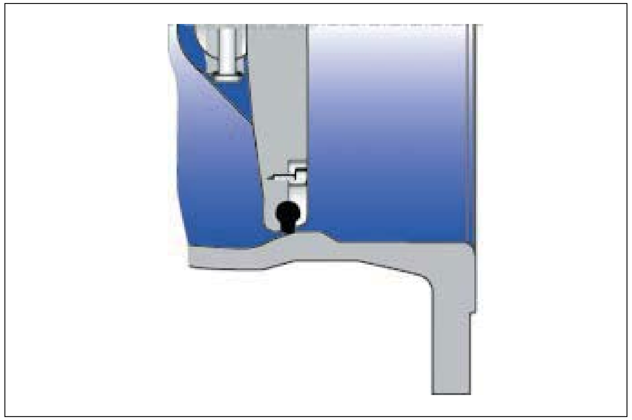

Fig. 7.4.2-17:
Sealing ring seated directly on the cast iron body

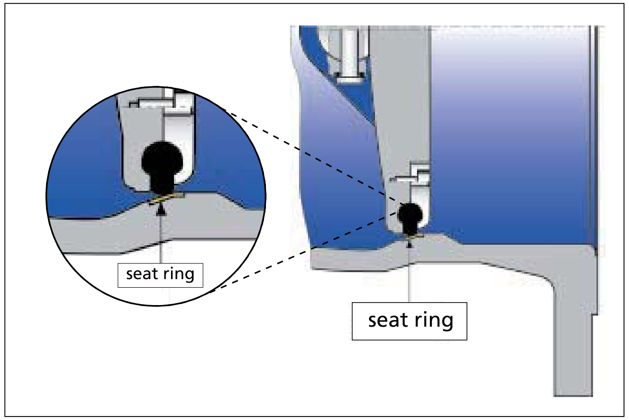

Fig. 7.4.2-18:
Sealing ring seated on the seat ring

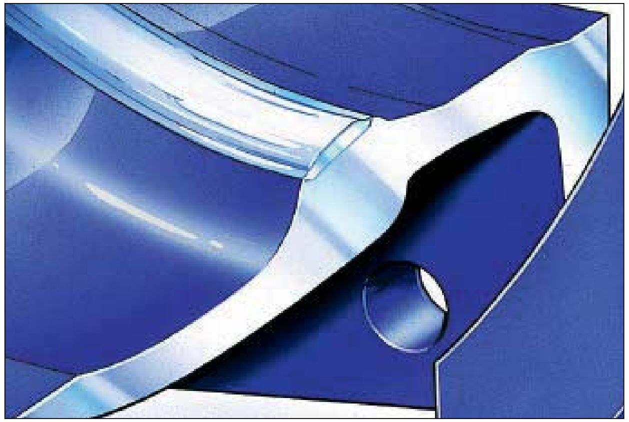

Fig. 7.4.2-19:
Sealing ring seated on a seating area produced by overlay welding

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.

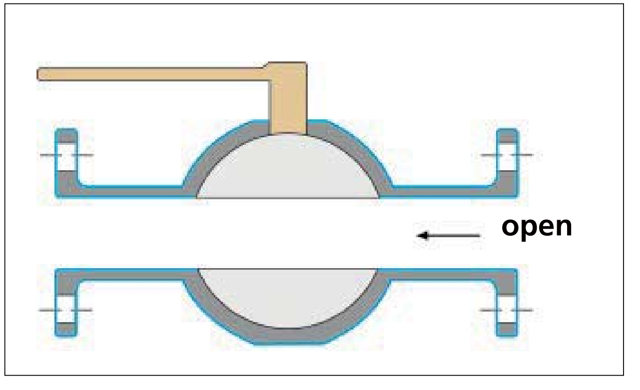

Fig. 7.4.3-01:
Ball valve position:
fully "open"

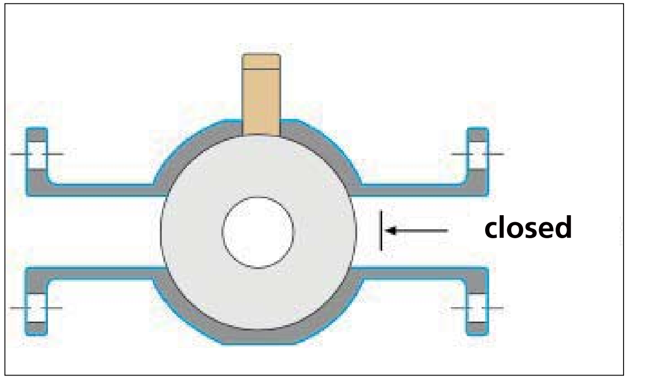

Bild 7.4.3-02:
Ball valve position:
fully "closed"

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.

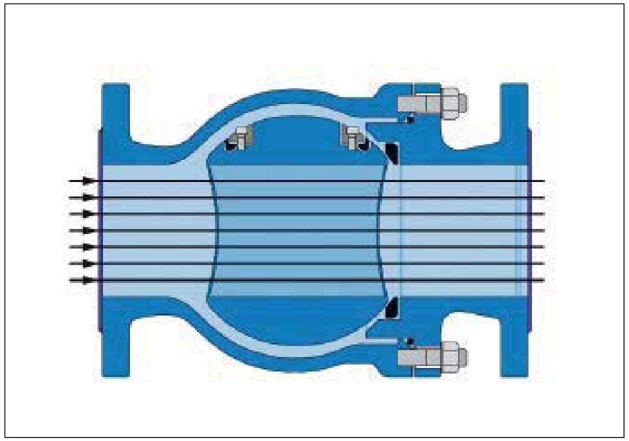

Fig. 7.4.3-06:
Ball valve fully open

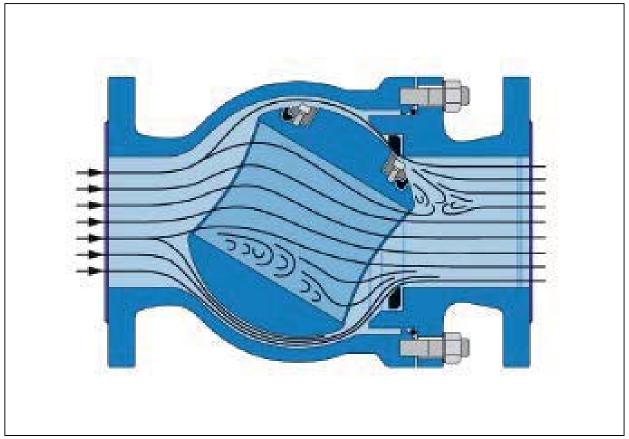

Fig. 7.4.3-08:
Ball valve half open

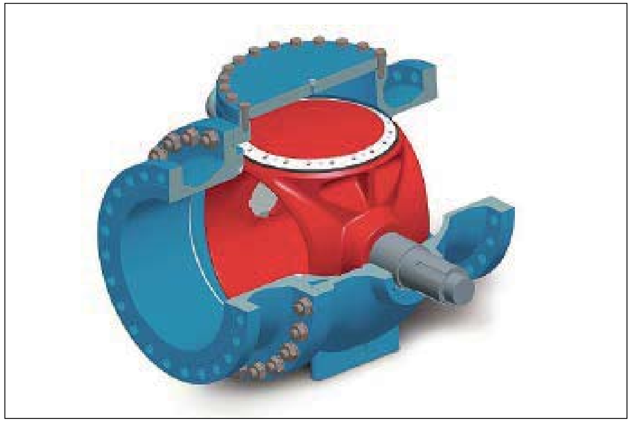

Fig. 7.4.3-07:
Cross-section of a ball valve – fully open position

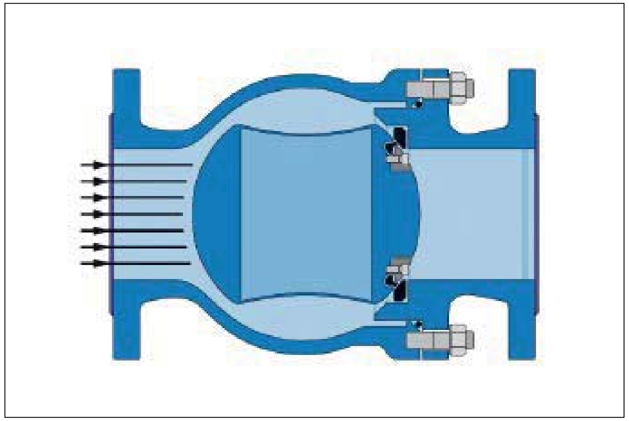

Fig. 7.4.3-09:
Ball valve closed

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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Prüfung
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supply –
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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.

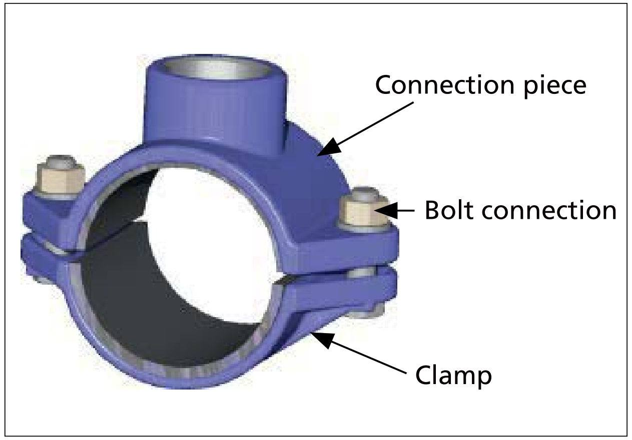


Fig. 7.5.2-01:
Tapping valve without operational shut-off, with clamp

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.

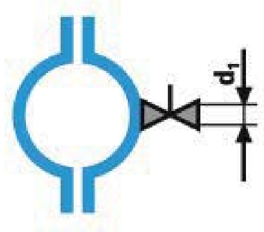
Tapping valves with operational shut-off can be equipped with an auxiliary shut-off device. Auxiliary shut-off devices are used while the pipeline is being tapped.

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:

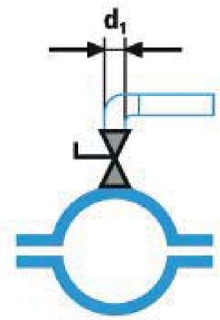
- as an additional shut-off integrated into the tapping valve for operational shut-off,
- an auxiliary and operational shut-off device in one unit,
- as a separate and reusable tool (is installed during the assembly of the tapping valve).

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)

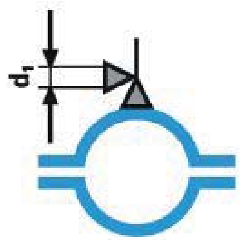


Fig. 7.5.3-01:
Different types of operational shut-off device according to DIN 3543-2 [7.5-01] – d_1 is equivalent to diameter of connection

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)**

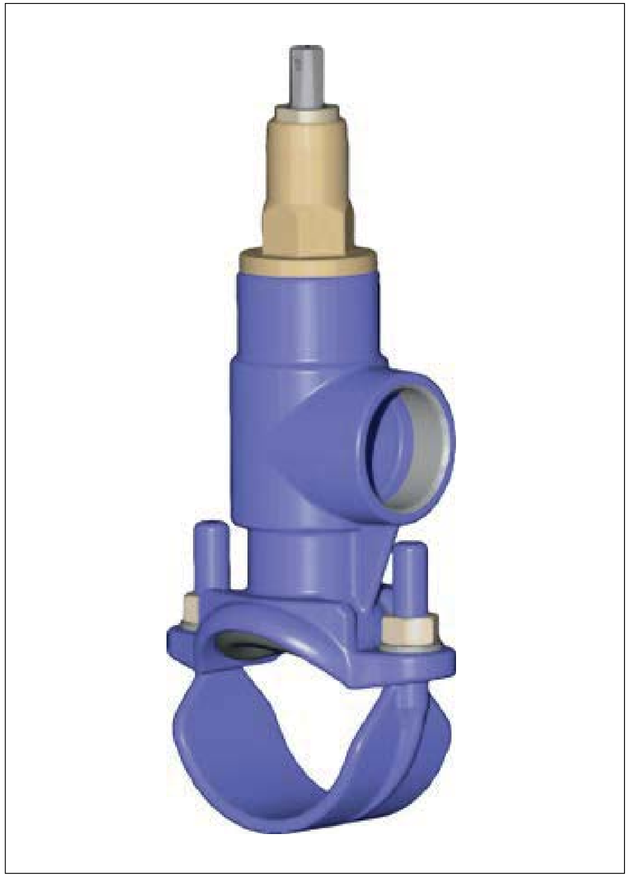


Fig. 7.5.3-02:
Tapping valve for cast iron pipelines with cast iron bracket

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)**.

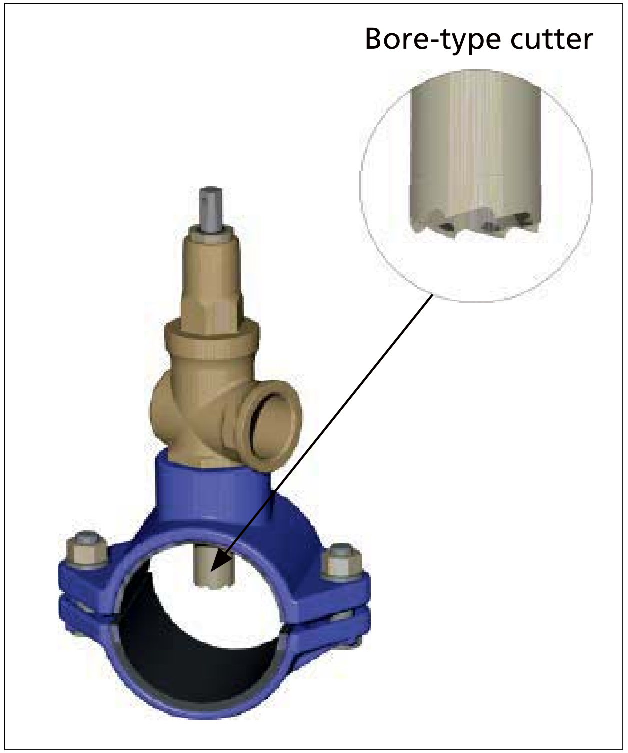


Fig. 7.5.4-01:
Tapping valve with integrated Bore-type cutter

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

Fig. 7.6.4:
Pilot-operated control valve

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-

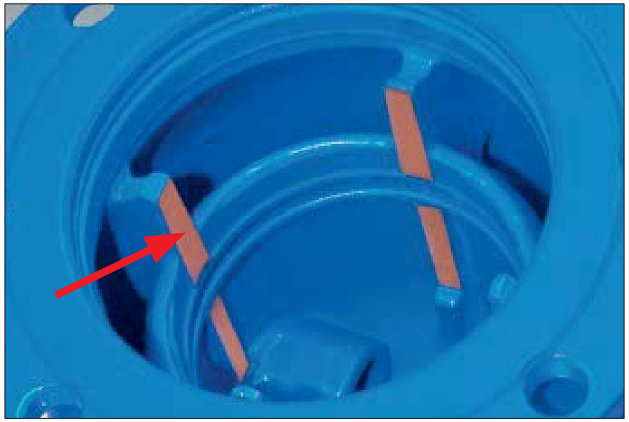

Fig. 7.6.11:
Longitudinal guides of the plunger valve

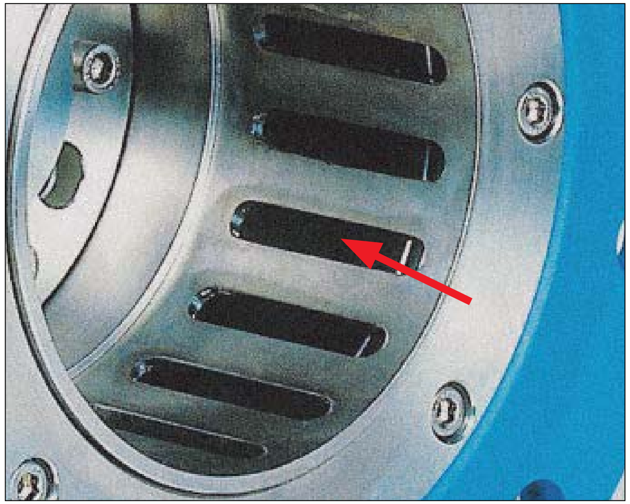

Fig. 7.6.12:
Slotted cylinder

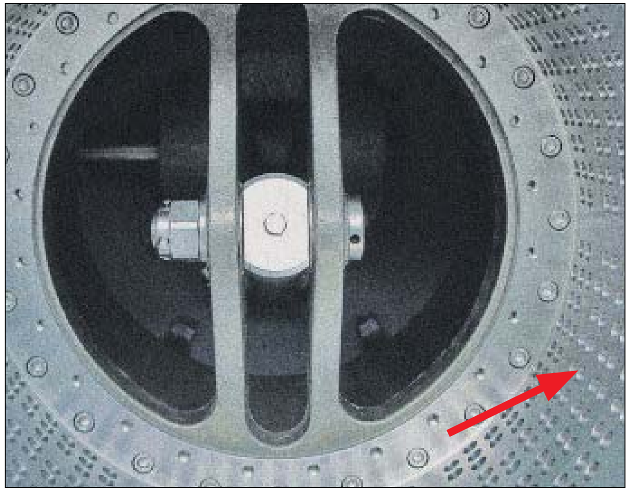

Fig. 7.6.13:
Perforated cylinder

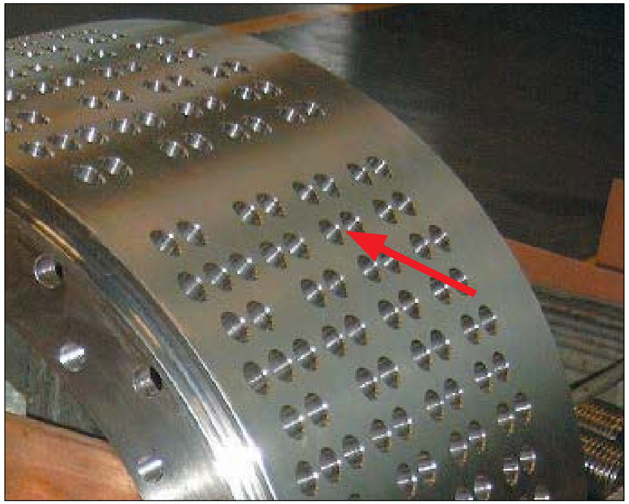

Fig. 7.6.14:
Special forms

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)**.

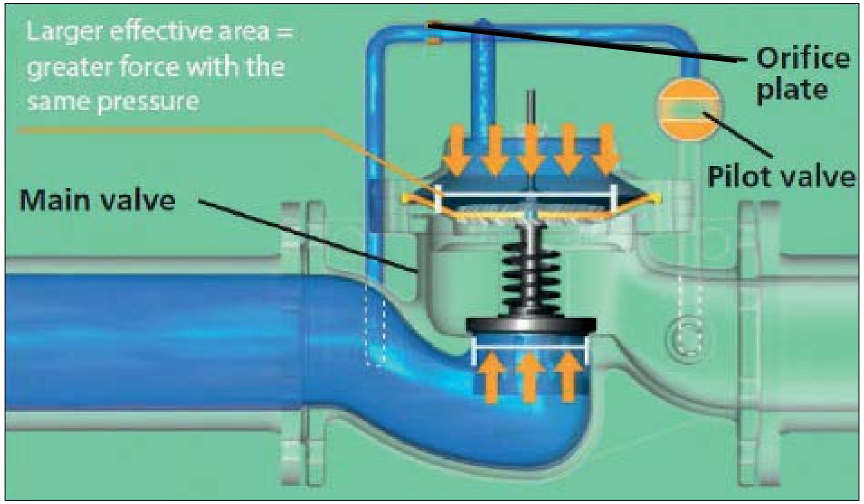

Fig. 7.6.15:
Main valve and pilot valve closed

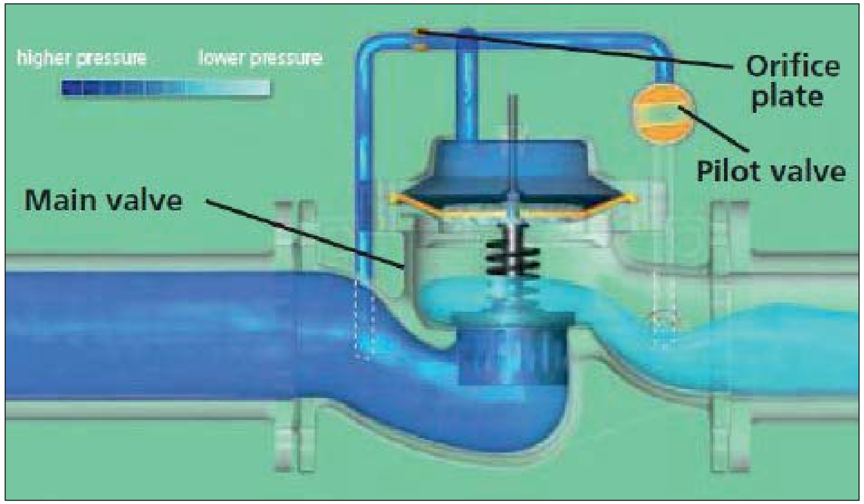

Fig. 7.6.17:
Main valve and pilot valve going into control mode

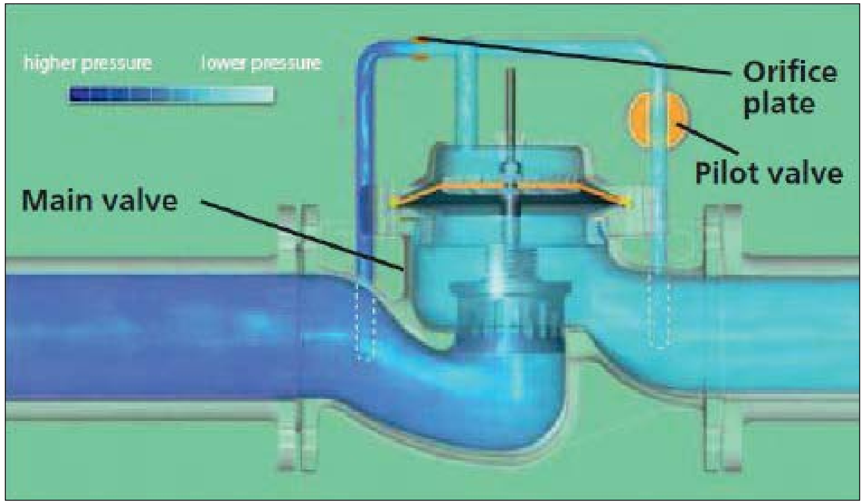

Fig. 7.6.16:
Main valve and pilot valve completely open

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.

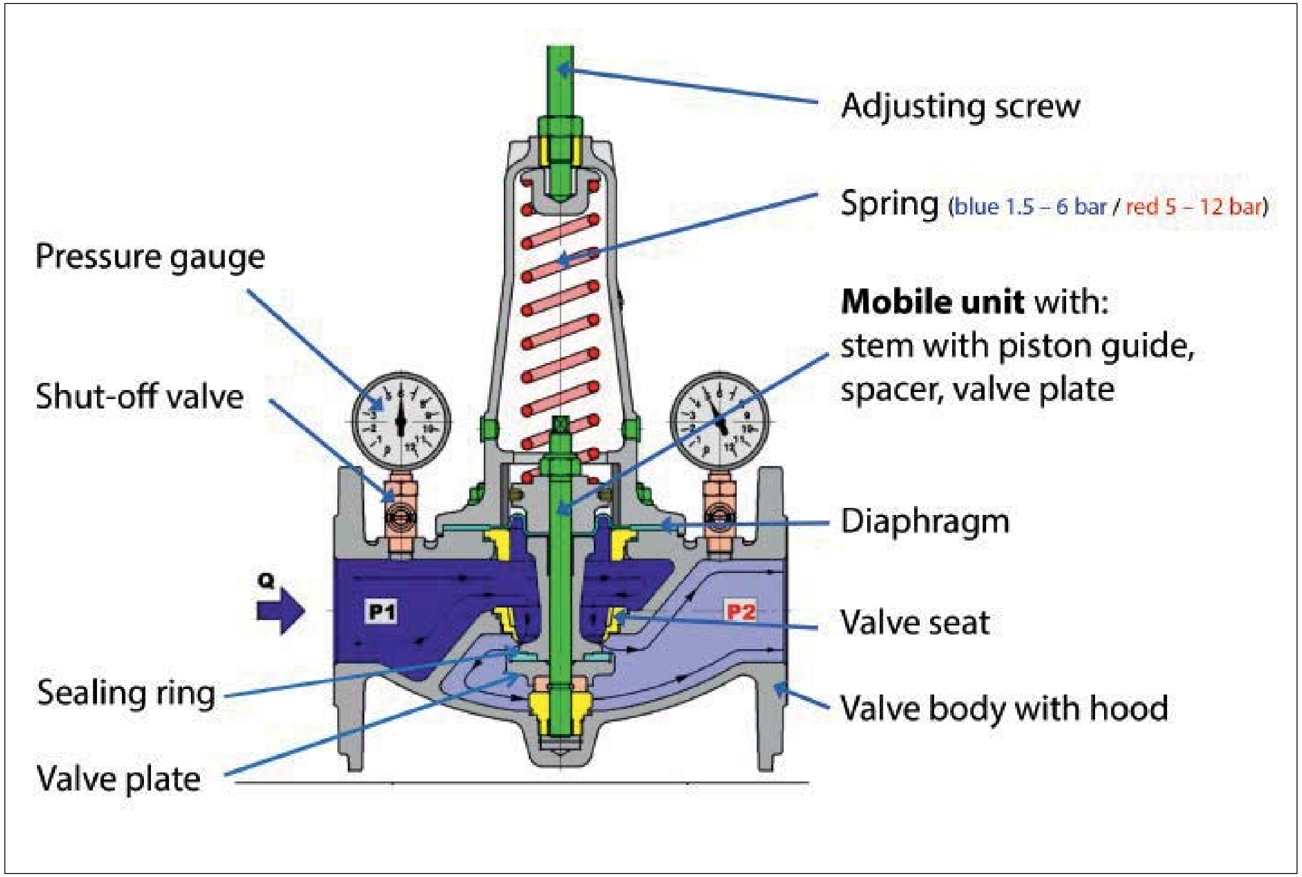

Fig. 7.6.19:
Construction of the valve

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)“
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[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]
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[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]
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[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.

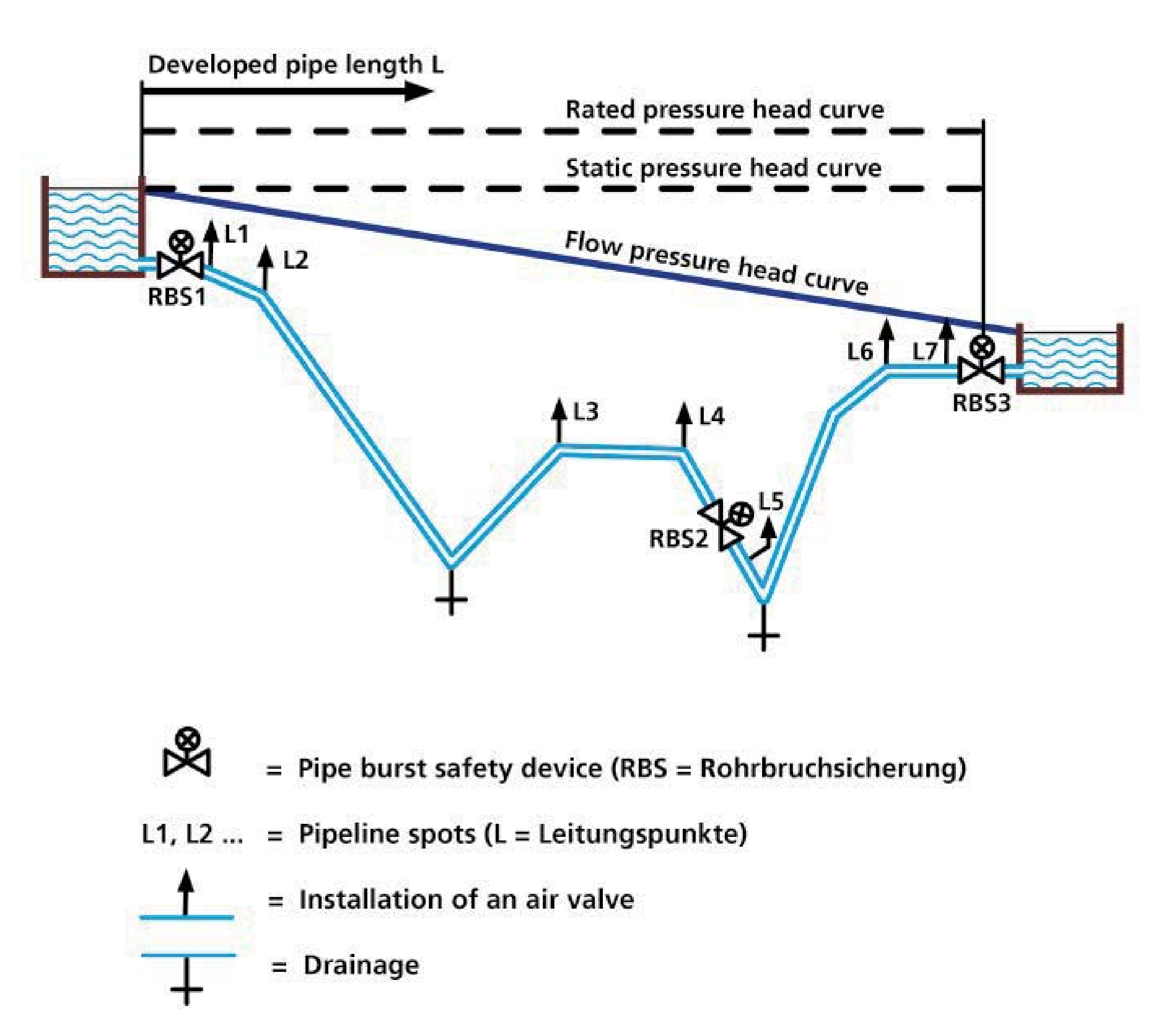

Fig. 7.7.1:
Installation locations of air valves in a pipeline

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.

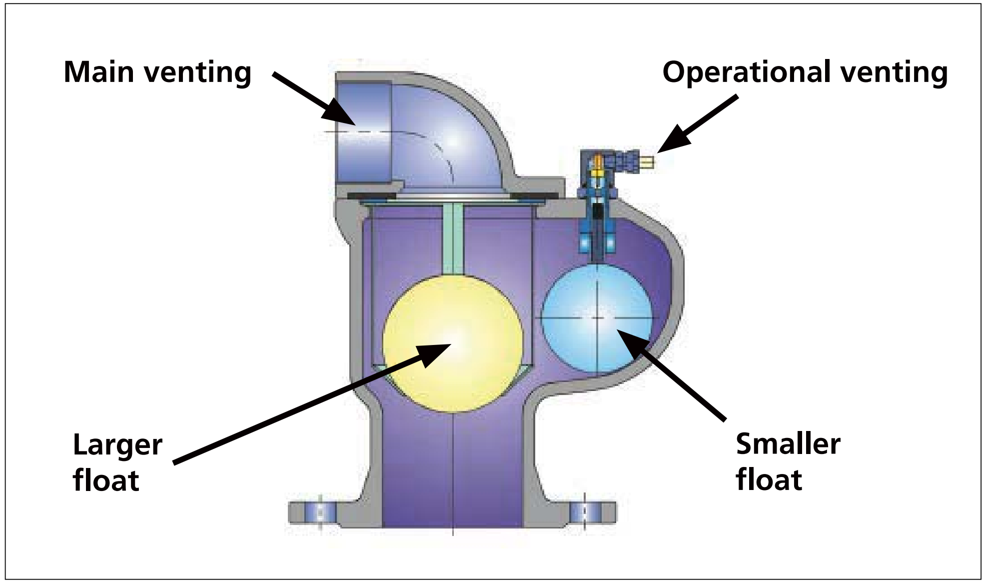

Fig. 7.7.3:
Air valve with large and small float in the open state

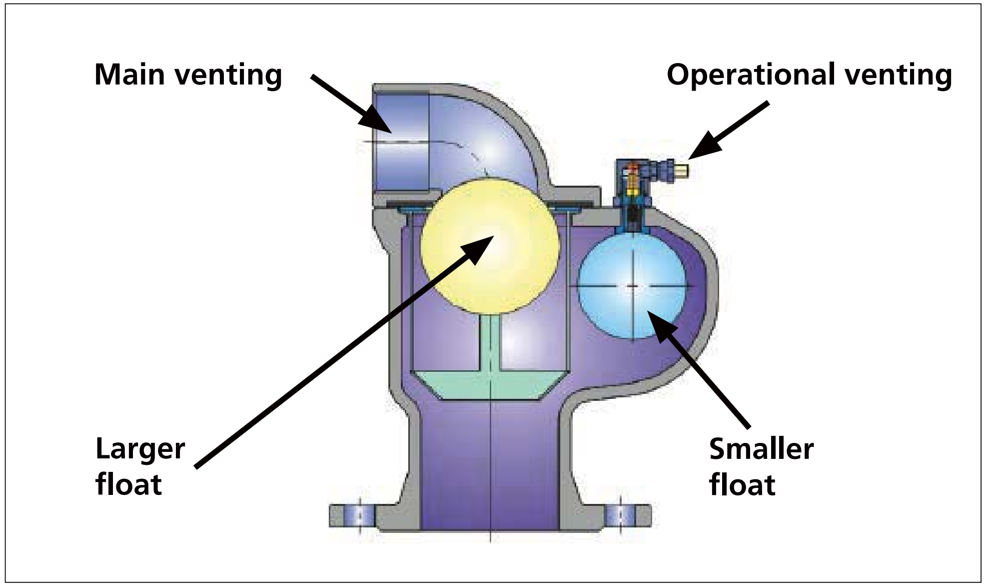

Fig. 7.7.4:
The valve is tightly closed.
Both main venting and operational venting are closed because there is no accumulation of air in the pipeline

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)**.

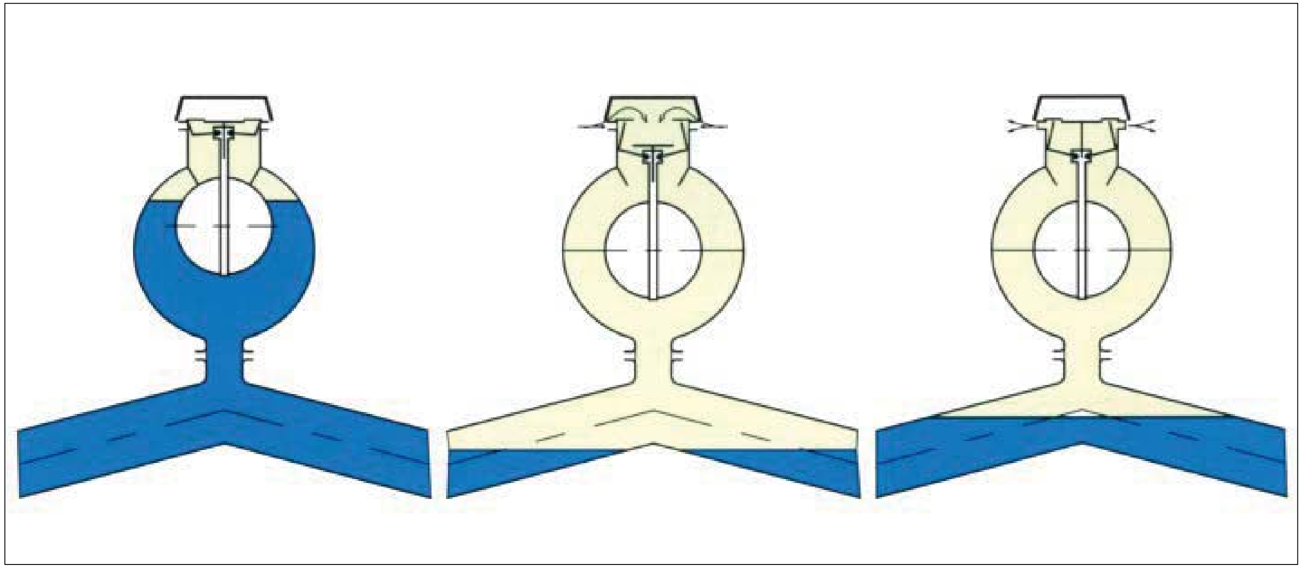

Fig. 7.7.5:
The float mechanism and valve lever function

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.

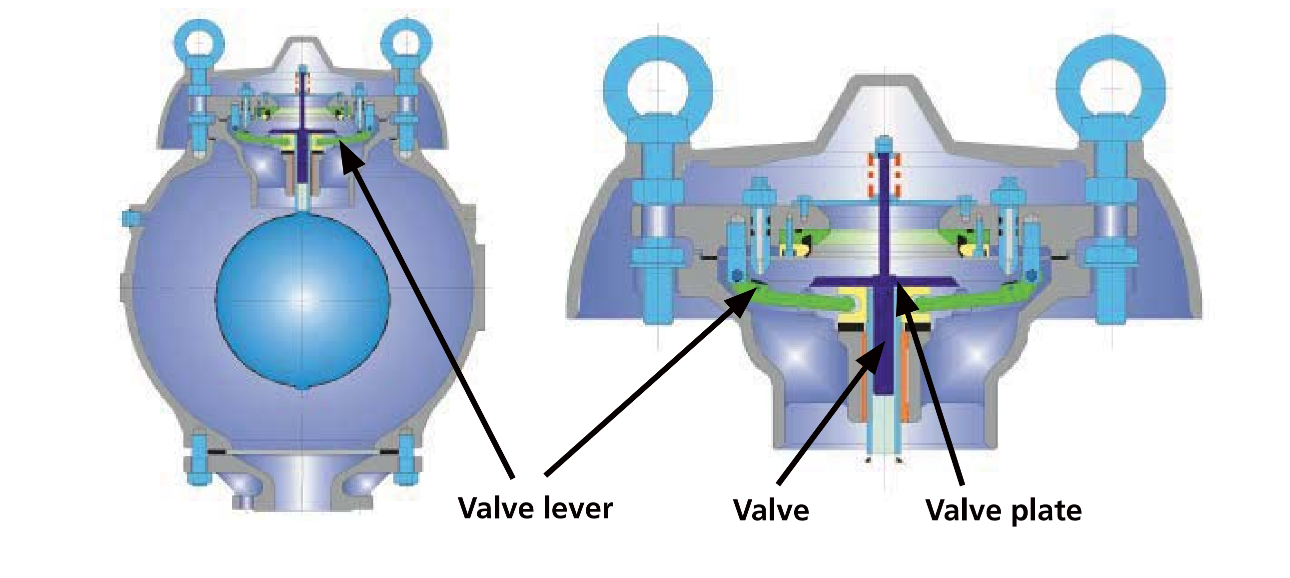

Fig. 7.7.6:
Sectional view of a single chamber valve with valve lever for small and large air volumes

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

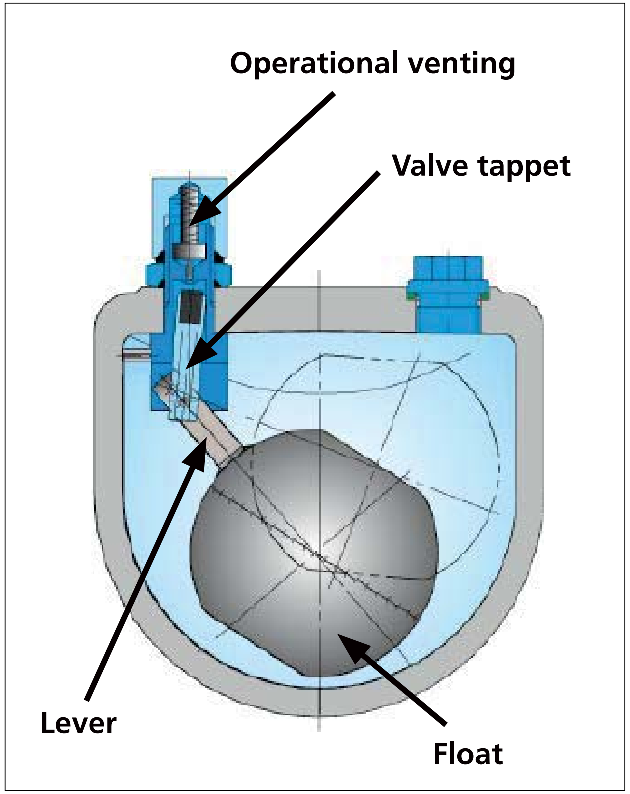

Fig. 7.7.8:
Different lever principles for air valves – the illustration shows the operational venting process. The float is attached to a lever. A valve tappet on the lever closes the venting hole under positive pressure. Under negative pressure the float drops and the hole is opened. Air can escape.

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.

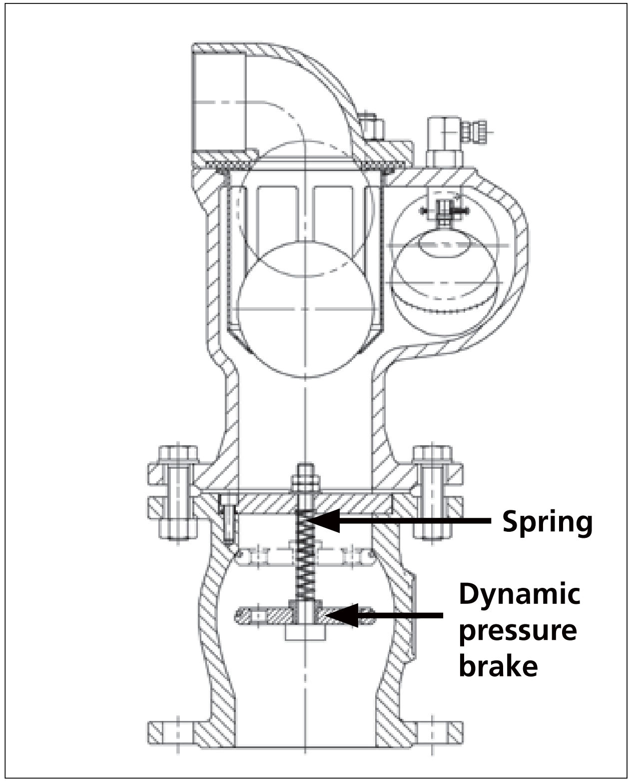

Fig. 7.7.9:
Air valve with dynamic pressure brake

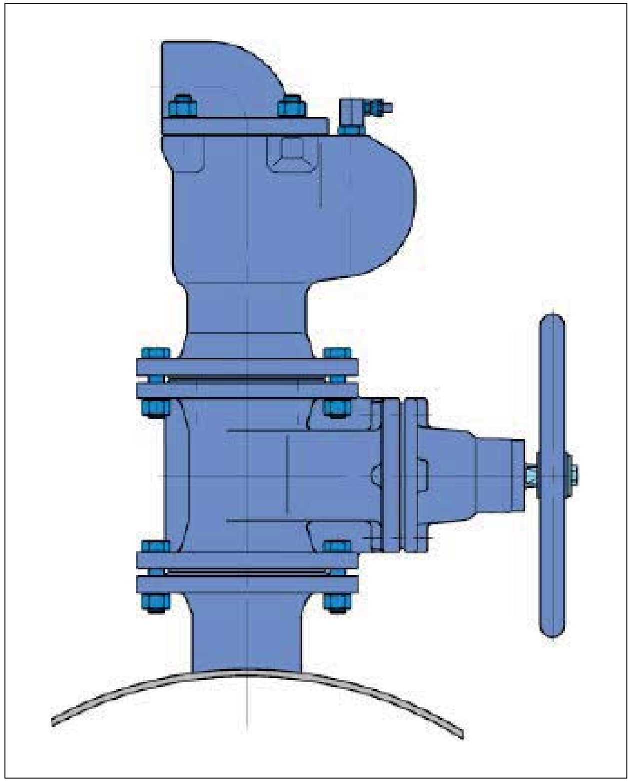

Fig. 7.7.10:
Air valve with gate valve

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.

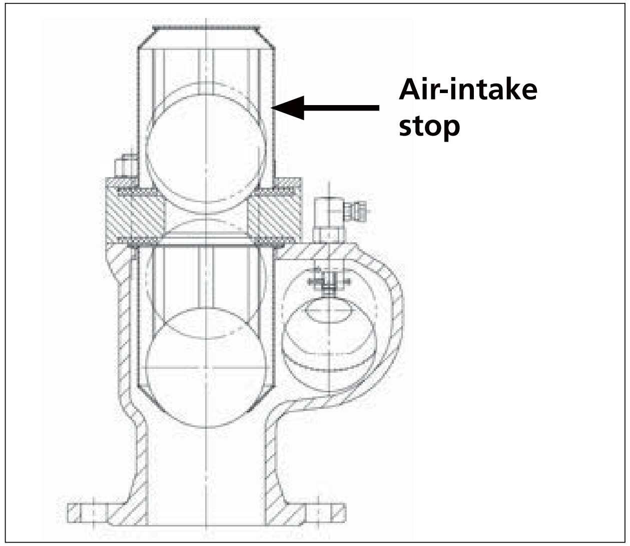

Fig. 7.7.11:
Air valve with air-intake stop

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.

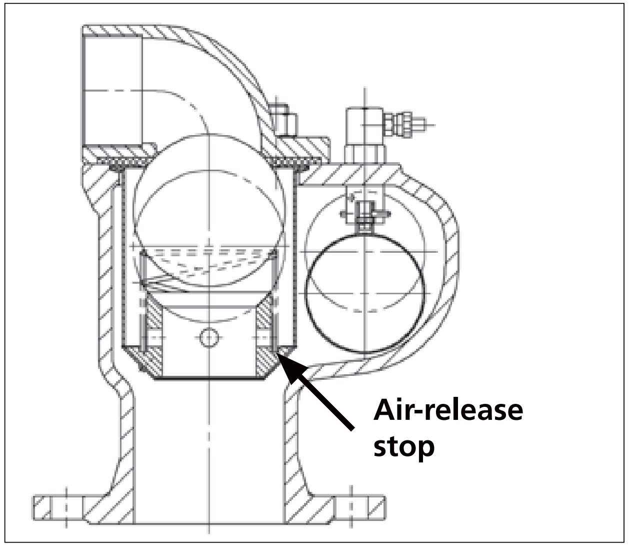

Fig. 7.7.12:
Air valve with air-release stop

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.

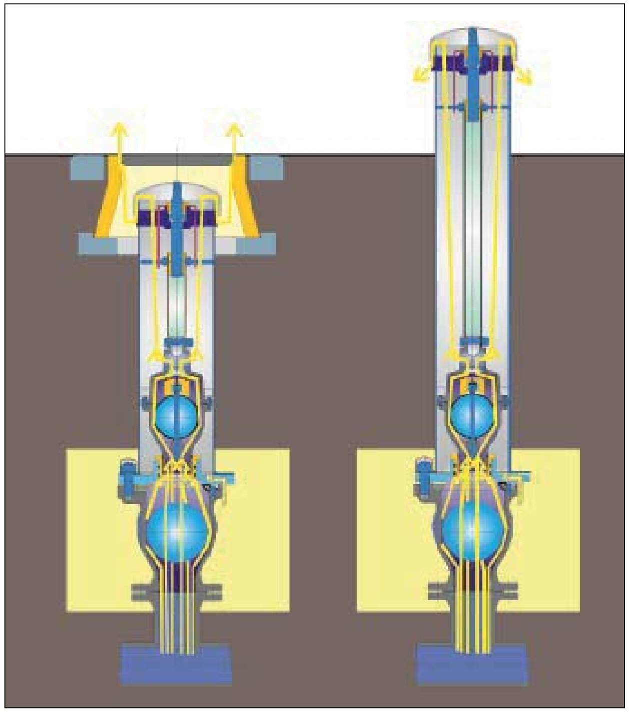

Fig. 7.7.13:
Air valve for buried installation

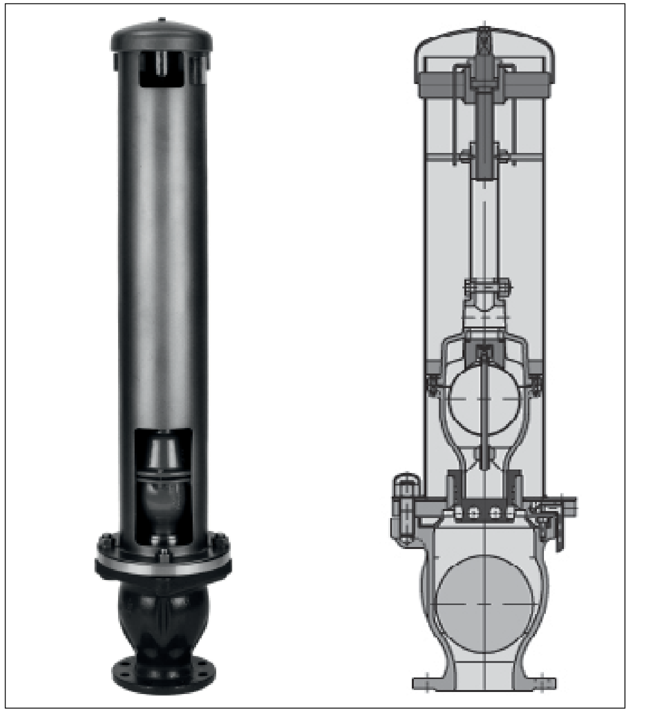

Fig. 7.7.14:
Air valve for buried installation – above ground design

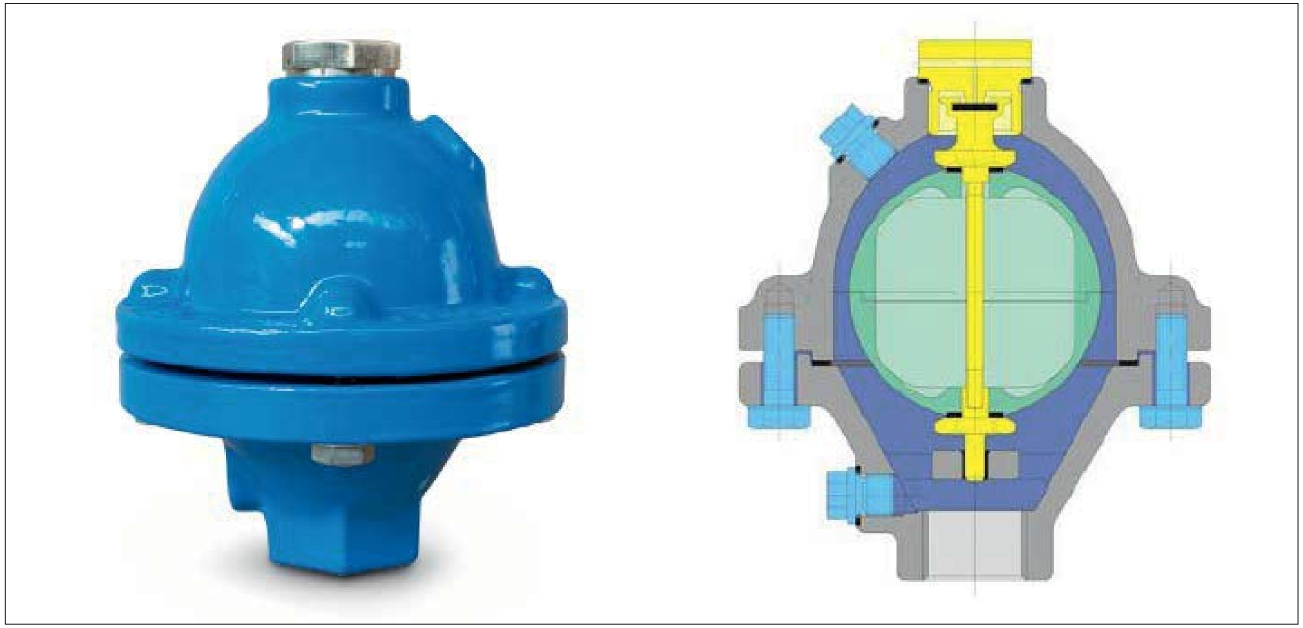

Fig. 7.7.15:
Air valve for small volumes of air with internal threaded connection

7.7.5 References Chapter 7.7

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[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.

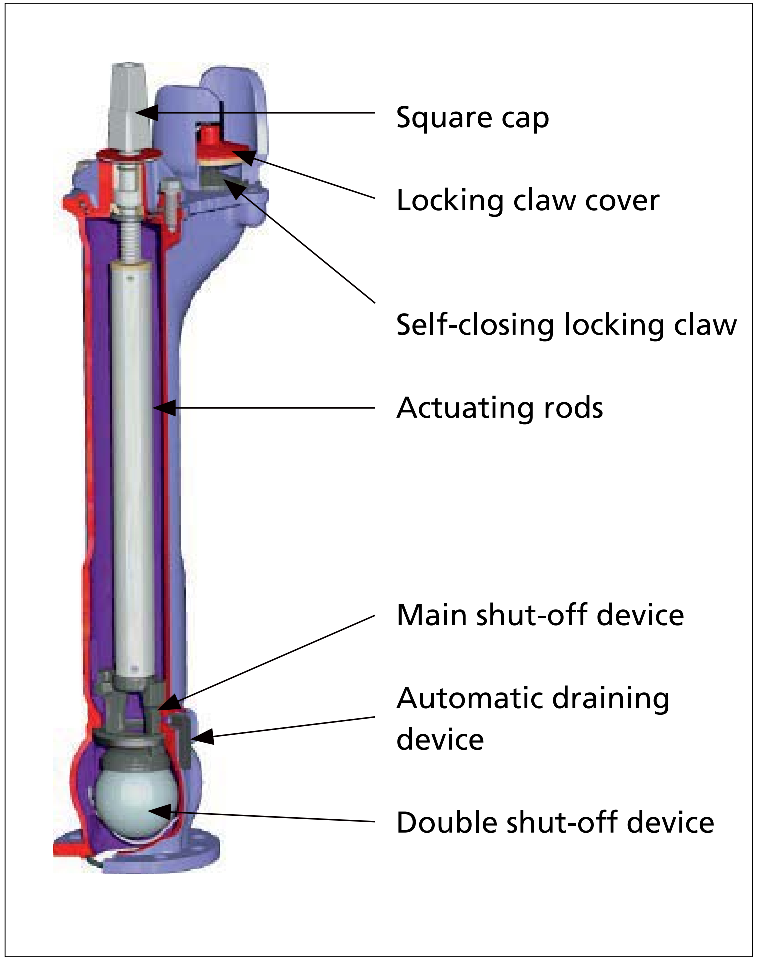

Fig. 7.8.4-01:
DN 80 underground hydrant – double shut-off, opening against the direction of flow – coating with epoxy resin powder

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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Auswahl, Einbau und Betrieb von Hydranten
[DVGW worksheet W 331 Selection, installation and operation of hydrants]
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Bereitstellung von Löschwasser durch die öffentliche Trinkwasserversorgung
[DVGW worksheet W 405 Provision of extinguishing water by the public drinking water supply system]
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Pillar fire hydrants
[Überflurhydranten]
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[7.8-04] EN 14339
Underground fire hydrants
[Unterflurhydranten]
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[7.8-05] EN 1074-6
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[Armaturen für die Wasserversorgung – Anforderungen an die Gebrauchstauglichkeit und deren Prüfung – Teil 6: Hydranten]
2008

[7.8-06] DVGW-Prüfgrundlage VP 325
Hydranten in der Trinkwasserverteilung – Anforderungen und Prüfung
[DVGW test specification VP 325 Hydrants in drinking water distribution – Requirements and testing]
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[7.8-07] EN 1563
Founding – Spheroidal graphite cast irons
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Wasserleitungen; Straßenkappe für Unterflurhydranten
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[7.8-11] DIN 14375-1
Standrohr PN 16; Standrohr 2 B
[Double outlet standpipes, nominal pressure 16]
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[7.8-12] DIN 3223
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8 Push-in joints

8 Push-in joints

Push-in joints act as axially movable joints and are able to withstand high loads. They remain leak tight even when the pipes are non-aligned or angularly deflected to the maximum extent.

8.1 General

For hundreds of years now, cast iron pipes have been fitted together with push-in joints to form pipelines. Modern-day push-in joints **(Fig. 8.1)** are quick and easy to connect and also provide some major technical and economic advantages when being installed.

With the introduction of European product standards EN 545 [8.1] and EN 598 [8.2] for ductile iron pipes, functional requirements for the joints were laid down for the first time. For reasons of compatibility, all that remained fixed was the diameter of the spigot end.

Fig. 8.1:
Ductile iron sewer pipes
with the TYTON® push-in joint

It is therefore the manufacturer's responsibility to design and produce the joint in such a way that the stringent functional requirements are met.

In EN 545 [8.1] and EN 598 [8.2], the following functional requirements are laid down for movable, non-restrained joints:

- angular deflection (as a function of nominal size, **Table 8.1**),
- axial mobility (declared by manufacturer)
- test conditions for the following pressures:
  1. positive internal hydrostatic pressure
  2. negative internal pressure
  3. positive external hydrostatic pressure
  4. cyclic internal hydrostatic pressure.

The maximum angular deflections for push-in joints can be seen from **Table 8.1.**

Table 8.1:
Angular deflection of the most important push-in joints

<table>
<tr><th rowspan="2">DN</th><th colspan="2">Maximum angular deflection</th></tr>
<tr><th>TYTON®</th><th>STANDARD</th></tr>
<tr><td>80 – 150</td><td rowspan="2">5°</td><td>5°</td></tr>
<tr><td>200 – 300</td><td>4°</td></tr>
<tr><td>350 – 400</td><td>4°</td><td rowspan="2">3°</td></tr>
<tr><td>500 – 600</td><td rowspan="3">3°</td></tr>
<tr><td>700 – 800</td><td>2°</td></tr>
<tr><td>900 – 1000</td><td rowspan="3">1,5°</td></tr>
<tr><td>1200 – 1400</td><td>1,5°</td></tr>
<tr><td>1600 – 2000</td><td>—</td></tr>
<tr><td colspan="3">Note: On a 6 m long pipe, an angular deflection of 3° produces a deflection of about 30 cm off the axis of the pipe or fitting installed previously.</td></tr>
</table>

When type tests are made to ensure that the functional requirements are met, the following binding limiting conditions have to be met **(Table 8.2)**.

Table 8.2:
Limiting conditions for the type tests on push-in joints

1	Joint of maximum annulus
2	Maximum angular deflection
3	Maximum axial withdrawal
4	Mean thickness of pipe wall
5	Aligned position with shear load

The programme of tests provided for restrained movable joints is substantially the same **(Chapter 9)**. Nominal sizes representative of given groupings of nominal sizes **(Table 8.3)** have to be tested in these tests.

Table 8.3:
Groupings of nominal sizes for type tests on push-in joints under EN 545 [8.1]

DN grouping	Preferred DN in each grouping
80– 250	200
300– 600	400
700– 1000	800
1100– 2000	1600

In Germany, the standard which governs designs of joints which meet the requirements described above is DIN 28603 [8.3]. The dimensions and permitted deviations (tolerances on dimensions) given in this standard are important for ensuring that the functional requirements are met. By specifying these characteristics, DIN 28603 [8.3] becomes one of the significant bases of DVGW Arbeitsblatt GW 337 [8.4], which is the document governing certification.

Under DVGW testing specification DVGW Arbeitsblatt GW 337 [8.4], which is mandatory for ductile iron pipes and fittings in Germany, the tests on the functional fitness for purpose of joints are carried out as externally monitored type tests. This attestation of conformity is an important part of the **FGR® quality seal** by which the members of EADIPS® (**E**uropean **A**ssociation for **D**uctile **I**ron **P**ipe **S**ystems) provide evidence of the suitability of their products (ductile iron pipes, fittings and valves) with regard to the safety, security, fitness for purpose, quality, hygiene and environmental compatibility required in water supply.
The requirements in these respects which are laid down by standards documents are fundamental to the ability of the ductile iron pipe system to perform properly and they can only be met by ensuring the following:

- The dimensions of the individual parts of the joint have to be properly matched to one another.
- The elastomeric gaskets have to withstand high stresses.

A joint of the present type will remain leak tight even under the highest loading from internal pressure and even when the end of a pipe is mis-aligned and angularly deflected to the maximum in the socket. The test certificates for the type tests which have to be carried out show this to be the case. The high dimensional stability of the sockets is one of the ways in which these characteristics are achieved

What all the push-in joint systems have in common is that they are able to move and act as longitudinally displaceable joints. Hence they do not transmit bending moments or longitudinal forces.

If longitudinal forces have to be transmitted from pipe to pipe or from pipe to fitting/valve, restrained designs of joint have to be used. These are dealt with in detail in **Chapter 9**. The long-term absence of leaks at the joints is ensured by the permanently elastic properties of the gasket itself but also by the match achieved by design between the spigot end of the pipe, the socket and the gasket.
Even when the permitted tolerances produce a worst-case pairing of dimensions at the joint and the spigot end is mis-

aligned to the maximum in the socket, the joint will remain leak tight under all the types of pressure-induced stress which may occur.

Because of their axial mobility and angular deflectability and because of the elasticity of the gaskets used, the joints are able to follow even large movements of the ground, e.g. mining subsidence or earthquakes, and to remain leak tight as they do so. A limit is set to the misaligning travel by the structural design, whereby forces due to differences in settlement are transmitted to the spigot end by the centralising collar and the gasket plays only a small part in transmitting the load.

Its sealing function is no more affected by high internal pressures than it is by partial vacuums or by pressures above atmospheric acting on the joint from outside.

For fitting in water and wastewater pipelines and sewers, the quality of the gaskets complies with EN 681-1 [8.5]

More detailed information on the gaskets can be found in **Chapter 13**.

8.2 Types of joint

8.2.1 The TYTON® push-in joint

The push-in joint most widely used in Germany is the TYTON® push-in joint system. There are standards for it over the range from DN 80 to DN 1400. Since it was launched on the German market in 1957, it has proved its worth a million times over in pipelines for drinking water, raw water, wastewater and sewage.

Fig. 8.2 is a cross-section showing the structural design of the joint.

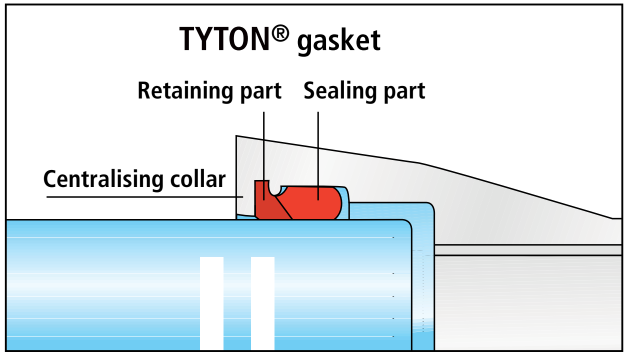

Fig. 8.2:
TYTON® push-in joint system

The significant dimensions of this joint are laid down in DIN 28603 [8.3] for the nominal sizes from DN 80 to DN 1400.

The sealing function in the TYTON® push-in joint is performed by a profiled gasket which consists of a softer rubber mixture (the sealing part) and a harder rubber mixture (the retaining part).

The design of the gasket can also be seen from **Fig. 8.2**. On being fitted into the socket, the gasket is seated in the sealing chamber with a small amount of precompression, i.e. the outside diameter of its softer sealing part is larger than the inside diameter of the sealing chamber in the socket. The result of this is that, at the sealing bead which it forms, about 30 % of the gasket projects into the cross-sectional area into which the spigot end of the pipe is going to be pushed. The suitably matched diameters of the sealing chamber, the sealing bead and the pipe cause the gasket to be highly deformed and hence a high pressure to be applied to the sealing surfaces.

If the spigot end of the pipe is mis-aligned, the gasket cannot be compressed to an excessive degree by an external load on the pipe because a structural limit is set for the mis-aligning travel firstly by the centralising collar and secondly by the limiter in the sealing chamber. Behaviour is similar when there are movements producing angular deflections, for which structural limits are likewise set.

The harder annular part of the gasket (the retaining part) is moulded to a claw-like shape and engages in the retaining groove in the socket. It holds the gasket firmly in position when the end of the pipe is pushed in and also later when a load is applied by the internal pressure.
Under a load applied by internal pressure, the retaining part is supported against the centralising collar and, by being so supported, closes off the gap between the centralising collar and the pipe. It thus prevents the gasket from being forced out even at very high internal pressures. The joint remains sealed even up to the bursting pressure of the pipe system.

The bead-like sealing part composed of softer rubber is compressed when the spigot end is pushed in in such a way that a reliable seal is obtained.

8.2.2 The STANDARD push-in joint

The structural design and the operation of the STANDARD push-in joint are comparable to those of the TYTON® push-in joint. In Germany, the dimensions of the joint are laid down in DIN 28603 [8.3] (Form C) for nominal sizes from DN 80 to DN 2000.

A schematic view of the joint is shown in **Fig. 8.3**.

The gasket consists of rubber of a single hardness.

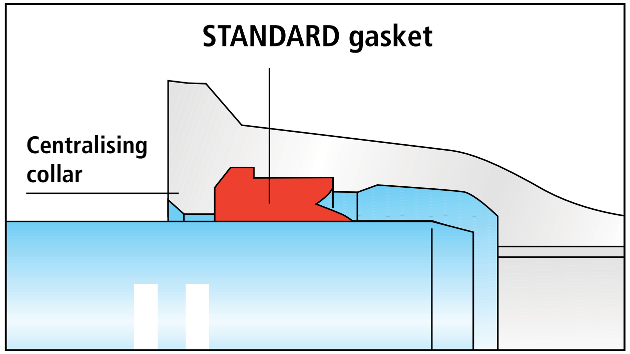

Fig. 8.3:
STANDARD push-in joint system

The maximum angular deflections for the TYTON® and STANDARD push-in joints can be seen from **Table 8.1**.

8.3 Fields of use

The purpose of joints between pipes is to help to provide a supply of satisfactory drinking water, to help to ensure that wastewater and sewage are safely disposed of and to help to protect bodies and watercourses of surface and underground water. Other fields of use for ductile iron pipes with push-in joints are in the transportation of raw water and process water and they are also used in irrigation and in systems for fire-fighting and snow-making – although it is mainly in a restrained form in which they are used in these latter cases **(Chapter 9)**.

In the case of pressure pipes of ductile iron, the TYTON® system and STANDARD system push-in joints are used in water pipelines to EN 545 [8.1] and in sewers and pipelines for sewage and wastewater to EN 598 [8.2].

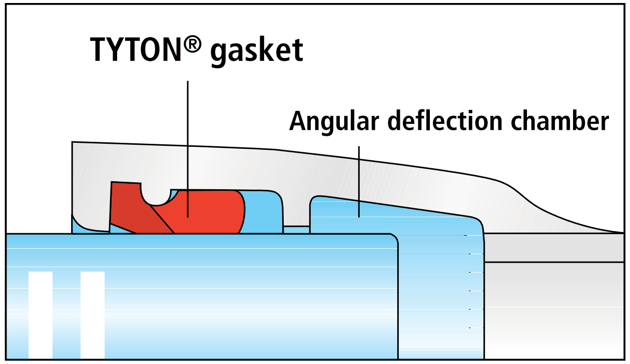

Fig. 8.4:
TYTON® long socket

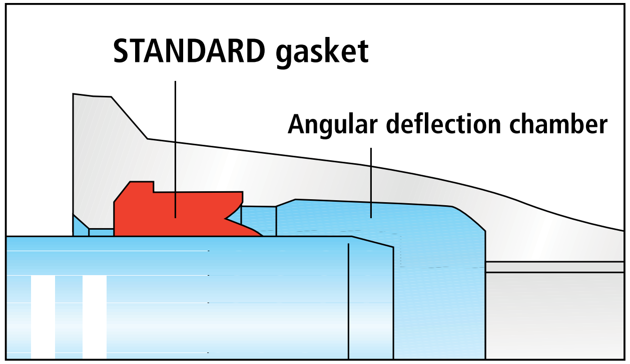

Fig. 8.5:
STANDARD long socket

Ductile iron fittings with the TYTON® or STANDARD push-in joint system are also covered by the above standards.

Ductile iron pipes and fittings with push-in joints are used in pressure pipelines as a function of the diameter of the pipes and the wall-thickness classes for allowable operating pressures as given in the above product standards and also in the manufacturers' catalogues.

For pipelines installed in unstable ground or in areas subject to mining subsidence, the TYTON® and STANDARD push-in joints are produced with a long socket (DIN 28603 [8.3], form B) which allows longer axial displacements than the usual form A socket **(Figs. 8.4 and 8.5)**.

As a percentage of the laying length of the pipe, axial displaceability increases to 0.8 % in the nominal size range from DN 700 to DN 1000. A marking line which can still be seen outside the socket shows the neutral position of the joint. If it is known exactly what axial movements can be expected, the spigot end can be inserted as far as the beginning or end, as the case may be, of the angular deflection chamber.

Pipes and fittings for ductile iron sewers and wastewater pipelines are designed for the operating pressures given in Table 5 of EN 598 [8.2]. A wide variety of stresses result from joints being used in, for example, gravity pipelines, pressure pipelines for sewage and wastewater, pressure pipelines for sludge and pipelines for leakage water. The joints have to withstand these stresses and to remain leak tight for decades.

This is also particularly true where pipelines are positioned in groundwater and when they are installed with large heights of cover.

A requirement which is particularly difficult to meet for push-in joints used in sewage and wastewater pipelines is resistance to root intrusion.
Extensive investigations carried out all over the world have shown that tree roots are able to penetrate into push-in joints sealed by rubber if the compression of the gasket is not high enough to resist the pressure exerted by the tip of the root. This is the case with lip seals for example. Because of the high tensile strength of ductile iron, it was possible

for the compression of the TYTON® and STANDARD gaskets to be selected, by design, to be so high that it can be relied upon that roots will not grow into the joint.
Root intrusion has in fact never been found in sewage or wastewater pipelines with properly assembled TYTON® push-in joints [8.6].

8.4 References

[8.1] EN 545
Ductile iron pipes, fittings, accessories and their joints for water pipelines –
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9 Restrained socket joints

9 Restrained socket joints

Restrained socket joints are needed when the forces generated by the internal pressure are not to be absorbed by thrust blocks or when the pipes and fittings are still to have a degree of mobility or flexibility. There are a number of different restraining systems. A variety of forces act on the pipeline and the resultant force arising from these has to be calculated. Some examples of installed pipelines are described. A further application is in the field of trenchless installation and replacement techniques (see Chapter 22).

9.1 General

A large number of forces, which can be divided into internal and external forces, act on pipelines and their joints.

External forces occur in the case of buried pipelines, e. g. in the form of stresses which are generated during the filling of the trench and the compaction of the fill; added to these there are the earth-load and the static and dynamic loads arising from the top cover and from traffic.

The internal forces are produced by whichever is the internal pressure in the given case (PEA or PFA).
PEA is the maximum hydrostatic pressure that a newly installed component is capable of withstanding for a relatively short duration, in order to insure the integrity and tightness of the pipeline.
PFA is the maximum hydrostatic pressure that a component is capable of withstanding continuously in service.

The internal pressure generates the following internal forces. In the wall of a pipe which is closed off at both ends, the internal pressure generates stresses which are in equilibrium within the pipe.

The internal pressure acts evenly in all directions. If the right-hand end of the closed-off pipe is imagined to be cut off and replaced by a flange socket and a blank flange **(Fig. 9.1)**, the force which acts on the area to which pressure is applied (the blank flange) is N:

$$N' = p \cdot \frac{d_i^2}{4} [kN] \quad (9.1)$$

$$N = p \cdot \frac{d_a^2}{4} [kN] \quad (9.2)$$

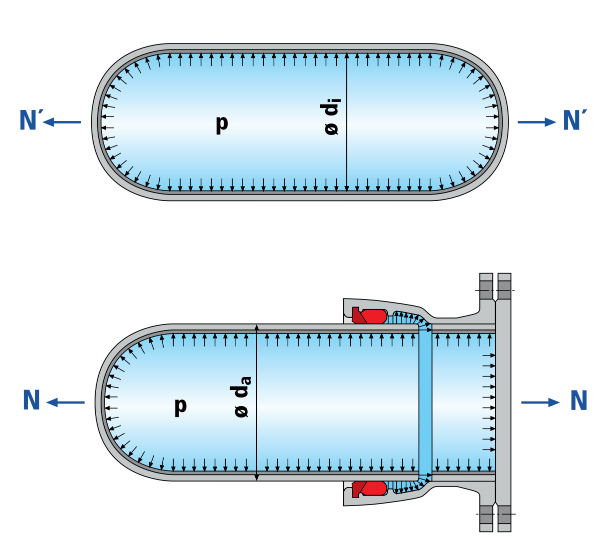

Fig. 9.1:
Forces due to internal pressure

The axial force has to be transmitted to the soil by thrust blocks installed at the left and right ends or by restrained joints. In this way, as in pressure testing as shown in **Fig. 9.2** for example, the axial force has to be transmitted to the soil over an enlarged area by suitable means in such a way that the allowable pressure per unit area on the soil is not exceeded.

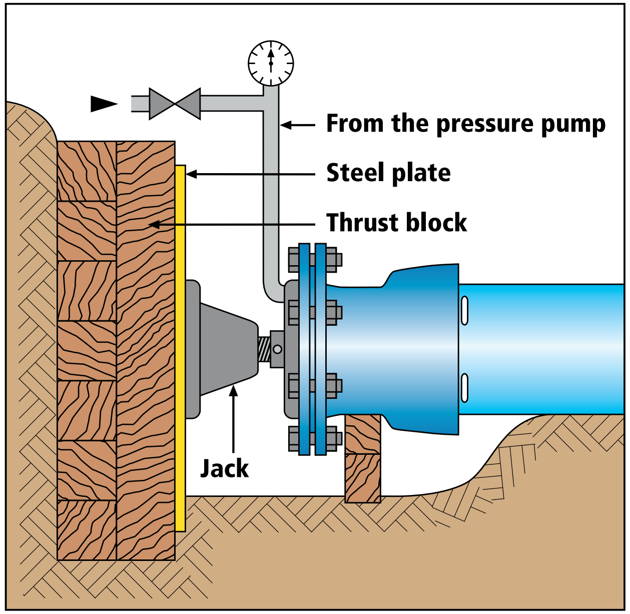

Fig. 9.2:
How a dead end is supported in a pressure test

The internal pressure also gives rise to forces *R* which have to be transmitted into the soil at changes of direction and cross-section and at branches and valves, doing so at bends for example in the way shown in **Fig. 9.3**.

$$R = 2 \cdot N \cdot sin\frac{\alpha_R}{2}[kN] \qquad (9.3)$$

The resultant force *R* can be transmitted into the soil either via thrust blocks, e.g. of concrete, or, via friction between the pipe and the soil, by means of restrained joints, or in other words by activating the passive soil pressure. The sizing and construction of concrete thrust blocks are dealt with in **Chapter 11**.

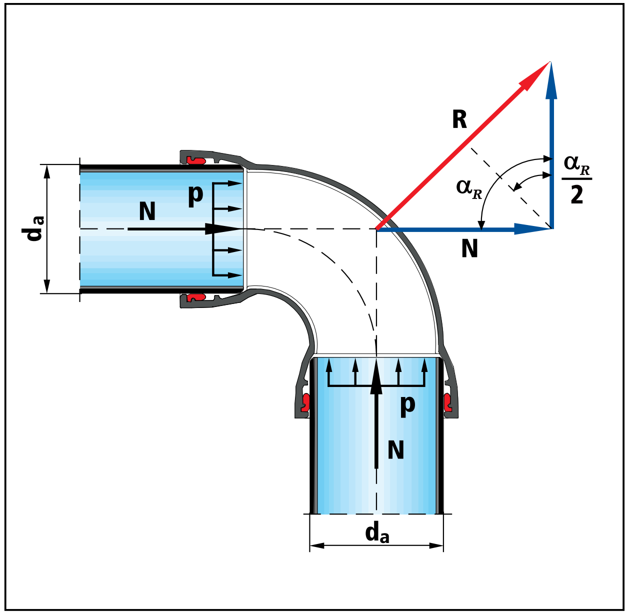

Fig. 9.3:
Resultant force R at a bend

9.2 Types of joint

If the joints which are used to install ductile iron pressure pipes and fittings are considered, they can be divided into the following two groups:

- **Socket joints** are used mainly for buried pipelines. They are considerably more economical to make and install than flanged joints. They can be deflected angularly and normally they are not restrained **(Chapter 8)**. The forces described above can be transmitted into the soil by using concrete thrust blocks **(Chapter 11)**.
- **Flanged joints** are used mainly in installations where the pipelines are not buried, such as for example as in pipeline-carrying tunnels, pump houses, waterworks, service reservoirs and industrial plants. They are rigid and restrained.

However, in practice there are cases where on the one hand restrained socket joints are required but on the other hand the joints need to be capable of deflecting angularly, e.g. in unstable soils where thrust blocks are not possible, in inner-city areas where there is not much room for thrust blocks, or where pipelines are pulled in in any trenchless installation techniques. Restrained socket joints are used in cases like these. **Chapter 22** on trenchless installation techniques provides detailed information on these techniques.

9.3 Bases for the design and dimensioning of restrained socket joints

DVGW-Arbeitsblatt GW 368 [9.1] specifies the following requirements to be met by restrained joints:

- Restrained joints must safely transmit the longitudinal forces which occur during the installation phase of pipelines, while they are being tested, and while they are in operation.
- The joints must withstand the forces which arise at the allowable test pressure
  $P_{Typ} = 1.5 \cdot PFA + 5$ bars.
- In the testing of restrained joints, it is permissible for slight displacements (of a few millimetres) to occur between the socketed ends of pipes and the plain ends. However, visible deformations of parts of restrained joints (tie-rods and the like) are not permissible.
- All parts of restrained joints must be adequately protected against corrosion.
- In new pipelines, it is not enough for only the joint between a bend and the next pipe to be restrained. The number of joints which need to be restrained depends on how high the test pressure is, on the friction between the outer wall of the pipes and the surrounding soil, on the level of the water table and on the length of the next directly adjoining pipe on either side of the bend. A minimum of 12 m on either side must have restrained joints (minimum dimensioning under GW 368 [9.1]). If a pipe connected to the bend is shortened, additional restraints are necessary.

A practical tip:
Do not use the shortened length of pipe at the bend itself **(Fig. 9.4)**.

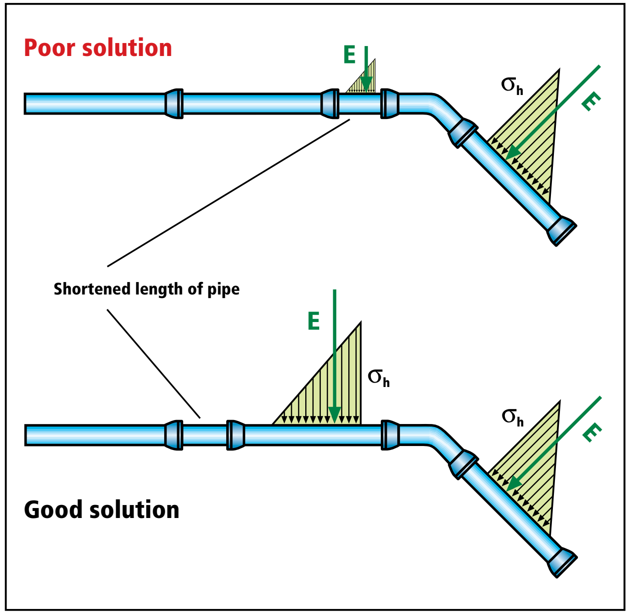

Fig. 9.4:
Increasing the activated soil resistance by connecting a pipe of the original length to the bend

Detailed information on determining the length *L* [m] of pipeline which has to be restrained can be found in **section 9.6**.

9.4 Types of restrained joint

A basic distinction which is made is between **positive locking** and **friction locking** designs. In positive locking joints, the forces are transmitted by elements which are formed to be integral with the pipes (e.g. welded beads on the spigot ends) in combination with force-transmitting elements. In the friction locking designs, the forces are transmitted by a frictional connection, e.g. by toothed elements which take a firm grip on the surface of the spigot end.

9.4.1 Positive locking joints

This type of restrained joint has existed since the end of the sixties.

At a fixed distance from the end of the pipe, a surrounding welded bead is applied to the spigot end. This is normally a factory applied build-up welding under a shielding gas.

In the case of cut pipes, the bead can be applied on the installation site by manual arc welding. For this purpose, a copper ring is fitted round the pipe as a guide and the bead is applied alongside it **(Fig. 9.5)**.

Rather than a welded bead, what may also be used is a BLS®/VRS®-T clamping ring **(Fig. 9.15)**.

Fig. 9.5:
A welded bead being applied on the installation site

In the case of fittings which have a spigot end, the bead which transmits force may also be integrally cast and machined. Its dimensions are the same as in the case of pipes of the nominal size concerned.

In the BAIO® positive locking system, the force-transmitting elements consist of integrally cast lugs on the spigot end and recesses in the sockets into which the lugs fit. The two parts are locked together by turning after the fashion of a bayonet joint. The system is used on fittings and valves.

Positive locking restrained joints with an internal retaining chamber

The positive locking joints with an internal retaining chamber which are widely used at the moment are the BLS® / VRS®-T, the Universal Ve and the BAIO® push-in joints. They cannot be combined with one another because there are differences between the force-transmitting elements, the form of the welded bead and the distance of the latter from the end of the pipe.

Positive locking restrained joints with an external retaining chamber

A design which has an external retaining chamber which has to be fixed separately to a collar on the socket is shown in **Fig. 9.13**. At the end face of the socket, the pipes have a collar extending round in a circle to which a ring containing the retaining chamber is fixed by means of hooked bolts. The longitudinal forces are transmitted from the welded bead on the spigot end, via a thrust-restraint ring, to the retaining chamber and from there via the hooked bolts to the socket of the next pipe.

Table 9.1 is an overview of the types of joint, their ranges of application and their allowable angular deflections.

Table 9.1: Overview of positive locking push-in joints

<table>
<tr><th colspan="2">Type of joint</th><th>Range of DN nominal sizes</th><th>Allowable operating pressure PFA [bar]</th><th>Allowable angular deflection [°]</th></tr>
<tr><td rowspan="14">Positive locking restrained joints with an internal retaining chamber</td><td>TIS-K®</td><td>100–300</td><td>As stated by manufacturer</td><td>3</td></tr>
<tr><td rowspan="6">UNIVERSAL Ve</td><td>350–400</td><td rowspan="6">As stated by manufacturer</td><td>3</td></tr>
<tr><td>500–800</td><td>2</td></tr>
<tr><td>900</td><td>1,5</td></tr>
<tr><td>1000</td><td>1,2</td></tr>
<tr><td>1200</td><td>1,1</td></tr>
<tr><td>BLS® / VRS®-T</td><td>80–150</td><td>As stated by manufacturer</td><td>5</td></tr>
<tr><td></td><td>200–300</td><td></td><td>4</td></tr>
<tr><td></td><td>400</td><td></td><td>3</td></tr>
<tr><td></td><td>500</td><td></td><td>3</td></tr>
<tr><td></td><td>600</td><td></td><td>2</td></tr>
<tr><td></td><td>800–1000</td><td></td><td>1,5</td></tr>
<tr><td>BAIO®</td><td>80–300</td><td>As stated by manufacturer</td><td>≤ 3</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Positive locking restrained joints with an external retaining chamber</td><td rowspan="2">Hydrotight</td><td>400–500</td><td rowspan="2">As stated by manufacturer</td><td>3</td></tr>
<tr><td>600–700</td><td>2</td></tr>
</table>

The TIS-K® system

In the TIS-K® restrained joint **(Fig. 9.6)**, force is transmitted from one pipe to the next, or from a fitting, via the welded bead and the retaining ring, into the socket. The retaining ring is slit or in segments and is matched to the outside diameter of the pipes.
The construction of the TIS-K® restrained push-in joint is the same for both pipes and fittings.

The joint still has the full original angular deflectability of the TYTON® joint **(Table 9.1)**.

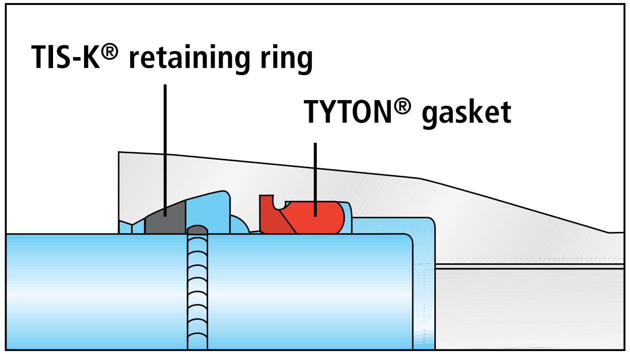

Fig. 9.6:
The TIS-K® restrained push-in joint

The UNIVERSAL Ve system

Longitudinal force is transmitted by the retaining ring of the TIS-K® system, whereas the gasket is part of the STANDARD system (form C under DIN 28603 [9.2]) **(Fig. 9.7)**.
The allowable angular deflections for pipes are given in **Table 9.1**.

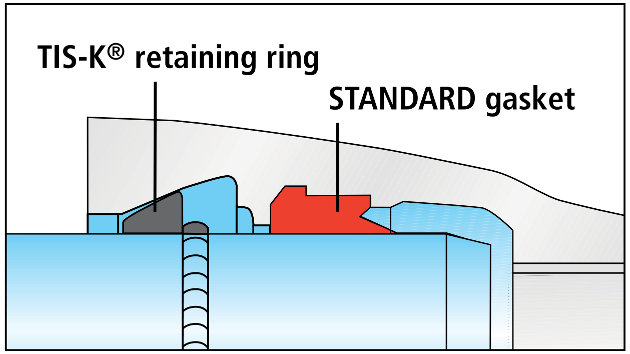

Fig. 9.7:
The UNIVERSAL Ve restrained push-in joint

The BLS®/VRS®-T system

The positive locking BLS®/VRS®-T system allows the two assembly operations

- make a seal, and
- lock,

to be broken down into two separate steps which have to be performed and checked one after the other. In the first step, the push-in joint (TYTON® or VRS®-T) is assembled. In a second step, it is then made restrained by the insertion of locking elements.

In the nominal size range from DN 80 to DN 500, the locking elements are locks **(Figs. 9.8 and 9.9)**, whereas from DN 600 to DN 1000 they are wide plate-like segments **(Fig. 9.10)**. In the case of the locks, a distinction has to be made between the “right” and “left” types and they have to be inserted as detailed in the installation instructions. When the assembly process has been completed, a rubber catch is inserted in the opening in the socket face which is still open to prevent the locks from shifting **(Fig. 9.9)**.

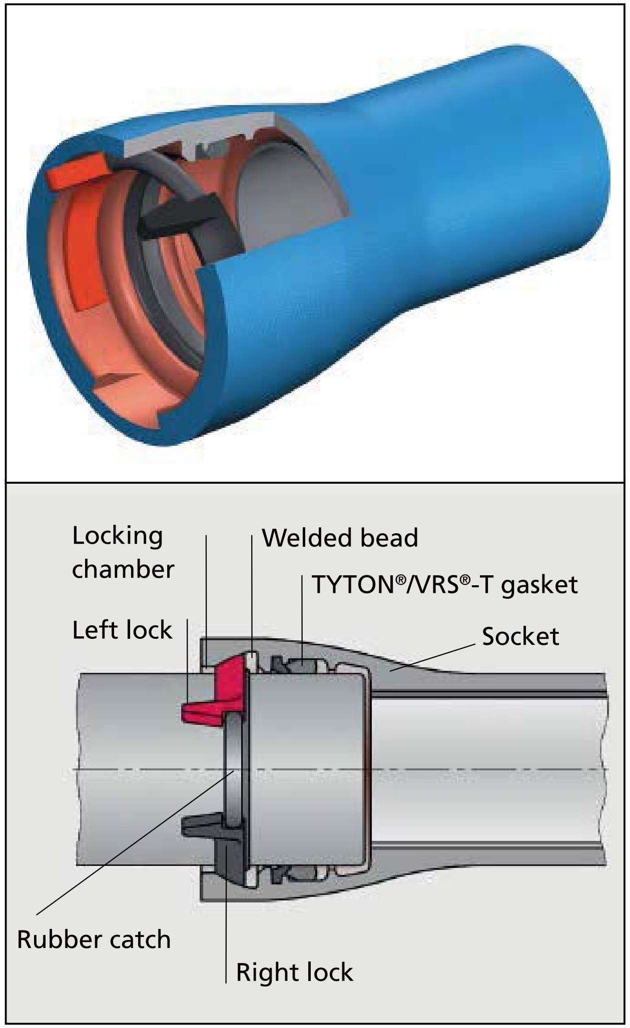

Fig. 9.8:
BLS®/VRS®-T restrained push-in joint with locks (DN 80 to DN 500 nominal sizes)

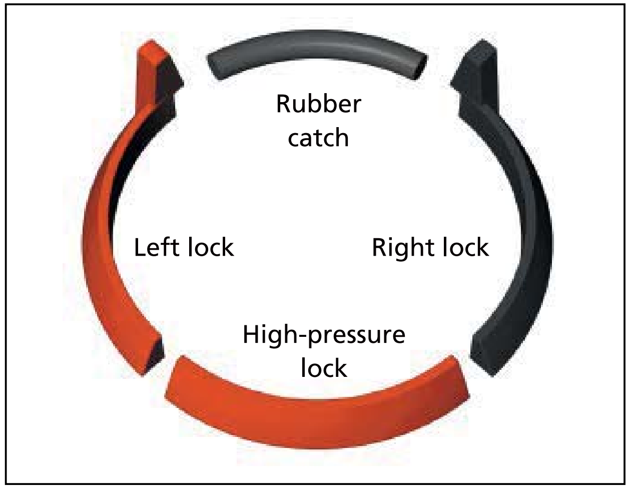

Fig. 9.9:
Layout of the locks and the rubber catch in the BLS®/VRS®-T joint (DN 80 to DN 500 nominal sizes); high-pressure lock only for DN 80 to DN 250 nominal sizes

In the case of the DN 600 to DN 1000 nominal sizes, the wide plate-like locking segments are inserted in the axial direction through the twin openings in the socket face and are then evenly distributed around the circumference. The openings should preferably be positioned at the crest of the pipe to simplify the process of inserting the locks **(Fig. 9.10)**.

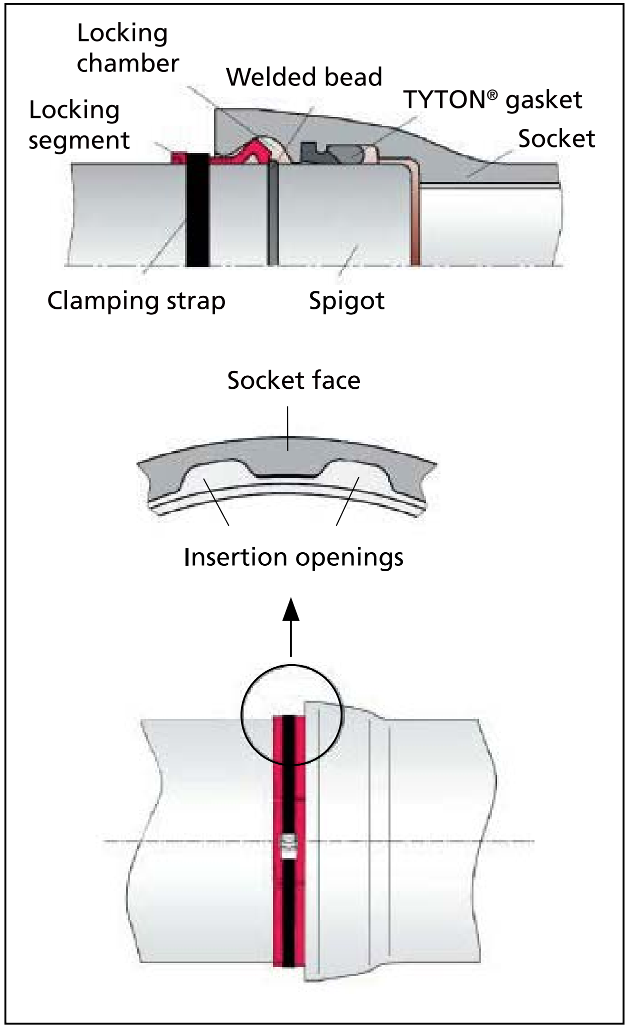

Fig. 9.10:
BLS® restrained push-in joint with insertion openings in the socket face and a clamping strap (DN 600 to DN 1000 nominal sizes)

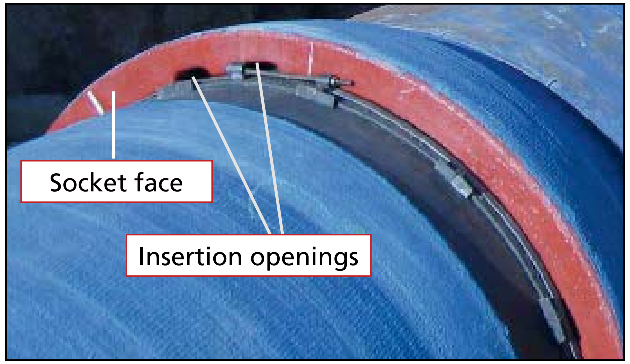

Fig. 9.11:
Fixing in place of the locking segments by a clamping clip

Fig. 9.12:
BIAO® system flanged socket (left) and spigot-ended dead end (right)

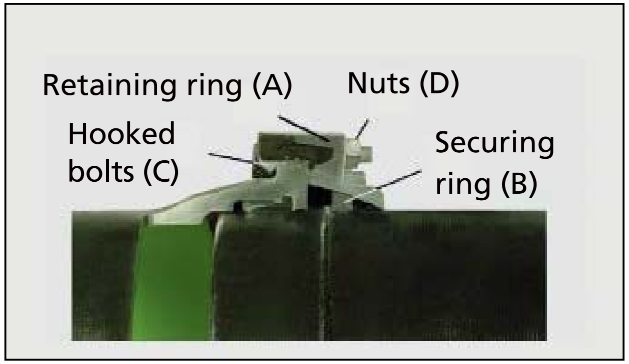

Fig. 9.13:
Cross-section through the Hydrotight positive locking external joint

Once the locking segments have all been inserted in the gap at the socket, they are all moved around the circumference until none of the humps on them can be seen through the openings in the socket and they are then fixed in place with a clamping strap or a clamping clip **(Fig. 9.11)**.

The BAIO® system

The positive locking BAIO® system is used for fittings and valves. On their outer face, the spigot ends carry four lugs evenly distributed around the circumference, while the sockets have a retaining chamber whose front wall contains four receiving openings which match the lugs on the spigot end. Once the spigot end has been inserted in the socket, it is turned through an eighth of a revolution and thus locked, on the bayonet principle.

Fig. 9.12 shows a positive locking BAIO® socket and the matching BAIO® spigot end of a dead end of the kind which is used as an end closure in a pressure test. For this purpose, the dead end has a screw-thread for a venting plug and two hand-levers to allow it to be turned.

The *Hydrotight* system

Fig. 9.13 is a cross-section through a joint of this kind when it has been completely assembled. Before the joint is assembled, the retaining ring (A) and the slit securing ring (B) are slid onto the spigot. When the joint has been made, the two rings are drawn up against the socket and screwed tight with the hooked bolts (C) and nuts (D). The joint is then extended so that all the force-transmitting members are resting against one another.

9.4.2 Friction locking push-in joints

Table 9.2 provides an overview of the types of friction locking push-in joint and their ranges of application and allowable angular deflections.

Type of joint	Range of DN nominal sizes	Allowable operating pressure PFA [bar]	Allowable angular deflection [°]
BRS®/ TYTON SIT PLUS®	80–300	As stated by manufacturer	3
	350–600		2
BLS®/VRS®-T with clamping ring	80–150	As stated by manufacturer	5
	200–300		4
	400		3
	500		3
STANDARD Vi	350–400	As stated by manufacturer	3
	500–600		2
Novo SIT®	80–400	As stated by manufacturer	3
	450–700		2
	800		1
Universal Vi	350–400	As stated by manufacturer	3
	500–700		2
BAIO-SIT	80–300	As stated by manufacturer	3
Hawle-STOP	80–200	As stated by manufacturer	3
Hydrotight internal	80–300	As stated by manufacturer	3
	400		3
	500		2
Hydrotight external	80–500	As stated by manufacturer	3
	600–700		2
The manufacturer's applications engineering department should be consulted before these joints are used in culverts or above-ground pipelines and before they are installed on slopes or in casing tubes or pipes or in utility tunnels.			

Table 9.2:
Overview of friction locking push-in joints

The BRS® system

In this system, a TYTON SIT PLUS® gasket which has stainless steel segments vulcanised into it **(Fig. 9.14)** is used in place of the usual gasket. These segments have sharp, hardened teeth which cut into the surface of the end of the pipe.

The BLS®/VRS®-T system with a clamping ring

With this system, the application of welded beads to pipes which have been shortened on site can be dispensed with. Instead of the locks, two halves of a clamping ring are inserted in the insertion openings in the socket and are clamped onto the spigot end with bolts **(Fig. 9.15)**.

On their inner side, the clamping rings have toothed pressure-applying surfaces. Under the rules shown below, their use is confined to buried pipelines and the rules also state that they may only be used in pipe sockets **(Fig. 9.16)**.

Clamping rings should not be used for trenchless installation techniques or in culvert or bridge-carried pipelines or on slopes or in casing tubes or pipes or in utility tunnels.

Fig. 9.14:
The BRS® friction locking push-in joint

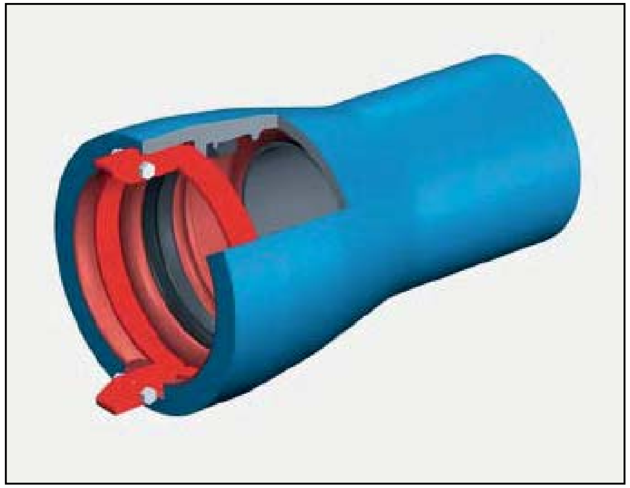

Fig. 9.15:
The BLS®/VRS®-T friction locking push-in joint with a clamping ring

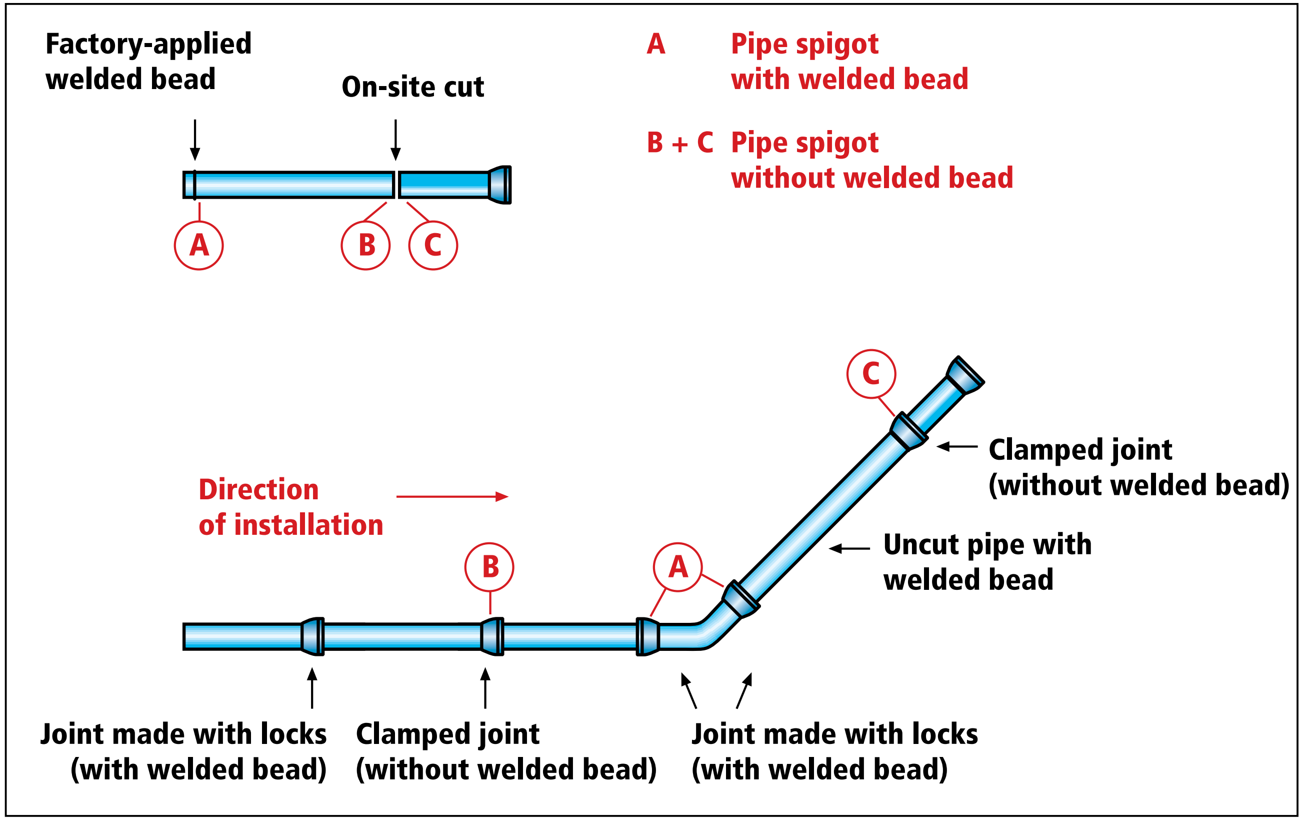

Fig. 9.16:
Rules for the use of clamping rings

The TYTON SIT PLUS® system

With the introduction of the TYTON SIT PLUS® system **(Fig. 9.17)** in 2003, the range of application of the Tyton SIT® friction locking joint was effectively widened when it was replaced by the TYTON SIT PLUS® joint.

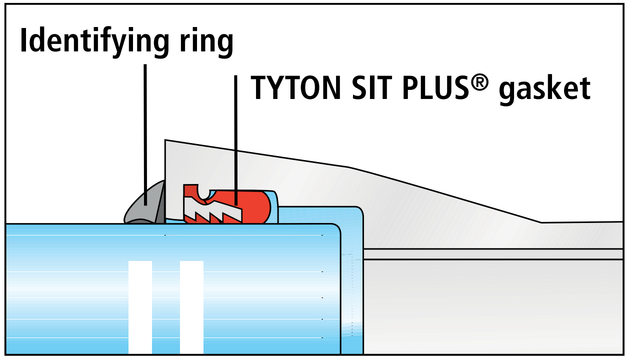

Fig. 9.17:
The TYTON SIT PLUS®
friction locking push-in joint

The STANDARD Vi system

The STANDARD Vi system operates on a similar principle **(Fig. 9.18)**. Stainless steel segments with hardened teeth which have been ground to a sharp edge are vulcanised into the STANDARD gasket. The teeth engage in the surface of the spigot end and thus transmit the longitudinal forces.

The Novo SIT® system

The socket has a integrally cast retaining chamber. In contrast to the TYTON SIT PLUS® system, the sealing and retaining functions are separate from one another. The design of the retaining ring causes it always to remain resting against the retaining chamber as the spigot end is inserted, which means that the travels for extending the joint are only short. **(Fig. 9.19)**.

The UNIVERSAL Vi system

In this case too the sealing and longitudinal-force-transmitting functions are separate from one another. The retaining, i.e. transmitting, function is performed by the Novo SIT® ring whereas the STANDARD gasket does the sealing **(Fig. 9.20)**.

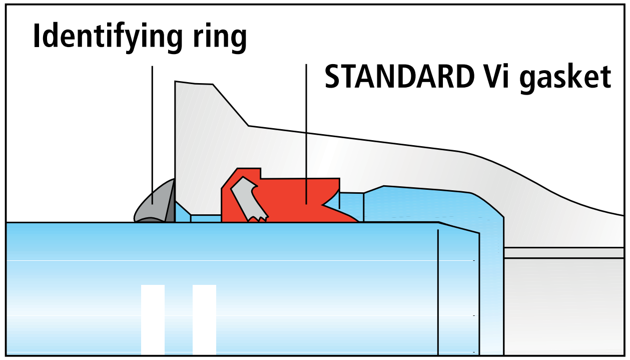

Fig. 9.18:
The STANDARD Vi friction locking push-in joint

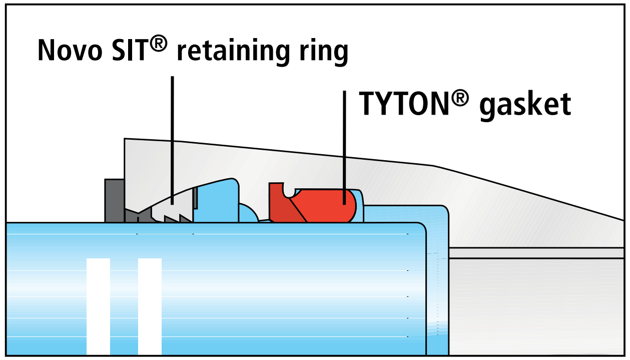

Fig. 9.19:
The Novo SIT® friction locking push-in joint

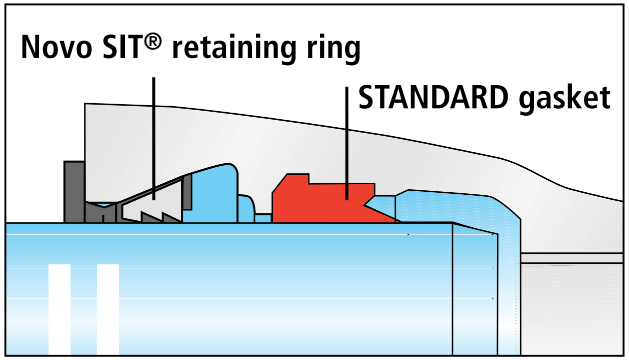

Fig. 9.20:
The UNIVERSAL Vi friction locking push-in joint

The BAIO-SIT and Hawle-STOP systems

In this case too the sealing and longitudinal-force-transmitting functions are separate from one another. The retaining, i.e. transmitting, function is performed by an annular retaining chamber which is locked on the bayonet principle to the external retaining cams on the BAIO® socket **(Fig. 9.21)**.

The retaining chamber holds a rubber ring which has stainless steel segments vulcanised into it. These have sharp, hardened teeth which cut into the surface of the spigot end.

In the Hawle-STOP joint the retaining teeth are inset into a polyamide ring **(Fig. 9.22)**.

Fig. 9.21:
The BAIO-SIT friction locking push-in joint

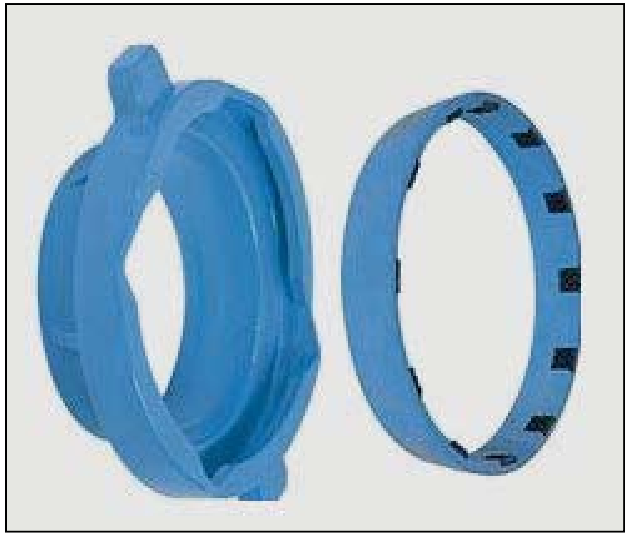

Fig. 9.22:
The Hawle-STOP friction locking joint

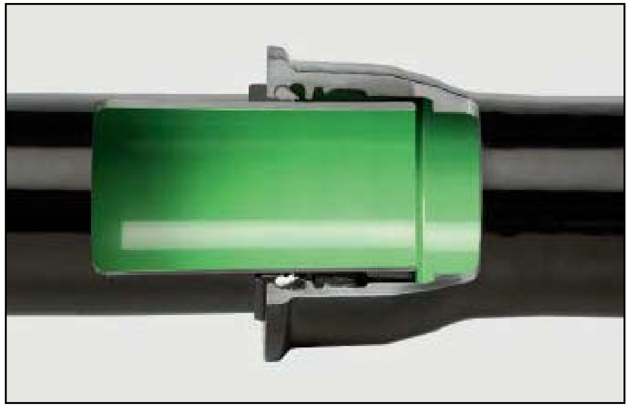

Fig. 9.23:
The Hydrotight internal friction locking joint (double-chambered socket)

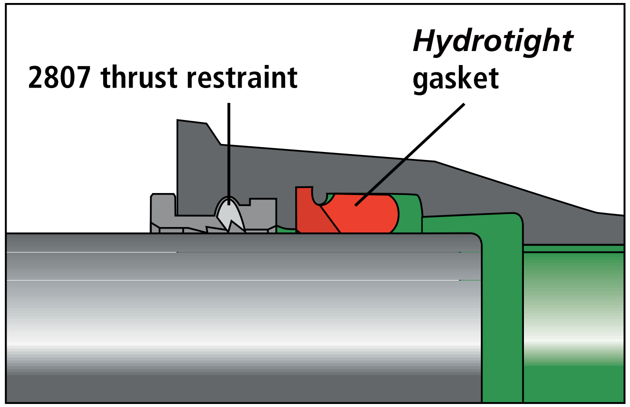

Fig. 9.24:
View in section of the Hydrotight internal friction locking joint (twin-chambered socket)

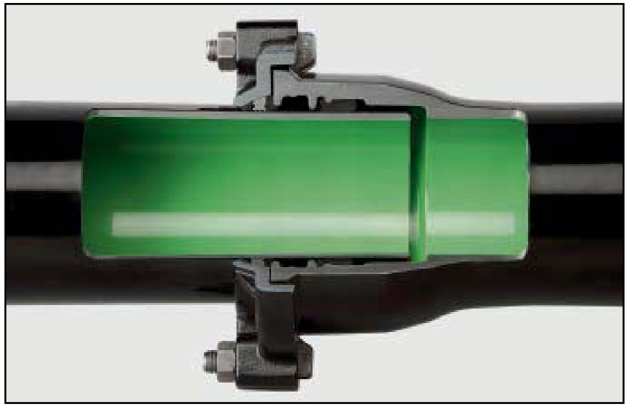

Fig. 9.25:
The Hydrotight external friction locking joint

The *Hydrotight* internal system (double-chambered socket)

There are two chambers extending round in a circle in the socket. One chamber holds the *Hydrotight* gasket while the thrust-restraint ring, an elastomer ring with toothed segments vulcanised into it, is seated in the second chamber. This ring also has a sealing lip which stops soil and moisture from penetrating into the joint. **(Figs. 9.23 and 9.24)**.

The *Hydrotight* external system

A thrust-restraint ring of ductile iron is fastened to the external collar on the socket by hooked bolts. This ring, together with the socket face, creates a chamber in which an elastomer ring with toothed segments vulcanised into it is seated. This ring also has small sealing lips which stop soil and moisture from penetrating into the joint. The toothed segments transmit the longitudinal forces from the socket to the next pipe **(Figs. 9.25 and 9.26)**.

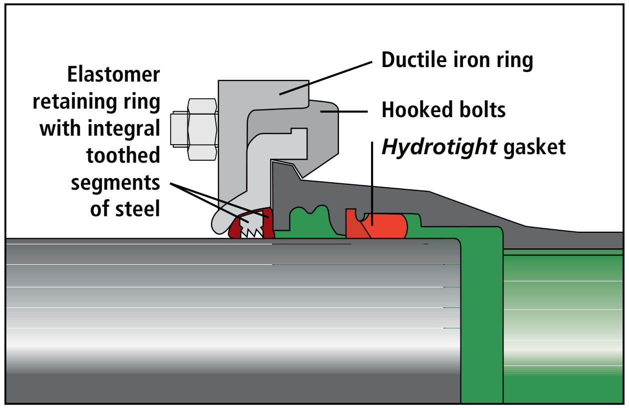

Fig. 9.26:
View in section of the Hydrotight external friction locking joint

9.4.3 Friction locking screwed-socket joints

Friction locking screwed-socket joints are used mainly for repairs. In the case of these joints a distinction is made between systems using locking elements and ones using a clamping ring.

In the case of the restrained screwed-socket joint which uses locking elements, the collar of the screwed ring, to which a wrench can be applied, contains tangential insertion passages, rectangular in cross-section, which are inclined in the inward direction in the opposite direction to that in which the ring is screwed in. Toothed wedges are driven in through these insertion passages and these cut into the spigot end and produce a restrained joint **(Fig. 9.27)**.

The screwed-socket systems which use a clamping ring exist in two variants: the variant using a single clamping ring **(Fig. 9.28)** and the variant using a special clamping ring **(Fig. 9.29)**.

Table 9.3 provides an overview of the friction locking designs of screwed-socket joint and of their ranges of application, operating pressures and allowable deflections.

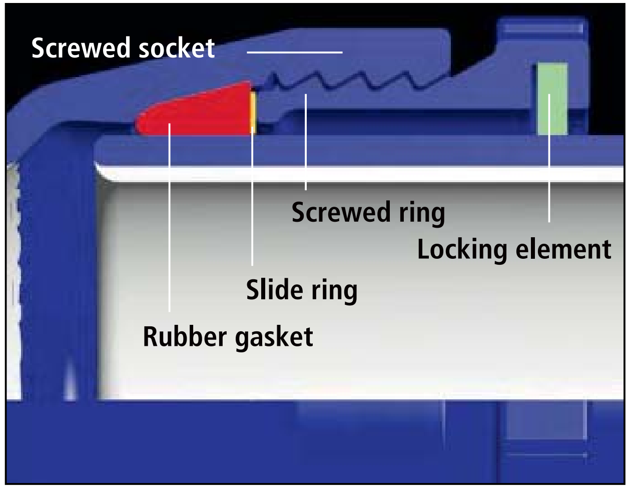

Fig. 9.27:
A restrained screwed-socket joint using locking elements

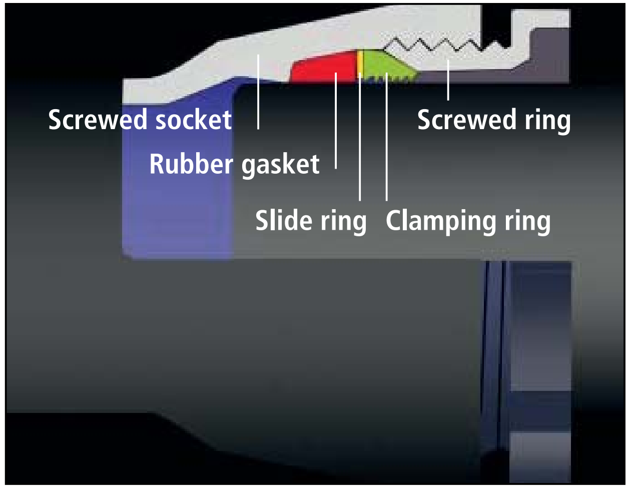

Fig. 9.28:
A screwed-socket joint using a single clamping ring

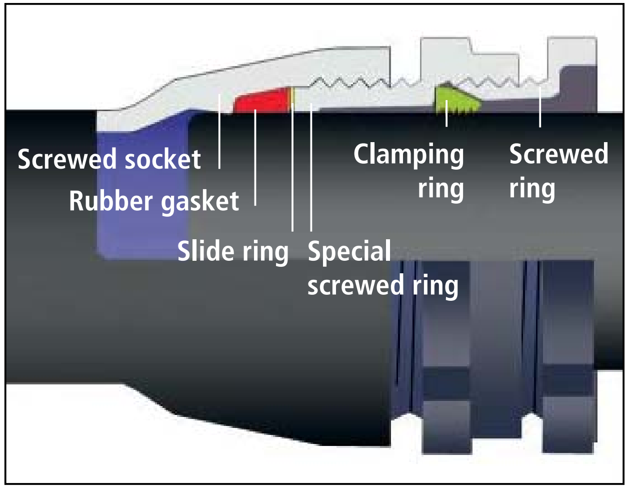

Fig. 9.29:
A screwed-socket joint using a special clamping ring

Table 9.3:
Range of application and angular deflectability of friction locking screwed-socket joints

Type of joint	Range of DN nominal sizes	Allowable operating pressure PFA [bar]	Allowable angular deflection [°]
Using locking elements	80–300	As stated by manufacturer	2
Using clamping ring	80–300	As stated by manufacturer	3
Using special clamping ring	300–400	As stated by manufacturer	3

Table 9.4:
Range of application of the type M clamp

Nominal size DN	Allowable operating pressure PFA [bar]	Angular deflection [°]
80 – 300	As stated by manufacturer	3
400		

9.4.4 Clamps for retrospective fitting

The clamp consists of two or three identical parts which are clamped together by bolts. The restraint is produced by the interaction between the retaining part, which engages behind the socket, and the toothed pressure-applying plates, which are pressed against the pipe. Clamps (type M) **(Fig. 9.30)** can be used for TYTON® joints and screwed-socket joints.

Clamps are fitted once the socket joint has been connected; the joint retains its full capacity for angular deflection.

Fig. 9.30:
A restrained push-in joint fitted with clamps (type M)

The range of application of the type M clamp is shown in **Table 9.4**.

9.5 Type tests

The manufacturer has to demonstrate the fitness for use of restrained joint systems by carrying out tests under EN 545 [9.3].

The requirements and testing conditions for this demonstration are dealt with in detail in **Chapter 8** "Push-in joints". For the "Tested" mark of the DVGW (German Technical and Scientific Association for Gas and Water) to be obtained, these fitness tests have to be carried out under external monitoring. In the final analysis, it is the details given in the manufacturers' catalogues which determine the field of application of restrained joints.

9.6 Determining the forces which occur and the lengths of pipe to be restrained

At changes of direction and cross-section and at branches, the internal pressure generates forces which have to be transmitted into the ground.

In DVGW Arbeitsblatt GW 368 [9.1], detailed rules for calculating these forces are given and are printed there in the form of easily used tables for the standard cases. The most important steps in the calculation process will be explained below by taking a bend fitting as an example.

At the bend, a resultant force R_N acts in the direction of the line bisecting the angle of the bend. The projected area of the bend acts on the compacted filling of the trench with this force. The pressure per unit area which this produces is generally higher than the compressive strength of the soil resting against the bend.

The soil deforms and the bend shifts in the direction of the resultant R_N.

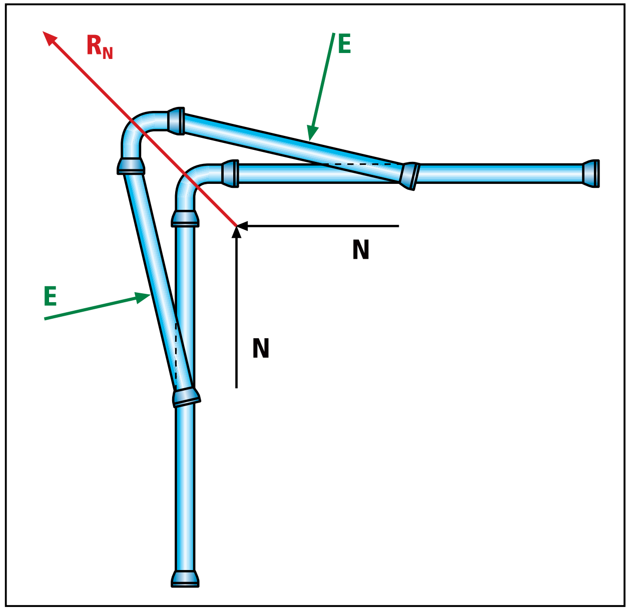

Fig. 9.31:
Activation of the soil resistance E by a shift of the bend on the line bisecting the angle

Because the pipe ends inserted in the sockets of the bend are locked but are able to deflect, the first two pipes undergo a sideways displacement when this shift in position occurs; as they are displaced, they activate the soil resistance E over their projected lateral area (diameter · length), as shown in **Fig. 9.31**.

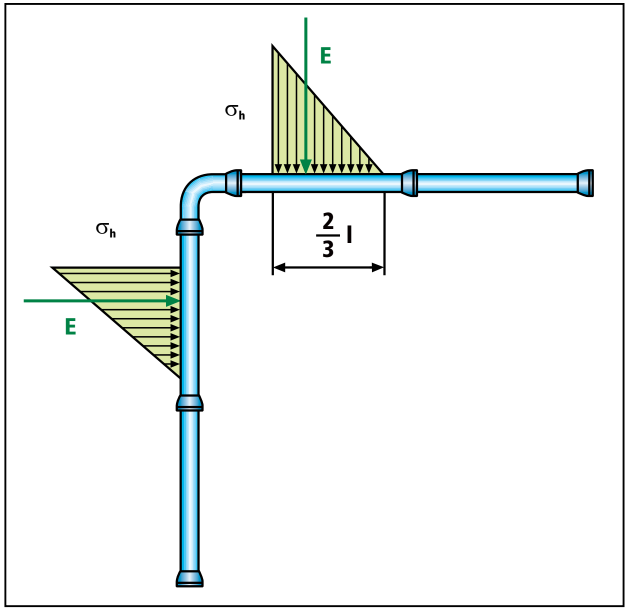

Fig. 9.32:
Soil resistance E that is activated

$$E = \frac{all.\sigma_h \cdot \frac{2}{3} \cdot l \cdot DE}{2} [kN] \qquad (9.4)$$

For safety reasons, only two thirds of the length of the pipes is used in the equation **(Fig. 9.32)**.

A practical tip

The shift of the bend which causes the soil resistance to be activated results in angular deflection of the two pipes in the sockets of the bend. If the two pipes are to deflect to a neutral angle, the shift of the bend can be anticipated by setting the two pipes to a negative deflection **(Figs. 9.33 and 9.34)**.

The other restrained pipes which follow the two mentioned will only be displaced axially, when the skin friction R will be activated. This friction depends on the length L [m] of the restrained section of the pipeline and on the weights of the earth load, the pipe and the filling of water.

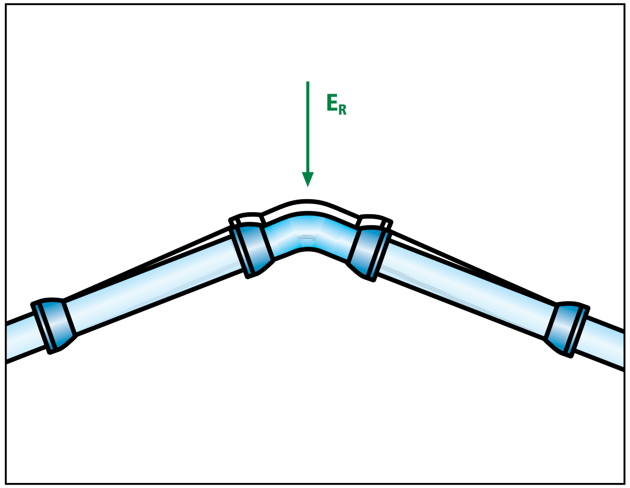

Fig. 9.33:
Anticipating the shift of the bend – negative angular deflections at the bend

Fig. 9.34:
Negative angular deflections at a bend – Checking the shift of the bend to the neutral-angle position

Frictional force from the earth load at the top of the pipe

The first frictional force R_1 is determined from the earth load above the pipe **(Fig. 9.35)**.

$$R_1 = \mu \cdot G_B = \mu \cdot DE \cdot H \cdot \gamma_B \left[kN/m\right] \tag{9.5}$$

Frictional forces from the earth load, filling of water and weight of pipe at the underside of the pipe

The second frictional force R_2, due to the earth load above the pipe and to the weight of the pipe and its filling of water, acts on the underside of the pipe **(Fig. 9.35)**. The full length of the pipe is used in the calculation in this case.

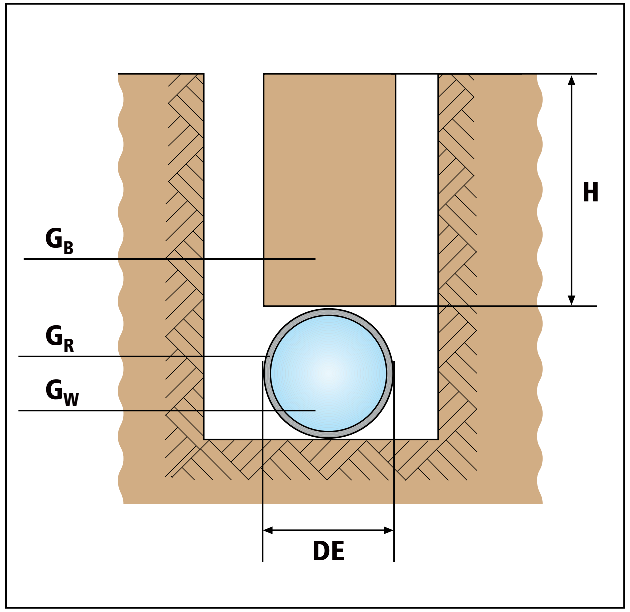

Fig. 9.35:
To calculate the friction due to the earth load and to the weight of the pipe and its filling of water

$$R_2 = \mu \cdot (G_B + G_W + G_R)[kN/m] \quad (9.6)$$

$$G_B = DE \cdot H \cdot \gamma_B [kN/m] \quad (9.7)$$

$$G_W = (DE)^2 \cdot \frac{\pi}{4} \cdot \gamma_W [kN/m] \quad (9.8)$$

$$G_R = \pi \cdot DE \cdot e_{min} \cdot \gamma_R [kN/m] \quad (9.9)$$

The weight G_R [kN/m] of the pipe can be found from the handbooks issued by ductile iron pipe manufacturers.

Frictional forces due to soil resistance

The third frictional force R_3 derives from the soil resistance E against the first pipes, multiplied by the coefficient of friction.

$$R_3 = \mu \cdot E[kN] \quad (9.10)$$

Note: this frictional force acts only on the first pipe after the bend.

The soil resistance E acting on the pipe is transmitted to the bend as a transverse force E_Q. This transverse force E_Q acts in opposition to the normal force N produced by the internal pressure **(Fig. 9.36)**.

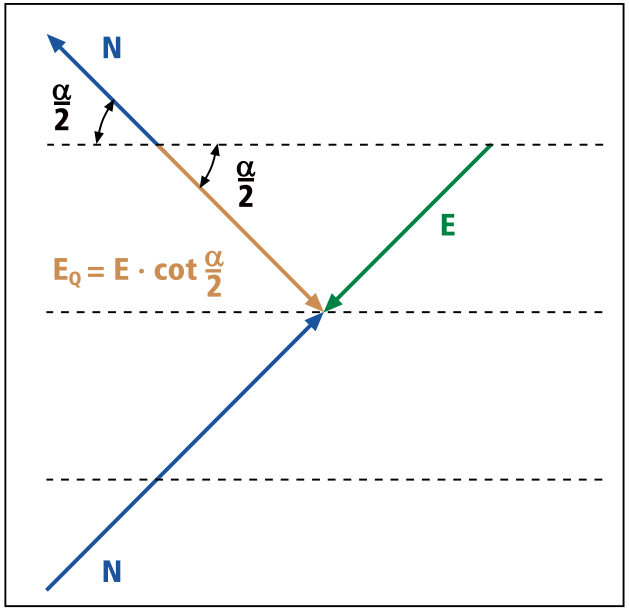

Fig. 9.36:
Determining the transverse force due to the soil resistance E

$$E_Q = E \cdot cot \frac{\alpha}{2} [kN] \quad (9.11)$$

$$cot \frac{\alpha}{2} = \frac{E_Q}{E} \quad (9.12)$$

Balance of the forces at the bend

For a balanced state **(Figs. 9.37 and 9.38)**, the forces due to the internal pressure and the restraining forces due to the total friction R and the transverse force E_Q must be equal to one another (equation 9.16).

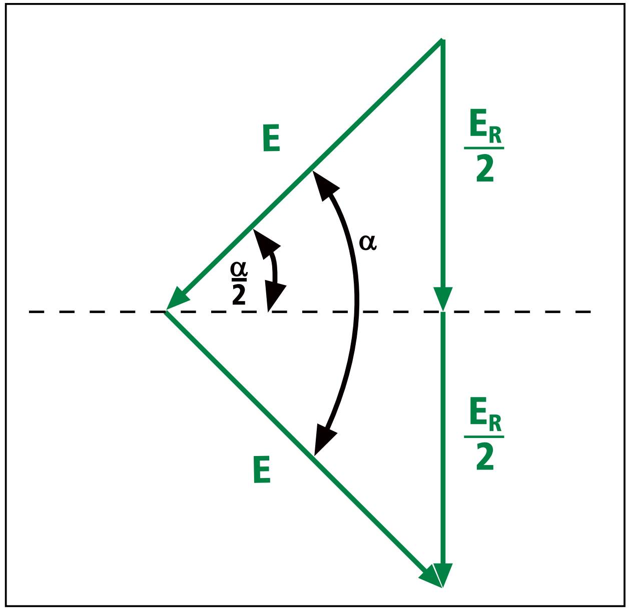

Fig. 9.37:
Determining the resultant soil resistance E_R at the bend

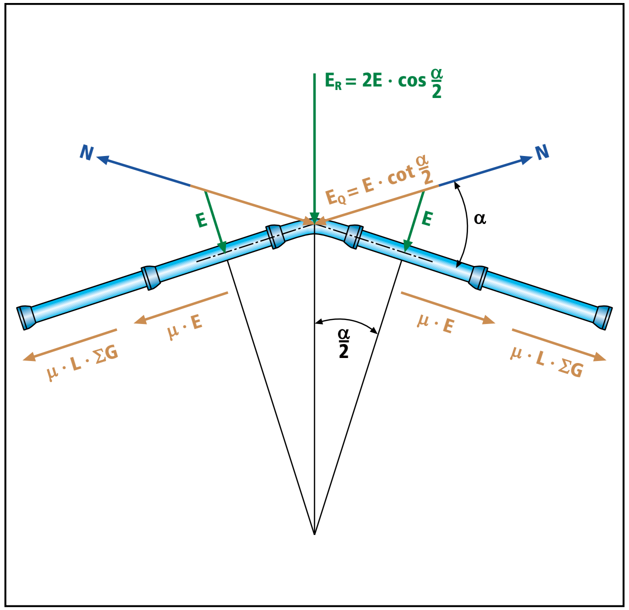

Fig. 9.38:
Interaction of thrust forces and soil resistance at the bend

$$\cos\frac{\alpha}{2} = \frac{\frac{E_R}{2}}{E} \qquad (9.13)$$

$$\frac{E_R}{2} = E \cdot \cos\frac{\alpha}{2}[kN] \qquad (9.14)$$

$$E_R = 2 \cdot E \cdot \cos\frac{\alpha}{2}[kN] \qquad (9.15)$$

$$N = \mu \cdot L \cdot \sum G + \mu \cdot E + E \cdot \cos\frac{\alpha}{2}[kN] \qquad (9.16)$$

$$\sum G = 2 \cdot G_B + G_W + G_R\,[kN/m] \qquad (9.17)$$

From this, the length L of pipeline which has to be restrained can be found.

Taking a pipe length of 6 m and the following values

$\gamma_B = 18$ kN/m³
$\gamma_W = 10$ kN/m³
$\gamma_R = 70.5$ kN/m³ (ductile cast iron)

the length L of pipeline which needs to be restrained can be calculated as follows for ductile iron water pipelines and for a system test pressure STP.

$$L = \frac{1}{\mu} \cdot \frac{0{,}79 \cdot STP \cdot DE - 2 \cdot all.\sigma_h \left(\mu + cot\frac{\alpha}{2}\right)}{36 \cdot H + 7{,}85 \cdot DE \cdot 221{,}5 \cdot e_{min}} [m] \qquad (9.18)$$

Where pipelines are within the water table, the resulting buoyancy reduces the forces due to weight and the soil resistance and hence the frictional force.
Where installation takes place within the water table in cohesive soils and where there are cohesive soils of soft and stiff consistency which are difficult to compact (soil types B 2 to B 4 under GW 310 [9.4]), the coefficient of friction μ tends towards zero. In these cases, it is recommended that the entire pipeline be safeguarded with restrained joints.
At changes in direction in a vertical plane, the resultant force acts outwards at the outside of the bend. As a result the forces G_w and G_R due to weight in equation 9.17 may tend towards zero.

DVGW Arbeitsblatt GW 368 [9.1] brings the results of these calculations together in tables, which saves one from having to do a vast amount of calculating work.
For calculations which are not covered by the values in the tables, an online calculating program is available under **"Tools for calculations"**, button **"DVGW GW 368"**, on the **www.eadips.org** website of the European Association for Ductile Iron Pipe Systems · EADIPS® / Fachgemeinschaft Guss-Rohrsysteme (FGR®) e.V.

After installation, individual socket joints are often in an unextended state and make it necessary for extension to be performed before the ends of the pipeline are connected to fixed points (e.g. structures, buried pipelines) **(Fig. 9.39)**. The extension travels of the individual restrained joint systems are a few millimetres.

During the planning phase and in the course of installation, particular care must be taken to follow the manufacturer's installation instructions and any special directions **(Chapters 19 and 22)**.

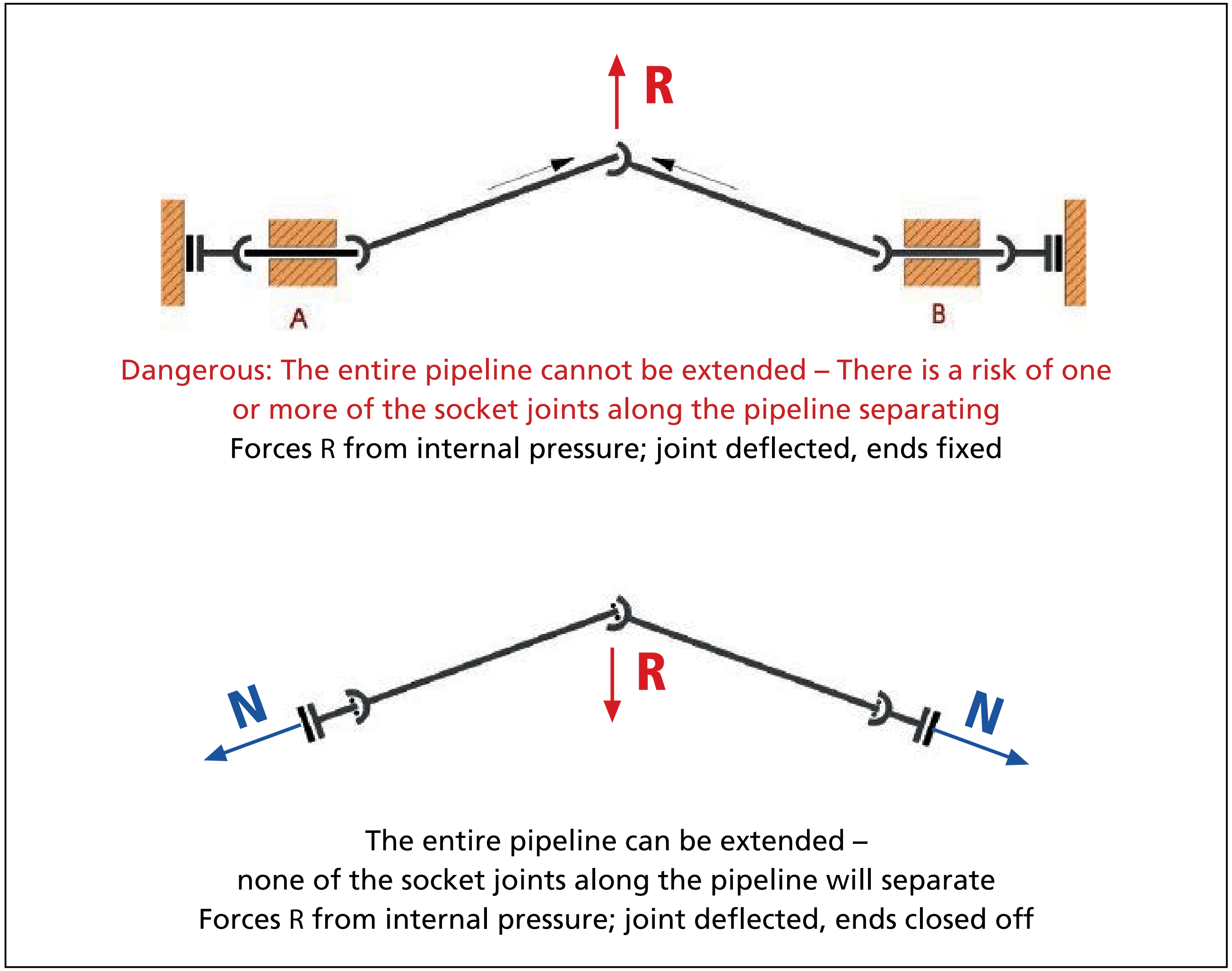

Fig. 9.39:
Effects of extension travels in restrained pipelines

9.7 Examples of installed pipelines

The follow examples are taken from practical installation work done over the past few years. They are all applications where restrained joints were used as a replacement for concrete thrust blocks.

The use of restrained socket joints in trenchless installation and replacement techniques is dealt with in **Chapter 22**.

- DN 700 ductile iron sewer pipes were used to install the drainage pipeline for ground water and rainwater at the new Berlin Brandenburg International Airport **(Fig. 9.40)**. During the construction phase, the pipeline is being operated as a pressure pipeline at an operating pressure of several bars. The use of Novo SIT® restrained push-in joints enabled expensive concrete thrust blocks to be dispensed with at changes of direction and the installation time to be considerably shortened in this way.

Fig. 9.40:
DN 700 ductile iron sewer pipes with Novo SIT® push-in joints

Fig. 9.41:
Parallel installation of DN 600 ductile iron pressure wastewater pipelines with BRS®/ TYTON SIT PLUS® push-in joints

Fig. 9.42:
Installation of restrained ductile iron bends

- Sewage pressure pipeline, a DN 600 twin pipeline, between Heidenau and Dresden runs through the flood zone of the river Elbe **(Fig. 9.41)**. The possibility of the soil being washed off the pipeline in at least parts of certain sections of the route cannot be ruled out in this case. Also, it is intended to be possible for the pipeline to remain in operation until the Elbe floods to a certain level, even though the ground may have become so soft at this time that the pipeline can be expected to be buoyant. For this reason, all the push-in joints have to be restrained. The joint system selected was the BRS® / TYTON SIT PLUS® system which, at a rated pressure of PN 10, can be used

Fig. 9.43:
A DN 600 ductile iron bypass pipeline with BLS® push-in joints

Fig. 9.44:
Renovation of a gate-valve-equipped pipeline intersection with BAIO® restrained joints.

for nominal sizes of up to DN 600. The design of this system combines the sealing and retaining functions in a single ring.

- There was a shortage of time and installation space for the replacement and relaying of an old DN 1000 drinking water main in Leipzig **(Fig. 9.42)**. The new pipelines were installed throughout with restrained joints and because of this there was no need for expensive pressure-distributing walls (i.e. thrust blocks) to absorb the forces.

- 6 km of a DN 1200 trunk main needs to be renovated by lining it with cement mortar without the transportation of drinking water being interrupted. Sections 2 km long are being bypassed at a time by a DN 600 bypass pipeline of restrained ductile iron pipes mounted above ground **(Fig. 9.43)**. Once the renovation work on the given section is completed, the ductile iron pipes are disconnected and used again for the next section, which is being done at least eight times. Max. test pressure for the bypass: 30 bars. Forces at the 45° bend: 720 kN. DN 600 pipes and fittings with BLS® push-in joints have been used **(Fig. 9.10)**.

- Flangeless restrained gate valves with restrained sockets, and transition fittings to old pipelines of different materials, were used to replace a complete gate-valve-equipped pipeline intersection which had had conventional flanged gate valves. There were four gate valves and a hydrant and with the new components the number of individual parts dropped from 546 to 47; the installation time went down by a factor of 5 **(Fig. 9.44)**.

- When there is a considerable difference in height between the intake structure at a spring and the communal service reservoir for drinking water, the local water supply can be combined with electricity generation at drinking water hydroelectric power stations. With a state-guaranteed remuneration for electricity fed onto the grid, the cost of installing the station is soon paid off. Ductile iron pipes with restrained push-in joints are equal to the high operating pressures and are easy to install, and the rugged material of which they are made will stand up to any external loads **(Fig. 9.45)**.

Fig. 9.45:
A DN 400 turbine pipeline

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9.8 Notation in equations

$DE = d_a$ [m]
Outside diameter of pipe

$DI = d_i$ [m]
Inside diameter of pipe

e_{min} [m]
Minimum wall thickness depending on the choosen pipe type

E [kN]
Soil resistance

E_R [kN]
Resultant soil resistance on the line bisecting the angle

E_Q [kN]
Transverse force due to soil resistance

G_B [kN/m]
Weight of the soil above the pipe

G_R [kN/m]
Force due to the weight of the pipe

G_W [kN/m]
Force due to the weight of the filling of water

H [m]
Height of cover above the pipe

l [m]
Length of pipe

L [m]
Length of pipeline to be restrained

N (N') [kN]
Axial force due to internal pressure

p [bar]
Internal pressure in a pipeline (1 bar = 100 kN/m²)

R [kN]
Resultant force from the internal pressure

R_1 [kN/m]
Frictional force from the earth load on the top of the pipe

R_2 [kN/m]
Frictional force from the earth load, the filling of water and the weight of the pipe, on the underside of the pipe

R_3 [kN]
Frictional force due to soil resistance

STP [kN/m²]
System **T**est **P**ressure (1 bar = 100 kN/m²)

α [°]
Angle of the bend

γ_B [kN/m³]
Specific weight of the soil

γ_R [kN/m³]
Specific weight of ductile iron

γ_W [kN/m³]
Specific weight of water

μ
Coefficient of friction between pipe and soil

$all.\sigma_h$ [kN/m²]
Allowable horizontal pressure on soil

9.9 References

[9.1] DVGW-Arbeitsblatt GW 368
Längskraftschlüssige Muffenverbindungen für Rohre, Formstücke und Armaturen aus duktilem Gusseisen oder Stahl
[DVGW worksheet GW 368
Restrained socket joints for ductile iron and steel pipes, fittings and valves]
2002-06

[9.2] DIN 28603
Rohre und Formstücke aus duktilem Gusseisen –
Steckmuffen-Verbindungen –
Zusammenstellung, Muffen und Dichtungen
[Ductile iron pipes and fittings –
Push-in joints –
Survey, sockets and gaskets]
2002-05

[9.3] 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]
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[9.4] DVGW-Arbeitsblatt GW 310
Widerlager aus Beton –
Bemessungsgrundlagen
[DVGW worksheet GW 310
Concrete thrust blocks –
Principles of sizing]
2008-01

10 Mechanical joints – wide-tolerance couplings and flange adaptors

10 Mechanical joints – wide-tolerance couplings and flange adaptors

Technical development has progressed and, as a result, dedicated types of joint, such as push-in socket joints or welded joints are now the norm for pipe systems of all materials. In addition, the latest technology includes dedicated couplings for specific materials. However, given the wide variety of materials used in the water industry, connecting pipeline components of different materials with long term reliability is a real challenge. This is a job which can be done by couplings which are able to cover pipe diameters of quite a wide tolerance range or ones which are even capable of adapting different connecting systems to each another.

10.1 General

Mechanical joints are used amongst other things for repairs, transitions between materials or connections to pipes of old dimensions, or for applications in which the connecting forces have to be kept low.

A basic distinction which can be made in the case of mechanical joints is between specific-size joints, such as those in Gibault couplings, and wide-tolerance joints, conforming respectively to EN 12842 [10.1] and EN 14525 [10.2].

Mechanical joints can be made without any high axial assembling forces because the gaskets offer hardly any resistance to the pushing-in of the pipe, but in return the bolts have to be tightened in a further operation. To ensure that the requisite connecting forces exist, manufacturers lay down bolt tightening torques in the installation instructions **(Table 10.1)**. These torques are often given as a range because they are affected by the dimensions of the pipe being connected.

Table 10.1:
Bolt tightening torques
(the example is for MEGA-Flex joints)

Nominal size	Bolt tightening torques in Nm
Up to DN 80	55 – 65
DN 100 and above	95 – 120

10.2 Construction and operation

A characteristic feature of mechanical joints is the seal between the inside surface of the socket and the outside surface of the pipe made by mechanical compression of the gasket. A gland is usually tightened against the body of the coupling or flange adaptor by means of axially positioned connecting bolts. When this is done, the axial movement of the gasket is re-directed radially onto the surface of the pipe by means of conical guiding surfaces. Such designs are therefore, in principle, developments of the bolted gland joint covered by DIN 28602 [10.3].

10.3 Wide-tolerance couplings

Wide-tolerance couplings **(Fig. 10.1 and Fig. 10.2)** connect two plain pipe-ends by making a mechanical joint to each pipe.

Due to the angular deflection possible at the two sockets, these couplings can even compensate for a limited amount of displacement between the pipes. The allowable axial gap between the pipes is found from the minimum depth of engagement required for the mechanical joints and the overall length of the couplings.

Minimum values for the allowable joint gap are laid down in EN 14525 [10.2] for wide-tolerance connectors of nominal sizes from DN 50 to DN 600 **(Table 10.2)**.

Fig. 10.1:
Flexible wide-tolerance coupling

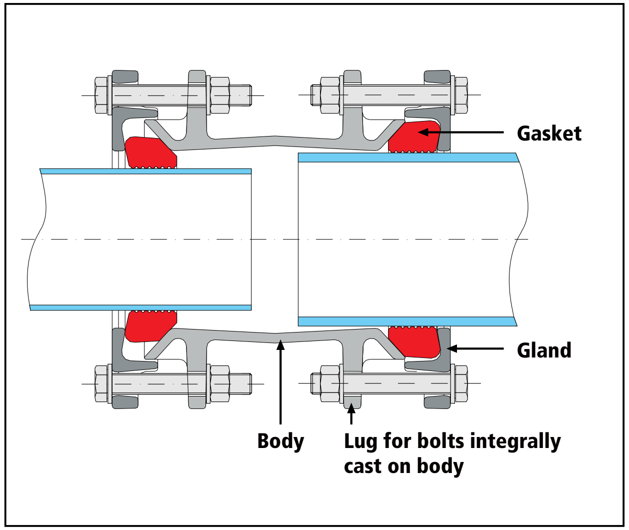

Fig. 10.2:
View in section of an assembled wide-tolerance coupling

Table 10.2:
Minimum values for the allowable joint gap under EN 14525 [10.2] for wide-tolerance connectors

Maximum OD or DN of the pipes to be connected		Joint gap (mm)	
OD (mm)	DN	Coupling	Flange adaptor
OD ≤ 110	DN 100	20	15
110 < OD ≤ 225	100 < DN ≤ 200	25	20
225 < OD ≤ 315	200 < DN ≤ 300	35	30
315 < OD ≤ 400	300 < DN ≤ 400	55	40
400 < OD ≤ 630	400 < DN ≤ 600	70	50

10.3.1 Through-bolts (single bolts)

There are designs of coupling and flange adaptor where the bolts either pull the glands at opposite ends directly towards one another or where they pull the gland towards the flange **(Fig. 10.3)**, the body of the coupling floating as it is clamped in between. The bodies of the couplings and flange adaptors may be single in this case but in couplings the same pre-loading force acts in both joints, i.e. the joints cannot be individually set.

The shortening of the distance between the glands causes a lengthening of the distance for which the bolts project beyond the nuts. In couplings of the present kind, the change in length at the two sockets adds up at the bolts, meaning that there may be cases where socket wrenches using standard-depth sockets cannot be used. Deep sockets giving a longer depth of penetration for bolts may be necessary to enable torque wrenches to be used to check that torques are as laid down by the manufacturer.

Fig. 10.3:
Through-bolts: the gland is pulled directly towards the flange

Fig. 10.4:
Wide-tolerance coupling for transitions between materials (fibre-cement pipe on the left, PE pipe on the right) where bolts are fastened to the body

10.3.2 Bolts fastening to the body (double bolts)

To enable the length of bolt needed to be reduced and the joints at opposite ends to be made in succession and if required with different connecting forces, there are alternative systems using double bolts **(Fig. 10.4)**.

In these designs, each joint has a set of bolts of its own which are fastened to lugs **(Fig. 10.2)** integrally cast on the body of the coupling.
In this case, the lengthening of the projecting part of the bolt is the result of the shortening of the mechanical joint at only one end of the coupling; also the applied pressure can be matched to the pipe connected to the given end **(Fig. 10.4)**.

10.4 Wide-tolerance flange adaptors

Wide-tolerance flange adaptors **(Fig. 10.5 and Fig. 10.6)** enable plain pipe ends to be connected to flanges and are therefore equipped with a mechanical joint at the end to which the pipe is connected and with a flange to EN 1092-2 [10.4] at the opposite end.

There are flange adaptors which are slid completely onto the pipes to be connected, but because of this the full area of the flange gasket may possibly not be covered because of the increase in inside diameter at the flange.

Fig. 10.5:
Flexible wide-tolerance flange adaptor

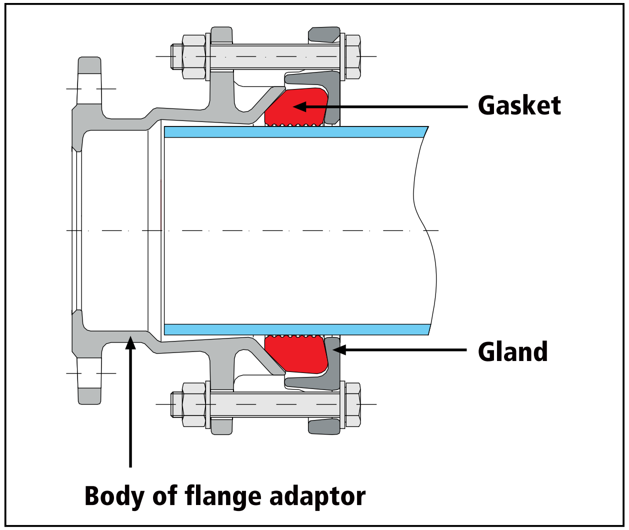

Fig. 10.6:
View in section of an assembled wide-tolerance flange adaptor

10.5 Preloading of gasket

The self-augmenting sealing action as the internal pressure rises which is known to occur as a result of the socket geometry in the case of TYTON® rubber gaskets does not occur in mechanical joints. In wide-tolerance couplings and flange adapters, the pressure with which the gasket system is applied must therefore make allowance for the long-term relaxation of the elastomer even at the time of connection, i.e. higher bolt tightening torques are required for reliable long-term operation even though considerably lower values may produce a short-term seal.

For this purpose, manufacturers draw attention in their documentation to clearly specified requirements. It has to be ensured that these requirements are complied by the use of suitable tools (torque wrenches) **(Table 10.1)**.

10.6 Ranges of pipe outside diameters

Specific-size mechanic joints, such as Gibault couplings for example, are designed for a relatively small range of pipe outside diameters and can thus often only be used for a single type of pipe. Under DN 14525, wide-tolerance couplings **(Fig. 10.4)** and flange adapters are designed for defined minimum working diameter ranges for each nominal size up to DN 600 **(Table 10.3)**.

Table 10.3:
Minimum working diameter range under EN 14525 [10.2]

Maximum OD or DN of the pipes to be connected		Minimum working diameter range
OD (mm)	DN	(mm)
OD ≤ 110	DN ≤ 100	10
110 < OD ≤ 225	100 < DN ≤ 200	15
225 < OD ≤ 315	200 < DN ≤ 300	20
315 < OD ≤ 400	300 < DN ≤ 400	25
400 < OD ≤ 630	400 < DN ≤ 600	30

10.7 Allowable angular deflection

The minimum value of angular deflection defined in EN 14525 [10.2] relates to the entire tolerance range of the given wide-tolerance connector. The bodies of wide-tolerance couplings and flange adaptors have to be designed for an angular deflection of at least 3° in the case of pipes of the maximum allowable outside diameter. Because of this, pipes of smaller outside diameters have considerably more space for angular deflection in the body of the wide-tolerance coupling or flange adaptor. Where required, it may therefore be necessary for the user to set a limit on the possible angular deflection to enable the joint to maintain its full sealing performance, which becomes less good the more the angular deflection specified by the manufacturer is exceeded.

A sideways, heightwise or angular displacement between the pipe ends to be connected can be compensated for by a wide-tolerance coupling within the limits set by the allowable angular deflections at the two joints.

Unless some additional support is provided, wide-tolerance couplings adjust to the displacement by "floating".

It needs to be borne in mind in this case that where pipes of widely differing outside diameters are connected, experience shows that there tends to be considerably more angular deflection at the connection to the smaller pipe. This is because of the amount of space available in the body and also because of the smaller overlap between the parts of the joint.

10.8 Restraint

In most applications, flexible joints such as MEGA-Flex joints are adequate regardless of their nature.

In the case of non-restrained pressure pipe systems, thrust blocks are installed. In Germany these are designed as specified in DVGW-Arbeitsblatt GW 310 [10.5]. Restrained pressure pipe systems do not require any thrust blocks. The number of restrained joints between pipes is calculated as specified in DVGW-Arbeitsblatt GW 368 [10.6] in Germany. Depending on the installation and operating conditions, there are pipe materials, such as polyethylene for example, which may be subject to considerable expansion when there are wide variations in temperature. The resulting changes in length may make it necessary for there to be restrained joints in a pipe system, possibly even when there are no thrust forces from the internal pressure.

On the basis of their construction, wide-tolerance joints of restrained design can be divided into integrated and independent systems.

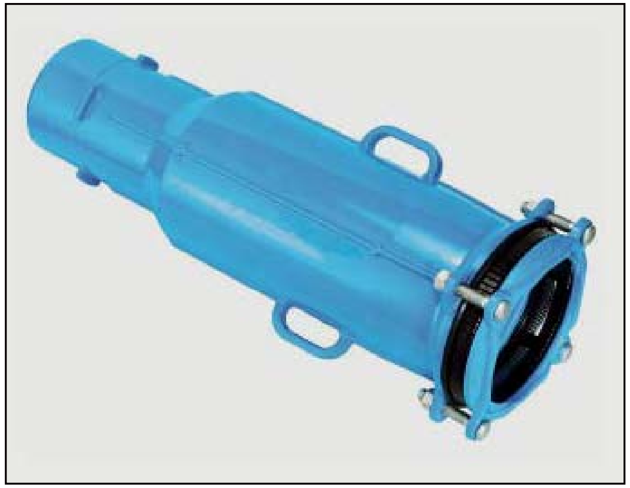

Fig. 10.7:
BAIO® - Multijoint® cut-in sleeve transition fitting

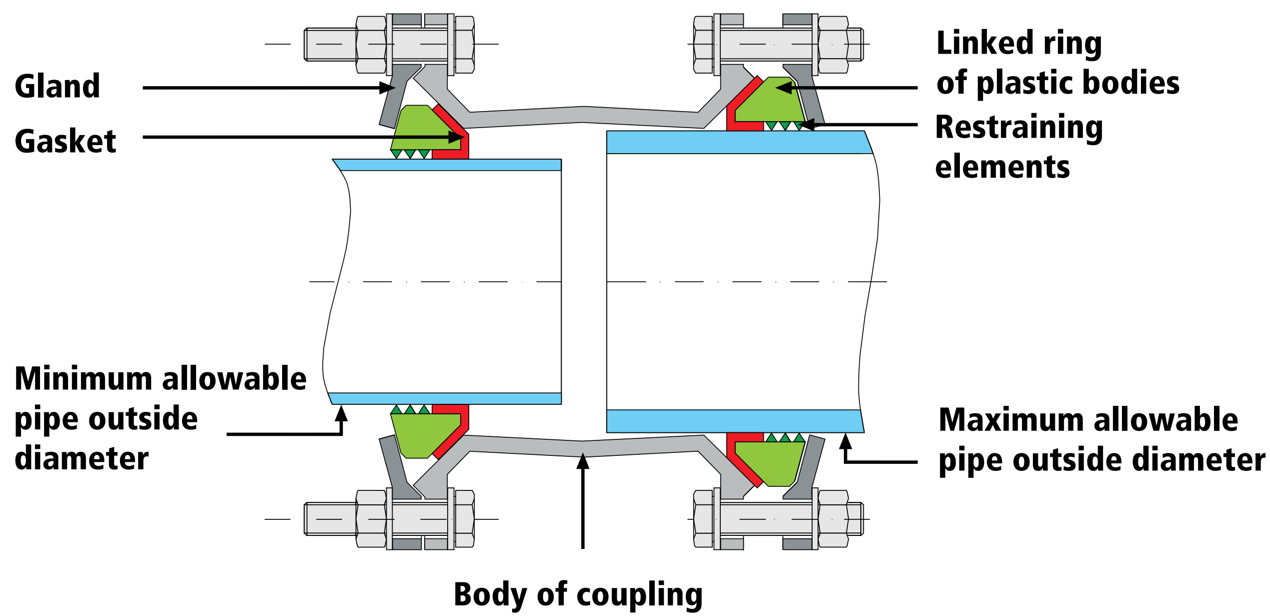

Fig. 10.8:
Coupling with mechanical joints and integrated restraint system (double bolts)

10.8.1 Integrated restraint system

In this compact design **(Figs. 10.7 and Fig. 10.8)**, the gasket and restraint ring are both compressed in a single operation.
The connecting force is transmitted to the body of the gasket by the restraint ring in this case. The gap between the socket and the surface of the pipe is filled by plastic bodies which can be moved relative to one another, and the dimensions of the gasket and the restraining elements are reduced to the minimum required.

10.8.2 Independent restraint system

In independent systems **(Fig. 10.9)**, the gasket and restraint ring operate independently of one another. At the time of connection, the gasket is first compressed against the pipe to be connected, and the restraint ring is then able to act on the pipe with whatever connecting forces are required in the given case regardless of the force with which the gasket is applied.

Because the gap between the gasket and pressure ring and the pipe has to be filled solely by the rubber gasket, these systems are fitted with rubber gaskets of very large volume.

This system is less compact and requires higher effort in installation but, if carefully handled, it does allow optimum settings to be made for the given application.

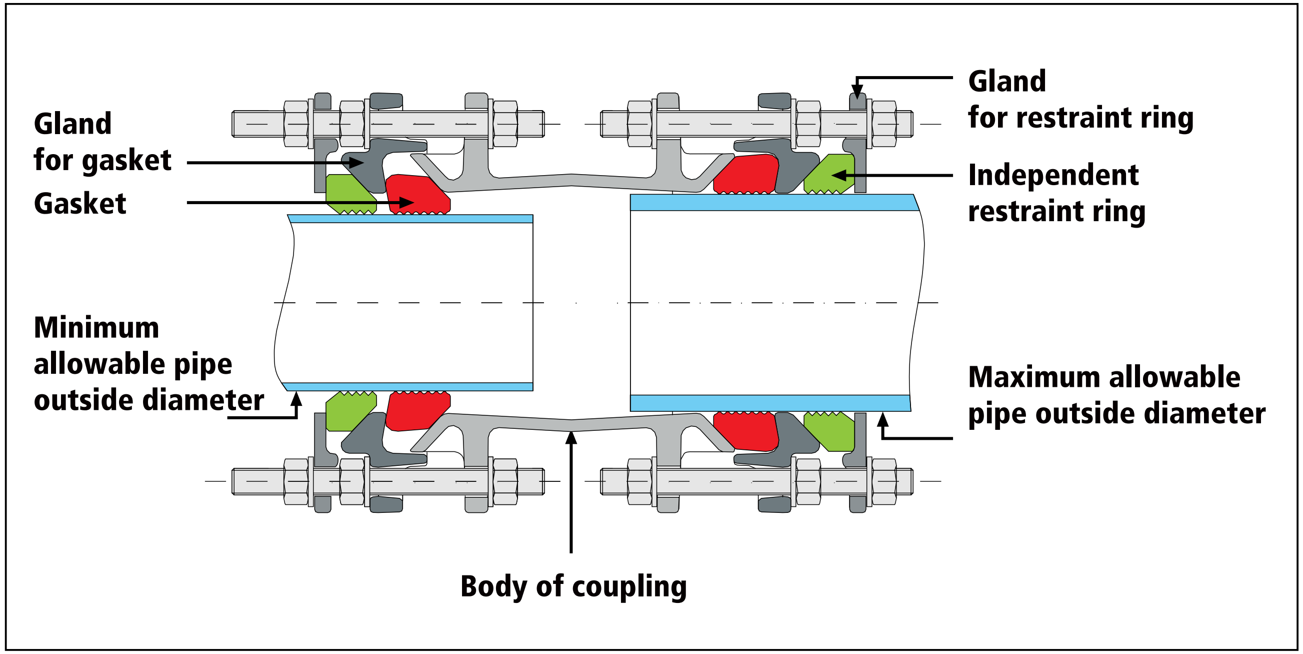

Fig. 10.9:
Coupling with mechanical joints and independent restraint system

10.9 References

[10.1] EN 12842
Ductile iron fittings for PVC-U or PE piping systems – Requirements and test methods
[Duktile Gussformstücke für PVC-U- oder PE-Rohrleitungssysteme – Anforderungen und Prüfverfahren]
2000

[10.2] EN 14525
Ductile iron wide tolerance couplings and flange adaptors for use with pipes of different materials: Ductile iron, grey iron, steel, PVC-U, PE, fibre-cement
[Großbereichskupplungen und -flanschadapter aus duktilem Gusseisen zur Verbindung von Rohren aus unterschiedlichen Werkstoffen: Duktiles Gusseisen, Grauguss, Stahl, PVC-U, PE, Faserzement]
2004

[10.3] DIN 28602
Rohre und Formstücke aus duktilem Gusseisen – Stopfbuchsenmuffen-Verbindungen – Zusammenstellung, Muffen, Stopfbuchsenring, Dichtung, Hammerschrauben und Muttern]
[Ductile iron pipes and fittings – Bolted gland joints – Assembly, sockets, counter ring, sealing ring, bolts and nuts]
2000-05

[10.4] EN 1092-2
Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories, PN designated – Part 2: Cast iron flanges
[Flansche und ihre Verbindungen – Runde Flansche für Rohre, Armaturen, Formstücke und Zubehörteile, nach PN bezeichnet – Teil 2: Gußeisenflansche]
1997

[10.5] DVGW-Arbeitsblatt GW 310
Widerlager aus Beton – Bemessungsgrundlagen
[DVGW worksheet GW 310 Concrete thrust blocks – Principles of sizing]
2008-01

[10.6] DVGW-Arbeitsblatt GW 368
Längskraftschlüssige Muffenverbindungen für Rohre, Formstücke und Armaturen aus duktilem Gusseisen oder Stahl
[DVGW worksheet GW 368 Restrained socket joints for ductile iron and steel pipes, fittings and valves]
2002-06

11 Safeguarding with concrete thrust blocks

11 Safeguarding with concrete thrust blocks

This chapter is being prepared.

12 Durability

12 Durability

This chapter is being prepared.

13 Gaskets

13 Gaskets

Buried ductile iron pipelines are almost without exception assembled using push-in joints. The gaskets for the TYTON® and STANDARD systems are extremely important. They are chambered compression gaskets with special fixing profiles. Their sealing function is ensured throughout the entire working life of the pipeline. The requirements for the material of the gasket concentrate on tightness over the long term. By using different source materials the rubber can be adapted to the requirements of the relevant medium.

13.1 General

It is not possible to provide constant checking and monitoring of buried pipelines. Therefore the long-term reliability of the gaskets in the pipe joints is particularly important.

The reliability and durability of the sealing material used contributes to a high degree to the security of the pipeline. This security serves to protect our most essential food – drinking water.

Gaskets are also a reliable means of preventing impurities and pollution of the groundwater caused by the escape of waste water and gases. The different fields of application often demand the use of different types of gaskets which need to be produced from high quality elastomer materials. The need for joints which are going to remain tight over the long term is reflected in a range of requirements for strength, resistance to deformation under pressure (resilience), ageing characteristics and chemical resistance.

By far the largest number of iron pipes are used in buried pipelines with push-in joints. Because of this the TYTON® and STANDARD systems have gained huge significance over the course of decades of practical applications.

A decisive factor in the tightness of push-in joints is the adaptability of a profiled rubber gasket. Because of its high degree of elasticity and durability, rubber is a particularly good sealing material.

Although in the past only gaskets made of vulcanised natural rubber (NR) were used, over the last 25 years or so gaskets have been exclusively made of synthetic rubber, which is superior to natural rubber in terms of chemical and temperature resistance as well as durability. EPDM (ethylene propylene diene monomer) is used for drinking water and NBR (acrylonitrile butadiene elastomer) is used for waste water. The field of application for push-in joints according to EN 545 [13.01], e.g. for drinking water, ranges from 0 °C to 50 °C for EPDM gaskets.

For waste water as per EN 598 [13.02] the upper limit for NBR gaskets depending on nominal sizes 45 °C (up to and including DN 200) and 35 °C (above DN 200).

For applications above these temperatures it is recommended that other synthetic elastomers are used, such as FPM (fluoro rubber) because of their resistance at higher temperatures.

Materials standard EN 681-1 [13.03] applies to gaskets in drinking water and waste water pipelines.

In the context of European construction products regulations, EN 681-1 [13.03] has since been harmonised to include the CE marking requirement. The national requirements for the production and testing of gaskets for push-in joints in ductile iron pipes are summarised in DVGW test specification VP 546 [13.04], to become DVGW worksheet W 384 [13.05].

13.2 Types of gaskets

13.2.1 TYTON® gasket

The profile of the TYTON® gasket is shown in cross-section in **Fig. 13.1.** It consists of a combination of two types of rubber: the one with a hardness of 55 IRHD (International Rubber Hardness Degree) is designed for optimum sealing function and long-term elasticity (sealing part).

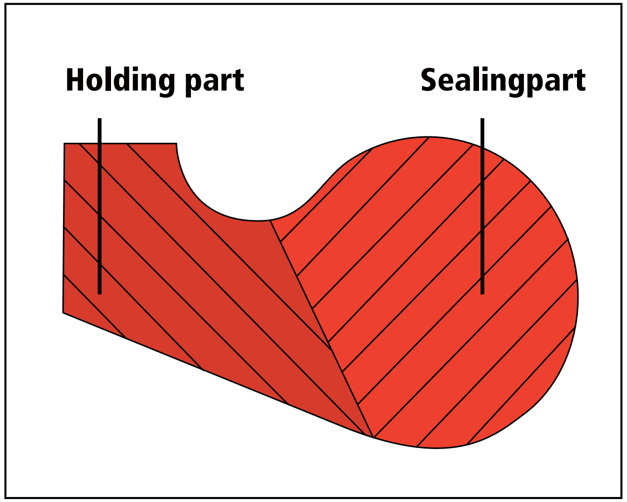

Fig. 13.1:
Cross-section of a TYTON® gasket

Fig. 13.2:
TYTON® gasket DN 300

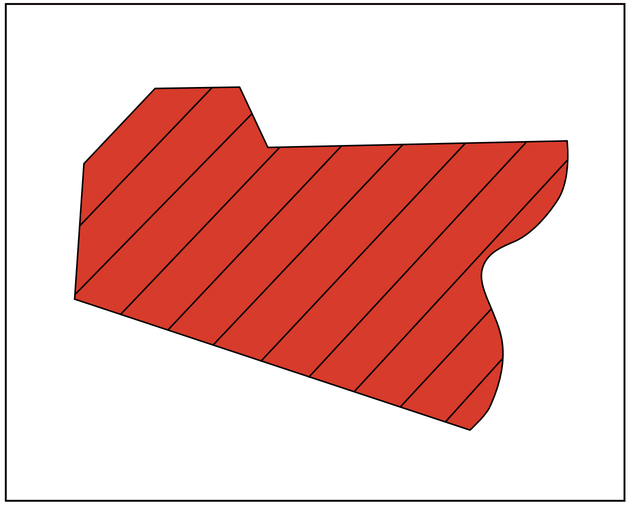

Fig. 13.3:
Cross-section of a STANDARD gasket

Fig. 13.4:
STANDARD gasket DN 300

The other part, with a hardness of 85 IRHD, has the job of keeping the gasket in place during the assembly of the joint (holding part).

Because the sealing part adapts itself to fit between the inside of the push-in joint and the outside of the pipe, high restoring forces are produced. The effect is to seal the joint, not only under low and high internal pressures but also in case of positive and negative outside pressures.

The TYTON® gasket **(Fig. 13.2)** is standardised in DIN 28603 [13.06] for the nominal sizerange from DN 80 to DN 1400. Depending on the area of use, as a rule it consists of synthetic rubber qualities EPDM or NBR.

13.2.2 STANDARD gasket

Fig. 13.3 shows the STANDARD gasket in cross-section. As with the TYTON® gasket the joint is sealed by the restoring force of the radially compressed ring.

The gasket consists of a homogenous rubber material with a hardness of 67 IRHD. The STANDARD gasket **(Fig. 13.4)** is standardised in DIN 28603 [13.06] for the nominal sizerange from DN 80 to DN 2000.

13.2.3 Flat gaskets

Flat gaskets are used for sealing flanged joints **(Fig. 13.5)**. The sealing effect is produced by the fact that two flanges are pressed against each

Fig. 13.5:
Example of a flat gasket to DIN EN 1514-1 [13.07]

other by means of bolts and nuts. Between the two flanges is the gasket, which ensures the sealing function by means of high contact pressure.

Flat gaskets generally consist of rubber with a hardness of < 80 IRHD. A steel core vulcanised into the rubber effectively prevents the joint from being displaced or blown out under high stresses.

Flat gaskets are available for all current nominal sizes, e.g. DN 80 to DN 2000, and for nominal pressures up to PN 63 (depending on nominal size). Their dimensions are specified in EN 1514-1 [13.08]. National requirements for production and testing can be found in DVGW test specification VP 547 [13.09], to become DVGW worksheet W 385 [13.10].

13.3 Properties

Elastomer gaskets have the task of reliably sealing pipe joints over decades. The following properties are essential:

- hardness,
- tensile strength,
- elongation at break,
- compression set,
- stress relaxation,
- resistance to ageing,
- behaviour in the cold,
- ozone resistance,
- chemical resistance.

13.3.1 Hardness

The hardness of rubber is its relative resistance to the penetration of an object. In order to test hardness, the test methods according to Shore-A and IRHD are used. In EN standards, rubber hardness is stated according to IRHD.

In order to determine rubber hardness according to Shore-A, simple hand-held test apparatus can be used **(Fig. 13.6)**. Measurement according to IRHD is more complicated. Therefore it is only used if there are higher requirements set for the measurement in terms of precision and reproducibility. The hardness depends on the composition of the rubber and its vulcanisation. Because these parameters necessarily modify other properties of a rubber material as well, the requirements for gasket materials are often summarised as hardness classes. The hardness of push-in joint gaskets is coordinated with the geometric shape and construction of the pipe joint.

Hardness is determined over the whole ring or on standard test pieces taken from the gasket or on sample plates of the mixture used.

Fig. 13.6:
Durometer for measuring rubber hardness according to Shore-A

13.3.2 Tensile strength and ultimate elongation

Tensile strength and ultimate elongation are properties of rubber which are easily determined. Ageing effects, which can be traced back to oxidative degradation, can easily be recognised by changes in tensile strength and ultimate elongation among other things.

13.3.3 Compression set

Good compression behaviour is necessary in order to ensure the function of the gasket even when the joint moves.

The sealing chamber gap of the pipe joint which is formed between socket and pipe must be permanently filled with rubber even during the settlement of the pipe in such a way that the gasket applies sufficient contact pressure force to the sealing surfaces.

Plastic (= permanent) deformations of the gasket, referred to as the compression set (CS), are to be taken into account right from the point of determining the dimensions and tolerances of all connection parts and when selecting the quality of rubber to be used.

$$CS = \frac{b}{a} \cdot 100\ [\%] \qquad (13.1)$$

The compression set according to **Equation 13.1** is determined on cylindrical specimens which are pressed together for a specified length of time at a given temperature in the axial direction by 25 % **(Fig. 13.7, a)**.

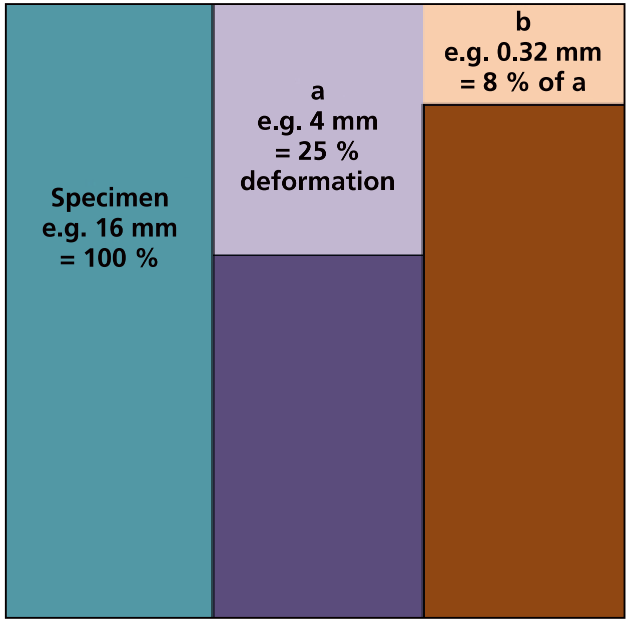

Fig. 13.7:
Definition of the compression set (CS) according to equation 13.1

With an ideal elastic behaviour, the specimen would resume its initial dimensions after the pressure is released. However the test shows that the specimen retains a slight permanent deformation **(Fig. 13.7, b)**, which is referred to as the compression set and stated as a % of the total deformation a.

13.3.4 Stress relaxation

As well as the compression set, stress relaxation is another measure of the elasticity of a rubber gasket. For the seal to have good durability, the gasket must have the lowest possible degree of stress relaxation.

Compressive stress relaxation (CSR) and compression set (CS) are identically loaded in the test period (25 % deformation). While with the CS it is the deformation path which determines the result, with CSR it is the residual stress which gives the result.

Stress relaxation is more difficult and expensive to determine and requires a longer time, which is why the compression set is preferred for routine testing.

The restoring force occurring with a constantly held deformation is measured as a function of time. The decrease in the restoring force over time, measured as a % of the initial value, is the stress relaxation.

13.3.5 Ageing

For a joint to remain tight and problem-free over decades, in addition to the elastic properties, the ageing behaviour of the rubber has a decisive role to play. Ageing is essentially influenced by light, oxygen, temperature and medium.

Therefore ISO 2230 [13.11] specifies that gaskets should be stored in cool and dark conditions.

The ageing behaviour is usually tested by means of a 7-day ageing test at +70 °C. Here the changes in hardness, tensile strength and elongation at breakmeasurements are compared with the condition as new.

13.3.6 Behaviour in the cold

At low temperatures, the hardness of rubber increases. This behaviour is reversible and does not cause any loss of quality. When it warms up again the rubber reverts to its original properties.

The change in properties brought about by cooling should however not exceed a certain level with rubber gaskets so that no difficulties occur during assembly at low temperatures. The following note has therefore been included in the assembly instructions for gaskets for ductile iron pipes:

Practical tip:
At temperatures below 0 °C gaskets may be subject to a certain increase in hardness. With assembly temperatures below 0 °C the gaskets should therefore be stored at a temperature above +10 °C wherever possible in order to simplify assembly. The gaskets should only be taken out of storage (e.g. in a heated contractor’s shed) shortly before assembling the joints. In order to test the behaviour of the gaskets when cold, the increase in hardness after storage in the cold is measured (70 hours at -10 °C). For higher requirements there is also the possible option of cold testing at -25 °C as per EN 681-1 [13.03].

13.3.7 Ozone resistance

A particular form of oxidative degradation – ozone cracking – is tested by checking ozone resistance.

For the test, a specimen of rubber is stretched and exposed to an ozone-charged atmosphere at a specified temperature and for a certain time. At the end of the test, no cracks should be visible on the surface of the rubber.

13.3.8 Chemical resistance

When they are used in drinking, untreated and industrial water pipelines, gaskets for push-in joints are not subject to any particular stresses as regards their chemical resistance.

However, for use in sewage drains and pipelines the gasket's resistance to waste water is to be established in accordance with EN 681-1 [13.03].

This is tested and evaluated on the basis of the change in volume of a specimen in accordance with ISO 1817 [13.12] after 7 days storage in distilled or deionised water at 70 °C. More far-reaching requirements are to be determined in accordance with EN 681-1 [13.03].

13.3.9 Time of storage

In order to guarantee a supply of gaskets which meets market requirements, longer-term storage is usual and necessary. In individual cases this may lead to storage for a number of years; however, because of the special formulation of the gaskets as regards their length of use, this is possible without problem as long as the prescribed storage conditions are observed.

According to ISO 2230 [13.11] the storage period should not exceed the storage times stated in **Table 13.1** (extract).

Table 13.1:
Extract from storage times as per ISO 2230 [13.11]

Material [a]	Storage time [b]	Extended storage time [b]
NR, SBR	5 years	+ 2 years
NBR, HNBR, IIR, CIIR, BIIR	7 years	+ 3 years
EPDM, FKM, VMQ	10 years	+ 5 years

[a] Selection specific to application as per ISO 2230 [13.11]
[b] Checking and evaluation as per ISO 2230 [13.11]

13.4 Gaskets for drinking water pipelines

TYTON® and STANDARD gaskets for use in drinking water pipelines are predominantly in EPDM as per EN 681-1 [13.03]. They should not affect the colour, the odour, the taste and the bacteriological properties of the drinking water.

The requirements for these gaskets are determined in DVGW test specification VP 546 [13.04], to become DVGW worksheet W 384 [13.05] in future. This defines the requirements with respect to hygiene in the rubber guidelines of the German Environmental Agency (UBA) [13.13] and the requirements with respect to microbiology of DVGW worksheet W 270 [13.14].

13.5 Gaskets for sewage drains and pipelines

Sewage drains and pipelines must be durably tight. For this reason, in addition to a functioning pipe and joint system, the gasket requires a rubber quality which offers the most durable possible resistance to the conditions to be expected in a sewage pipeline, above all from aggressive media. As a rule, gaskets in NBR are used for this.

In order to provide evidence of the resistance of NBR material against the organic impurities most commonly found in waste water, extensive investigations have been carried out [13.15], [13.16] and [13.17].

More far-reaching information on gaskets as regards technique and application can be found in **Chapters 8 and 9**.

13.6 References

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Ductile iron pipes, fittings, accessories and their joints for water pipelines –
Requirements and test methods
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2007 + A1:2009

[13.03] 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 Wasser-versorgung und Entwässerung –
Teil 1: Vulkanisierter Gummi]
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Dichtungen für Muffenverbindungen in Rohrleitungen aus duktilem Gusseisen oder Stahl –
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Gaskets for push-in joints in ductile iron or steel pipelines –
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2007-06

[13.05] Gelbdruck, DVGW-Arbeitsblatt W 384
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2013-04

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Part 1: Non-metallic flat gaskets with
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1997-08

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Flanges and their joints –
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Gusseisen –
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[DVGW test specification VP 547
Gaskets for flange connections in
ductile iron pipelines –
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2002-03

[13.10] Gelbdruck, DVGW-Arbeitsblatt W 385
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Gaskets for flange connections in
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methods]
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Rubber, vulcanized –
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Leitlinie zur hygienischen Beurteilung
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[UBA-Rubber Guideline
Guideline for the hygienic assessment
of elastomer materials in contact
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(Elastomer Guideline)]
2012-05

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Enhancement of microbial growth on materials in contact with drinking water – Test methods and assessment]
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[Diffusion behaviour of chlorinated and aromatic hydrocarbons by NBR sealing rings in TYTON joints]
FGR GUSSROHR-TECHNIK,
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14 Coatings

14 Coatings

Coatings provide lasting protection for ductile iron pipelines. Coatings which are applied to pipes, fittings and valves in the works cater for soil conditions and are added to on site if necessary. Corrosion protection provisions specific to ductile iron pipes, and their fields of use, are described below.

14.1 General

As a general principle, pipes, fittings and valves are supplied with works-applied coatings which are added to on site if necessary. It is important for the provisions for corrosion protection to be selected in such a way as to ensure durability for the pipeline.

For this, it is necessary for an accurate knowledge to exist of the types of soil in which the pipelines are going to be laid.

The European product standards EN 545 [14.1] and EN 598 [14.2] include an informative Annex D in which the limits of use are given for different coating systems for pipes, fittings and accessories. These limits relate to important soil parameters which encourage the corrosion of ductile iron and these parameters include:

- resistivity of the soil,
- pH,
- reserve of acidity,
- position relative to the water table,
- heterogeneity (mixed soils),
- presence of refuse, cinders, slag, pollution from wastes or industrial effluents,
- peaty soils,
- occurrence of stray currents.

Whereas the polyethylene (EN 14628 [14.3]), polyurethane (EN 15189 [14.4]) and epoxy (EN 14901 [14.5]) coatings, which give high-resistance electrical insulation, and the conductive cement mortar coating (EN 15542 [14.6]) can be used in soils of all kinds, when the different variants of zinc-based active coatings are being selected attention must be paid to the soil parameters laid down for these coatings. These soil parameters have been selected in such a way as to rule out the use of the given variant. A table providing an overview of the fields of use follows in **section 14.2.1**.

Under the German rules, a systematic approach is adopted as follows: after a thorough investigation of the soil under DIN 50929-3 [14.7] along the route to be followed by the pipeline, the soil is classified as belonging to one of three classes of corrosiveness.

DIN 30675-3 [14.8] then governs the fields of use of the different types of corrosion protection for underground pipelines of ductile iron. The standard provides an overview of works-applied coatings and on-site measures as a function of the level of corrosiveness of the soil.

The fields of use for coatings for pipes, fittings and valves are grouped together in **table 14.1**.

Table 14.1:
Fields of use for underground pipelines of ductile iron with coatings to EN 14628 [14.3], EN 15189 [14.4], EN 15542 [14.6], DIN 30674-3 [14.9] and -5 [14.10], EN 14901 [14.5], DIN 51178 [14.14] in conjunction with DIN 30675-2 [14.8] for pipes, and EN 14901 [14.5] and DIN 51178 [14.14] for fittings and valves.

No.	Coating on pipes	Thickness of coating	Coating recommended for joints	Suitable bedding for corrosion protection	Fields of use in the form of soil classes
1	Zinc coating with finishing layer (cover coating), to DIN 30674-3 [14.9]	130 g/m² of zinc with finishing layer to EN 545 [14.1]	None	Not provided Provided	I, II I, II, III [2)]
2	Zinc coating with finishing layer, to OENORM B 2560 [14.11]	200 g/m² of zinc with ≥ 100 µm polyurethane finishing layer	None	Not provided Provided	I, II I, II, III [2)]
3	Cement mortar coating to EN 15542 [14.6]	5.0 mm	Heat-shrinkable material or B-50M[1)] coating to DIN 30672 [14.12] or rubber collars	Not provided	I, II, III
4	Polyethylene coating to EN 14628 [14.3]	1.8 to 3.0 mm	Heat-shrinkable material or B-50M[1)] coating to DIN 30672 [14.12]	Not provided	I, II, III
5	Polyurethane coating to EN 15189 [14.4]	≥ 700 µm	None	Not provided	I, II, III
6	Polyethylene sleeving to DIN 30674-5 [14.10] in conjunction with DIN 30674-3 [14.9]	0.2 mm	Same as pipes	Provided[3)]	I, II, III

No.	Coating on pipes	Thickness of coating	Coating recommended for joints	Suitable bedding for corrosion protection	Fields of use in the form of soil classes
7	Epoxy coating to EN 14901 [14.5]	≥ 250 µm	■ None if pipes are zinc coated (nos. 1 and 2) ■ Heat-shrinkable material or B-50M[1)] coating to DIN 30672 [14.12] or rubber collars, if pipes are coated as in nos. 3 to 5	Not provided	I, II, III
8	Coating of technical enamel to DIN 51178 [14.14]	≥ 250 µm	■ None if pipes are zinc coated (nos. 1 and 2) ■ Heat-shrinkable material or B-50M[1)] coating to DIN 30672 [14.12] or rubber collars, if pipes are coated as in nos. 3 to 5	Not provided	I, II, III

1) At sustained temperatures of T ≤ 330 °C, the B-50M coating to DIN 30672 [14.12] or the C-30M coating to DIN 30672 [14.12] may be used for joints.
2) Not suitable when there is constant exposure to eluates of pH < 6 and in peaty, boggy, muddy and marshy soils
3) The directions given in section 4.1 need to be followed.
Note: By agreement, materials for corrosion protection covered by DIN 30672 Part 1 [14.12] may be used for coating ductile iron pipes away from the joints

There is also standard DIN 30675-2 [14.8] which provides information on provisions for corrosion protection when there is an electrochemical action. As part of this it also deals with electrically insulating socket joints.

14.2 Works-applied coatings on pipes

14.2.1 Zinc coating with finishing layer

The standard coating given to ductile iron pipes is a zinc coating with a finishing layer, to EN 545 [14.1] and EN 598 [14.2]. In the majority of soils, this active coating provides lasting protection against damage by corrosion. The zinc coating and the finishing layer act synergistically, i.e. the combined effect they have in protecting against corrosion is better than the sum of the effects that the individual coatings would have.

For some years now, a coating which comprises a zinc-aluminium layer (proportion of zinc by mass 85 % and proportion of aluminium by mass 15 %) and an epoxy finishing layer has been available. For this coating, the mass of metal is increased to 400 g/m².

Another of the active protective systems is zinc applied in a mass of ≥ 200 g of Zn/m² with a polyurethane finishing layer at least 100 µm thick. There is a standard for this coating in Austria in the form of OENORM B 2560 [14.11].

The fields of use of these active protective systems are laid down in Annex D of EN 545 [14.1] in the form of exclusion criteria and they are shown in **Table 14.2**.

Under the German rules, these stipulations are supplemented by DIN 30675-2 [14.8]; Germany also recognises what is known as bedding suitable for corrosion protection. This consists of chemically neutral sands which stop the pipeline from coming into direct contact with corrosive types of soil.

Table 14.1 shows the fields of use for the systems, the soil classes being determined as indicated in DIN 50929-3 [14.7]. If the soil conditions call for a higher standard of corrosion protection, then the polyethylene coating to EN 14628 [14.3], the cement mortar coating to EN 15542 [14.6] or the polyurethane coating to EN 15189 [14.4] may be used, as desired.

The “zinc coating with protective finishing layer” corrosion protection system is stable in its field of use, the cast iron being separated from the soil by the finishing layer.

Pores in the finishing layer or injuries to the coating when the pipes are being installed “heal” and close due to the products of reaction produced by the zinc, which are only sparingly soluble in moist ground (a dielectric). These products form when metallic zinc reacts with constituents of the surrounding soil.

Fig. 14.1 shows the remote action of the zinc coating: in the rectangular areas, the coating had been injured by removing it before the test pipes were buried for nine years in a test field.

Table 14.2:
Fields of use and soil conditions for zinc-based active coatings, as specified in Annex D of EN 545 [14.1]

Type of protection under section 4.4.2 of EN 545 [14.1]	Soils in which protection of the given type is not to be used
Zinc coating ≥ 130 g of Zn/m^2 and finishing layer ≥ 70 µm	■ Soils with a resistivity < 1,500 Ω cm when laid above the water table, < 2,500 Ω cm when laid below the water table ■ Mixed soils. i.e. comprising two or more soil natures ■ Soil with a pH < 6 and a high reserve of acidity ■ Soils containing refuse, cinders, slag or polluted by waste or industrial effluents ■ If stray currents occur
Zinc coating ≥ 200 g of Zn/m^2 and finishing layer ≥ 100 µm	■ Soils with a resistivity < 1,500 Ω cm when laid above or below the water table ■ Mixed soils. i.e. comprising two or more soil natures ■ Soil with a pH < 6 and a high reserve of acidity ■ Soils containing refuse, cinders, slag or polluted by waste or industrial effluents ■ If stray currents occur
Zinc coating ≥ 400 g of $ZnAl/m^2$ and finishing layer ≥ 70 µm	■ Acidic peaty soils ■ Soils containing refuse, cinders, slag or polluted by waste or industrial effluents ■ Soils below the marine water table with a resistivity < 500 Ω cm ■ If stray currents occur

Fig. 14.1:
Autogenous healing of artificial injuries by products of reaction of zinc

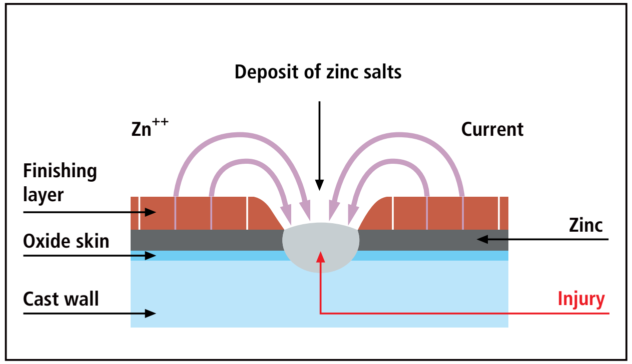

Fig. 14.2:
Cathodic protective effect of the zinc at injuries to the protective layer

By passing through the porous finishing layer for a few millimetres, the zinc ions are able to protect the exposed surface by depositing products of reaction which are hard to dissolve (a scarring or autogenous healing process). **Fig. 14.2** is a simplified schematic representation of the process.
All the relevant requirements for the pipe system are brought together in DVGW Arbeitsblatt GW 337 [14.13]. An additional requirement is that the mean mass of zinc per unit area must be at least 200 g/m² and for the Zn 85 – Al 15 system must be at least 400 g/m². In this way there is enough metallic zinc available for the zinc to be activated should any injuries occur at a later date, due say to movements of the ground or to subsequent digging work.

Under EN 545 [14.1] and EN 598 [14.2], the zinc coating on ductile iron pipes may also be provided with an at least 70 µm thick coating of bituminous paint. **Fig. 14.3** shows ductile iron sewer pipes to EN 598 [14.2] which have a reddish-brown coloured finishing layer of bituminous paint.

Fig. 14.3:
Ductile iron sewer pipes to EN 598 [14.2] with a zinc coating and a reddish-brown coloured finishing layer of bituminous paint.

14.2.2 Cement mortar coating

Ductile iron pipes with a cement mortar coating, **Fig. 14.4**, can be used in soils of all types. The cement mortar coating stops corrosive media from penetrating and withstands mechanical stresses during transport and installation. This coating has proved its worth particularly for the trenchless installation techniques of which increasing use is now being made. Under EN 15542 [14.6], the ability of the cement mortar coating to withstand mechanical loads is determined by two requirements:

- bond strength
- impact strength.

These requirements are formulated in such a way that the possibility of damage to the layer of cement mortar can be ruled out both in the course of proper transport and when installation takes place even in the most difficult terrain. For the production of the cement mortar coating see **Chapter 3**, **section 3.5**. Ductile iron pipes with a cement mortar coating are shown in **Fig. 14.4**.

Fig. 14.4:
Ductile iron pipes with a cement mortar coating

Should injuries nevertheless happen to occur (e.g. when installation is by the burst lining technique), the damaged areas are protected by the layer of zinc and the remote action which it has.

The joint regions are protected after assembly, see **section 14.4.2.**

14.2.3 Polyethylene coating

The polyethylene coating forms a layer of high electrical resistance separating the cast iron from the native soil. The layer needs to be at least 1 mm thick purely to provide corrosion protection and the rest of its thickness serves to improve the ability of the protective layer to withstand mechanical loads. **Fig. 14.5** shows ductile iron pipes with a polyurethane coating.

Fig. 14.5:
Ductile iron pipes with a polyethylene coating

EN 14628 [14.3] makes a distinction between the standard thickness coating and the increased thickness coating.

The requirements and tests specified in EN 14628 [14.3] are formulated in such a way that the polyethylene coating will withstand the usual stresses which occur during transport, storage and installation. The joint regions are protected after assembly, see **section 14.4.2**.

14.2.4 Polyurethane coating

The polyurethane coating **(Fig. 14.6)** forms a layer of high electrical resistance separating the cast iron from the native soil. Polyurethane resins are members of the thermoset family whose mechanical properties vary only slightly with temperature and which are not subject to cold flow.

The two-component resin system is sprayed onto the surface of the cast iron pipe, which has been blast-cleaned and heated, without solvents. Because of its relatively high hardness, impact resistance and resistance to indentation, a layer of a nominal thickness of 900 µm is adequate for the normal stresses occurring during transport, storage and installation. The polyurethane coating has also proved its worth for trenchless installation techniques. There is no need for the joint region to be provided with protection on site.
EN 15189 [14.4] lays down requirements and tests for the polyurethane coatings of ductile iron pipes.

Fig. 14.6:
Ductile iron pipes with a polyurethane coating

14.3 Coating of fittings and valves

Fittings and valves come in a wide variety of shapes and designs and because of this the characteristic feature of the methods and processes for coating them is often that the coating materials are applied simultaneously to all the surfaces of the components, i.e. both the internal and external surfaces, in a single step.

Automated processes employing programmed manipulators are increasingly being used for this purpose.

14.3.1 Epoxy coating

For use in both the drinking water field and for carrying sewage and wastewater, fittings and valves are usually given an epoxy coating **(Figs. 14.7 and 14.8)**. The coating is applied internally and externally in a mean thickness of at least 250 µm, predominantly in the form of epoxy powder, and the standard which applies to the coating is EN 14901 [14.5].

Fig. 14.7:
Epoxy coated resilient seated gate valve

Fig. 14.8:
Epoxy coated fittings for sewage and wastewater

The quality and testing requirements for powder coatings of valves and fittings which are laid down in RAL-GZ 662 [14.20] are more demanding than those in EN 14901. The bond strength is higher than in EN 14901 (12 N/mm² as compared with 8 N/mm²) and the test voltage for freedom from pores is 3 kV rather than 1.5 kV. Also, the cathodic disbonding test was introduced as an indicator of resistance to undermining of the coating at injuries. The layer thickness and impact resistance are of the same levels. An extensive system of in-house and external monitoring ensures that the quality of the coating remains consistently high.

The method of producing the coating is described in **section 3.5.2**.

The coating can be used in soils of any desired corrosiveness.

14.3.2 Enamel coating of fittings and valves

Technical enamel can be used as a coating material for fittings and valves in soils of all types. DIN 51178 [14.14] , English title: Vitreous and porcelain enamels – Inside and outside enamelled valves and pressure pipe fittings for untreated and potable water supply – Quality requirements and testing, was published in October 2009.

The enamelling creates a strong physical and chemical bond (an ion bond) to the ductile iron. It is formed by processes of diffusion from the substrate material to the enamel and vice versa. Requirements and tests are given in DIN 51178 [14.14]. **Fig. 14.9** shows some fully enamelled fittings.

Fig. 14.9:
Fully enamelled fittings

The properties of the internal and external enamel coatings are as follows:

- internal corrosion protection of proven effectiveness,
- high resistance to corrosion in all soils,
- coating is continuous internally and externally,
- high resistance to mechanical stresses,
- secure against undermining of coating, even when the surface is injured locally,
- resistance to ageing

The enamelling process is described in **section 3.5.2**. Enamel coatings can be used in soils of any desired corrosiveness.

14.3.3 Bitumen coating of fittings

Ductile iron fittings are also available with an external coating of bituminous paint.

The thickness of the layer is at least 70 µm. Fittings coated in this way are generally provided with a cement mortar lining **(section 3.5.2)**.

Recently there has been an increasing trend towards this type of coating being replaced by the epoxy coating to EN 14901 [14.5].

Fig. 14.10 shows fittings with an external coating of bituminous paint and a variety of linings.

Fig. 14.10:
Fittings with an external coating of bituminous paint and a variety of linings
a) enamel
b) & c) cement mortar
d) bituminous paint

14.4 On-site measures

A distinction is made between measures at installation and repair measures in the case of the on-site measures.

Measures at installation supplement works-applied coatings which are already present. The pipeline or a section of the pipeline is provided with additional protection in this case. In the case of pipe coatings such as cement mortar or polyethylene coatings, it is the fittings which are provided with this later protection.

14.4.1 Bedding suitable for corrosion protection

Bedding suitable for corrosion protection is a layer of soil of soil class 1 (non-corrosive or only slightly corrosive under DIN 50929-3 [14.7]) which rests in a homogenous form against the surface of the pipeline on all sides.

Under DIN 30675-2 [14.8] it is used as a supplement to the zinc plus finishing layer system. Under EN 805 [14.15] and EN 1610 [14.16], it consists of the initial backfill, the side fill and the upper and lower bedding **(Fig. 14.11)**. This measure produces a homogeneous zone surrounding the pipeline, particularly in highly corrosive heterogeneous soils.

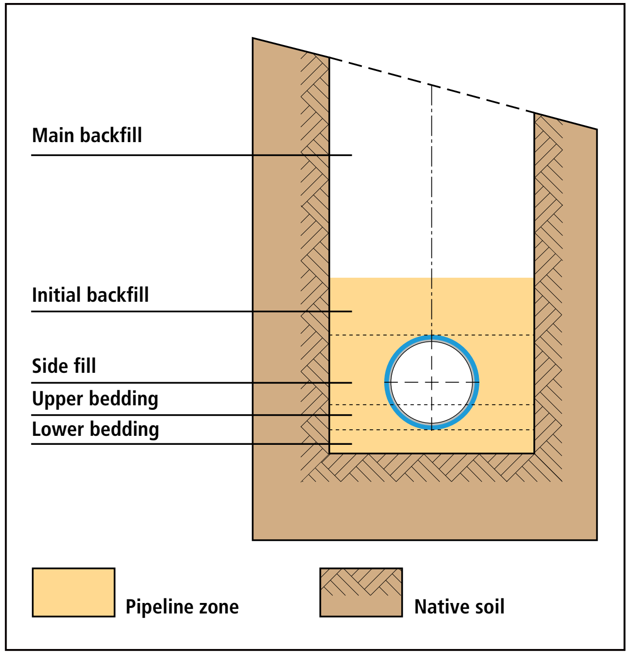

Fig. 14.11:
Terms relating to the bedding of pipes

As a result of this, spatially separated anode and cathode regions, which might cause deep or shallow pitting, do not form. Bedding suitable for corrosion protection should not be used where there is constant exposure to eluates whose pH is < 6 or in peaty, boggy, clayey or marshy soils.

14.4.2 Corrosion protection of joint regions

Once the joints have been assembled, the joint regions of pipelines with polyethylene or cement mortar coatings are coated as directed in the manufacturer's installation instructions (DIN 30675-2 [14.8]) **(Fig. 14.12)**.

What have proved successful for the protection of socket joints in polyethylene coated pipes is heat shrinkable material and, as an alternative for cement mortar coated pipes, rubber collars **(Fig. 14.13)**.

Fig. 14.12:
Application of a shrink sleeve

Fig. 14.13:
Ductile iron pipes with a cement mortar coating and with rubbers collars to protect the socket joints

14.4.3 Measures when there is electrochemical action

Corrosion protection when there is electrochemical action is dealt with in detail in DIN 30675-3 [14.8]. "Generally speaking, electrochemical action should not be expected in ductile iron pipelines with non-restrained joints due to the electrical break caused by the rubber-sealed joint between the pipes which occurs roughly every 6 m. Any measures to protect against electrochemical action can therefore be dispensed with."

What this standard mentions as causes of electrochemical actions are "Formation of electrochemical couples with extraneous cathodes and stray currents from direct current systems". The above is also true of pipelines with restrained joints where the restrained joints act as electrical insulators. It is only in pipelines with restrained joints where the joints are metal and conductive that provisions need to be made for electrochemical protection, such for example as:

- installation of pipe joints which act as electrical insulators approximately every 100 m,
- maintaining of an adequate distance from systems which have cathodic protection, by following the recommendations of the DVGW/VDE Working Party on Questions of Corrosion (the AfK) given in AfK 2 [14.17],
- drainage or forced drainage of stray currents in accordance with DIN EN 50162 and VDE 0150 [14.18].

Corrosion of buried ductile iron pipelines due to alternating current is dealt with in [14.19].

It is stated in the above article that the position is similar to that stated in DIN 30675-2 [14.8] for direct currents, namely that the only pipelines with restrained joints which are at risk from corrosion are ones more than about 100 m long which have metal conductive joints and whose coatings act as electrical insulators to alternating currents.

14.4.4 Repair measures

The coatings of pipes, fittings and valves are selected to be sufficiently robust for no significant injuries to occur to them provided they are properly handled.

If repairs nevertheless have to be made, e.g. if incorrect handling occurs or tapping or cutting is necessary, the manufacturer's installation instructions must be followed.

14.5 References

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[External corrosion protection of buried pipes –
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15 Linings

15 Linings

What is meant by linings is protective coatings on the internal surfaces of pipelines. Their purpose is to protect the material of the pipes against chemical reactions with the medium flowing through the pipes. The aim is above all that drinking water, as a medium, will be transported to the end consumer without suffering any adverse effects. Ductile iron pipes are lined as standard with cement mortar or polyurethane (PUR). These linings are considered to be an integral part of the pipe.

Ductile iron fittings and valves on the other hand are, in the majority of cases, coated internally and externally with epoxy, although polyurethane and vitreous enamelling are becoming increasingly important in this application. Cement mortar linings however are becoming less frequently used in fittings.

Generally speaking, the types of lining depend on the applications for which ductile iron pipe systems are used.

15.1 General

Ductile iron pipelines are normally equipped with factory-applied linings, with the linings differing between pipes on the one hand and fittings and valves on the other due to the application processes used. Basically, the linings are matched to the types of water or other mediums such as sewage which are being transported. **Table 15.1** is a listing of the types of water and other mediums, together with their special properties and the main requirements which are important in each case.

Table 15.1:
Overview of types of water and similar media to be transported and the main requirements which the lining has to meet

Medium transported	Main properties of the medium	Requirements for the lining
Drinking water meeting the drinking water regulations	In lime-carbonic acid equilibrium	■ Corrosion protection ■ Drinking water hygiene
Water similar to drinking water such as water for non-drinking use and cooling water	In lime-carbonic acid equilibrium	■ Corrosion protection ■ Drinking water hygiene
Raw water not meeting the drinking water regulations	Often lime-dissolving (acid)	■ Corrosion protection
Wastewater complying with DWA (German Association for Water, Wastewater and Waste) Merkblatt M 115-2 [1]	Meets the guideline values laid down in DWA Merkblatt M 115-2 [1]	■ Corrosion protection in the submerged area and in the atmosphere in the drainage sewer ■ Abrasion resistance ■ Resistance to chemicals ■ Resistance to jet cleaning
Industrial wastewater which is outside the requirements of DWA (German Association for Water, Wastewater and Waste) Merkblatt M 115-2 [1]	Contains acid to alkaline components	■ Corrosion protection in the submerged area and in the atmosphere in the drainage sewer ■ Abrasion resistance ■ Resistance to chemicals ■ Resistance to jet cleaning ■ Temperature resistance
Brines	High in salt	■ Corrosion protection ■ Abrasion resistance

Tables 15.2 and 15.3 provide information on the linings commonly used for ductile iron pipelines for transporting water of all kinds and sewage. The tables relate to the coatings used for the internal surface of pipes **(Table 15.2)** and of fittings and valves **(Table 15.3)** and to the coatings used on the surfaces in the joint region.

Table 15.2:
Overview of the applications of linings for ductile iron pipes

Field of application	Internal surfaces of pipes	Surfaces in the joint region
Drinking water under EN 545 [2]	Cement mortar lining based on blast furnace cement	Coating based on bitumen or on epoxy paint
	Polyurethane lining to EN 15655 [3]	Coating based on polyurethane or epoxy paint
Sewage under EN 598 [4] and other types of water	Cement mortar lining based on high-alumina cement	Coating based on epoxy paint
	Polyurethane lining to EN 15655 [3]	Coating based on poly-urethane or epoxy paint
Industrial wastewater	Cement mortar lining based on high-alumina cement	Coating based on epoxy paint
	Polyurethane lining to EN 15655 [3]	Coating based on poly-urethane or epoxy paint

Table 15.3:
Overview of the applications of linings for fittings and valves

Field of application	Type of lining on		
	Internal surfaces of fittings	Internal surfaces of valves	Surfaces in the joint region
Drinking water under EN 545 [2]	Lining of polymer-modified cement mortar	Epoxy coating to DIN 3476 [7] and RAL GZ 662 [6]	Coating based on bitumen or on epoxy paint
	Epoxy coating to EN 14901 [5] and RAL GZ 662 [6]		
	Vitreous enamel to DIN 51178 [8]	Vitreous enamel to DIN 51178 [8]	As for internal surfaces
	Polyurethane lining to EN 15655 [3]	—	As for internal surfaces
Sewage under EN 598 [4] and other types of water	Lining of polymer-modified cement mortar	Epoxy coating to DIN 3476 [7] and RAL GZ 662 [6]	Coating based on poly-urethane or epoxy paint
	Epoxy coating to EN 14901 [5] and RAL GZ 662 [6]		
	Vitreous enamel to DIN 51178 [8]	Vitreous enamel to DIN 51178 [8]	As for internal surfaces
	Polyurethane lining to EN 15655 [3]	—	As for internal surfaces
Industrial wastewater	Epoxy coating to EN 14901 [5] and RAL GZ 662 [6]	Epoxy coating to DIN 3476 [7] and RAL GZ 662 [6]	As for internal surfaces
	Vitreous enamel to DIN 51178 [8]	Vitreous enamel to DIN 51178 [8]	As for internal surfaces
	Polyurethane lining to EN 15655 [3]	—	As for internal surfaces

15.2 Linings of pipes, fittings and valves for drinking water pipelines

15.2.1 Cement mortar linings of pipes and fittings

The cement mortar linings of ductile iron pipes and fittings are considered to be an integral part of the product. The requirements and test methods for them are therefore given in the product standard EN 545 [2].

The purposes of the cement mortar lining are as follows:

- To optimise hydraulic properties
- To prevent damage from corrosion. Such damage includes:
  - damage to the metallic material of pipes due to reactions with water and with substances dissolved in the water,
  - adverse effects on the operation of the pipeline caused by products of reaction on the inner wall of pipes (e.g. incrustation),
  - adverse effects on the water caused by products of reaction, e.g. non-allowable changes in parameters of the water (contamination, discoloration or turbidity).

The fields of use and limits of use of the cement mortar coating described are given in informative Annex E to EN 545 [2].

Under the above, the standard lining with blast furnace cement mortar as a binder is, in general, suitable for unrestricted use in the field of drinking water if the drinking water being transported complies with the European drinking water directive or national drinking water regulations.

For wastewater, sewage and other types of water (e.g. raw water, water for non-drinking uses), other cements can be used as binders as shown in **Tables 15.2 and 15.3**.

DIN 2880 [9] provides a wide range of information on the fields of use and special features of cement mortar linings for metal pipes. It defines the behaviour of and requirements for the linings for all types of water, sewage, salt water and brines. In addition, it gives direction for assessing shrinkage cracks and drying cracks in cement mortar linings and information on their self-healing characteristics.

Fig. 15.1:
Charging the pipe with cement mortar before the spin centrifuging

DVGW Arbeitsblatt W346 [10] provides practical recommendations on the pressure testing, flushing, disinfection, running-in and operation of drinking water pipelines with cement mortar linings.

DVGW Arbeitsblatt W 347 contains drinking water hygiene requirements and test methods for cementitious materials used in the drinking water field and thus covers cement mortar linings for ductile iron pipes and fittings.

The methods by which linings are produced are described in detail in **Chapter 3**, Production of pipes, fittings and accessories. **Fig. 15.1** shows a ductile iron pipe which is going to be lined with cement mortar, before the spin centrifuging.

15.2.2 Polyurethane linings for pipes and fittings

The polyurethane lining to EN 15655 [3] is applied to the smoothed and abrasive blasted internal surfaces of pipes and fittings by the two-component hot spraying technique **(Fig. 15.2)**.

The polyurethane lining acts as a high-resistance electrical insulator between the medium flowing through and the iron.

Fig. 15.2:
The polyurethane lining being applied in a pipe

Where pipes are cut on the installation site, the new cut face has to be re-coated with an epoxy-based repair paint.

The lining meets the requirements of the Guideline issued by the German Federal Environmental Agency (UBA) on the hygienic assessment of organic coatings in contact with drinking water and the requirements of DVGW-Arbeitsblatt W 270 [12].

15.2.3 Epoxy coating of fittings and valves

The technique usually employed for coating with epoxy powder consists of the following steps:

- activation of the surface of the fully fettled castings by blasting with sharp-edged steel grit – grade of cleanliness of the surface: SA 2 ½,
- heating in a continuous preheating oven,
- application of the powder by automated dipping into a fluidised bed of powder **(Fig. 15.3)** or by applying the powder with a spray gun **(Fig. 15.4)**,
- cross-linking of the fused-on layer of epoxy powder in a drying oven.

Fig. 15.3:
Application of epoxy powder by robot, using the fluidised bed technique

Fig. 15.4:
Electrostatic application of epoxy powder by means of a spray gun

The process technology, the monitoring to ensure that the production parameters laid down are observed and the quality testing of the finished coating are governed by the RAL-GZ 662 [6] quality assurance test specifications entitled "Heavy-duty corrosion protection of powder coated valves and fittings" which are issued by the GSK Quality Association for the Heavy Duty Corrosion Protection of Powder Coated Valves and Fittings.

The epoxy coating is also one of those listed in standards EN 545 [2] and EN 598 [4] and there are standards for the coating itself in the form of EN 14901 [5] and DIN 3476 [7].

15.2.4 Lining of fittings and valves with vitreous enamel

Enamel coatings have long proved their worth in the field of the lining of valves for use in drinking water applications **(Fig. 15.5)**. This lining is also being increasingly widely used for ductile iron fittings **(Fig. 15.6)**. There is a standard for it in the form of DIN 51178 [8].

Fig. 15.5:
Fully enamelled butterfly valve

Fig. 15.6:
Fittings during the enamel firing

15.2.5 Organic linings/coatings for the joint region

The surfaces in pipe joints are coated with organic materials. Such coatings are generally based on bitumen, epoxy or polyurethane.

Fig. 15.7 is a section through a push-in joint; it clearly shows that both the external surface of one pipe and the internal outline of the socket of the other pipe are in contact with drinking water.

The materials used for the epoxy coatings have to meet the requirements of the Guideline issued by the German Federal Environmental Agency (UBA) on the hygienic assessment of organic coatings in contact with drinking water.

The requirements for bituminous paints in the joint region are included in DVGW-Arbeitsblatt W 348 [13].

Generally speaking, all coatings and linings which are in contact with drinking water and which have organic constituents also have to be tested under DVGW-Arbeitsblatt W 270 [12] for their tendency to enhance microbial growth.

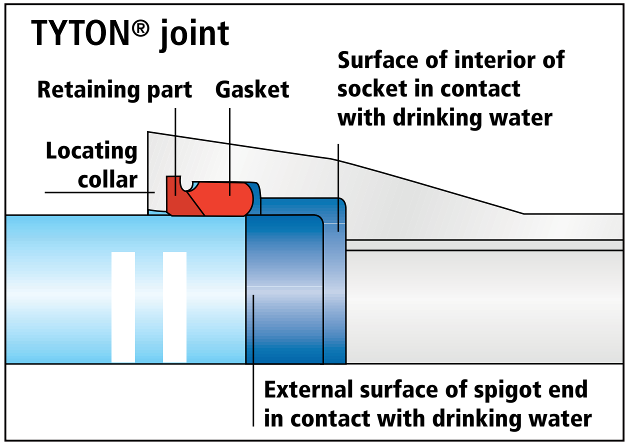


Fig. 15.7:
Surfaces in contact with drinking water in the region of the TYTON® joint

15.2.6 European rules and regulations

One special feature which exists in the field of drinking water is that there is a standard for pipelines for drinking water in the form of the European Construction Products Directive. The aim of this is to prevent there from being trade barriers of the sort which would result from differing national requirements.

The intention is however for the individual national rules and regulations to continue to exist. This means that a European approval procedure has to be set up under which requirements and test methods for components in contact with drinking water will be developed which can be adopted in all the member states without the national levels of protection having to be abandoned. Once this procedure comes into force, it will be possible for approval from the point of view of drinking water hygiene to be obtained for the component concerned in all the states of the EU by the passing of a single approval test.

15.3 Linings in pipelines for raw water

Raw water often does not meet the drinking water regulations. It is often highly lime-dissolving acid water.

In the course of time, lime-dissolving water may adversely affect the strength of cemetitious materials by dissolving the calcium carbonate containing in them.

The processes which this involves are all the more intensive the higher is the lime-dissolving capacity and the lower is the compaction of the lining.

Cement mortar linings based on high-alumina cement have proved successful for raw water which does not meet the drinking water directives. This lining is applied in pipes by the spin centrifuging technique and is therefore very highly compacted. High-alumina cement mortar contains virtually no free lime and is resistant to lime-dissolving water. Polymer-modified cement mortar too is resistant to lime-dissolving water.

Pipes with polyurethane linings to EN 15655 [3], fittings and valves with epoxy coatings to EN 14901 [5] and fittings and valves which are enamelled to DIN 51178 [2] are likewise suitable for transporting raw water.

15.4 Linings of pipes, fittings and valves for pipelines for wastewater and sewage

Wastewater and sewage contain considerably more materials than drinking water or raw water. Wastewater in public drainage systems must meet the guideline values given in DWA-Merkblatt M 115-2 [1]. This gives general guideline values for the most important criteria governing the characteristics of, above all, non-domestic wastewater.
However, there are many cases where these guideline values are exceeded by industrial wastewater before it is treated.

15.4.1 Cement mortar linings of pipes and fittings

There is a standard for ductile iron pipes and fittings for sewage disposal in the form of EN 598 [4]. The field of use in this case covers gravity and pressure sewers. The lining must withstand different mechanical and chemical stresses in the long term. It is produced with high-alumina cement as a binder.

This enables it to withstand not only chemical stresses such as those from soft, acid or very salt water but also mechanical stresses caused for example by detritus in the wastewater or sewage or by high-pressure jet-cleaning.

The lining of high-alumina cement mortar is highly compacted by the spin centrifuging process and is cured at high temperatures in special curing chambers in such a way that the aluminium hydrates acquire the stable cubic crystalline structure which is the basis for the high resistance of this lining.

The joint region is protected against attack by an epoxy coating.

15.4.2 Polyurethane linings of pipes and fittings

There is a standard for ductile iron pipes and fittings with polyurethane linings for sewerage applications in the form of EN 598 [4]. The field of use in this case covers gravity and pressure sewers. In the long term, the lining must withstand different mechanical and chemical stresses such as those from soft, acid or very salt water and also mechanical stresses caused for example by detritus in the sewage or by high-pressure jet-cleaning.

The polyurethane lining to EN 15655 [3] is applied to the smoothed and abrasive blasted internal surfaces of pipes and fittings by the two-component hot spraying technique. It acts as a high-resistance electrical insulator between the medium flowing through and the iron and ensures resistance to wastewater and sewage of all kinds.

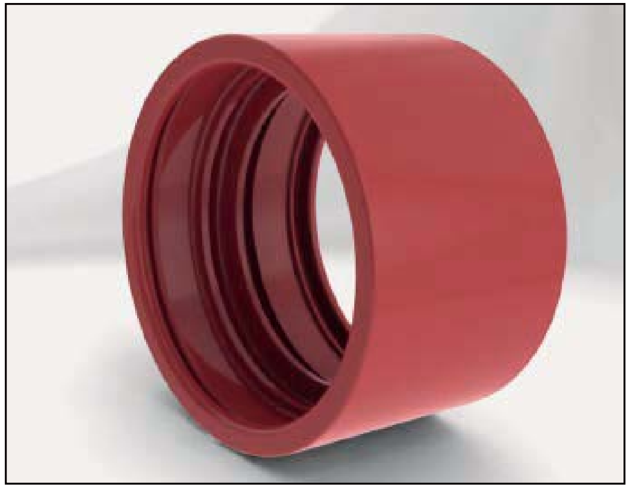


Fig. 15.8:
Sewer fitting with epoxy powder coating

15.4.3 Epoxy coating of fittings and valves for the transport of wastewater and sewage

In the wastewater and sewage field, fittings are provided as standard with an epoxy coating both internally and externally. The epoxy coating is listed in EN 598 [4] and the standard for it is EN 14901 [5]. **Fig. 15.8** shows a TYTON® collar which has an internal and external epoxy powder coating.

15.4.4 Lining of fittings and valves with vitreous enamel

Coatings and linings of vitreous enamel complying with DIN 51178 [8] are a possibility in the wastewater and sewage field. **Fig. 15.9** shows an enamelled gate valve for use in wastewater pressure pipelines.

Fig. 15.9:
Enamelled gate valve for use in wastewater pressure pipelines

15.5 Linings in pipelines for non-drinking and cooling water

Pipes and fittings from the range intended for drinking water can be used for transporting non-drinking and cooling water. Where there is any doubt it has to be established whether they are suitable. The technical departments of the various manufacturers provide advice on this.

With lime-dissolving water, what are suitable are pipes with linings based on high-alumina cement or polyurethane linings. The fittings and valves in such pipelines have to be protected with epoxy to EN 14901 [5] or vitreous enamel to DIN 51178 [8].

15.6 References

[15.1] DWA Merkblatt M 115-2
Indirekteinleitung nicht häuslichen Abwassers –
Teil 2: Anforderungen
[DWA technical information sheet M 115-2
Indirect discharging of non-domestic sewage –
Part 2: requirements]
2005-07

[15.2] 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

[15.3] EN 15655
Ductile iron pipes, fittings and accessories –
Internal polyurethane lining for pipes and fittings –
Requirements and test methods
[Rohre, Formstücke und Zubehörteile aus duktilem Gusseisen –
Polyurethan-Auskleidung von Rohren und Formstücken –
Anforderungen und Prüfverfahren]
2009

[15.4] EN 598
Ductile iron pipes, fittings, accessories and their joints for sewerage applications –
Requirements and test methods
[Rohre, Formstücke, Zubehörteile aus duktilem Gusseisen und ihre Verbindungen für die Abwasserentsorgung –
Anforderungen und Prüfverfahren]
2007+A1:2009

[15.5] 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

[15.6] 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 coatings –
Quality assurance]
2008

[15.7] 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 powder (P) or liquid varnishes (F) – Requirements and Test]
1996-08

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

[15.9] DIN 2880
Anwendung von Zementmörtel-Auskleidung für Gußrohre, Stahlrohre und Formstücke
[Application of cement mortar lining for cast iron pipes, steel pipes and fittings]
1999-01

[15.10] DVGW-Arbeitsblatt W 346
Guss- und Stahlrohrleitungsteile mit ZM-Auskleidung – Handhabung
[DVGW worksheet W 346
Pipeline components of cast iron or steel with cement mortar lining – Treatment]
2000-08

[15.11] DVGW-Arbeitsblatt W 347
Hygienische Anforderungen an zementgebundene Werkstoffe im Trinkwasserbereich – Prüfung und Bewertung
[DVGW worksheet W 347
Hygienic requirements for cementitious products in contact with drinking water – Test methods and assessment]
2006-05

[15.11] 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

[15.13] DVGW-Arbeitsblatt W 348
Anforderungen an Bitumenbeschichtungen von Formstücken aus duktilem Gusseisen und im Verbindungsbereich von Rohren aus duktilem Gusseisen, unlegiertem und niedrig legiertem Stahl
[DVGW worksheet W 348
Requirements for bituminous coatings of ductile iron fittings and of the joint area of ductile iron pipes and pipes of unalloyed or low-alloy steel]
2004-09

16 Structural design

16 Structural design

This chapter is being prepared.

17 Hydraulic design

17 Hydraulic design

This chapter is being prepared.

18 Welding of ductile iron pipes

18 Welding of ductile iron pipes

This chapter is being prepared.

19 Transport, storage and installation

19 Transport, storage and installation

If ductile cast iron pipelines are handled and installed correctly and professionally, a high degree of reliability and a long working life can be expected of them. Because of their specific properties ductile cast iron pipes, fittings and valves are suitable for various installation techniques and a large number of applications.

19.1 General

Pipelines for the transport of drinking water and wastewater, and also such applications as turbine and snow-making equipment, are civil engineering projects – ones which involve high investment costs. Also correspondingly high are expectations of operational security and useful life. Therefore it is understandable that great importance is attributed to the choice of pipe material, manufacturing and above all correct handling and installation.

Experienced personnel need to be recruited for carrying out and supervising such projects who are able to assess the quality of the work in terms of standards EN 805 [19.1] and EN 1610 [19.2]. The companies used by the client must have the necessary qualifications for carrying out the work. It is important for the client to satisfy himself of the existence of these qualifications. This also applies accordingly for the choice of planning engineers.

Suitable evidence of the contractor's qualification may for example be possession of DVGW certification according to DVGW worksheet GW 301 [19.3]. There is a comparable provision in SVGW guideline W4-3 [19.4].

The increasing use of restrained push-in joints, especially when using trenchless laying techniques, prompted the development of a training and test plan for engineers installing metal pipes with push-in joints. DVGW worksheet W 339 [19.5] for specialists in joint technology for metal piping systems is applicable for this in Germany while SVGW guideline W4-3 [19.4] applies in Switzerland.

In Germany, civil engineering companies are increasingly requiring certification by the "Güteschutz Kanalbau" quality association for the installation of sewers and wastewater pipelines. This or similar certification is required for construction work in drinking water protection zones, in accordance with ATV-DVWK-A 142 [19.6].

19.2 Pipeline installation regulations

For the installation of pipelines, depending on the medium being transported, standards EN 805 [19.1] are to be followed for water pipelines and EN 1610 [19.2] for wastewater pipelines. For standards EN 805 [19.1] and EN 1610 [19.2] there are supplementary sets of rules available in different European countries to complete these. **Table 19.1** provides a summary for individual countries.

With pipelines for transporting the food “drinking water”, the highest requirements are set not just for the components but also for the planning and construction engineers. European directive 98/83/EC [19.13] on the quality of water intended for human consumption has been implemented in the EU member states and is to be observed.

Table 19.1:
Summary of rules specific to individual countries as a supplement to EN 805 [19.1] and EN 1610 [19.2]

Country	Supplementary rules for	
	EN 805 [19.1]	EN 1610 [19.2]
Germany	DVGW worksheet W 400-2 [19.7]; DIN 2000 [19.8]	DWA-A 139 [19.9]; ATV-DVWK-A 142 [19.6]
Austria	OENORM B 2538 [19.10]	OENORM B 2503 [19.11]
Schwitzerland	SVGW guideline W4-3 [19.4]	SIA 190; SN 533190 [19.12]

19.3 Transport of ductile cast iron pipes, fittings and valves

Ductile iron pipes, fittings and valves for drinking water and wastewater pipelines are to be protected by appropriate means against damage and pollutions during transport and storage. EADIPS®/FGR® standard 74 [19.14] is to be followed for the packaging of fittings and valves.
The manufacturer’s instructions for transport, storage and installation must be observed.

19.3.1 Transport and storage of pipes

19.3.1.1 Loading and unloading

Ductile iron pipes ≤ DN 350 are delivered as pipe bundles and larger ones as single pipes. The precise number of pipes per bundle, as well as the weight in each case, can be found in the manufacturer’s documentation.

When loading and unloading pipes and pipe bundles by crane, lifting straps are to be used. Where individual pipes are unloaded using crane hooks, this must be done with wide, padded hooks **(Figure 19.1)** which are attached to the head ends as otherwise there is a danger of damaging the pipe and its coating.

Figure 19.2 gives an idea of how lifting tackle should be used for transporting pipes.

As an alternative to loading and unloading by crane, suitable forklift trucks can also be used.

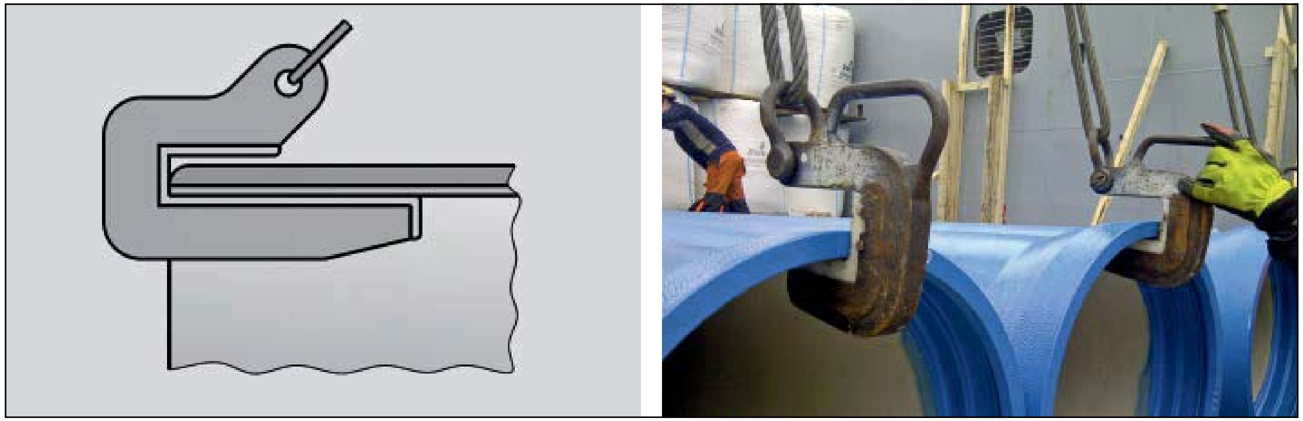


Fig. 19.1:
Padded hook for pipe transport

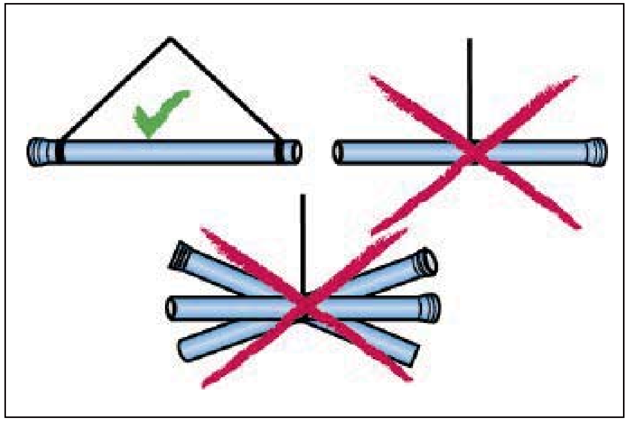


Fig. 19.2:
Attaching lifting tackle

Particular attention must be paid here to ensure that

- the pipes cannot tip sideways over the fork (the fork should be ≥ 1.5 m wide),
- the pipes cannot roll off the fork,
- the fork is sufficiently padded so that damage to the pipe is avoided.

During the loading and unloading process nobody must be beneath or on top of the pipe or pipe bundle, or within the hazard area of the crane.

Pipes and pipe stacks should only be set down on wooden beams or other suitable materials.
They should

- not be set down abruptly,
- not be shed by the vehicle,
- not be hauled or rolled,
- be secured against rolling and slipping,
- be stored on a level, load-bearing surface.

If ductile iron pipes are stored in a stack then they should be laid on wooden supports at least 10 cm wide, with a distance of approx. 1.5 m from the pipe ends **(Figures 19.3, 19.4 and 19.5)**.

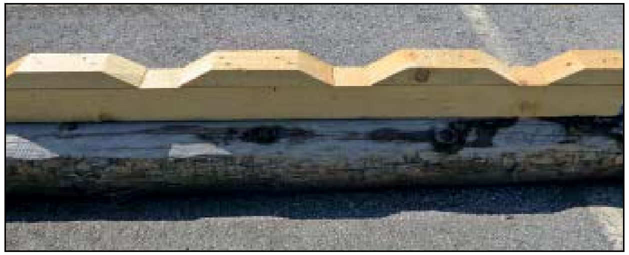


Fig. 19.3:
Sleeper for stacking ductile iron pipes

The ductile iron pipes are prevented from rolling off flat wooden beams by nailing on wooden wedges **(Figure 19.6)**.

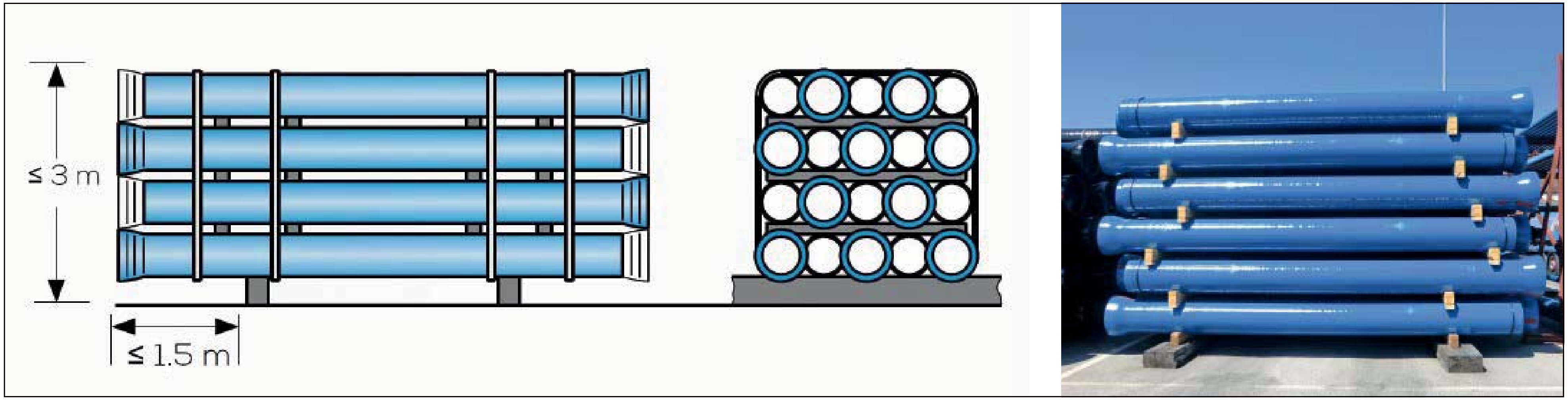


Fig. 19.4:
Arrangement of wooden supports for stacking ductile iron pipes

Fig. 19.5:
Ductile iron pipes set down
on wooden supports

Fig. 19.6:
Ductile iron pipes stacked with the help of wooden supports

Stacking heights for ductile iron pipes are stated in the manufacturer's information. Stacking heights of more than 3 m on the installation site are to be avoided for safety reasons.

Individual pipes are to be secured using wooden wedges **(Figure 19.7)**.

19.3.1.2 Opening up pipe bundles

The pipe bundles are secured with steel or plastic straps. The straps should only be cut using suitable tools (plate shears or side cutters) to avoid damage to the pipes and the risk of injury to personnel.

Before cutting the steel straps it is important to make sure that

- the pipe stack stands on firm ground which is as level as possible and does not slope,
- the pipes are secured against rolling and slipping,
- nobody is standing on or in front of the stack of pipes.

19.3.1.3 Distributing the pipes along the installation site

If the pipes are laid out alongside the pipe trench before being installed, they are to be placed on wooden supports or similar as already described and secured against slipping and rolling **(Figure 19.8)**. The protection caps on drinking water pipes should only be removed immediately before installation **(Figure 19.9)**.

19.3.2 Transport and storage of fittings

In accordance with EADIPS®/FGR® standard 74 [19.14] fittings should preferably be dispatched in cage pallets **(Figure 19.10)**. Consignment on disposable pallets is permissible for site deliveries **(Figure 19.11)**. Fittings must be stacked and arranged in such a way that they cannot damage each other.

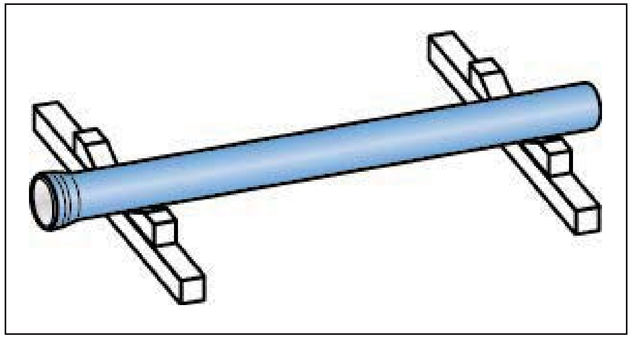


Fig. 19.7:
Securing individual pipes

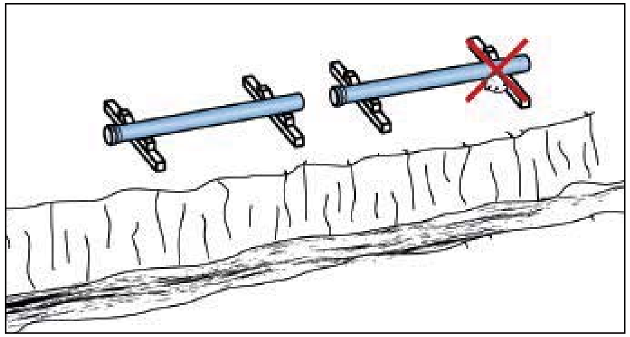


Fig. 19.8:
Securing ductile iron pipes on the installation site

Fig. 19.9:
The protective caps of ductile iron pipes for drinking water supply are only to be removed directly before installation

Fig. 19.10:
Ductile fittings in a cage pallet ready for dispatch

Fig. 19.11:
Preparation of fittings ready for dispatch on disposable pallets

Individual parts or articles which do not fit into a cage pallet are to be packed and dispatched on Europallets or disposable pallets. Wherever possible the individual parts should not project beyond the edge of the pallet.

The following advice [19.14] should also be followed for fittings:

- Up to DN 300 openings should be closed with the corresponding EADIPS®/FGR® protective caps.
- As from DN 350 openings are also to be closed by suitable means, e.g. covers in weather-resistant materials, shrink film or similar. When using steel straps, the coating of the fittings is to be protected at the points of contact with the steel straps.

Fig. 19.12:
Valves in a cage pallet ready for dispatch

19.3.3 Transport and storage of valves

According to EADIPS®/FGR® standard 74 [19.14] it is preferable for valves to be dispatched in cage pallets **(Figure 19.12)**. Consignment on disposable pallets is permissible for site deliveries **(Figure 19.13)**.

The stacking and arrangement must ensure that the parts cannot damage each other.

Fig. 19.13:
Arrangement of valves on disposable pallets ready for dispatch

The body ends must be protected in order to prevent the ingress of foreign matter and moisture. For valves with polymer or elastomer seats, it is important that these seats are also protected against UV radiation. The protective caps for valves with flange connections must correspond to EN 12351 [19.15]. Valves with polymer or elastomer seats must be delivered in such a way that the sealing material is not put under compressive stress. With all other valves, the closing device must be in the closed position during delivery.

Individual parts or articles which do not fit in cage pallets are to be packed and dispatched on Europallets or disposable pallets. Wherever possible the individual parts should not project beyond the edge of the pallet.

19.3.4 Storage of accessories

The manufacturer's instructions contain information about the storage of parts such as gaskets.

Explanations about the storage conditions for gaskets can be found in Chapter 13.3.9, taking account of ISO 2230 [19.16].

19.4 Installation of ductile iron pipe systems

The most important condition for the successful construction of these systems lies in following the manufacturer's installation instructions.

The condition of pipes, fittings and valves in ductile cast iron as well as accessories needs to be checked before installation.

19.4.1 Installation of pipes

DVGW worksheet W 346 [19.17] supplements the specific instructions and recommendations for cement mortar linings.

For ductile iron pipes with restrained flexible push-in joints the allowable operating pressure marking (PFA) is to be observed in accordance with EADIPS®/FGR® standard 75 [19.18] **(Chapter 3.6.1)**.

19.4.1.1 Cutting of pipes

The outside diameter of pipes up to DN 300 is at least up to 2/3 of the pipe length away from the spigot end in the permissible area **(Table 19.2)**, i.e. these pipes can be cut on site within this area. Individual manufacturers also allow larger cutting areas **(Figure 19.14)**.

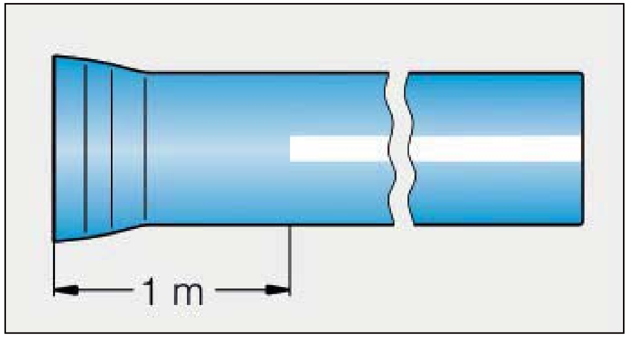


Fig. 19.14:
Example of marking on a ductile iron pipe – the pipe can be cut in the area with a longitudinal stripe

Table 19.2:
Permissible outside pipe diameters for cutting ductile iron pipes in mm

DN	$Dext_{max}$	$Dext_{min}$	C_{max}	C_{min}
80	99	95.3	311.0	299.4
100	119	115.2	373.8	361.9
125	145	141.2	455.5	443.6
150	171	167.1	537.2	525.0
200	223	219.0	700.6	688.0
250	275	270.9	863.9	851.1
300	327	322.7	1027.3	1013.8
400	430	425.5	1350.9	1336.7
500	533	528.2	1674.5	1659.4
600	636	631.0	1998.1	1982.3
700	739	733.7	2321.6	2305.0
800	843	837.5	2648.4	2631.1
900	946	940.2	2971.9	2953.7
1000	1049	1043.0	3295.5	3276.7

Dext = external diameter, C = circumference

Fig. 19.15:
Ductile iron pipes > DN 300 suitable for cutting on site – marked with a longitudinal white stripe

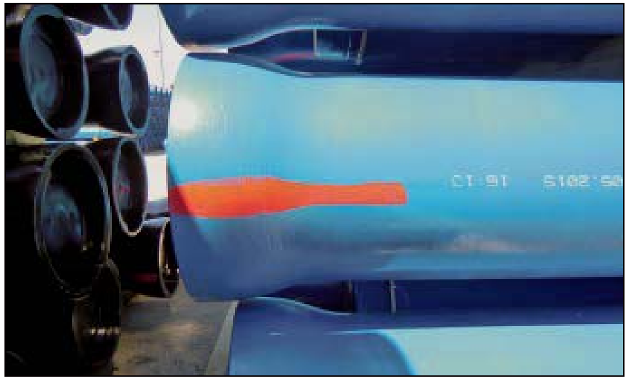


Fig. 19.16:
Cuttable ductile iron pipes > DN 300 – marked with a red stripe on the socket – cutting of the pipes from the spigot end to up to 1 m before the socket end-face

Cuttable pipes above DN 300 are identified with longitudinal stripes **(Figures 19.15 and 19.16)**. All pipes are cuttable with certain manufacturers.

When shortening (cutting) the pipes, attention must be paid to accident prevention rules. For example angle grinders with resin-bonded stone disks, e.g. type C 24 RT Special in silicon carbide are used for cutting pipes **(Figure 19.17)**.

The swarf produced when cutting the pipes is to be removed.

The cut surfaces of the shortened pipes must be sealed again according to the manufacturer's instructions. The new spigot end is to be chamfered according to the original spigot end. The manufacturers provide directions for this in the installation instructions **(Figure 19.18)**.

After cutting and chamfering the pipe, the insertion marking (e.g. two white lines) is to be transferred to the new spigot end **(Figure 19.19)**.

Fig. 19.17:
Separation cut on a pipe

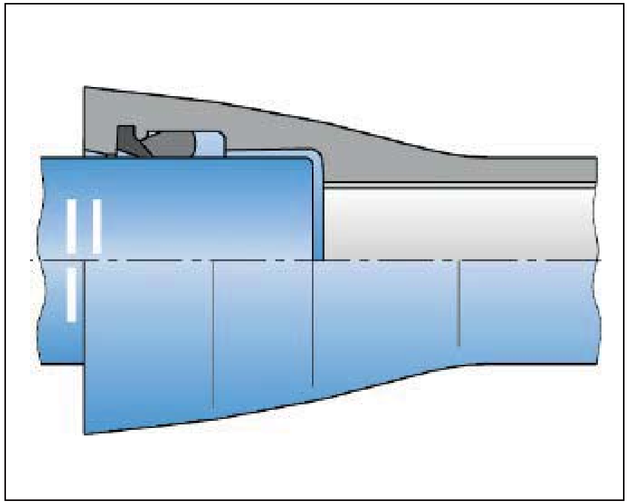


Fig. 19.19:
Spigot end with insertion marking

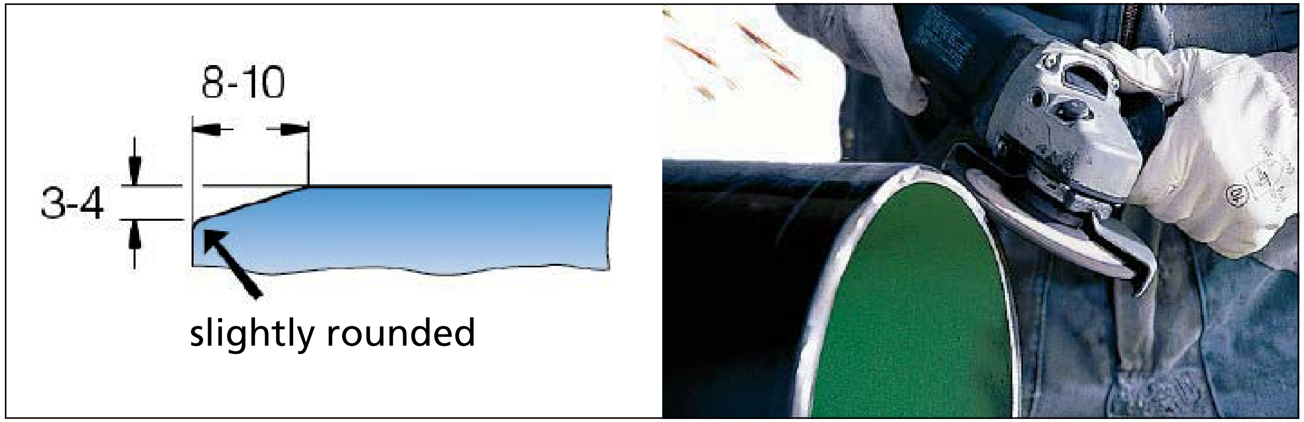


Fig. 19.18:
Example of how to chamfer a spigot end

19.4.1.2 Repair of any deformation of pipe ends occurring after cutting (rounding)

The spigot ends of larger diameter pipes or the cut ends produced after shortening pipes may not be perfectly round. However, by taking advantage of the elastic properties of the material, rounding the pipes is possible. To do this, e.g. a jack is put on the inside of the pipe. So as not to damage the cement mortar lining by this process, the jack is tightened between pieces of hardwood which are shaped to fit the inside of the pipe **(Figure 19.20)**.

Pipes with push-in joints > DN 1000 can generally be assembled without difficulty without any rounding device, even if some ovalisation has occurred due to storage and transport.

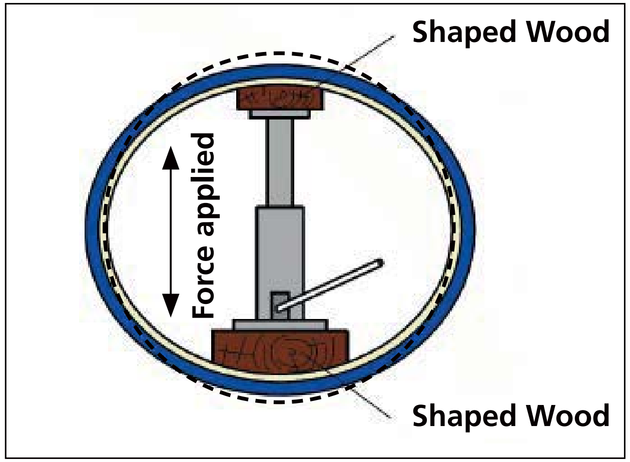


Fig. 19.20:
Rounding a pipe spigot end with a jack

Fig. 19.21:
Example of assembly equipment for pulling ductile iron pipes ≤ DN 300 together

19.4.1.3 Assembling push-in joints

Non-restrained push-in joints are described in **Chapter 8.2** and restrained push-in joints in **Chapter 9.2**.

Information is provided in the installation instructions from ductile iron pipe manufacturers for the installation of push-in joints covering cleaning, applying suitable lubricants, inserting rubber gaskets and checking the correct seating of the rubber gasket.

Appropriate assembly equipment is listed for the various nominal size ranges by the manufacturers of ductile iron pipes **(Figures 19.21, 19.22 and 19.23)**.

When assembling pipe joints using an excavator, a suitable intermediate layer is to be provided between pipe and excavator shovel, e.g. a shaped wooden block.

Insertion must be done smoothly and slowly. This ensures that the gasket is not pushed out of the retaining groove. The correct seating of the gasket can be checked by feelers after assembly. With all assembly techniques, the pipes must be aligned centrally and axially before and during the assembly of the pipes.

19.4.1.4 Assembling screwed socket joints

Screwed socket joints are described in **Chapter 1.3.3 (Figure 1.7)** and **Chapter 9.4.3**. For the assembly of screwed socket joints **(Figure 19.24)** special tools are required **(Figure 19.25)**. The manufacturer's installation instructions are to be followed.

Fig. 19.22:
Example of assembly equipment for pulling ductile iron pipes $\geq$ DN 350 together

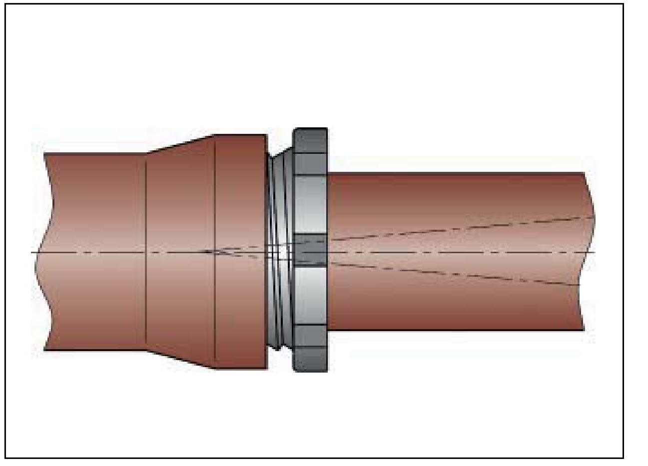


Fig. 19.24:
Screwed socket joint

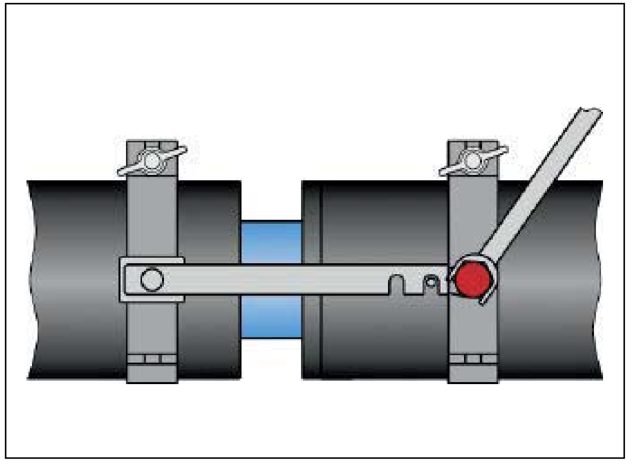


Fig. 19.23:
Assembly equipment for pulling pre-insulated pipes together

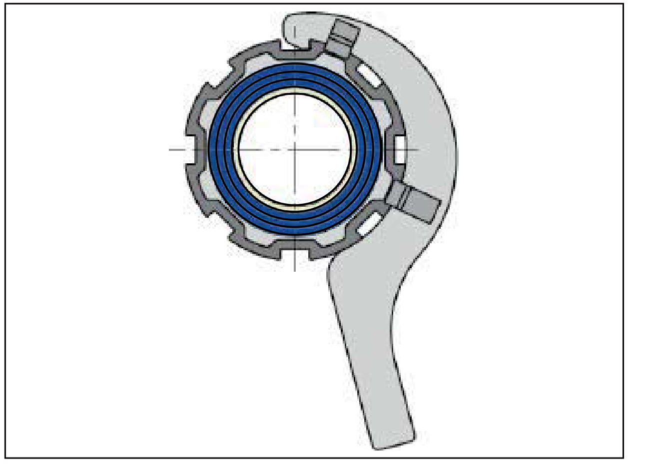


Fig. 19.25:
Hook wrench for assembling screwed socket joints

19.4.1.5 Assembling flanged joints

Flanged joints are described in **Chapter 1.3.1 (Figure 1.4)** and **Chapter 9.2**. Flanged pipes are dealt with in **Chapter 3.3.5 (Figure 3.13)**. The manufacturer's installation instructions are to be observed for the assembly of flanged joints; recommendations for the screw lengths for flanged joints can be found in EADIPS®/FGR® standard 30 [19.19].

19.4.1.6 Assembling bolted gland joints

Bolted gland joints are described in **Chapter 1.3.4 (Figure 1.8)**. The manufacturer's installation instructions are to be observed for the assembly of bolted gland joints **(Figure 19.26)**.

19.4.1.7 Welding onto ductile iron pipes

Chapter 18 (this chapter is being prepared) contains explanations about welding onto ductile iron pipes, such as the welding on of flanges, branches, outlets and puddle flanges as well as the application of welding beads for restrained pipes.

19.4.2 Installation of fittings

Fittings must not be cut, ground or otherwise processed.

19.4.2.1 Assembling push-in joints

With all assembly techniques, the fittings are to be aligned centrally and axially before and during the assembly of the push-in joint pipes. For the correct assembly of the joint the use of assembly equipment **(Figures 19.27 and 19.28)** is advisable. The manufacturer's installation instructions are to be followed.

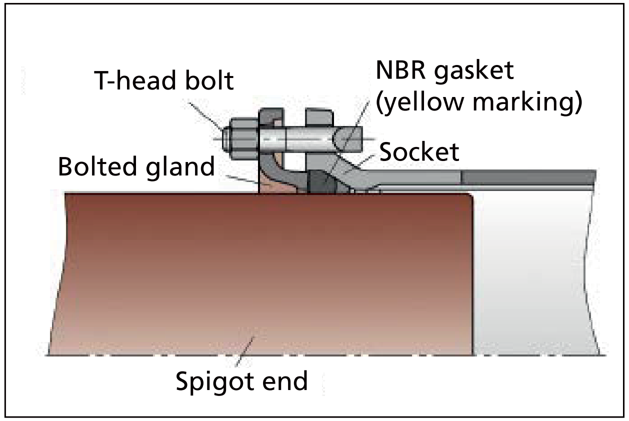


Fig. 19.26:
Representation of a bolted gland joint

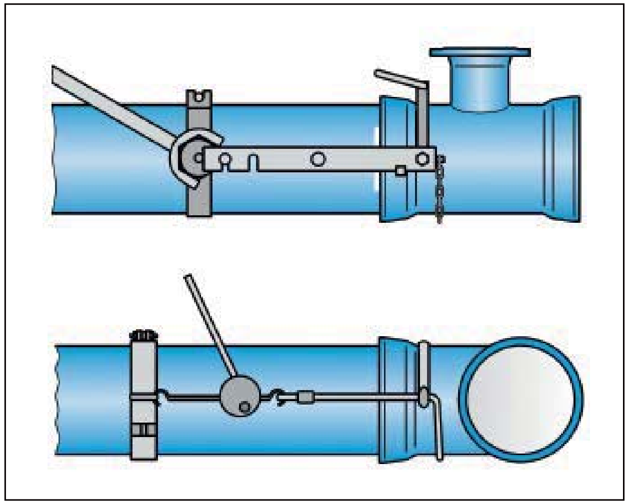


Fig. 19.27:
Use of assembly equipment specific to nominal diameter

Fig. 19.28:
Example of assembly equipment for nominal sizes DN 350 to DN 700

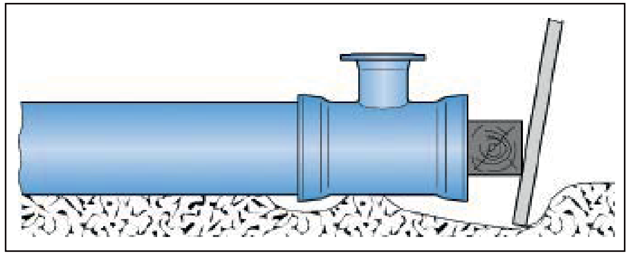


Fig. 19.29:
Assembly of a double socket tee on the spigot end of a ductile iron pipe

When assembling fittings using an excavator, a suitable intermediate layer is to be provided between pipe and excavator shovel, e.g. a shaped wooden block **(Figure 19.29)**.

19.4.2.2 Assembly of a connection branch

The assembly of a connection branch is done in a number of stages:

1. Drilling with the core bit **(Figure 19.30)**,
2. Drilling the holes for the retaining screws **(Figure 19.31)**,
3. Inserting the gasket, fixing the retaining screws **(Figure 19.32)**,
4. Final assembly of the connection branch **(Figure 19.33)**.

Burrs are to be removed from the drill holes. The cut surfaces of the drill holes are to be sealed according to the manufacturer's instructions.

Only carbide-tipped drill or core bits are to be used for drilling.

19.4.2.3 Welding on connection pieces and outlets

Explanations for welding on connection branches and outlets can be found in **Chapters 18.3.3 and 18.3.4** (these chapters are being prepared).

Fig. 19.30:
Drilling with the core bit

Fig. 19.31:
Drilling the holes for retaining screws of the connection branch

Fig. 19.32:
Gasket inserted and retaining screws fitted

Fig. 19.33:
The connection branch is positioned and then fixed to the ductile iron pipe with retaining screws

19.4.3 Installation, servicing and maintenance of valves

19.4.3.1 Installation

All packaging materials are to be removed from the valve. In order to protect e.g. gate valves from damage they should be transported using suitable lifting equipment such as wide belts. Chains and wire cables are to be avoided. Before installation the pipeline is to be inspected for contamination and foreign matter and cleaned if necessary. Care must be taken to ensure that the valves are accessible for operation and maintenance. For installation in the open air, the valves should be protected on site from direct exposure to the weather.

<u>Installation of flanged valves</u>
Steel-reinforced rubber gaskets are recommended for sealing the flanges. When assembling the valve the distance between pipeline flanges should be at least 20 mm greater than the face-to-face length of the valve to prevent damage to the mating surfaces and allow the gaskets to be inserted. The counter flanges of the pipeline must be plane-parallel and concentric. The connecting bolts must be tightened evenly, taking them crosswise, to avoid distortion strain. The pipeline is to be assembled tension-free. Adaptor and extension pieces facilitate assembly as well as removal for subsequent maintenance purposes. In Germany the installation guidelines according to DVGW worksheet W 332 [19.20], part IV are to be observed, as well as EN 805 [19.1].

<u>Installation of socket valves for ductile iron pipes</u>
Gaskets specific to the pipe are to be used **(Chapter 13)**. The spigot ends must be cleaned. Assembly should be carried out according to the manufacturer's installation guidelines. It is to keep in mind that different types of gaskets do not have a restraining effect **(Chapter 8)**. If necessary thrust resistance systems are to be used **(Chapter 9)** or thrust blocks installed, e.g. according to DVGW worksheet GW 310 [19.21]. SVGW guidelines W4-2 [19.22] and W4-5 [19.23] apply for Switzerland.

Installation of weld-end valves
With weld-end valves care must be taken to ensure that parts which are heat sensitive (e.g. coatings or elastomers) are not damaged.

Installation of tapping valves
The tapping process for tapping valves is described in **Chapter 7.5.4**. Only carbide-tipped drill or core bits are to be used for tapping **(Figure 19.34)**.

19.4.3.2 Servicing and maintenance

The relevant manufacturer's instructions are to be followed for the servicing of valves. Functional capability and tightness should be monitored in regular cycles at intervals of ≤ 4 years e.g. in accordance with DVGW technical information sheet W 392 [19.24]. Before commencing maintenance work all pressurised pipelines are to be depressurised and secured against repressurisation! Once the maintenance work has been completed, all connections are to be checked for tightness and firm seating.

Fig. 19.34:
Tapping ductile iron pipe using a tapping valve

19.5 Installation

19.5.1 Installation in an unshored trench

The planning principles of EN 805 [19.1] and EN 1610 [19.2] are to be observed. For construction work in Germany, for example, account should be taken of DIN 4124 [19.25] and ZTV A-StB 2012 [19.26].

Pipe trenches which are deeper than 1.25 m must be secured against the risk of collapse. This can be done by means of sloping or shoring the trench **(Figure 19.35)**. For unshored trenches up to a depth of 1.25 m there are no additional instructions to be followed for installing the pipes.

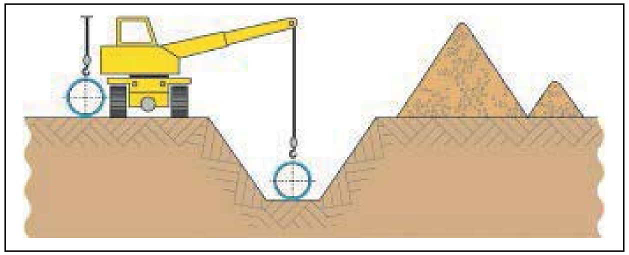


Fig. 19.35:
Sloped trench

19.5.2 Installation in a shored trench

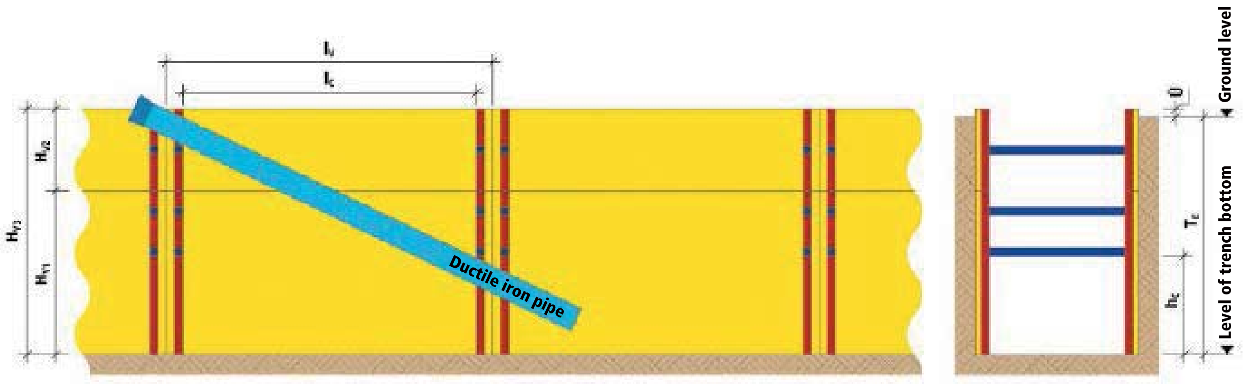
19.5.2.1 Inserting the pipe within one shoring unit

Two slings are placed around the pipe (one approximately in the middle and one in the socket area) and it is threaded into the trench beneath the lowest level of struts **(Figure 19.36)**.

19.5.2.2 Inserting the pipe within two shoring units

Where the lowest level of struts is very deep, geometric factors may mean that the pipe cannot be threaded in within just one shoring unit but that two units are required for this. In this case the slings have to be attached and removed. A secure fixing of the pipe must always be ensured here **(Figure 19.37)**.

Deeper anchoring of the shoring may mean that insertion over two shoring units and the deep layer of struts are not necessary.



Key:

H_{V1} height of ground shoring
H_{V2} height of top unit
H_{V3} height of shoring unit

l_V length of shoring unit
l_c pipe passage length
h_c pipe passage height
OK top

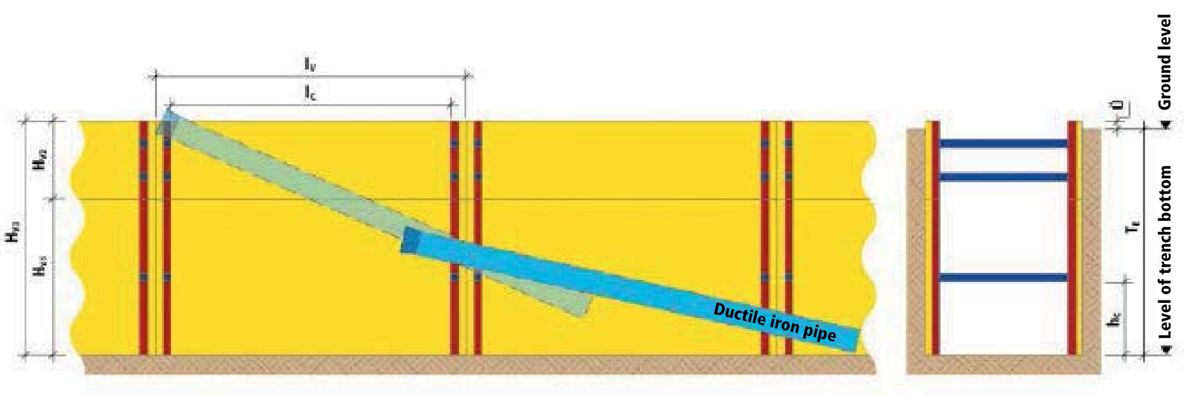
T_E installation depth (= H_{V3} – Ü)
Ü protrusion of shoring unit above ground level (= 0.1 m)

Shoring panels
Vertical bars
Horizontal struts

Note:
The pipe manufacturer's installation instructions are to be observed; in Germany TB Bau specifications are also to be observed

Fig. 19.36:
Threading in within one shoring unit

Another possibility for avoiding threading over two shoring units is making the bottom of the trench deeper. In this case attention must be paid to the anchoring depth of the shoring. These alternatives do not necessarily apply for every shoring unit, but should only be used in areas where this makes sense. The pipes can then be threaded in at these locations and transported horizontally within the shored trench.



Key:

H_{V1}	height of ground shoring	l_V	length of shoring unit	T_E	installation depth (= H_{V3} – Ü)		Shoring panels
H_{V2}	height of top unit	l_c	pipe passage length	Ü	protrusion of shoring unit above ground level (= 0.1 m)		Vertical bars
H_{V3}	height of shoring unit	h_c	pipe passage height				Horizontal struts
		OK	top				

Note:
The pipe manufacturer's installation instructions are to be observed; in Germany TB Bau specifications are also to be observed

Fig. 19.37:
Threading in within two shoring units

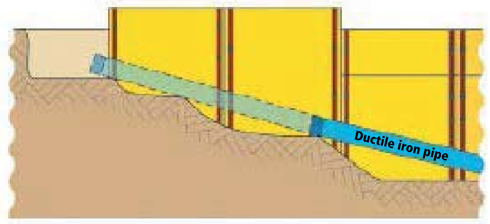
19.5.2.3 Head-on installation

With this technique the pipes are not introduced only after the shoring has been completed to its final depth but as the shoring is gradually lowered to graduated depth levels. To do this, the lifting gear takes up the pipe a number of times, each time laying it down on the slope until the bottom of the trench is reached. This installation method is suited above all for so-called travelling shoring in sections **(Figure 19.38)**.

19.5.2.4 Swinging in

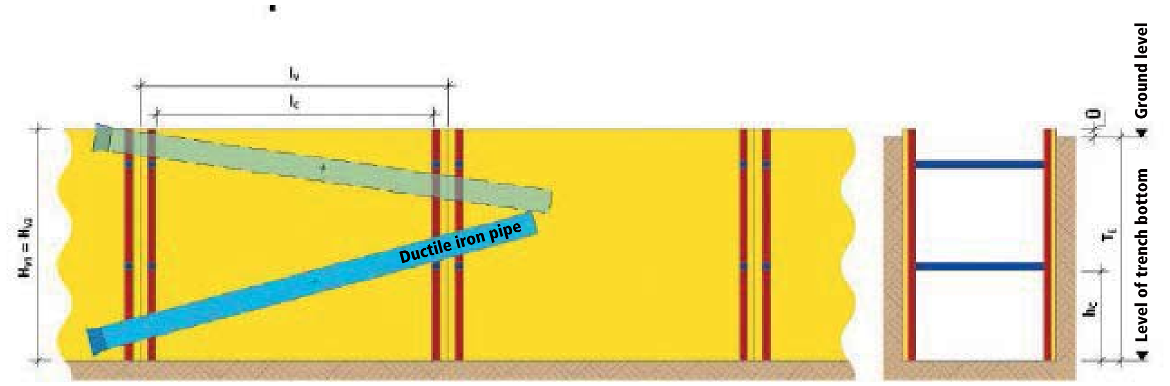
To swing in the pipe a sling is attached to its centre of gravity. By changing its inclination while simultaneously guiding it horizontally the pipe is positioned on the pipe bed inside a shoring unit **(Figure 19.39)**.

As the inclination and guiding of the pipe is assisted manually, attention needs to be paid to the secure attachment of the pipe; inclining the pipe too steeply is to be avoided.



Note:
The pipe manufacturer's installation instructions are to be observed; in Germany TB Bau specifications are also to be observed

Fig. 19.38:
Head-on installation



Key:

$H_{V1} = H_{V3}$ height of ground shoring = height of shoring unit
l_V length of shoring unit
l_c pipe passage length
h_c pipe passage height
OK top
T_E installation depth (= H_{V3} – Ü)
Ü protrusion of shoring unit above ground level (= 0.1 m)
Shoring panels
Vertical bars
Horizontal struts

Note:
The pipe manufacturer's installation instructions are to be observed; in Germany TB Bau specifications are also to be observed.

Fig. 19.39:
Swinging in the pipe

19.6 Pipe trenches

19.6.1 Execution, working space

For the execution of excavation pits and trenches using traditional techniques, accident prevention regulations are applicable along with EN 805 [19.1] and EN 1610 [19.2] as well as their national supplements and regulation sheets as per **Table 19.1**.

In rural areas, away from roads, the use of trench cutters is becoming increasingly more common. Pipes in ductile cast iron can be installed in trenches produced in this way without problem.

Because of the high load bearing capacity of these pipes, there may be no need for "pipe benching" if local conditions permit; beneath roads, homogeneous compacting of the laying zone is necessary to prevent subsidence.

19.6.2 Trench bottom

The pipe trench is to be produced in such a way that the pipeline is supported along its whole length. Corresponding depressions (head access holes) are to be excavated in the trench bottom for the pipe joints **(Figure 19.40)**.

19.6.3 Pipe bed

The pipe bed must ensure an even distribution of pressure in the supporting area. As a rule, the existing soil is suitable as a pipe bed. Stone, rock and non-load bearing soils are not suitable for direct bedding.

If the trench bottom is suitable for bedding the pipes, then the trench bottom becomes the lower bedding. If a lower bedding of compactable sand, gravel sand or sieved soil has to be introduced, in its compacted condition it should be to a height of 100 mm + 1/10 of the outside diameter of the pipe, but at least 15 cm below the pipe shaft and at least 10 cm under flanges, sockets, attachments and fittings.

According to EN 805 [19.1], determining the thickness of the lower bedding layer is left to the planning engineer.

In EN 1610 [19.2] the thickness of the lower bedding layer is stated as 10 cm with normal soil conditions; with rocky or consolidated subsoils it should be at least 15 cm.

Figure 19.41 includes the terms used in EN 805 [19.1] and EN 1610 [19.2] for the subdivisions of the pipe-laying zone.

Table 19.3 gives a summary of the thicknesses of the lower bedding layer in the various national and European regulations. For pipes in ductile cast iron, the pipe manufacturers state a standard minimum value of 100 mm for the thickness of the lower bedding layer for all types of external protection of pipes.

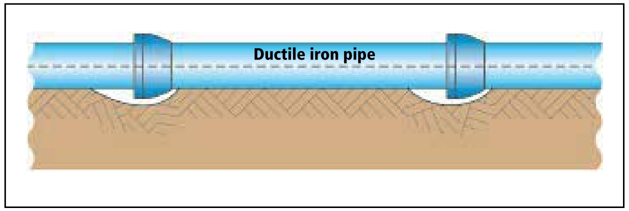


Fig. 19.40:
Trench bottom with head access holes

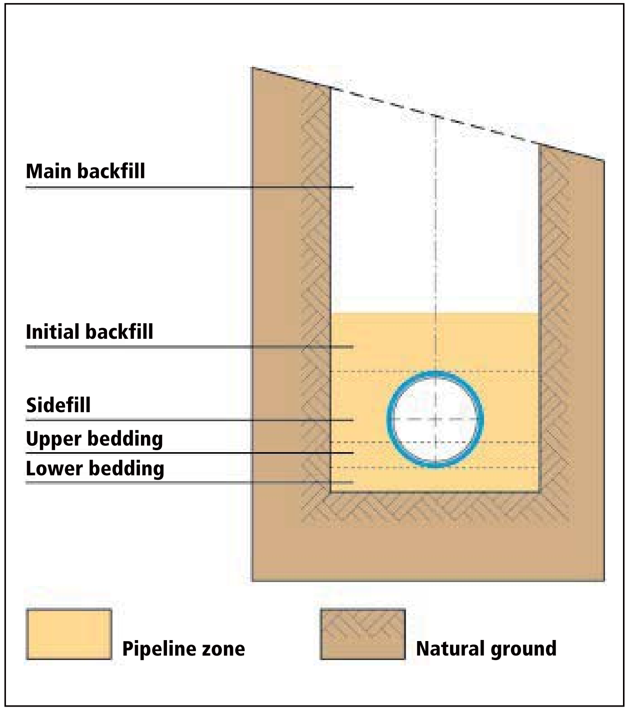


Fig. 19.41:
Pipeline zone and cover – terms according to EN 805 [19.1] and EN 1610 [19.2]

Table 19.3:
Thickness of the lower bedding layer

Thickness of the lower bedding layer [mm]					
Example	**EN 805 [19.1]**	**DVGW W 400-2 [19.7]**	**EN 1610 [19.2]**	**DWA A 139 [19.9]**	**EADIPS®/FGR®**
DN	No Data	100 + 0,1 da min. 150	min. 100 (normal) min. 150 (firm)	100 + 0.1 DN (normal) 100 + 0.2 DN (firm)	All type of coating
250	–	150	100 (normal) 150 (firm)	125 (normal) 150 (firm)	100
600	–	163	100 (normal) 150 (firm)	160 (normal) 220 (firm)	100

19.6.4 Embedding the pipes

Embedding is very important in determining the load and stress distribution over the circumference of the pipe.

For embedding purposes, suitable soil which will not damage the parts of the pipeline and the coating is to be filled in layers on either side of the pipeline and sufficiently compacted.

The thickness of the cover in the compacted state should reach a height of 15 cm above the crown of the pipe when more lightweight compaction equipment is used and 30 cm with heavier compaction equipment before starting on the compaction of the main filling.

Pipelines which are subject to a risk of floating must be provided with buoyancy protection.

19.6.5 Cover height

The cover height is the distance between the crown of the pipe and ground level. For drinking water pipelines it is important that they are installed at a frost-free depth. The limit values for cover heights at which ductile iron pipes can be installed without structural analysis are given in the applicable standards EN 545 [19.27] and EN 598 [19.28].

For cover heights outside the areas stated or more favourable installation conditions, separate static calculations may be necessary. Structural design is stipulated in e.g. ATV-DVWK-A 127 [19.29], Austrian standard B 5012 [19.30], [19.31] and SIA 190 [19.12].

19.6.6 Bedding material

A homogenous, well-compactable filling material is to be used as the pipe bedding material. The permissible grain sizes depend on the pipe coating and can be found in the pipe manufacturer's installation instructions. Before use, the bedding material is to be evaluated with respect to its corrosion likelihood according to DIN 50929-3 [19.32], [19.33], DVGW worksheet GW 9 [19.34] or Austrian standard B 5013-1 [19.35] and tested as regards its suitability for the pipe coating envisaged according to DIN 30675-2 [19.36].

19.7 Special pipeline installation cases

The features of certain important application cases are described below. Otherwise the Technical Department of the cast iron pipe manufacturer should be consulted for help with technical problems.

19.7.1 Pipelines in sloping and steep areas

When installing pipes in sloping and steep areas, additional forces come into play which require corresponding safeguarding measures depending on the gradient, such as restrained push-in joints and cross supports. As a rule this is necessary with gradients of more than 15°.

The installation of concrete, wood or heavy clay barriers prevents the backfilled pipe trench from acting like a drainage ditch and so allowing water to run under the pipeline.

19.7.2 Laying pipes uphill

Where the soil is sufficiently firm, there are cross supports which can support a pipeline on a steep slope. In such a case a concrete thrust block secures the bottom bend (at the foot) and the pipes to be installed upwards from there are driven so far into the socket that they stand in the base of the socket.

On the hillside itself then, depending on the gradient, every 2nd or 3rd pipe is secured behind the socket with a concrete block which is anchored in the natural soil **(Figure 19.42)**. At the same time the concrete blocks act as protection against the undercutting of the pipeline. Their dimensions are based on e.g. DVGW worksheet GW 310 [19.21]. Slopes on which landslides are to be expected require the installation of geotextiles as a slidable pipe surround in order to release the pipe from ground forces.

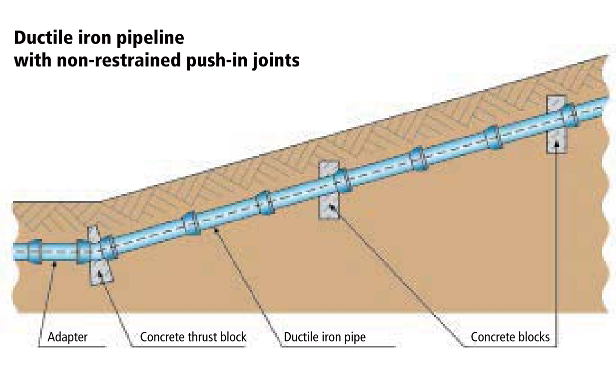


Fig. 19.42:
Uphill installation of pipes – ductile iron pipeline on a slope with concrete blocks

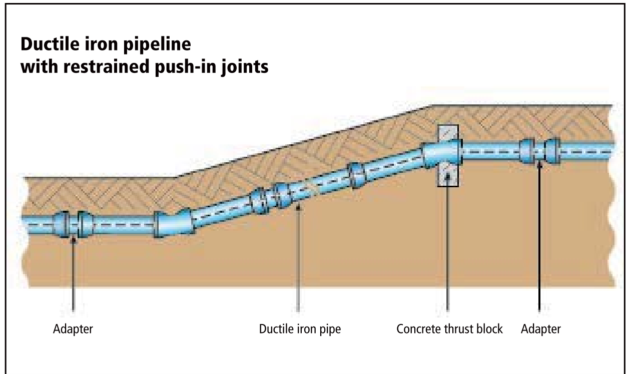


Fig. 19.43:
Downhill installation of pipes – restrained ductile iron pipeline with a concrete thrust block at the upper inflexion point

19.7.3 Laying pipes downhill

If a pipeline is to be installed downhill, then pipes with restrained push-in joints are to be assembled in such a way that the restrained locking is direct and prevents the slipping of the pipes.

The entire pipeline must then be secured at the upper end either by a fixed point (concrete thrust block or structure) or by a restrained push-in joint **(Figure 19.43)**.

A thrust block at the lower bend is not necessary if the horizontal section of pipeline leading to the inflexion point is fitted with restrained push-in joints over a sufficient length.

19.7.4 Installation in unstable ground

In soils with poor load-bearing characteristics, particular measures are to be taken to prevent the sinking of the pipeline. Particularly susceptible to subsidence are pipelines in boggy and peaty ground and in silty and organic soil types.

In most cases this can be managed by improving the subsoil, e.g. soil replacement, ballast beds or geotextile-gravel cushions. If these measures are not sufficient there is the possibility of installation on pile heads **(Figure 19.44)**. In normal cases ductile iron pipes only require one support per pipe **(Figures 19.45, 19.46 and 19.47)**.

In areas affected by mining, in some cases considerable subsidence can occur if the seams are not filled after mining is finished. As a rule, this causes tractive strains in the marginal zones of the subsidence and compressive strains in the middle. These can amount to up to 15 mm/m. Ground subsidence of up to 7 cm in five days has been observed, with gradient changes of 36 cm over a length of 40 m occurring in one month. Under these circumstances, pipelines should not be rigid. Pipes in ductile cast iron with their flexible push-in joints are particularly suitable. According to product standards EN 545 [19.27] and EN 598 [19.28] deflections in pipe and fitting sockets of up to 5° are possible.

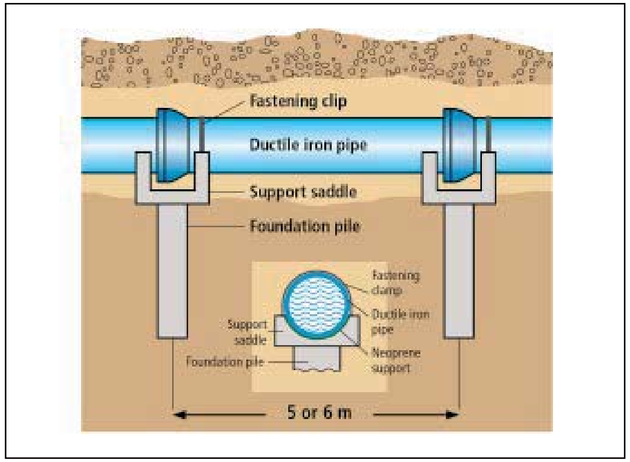


Fig. 19.44:
Pipeline on pile heads – double mounting

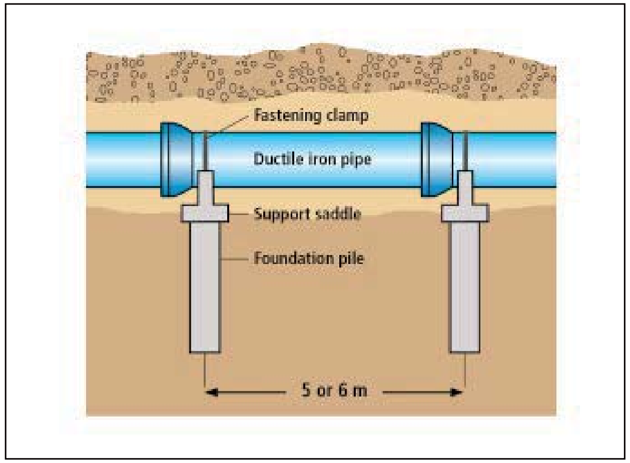


Fig. 19.45:
Single mounting of ductile iron pipes on piles

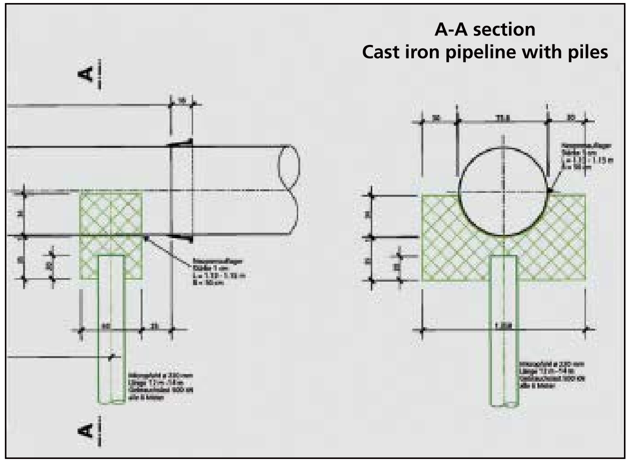


Fig. 19.46:
Example of a construction drawing for a concrete support saddle

Fig. 19.47:
Concrete support saddle with neoprene support for ductile iron pipes

19.7.5 Installation in groundwater

With high groundwater levels, the pipes are to be secured against buoyancy. With the kind of high groundwater levels which are often found in lowlands close to bodies of water, ductile iron pipes with restrained push-in joints can be assembled alongside the trench over a long stretch of pipeline and then lowered with a number of lifting devices **(Figure 19.48)**.

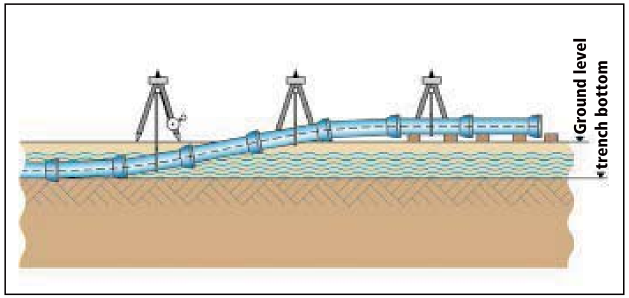


Fig. 19.48:
Pre-assembled pipeline being lowered into the trench

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Schraubenlängen für Flansch-Verbindungen
[Ductile iron pipes, fittings and valves –
Length of bolts for flanged joints]
2013-06

[19.20] DVGW-Merkblatt W 332
Auswahl, Einbau und Betrieb von metallischen Absperrarmaturen in Wasserverteilungsanlagen
[DVGW technical information sheet W 332
Selection, installation and operation of metallic shut-off valves in water distribution systems]
2006-11

[19.21] DVGW-Arbeitsblatt GW 310
Widerlager aus Beton –
Bemessungsgrundlagen
[DVGW worksheet GW 310
Concrete thrust blocks –
Principles of sizing]
2008-01

[19.22] SVGW-Richtlinie W4-2
Richtlinie für Wasserverteilung –
Planung, Projektierung, Bau, Prüfung sowie Betrieb und Instandhaltung der Trinkwasserverteilung außerhalb von Gebäuden –
Teil 2: Planung und Projektierung

[Guideline for water distribution – Planning, project development, construction, testing as well as operation and maintenance of drinking water distribution systems outside buildings – Part 2: Planning and project development]
2013-3

[19.23] SVGW-Richtlinie W4-5
Richtlinie für Wasserverteilung – Planung, Projektierung, Bau, Prüfung sowie Betrieb und Instandhaltung der Trinkwasserverteilung außerhalb von Gebäuden – Teil 5: Praxisunterlagen, Themenblatt Nr. 7: Rohrnetzspülung
[Guideline for water distribution – Planning, project development, construction, testing as well as operation and maintenance of drinking water distribution systems outside buildings – Part 5: Practical data sheet, data sheet No. 7: Network flushing]
2013-3

[19.24] DVGW-Arbeitsblatt W 392
Rohrnetzinspektion und Wasserverluste – Maßnahmen, Verfahren und Bewertungen
[DVGW worksheet W 392 Piping network inspection and water losses – Activities, procedures and assessments]
2003-05

[19.25] DIN 4124
Baugruben und Gräben – Böschungen, Verbau, Arbeitsraumbreiten
[Excavations and trenches – Slopes, trench shoring, breadth of working space]
2012-01

[19.26] ZTV A-StB 12
Zusätzlichen Technischen Vertragsbedingungen und Richtlinien für Aufgrabungen in Verkehrsflächen
[Additional technical contract conditions and guidelines for excavations in traffic areas]
2012

[19.27] 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

[19.28] EN 598
Ductile iron pipes, fittings, accessories and their joints for sewerage applications – Requirements and test methods
[Rohre, Formstücke, Zubehörteile aus duktilem Gusseisen und ihre Verbindungen für die Abwasser-Entsorgung – Anforderungen und Prüfverfahren]
2007+A1:2009

[19.29] ATV-DVWK-A 127
Statische Berechnung von Abwasserkanälen und -leitungen (korrigierter Nachdruck 2008-04)
[Structural design of drains and sewers (corrected reprint 2008-04)]
2000-08

[19.30] OENORM B 5012
Statische Berechnung erdverlegter Rohrleitungen für die Wasserversorgung und die Abwasser-Entsorgung
[Structural design of buried water and sewerage pipelines]
2008-10-01

[19.31] OENORM B 5012/A
Statische Berechnung erdverlegter Rohrleitungen für die Wasserversorgung und die Abwasser-Entsorgung (Änderung)
[Structural design of buried water and sewerage pipelines (Amendment)]
2014-09-01

[19.32] 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

[19.33] DIN 50929-3 Beiblatt 1
Korrosion der Metalle – Korrosionswahrscheinlichkeit metallischer Werkstoffe bei äußerer Korrosionsbelastung – Teil 3: Rohrleitungen und Bauteile in Böden und Wässern – Beiblatt 1: Korrosionsraten von Bauteilen in Gewässern
[Corrosion of metals – Probability of corrosion of metallic materials when subject to corrosion from the outside – Part 3: Buried and underwater pipelines and structural components – Supplement 1: Corrosion rates of structural components in water]
2014-11

[19.34] 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

[19.35] 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]
2013-12-15

[19.36] DIN 30675-2
Äußerer Korrosionsschutz von erdverlegten Rohrleitungen – Schutzmaßnahmen und Einsatzbereiche bei Rohrleitungen aus duktilem Gusseisen
[External corrosion protection of buried pipes – Corrosion protection systems for ductile iron pipes]
1993-04

20 Pressure tests

20 Pressure tests

This chapter is being prepared.

21 Commissioning of ductile iron pipelines for drinking water

21 Commissioning of ductile iron pipelines for drinking water

Drinking water legislation lays down requirements for our most important food – drinking water. Water supply companies are obliged to supply hygienically impeccable water and it is for this reason that comprehensive standards and regulations specifying requirements, test methods and practices are available both for extraction and storage equipment and for distribution networks.

21.1 Preliminary comment

Apart from their fittings and valves, ductile iron pipelines consist mainly of pipes with cement mortar linings. DVGW worksheet W 346 [21.1] describes the handling of pipes and fittings with this tried and tested lining and provides advice on commissioning pipelines and putting them into operation in its two annexes, Annex 1: Changes in the pH value, Annex 2: Flushing and disinfecting.

Formerly, disinfection was the general term usually used for measures for getting the equipment into a hygienically impeccable condition.

Hence the title of DVGW worksheet W 291 "Disinfection of water supply equipment" which appeared in 1986. However experience has taught us that disinfection alone rarely produces the desired result. Preventive measures and cleaning play an important role. The revised edition of DVGW worksheet W 291 [21.2] bears the title "Cleaning and disinfection of water distribution equipment" in order to indicate the importance of careful preliminary cleaning. The worksheet places the emphasis on cleaning, while disinfection is seen as an additional safety measure. In Switzerland this issue is dealt with in the "Recommendations for the cleaning and disinfection of drinking water pipelines", SVGW guideline W1000 [21.3]; in Austria in ÖVGW guideline W 55 "Hygiene in reservoirs and pipeline networks" [21.4].

It is important that no substances should be found in the pipeline which can serve as nutrient substrates for microorganisms. Basically these substrates can originate from inappropriate pipe materials and assembly agents or they can be introduced via impurities.

The first possibility can be avoided if components with DVGW certification, for example, are envisaged right from the planning stage. This requirement is included in e.g. DIN 2000 [21.5] (Section 6.6: Materials, Section 6.6.1: Microbiological and sanitary requirements, Section 6.6.3: Testing and certification). Basically, only materials with valid sanitary certificates should be used. Components with e.g. DVGW certification guarantee that the corresponding qualifications have been met. Also Section 17 of the latest version of the German drinking water ordinance dated 2 August 2013 [21.6] specifies requirements for the extraction, processing and distribution of drinking water. These components are to be planned, constructed and operated at least in accordance with the generally accepted technical rules and standards. The entrepreneur and other owners of equipment of this kind must make sure that only suitable materials and substances are used for new constructions or during servicing and maintenance. The German Federal Environment Agency (UBA) determines assessment criteria so that the requirements can be met in practice [21.7]. For the area of drinking water, accredited certification bodies issue certificates to confirm that these requirements have been met. Similarly in Switzerland, according to SVGW guideline W4-1 [21.8] (Planning, project organisation, construction, testing, operation and maintenance of drinking water networks outside buildings) products with SVGW certification are considered to be suitable for the construction of drinking water supply equipment. In Austria this subject is regulated in Austrian standards B 5014-1 [21.9] and B 5014-2 [21.10].

The second possible means of ingress for impurities arises during the manufacturing of pipeline components, during their handling – including storage and transport – and during their installation. By means of appropriate packaging, for example protective caps for pipes, fittings and valves, the contamination of surfaces in contact with water can be avoided. Instructions for this can be found in EN 805 [21.11] and also in DVGW worksheet W 400-2 [21.12] (Section 5: Incoming goods inspection, transport and storage of parts for pipelines, Section 7.2: Cleaning parts for pipelines) for all pipeline parts during transport and storage, DVGW worksheet W 346 [21.1] for cast iron pipes and fittings and EN 1074-1 [21.13] (Section 8: Packaging) for valves. For fittings and valves, EADIPS®/FGR® standard 74 [21.14] should also be observed.

When installing a new pipeline it should also be borne in mind that, for example, only assembly agents certified according to DVGW test specification VP 641 [21.15] should be used. These are only used for the assembly process itself and must be able to be flushed out. For checking the characteristics of assembly agents in terms of rinsing/flushing them out of valves, DVGW test specification W 363 [21.16], standard Annex A "Checking the rinsing/flushing capability of assembly agents" and [21.17] are applied in Germany. Thread cutting agents must meet the requirements of DVGW worksheet W 521 [21.18] in Germany.

Appropriate cleaning mobilises and removes the unavoidable substances which could adversely affect the quality of the drinking water. Finally, disinfection has the aim of killing or damaging microorganisms which, despite careful cleaning, still remain in the equipment.

For the successful commissioning of a drinking water pipeline there are three terms to be found in DVGW worksheet W 291 [21.2] and similarly in SVGW guideline W1000 [21.3], SVGW guideline W4-3 [21.19] and ÖVGW guideline W 55 [21.4]:

- preventive measures,
- cleaning,
- disinfection.

These terms serve as guidelines and are explained below.

21.2 Preventive measures

A condition for the problem-free commissioning of newly installed drinking water pipelines is compliance with sanitary requirements right from the planning stage and throughout installation. Hence the preventive measures properly begin with the correct choice of pipeline parts along with their storage, transport and installation. Pipes and fittings in ductile cast iron for the production of drinking water pipelines are basically fitted with pipe caps when they leave the production line. The same applies for valves, where foil often protects the packaging units. The caps are there to prevent impurities and even small animals from getting inside the components during storage and transport. Obviously these caps must stay in place until the joints are assembled with the components.

Impurities introduced by personnel, by working materials such as dirty rags for wiping off the sockets and pipe brushes as well as pollutants introduced from the air (the oily mist of exhaust gas given off by 2-stroke pipe cutters!) must be excluded. During breaks in work and overnight the ends of the pipeline need to be sealed to be watertight. There is often a risk that heavy rain or groundwater will inundate the pipe trenches. Soil getting into the pipeline is the main cause of persistent recontamination. The ends of pipelines must be closed off sufficiently tightly so that neither groundwater and dirty water nor animals can penetrate.

21.3 Cleaning measures

The cleaning of pipelines is aimed at getting rid of impurities, deposits and other undesirable substances. Such substances can lead in the long term to the proliferation of micro-organisms on surfaces in contact with water and hence to a multiplication of the colony count in the water or to contamination of the water. The first stage involves mobilising these substances. After that they must be completely flushed out of the system. In no case should they be allowed to be deposited again elsewhere, thereby resulting in further detrimental effects to the water. For cleaning purposes a basic distinction needs to be made between newly installed pipelines and existing ones.

Newly installed pipelines contain agents to assist with assembly as well as impurities occurring unintentionally. In all cases these are to be mobilised and flushed away. In the event of “incidents” such as unforeseen and unplanned events like the ingress of mud in bad weather during the

Table 21.1:
Flushing process for pipelines

Flushing process	Description
Flushing water	A simple, conventional process
Flushing with water and air	Flushing with an air/water mix
	Pulsed flushing technique
Combined flushing and pigging	Flushing with water and sponge rubber balls
	Flushing with water and plastic pigs
Special cleaning techniques	High-pressure cleaning
	Cleaning with scrapers

assembly phase, intensive flushing is indicated. The aim is to remove micro-organisms and above all the nutrient substrates for micro-organisms from the pipeline. The more thorough the cleaning, the more effective and likely to succeed the subsequent disinfection measures will be.

The cleaning of water distribution systems (pipelines and reservoirs) is described in DVGW worksheet W 291 [21.2]. ÖVGW guideline W 55 applies in Austria [21.4]. Data sheet no. 7 on the flushing of pipelines in Swiss SVGW guideline W4-5 [21.20] also describes the measures necessary for this. The type of cleaning technique to be used will depend on the nominal size of the pipeline and the level of its contamination. Basically, mechanical cleaning is to be preferred over cleaning with chemicals here. With pipelines it is practically only mechanical techniques which are used. A distinction is made between accessible pipelines with nominal sizes greater than DN 600 and pipelines which are not accessible. In all cases the sections of pipeline to be cleaned must be shut off from the rest of the network before cleaning in order to prevent the flushing water from contaminating the drinking water. In pipelines it is predominantly the flushing techniques described in **Table 21.1** that are used.

21.4 Flushing with water

The simplest cleaning process is flushing with drinking water. For the flushing to be successful it is important that the water in the pipeline achieves a sufficient speed of flow of between 2 m/s and 3 m/s, which is normally possible in pipelines up to DN 150. With larger nominal sizes both the amount of drinking water required and the resulting amount of flushing water are increased. **Figure 21.1** provides information on the water required for flushing pipelines according to the nominal size.

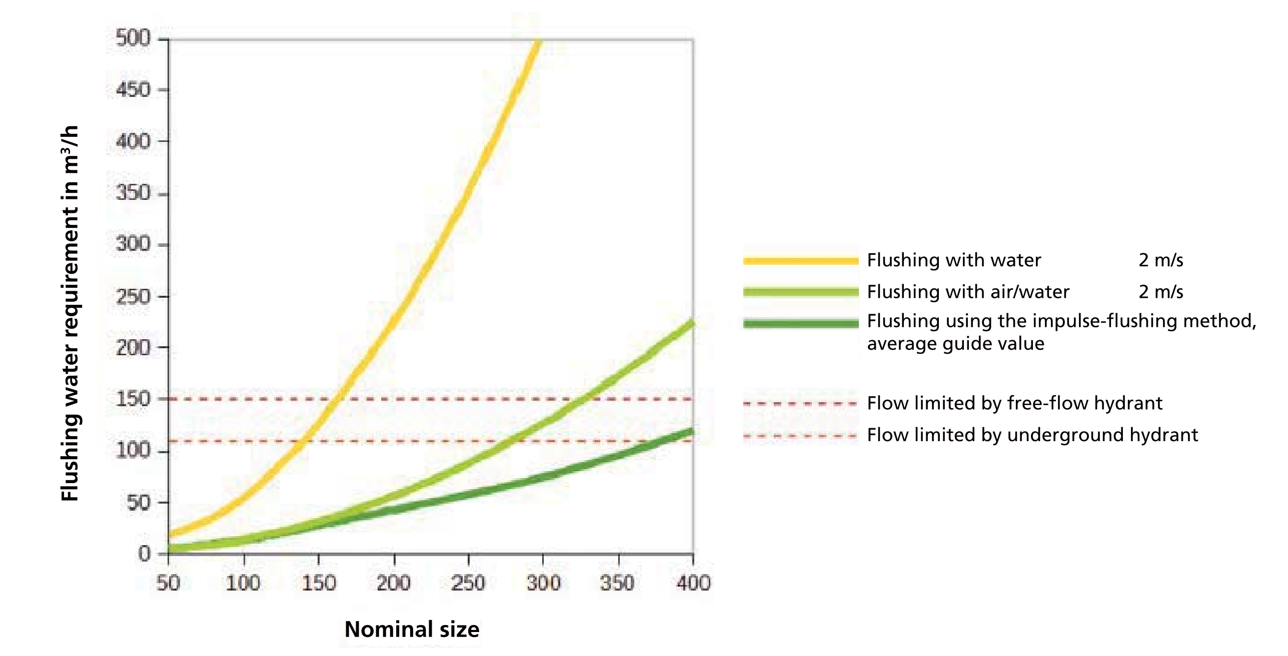

Fig. 21.1:
Water requirement for flushing pipelines where the flow is limited by underground hydrants (source: Hammann GmbH)

Depending on the cross-section of the pipeline, at least three to five times the capacity of the pipeline should be envisaged as the volume of water required. In principle, gravity flow pipelines should be flushed from the top downwards. Effects on the adjacent pipeline network must be taken into account. This means that the supply in adjacent pipelines should not be subject to any pressure drop during flushing. Also the mobilisation of deposits in pipelines upstream caused by a high flow speed should not cause turbidity of the drinking water. When draining off the flushing water local regulations and legislation must be observed. If hydrants are used in the flushing process the capacity of these fixtures needs to be taken into account. With conventional hydrants this is around 110 m^3/h and with free-flow hydrants it is around 150 m^3/h. Above DN 150 their capacity is no longer sufficient. There are modern techniques available for this, particularly for DN > 150. **Figure 21.1** provides information on the water volume required for flushing with water, with air and water and with the pulsed flushing technique as well as flow limiting by flushing hydrants.

21.5 Flushing with water and air

As compared with flushing with water, the work according to this technique sets high process and safety technology requirements and should only be carried out by experienced experts. Only purified air should be used. It must be oil-free with a low particle and germ count. The flushing water/flushing air ratio is between 1 : 1 and 1 : 3.

The inclusion of air improves the performance of the cleaning process. However, if air bubbles collect in the crown of the pipe, this effect may be limited to the bottom of the pipe only. Uncontrolled pressure surges can cause pipe bursts.

21.6 Impulse-flushing method

An alternative to flushing with water and air is the impulse-flushing method. Purified compressed air is delivered in pulses into a defined section to be flushed, without exceeding the dead pressure of the network **(Figure 21.2)**. This produces high-speed blocks of air and water in the section to be flushed. The turbulent flow covers a broad area and produces locally high forces to mobilise the deposits.

This drastically reduces the amount of water required as compared with flushing with water only **(Table 21.2)**.

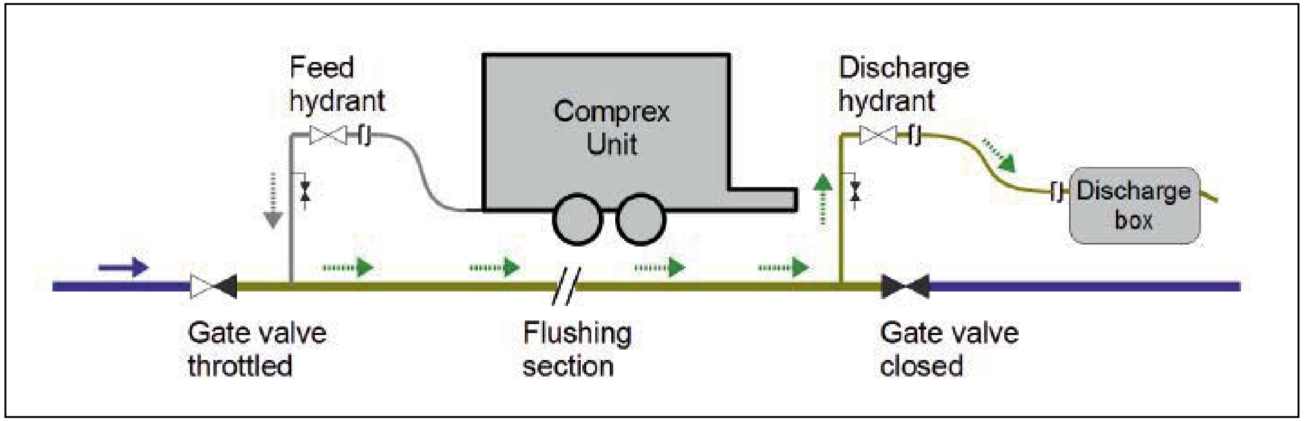

Fig. 21.2:
Cleaning a defined section of pipeline using the impulse-flushing method (source: Hammann GmbH)

This means that negative effects in adjacent networks and pipelines upstream can largely be avoided.

Research projects have enabled the effectiveness of cleaning to be increased while using less water. The blocks of water produced in partially filled pipelines reach flow speeds of more than 15 m/s. A lower water requirement also means less flushing water to be disposed of, which is of particular significance with pipelines of higher nominal sizes.

The advantages of the impulse-flushing method as compared with conventional processes can be summarised as follows:

- more intensive cleaning,
- up to 90 % less water required,
- no turbidity and pressure drops in networks upstream,
- water supply can be maintained outside the section being flushed,
- improvement in the functioning of valves.

Table 21.2:
Water required for flushing with water and for the impulse-flushing method

Nominal size	Water requirement in m³/h			
	Flushing with water at flow speed of		Impulse-flushing method indicative value	
	2 m/s	3 m/s	Low	High
80	36	54	5	15
100	57	85	8	25
125	88	133	10	30
150	127	191	20	38
175	173	260	23	50
200	226	339	35	70
225	286	429	40	80
250	353	530	42	85
300	509	763	50	100
350	693	1039	70	110
400	905	1357	90	150
450	1145	1718	110	190
500	1414	2121	140	230
550	1711	2566	180	280
600	2036	3054	220	330

The pulsed flushing technique is used first and foremost for cleaning drinking water distribution systems. New process techniques in recent years mean that even large transport pipelines with nominal sizes of up to DN 1200 can now be cleaned. In these pipelines, because of the water requirement, cleaning is often only possible using the impulse-flushing method [21.21].

Reducing the amount of water required has gained in importance over recent years. In contrast to drinking water pipelines, in times of low consumption well galleries and raw water pipelines could be cleaned without interrupting their operation and the flushing water purified at the waterworks [21.22].

Persistent impurities can not only form in old pipelines; they can also come about after “incidents”, for example in case of unforeseen and unplanned events during the installation phase of new pipeline sections. The performance of the cleaning process can be increased in such cases with the addition of solids, e.g. pieces of ice.

21.7 Other cleaning techniques

With particularly persistent contaminations, combined flushing and pigging or special cleaning techniques can be used. For pigging, sponge rubber balls or plastic pigs come into use. In both cases equipment needs to be provided for the insertion and removal of the pigs. Hydrants, and preferably free-flow hydrants, are suitable for the sponge rubber balls. With pipelines which need to be cleaned frequently, e.g. for raw or process water, pigging fittings are to be recommended.

Sponge rubber balls are normally used for cleaning pipelines up to DN 150. While more loosely adhering deposits and sediments can be mobilised and flushed out using sponge rubber balls, special pigs can also remove persistent deposits. Attention must be paid to cleanliness during the handling and storage of pigs for drinking water pipelines. During the cleaning process, precautions are to be taken to ensure that the pig does not become stuck in the section being cleaned. And if, for example, pig diameters are too small, water for carrying away the mobilised deposits can get into the section of pipeline to be cleaned.

In special cases, high-pressure cleaning and cleaning with scrapers are methods which are used. High-pressure cleaning can be used regardless of surface quality. However, the cleaning nozzles, pressure and distance from the wall must be adapted to the type of surface in order to avoid damage. Hot water can improve the cleaning. In addition a disinfecting agent can be used sparingly in a targeted manner. Particularly in this case measures should be taken to dispose of or process the flushing water appropriately.

For pipelines which are not accessible, jetting lances are used with the jet directed backwards and a free outflow of the flushing water. In accessible pipelines short sections can be cleaned manually. In this case it is possible to concentrate the cleaning on particularly heavily soiled areas. Safety specifications are to be observed in all cases.

Cleaning with scrapers is predominantly carried out before the renovation of old cast iron pipelines with cement mortar.

21.8 Disinfection process

The simplest process for disinfecting pipelines which is still widely used today is the standing technique. The disinfecting agent is left to stand in the completely filled section of pipeline for at least 12 hours.

With the standing technique, the disinfecting agent gets into the pipeline by adding the solution to be applied to the water by means of metering pumps or injectors providing a constant ratio via a connection piece, an air valve or a hydrant. During the standing time fittings in the section of pipeline being treated, such as valves or hydrants, should be operated so that the disinfectant can also get into areas where the flow is poor.

At the end of the standing time a residual concentration of the disinfecting agent should still be able to be detected in the water.

The standing technique is a static disinfection process. The disinfecting solution stands in the pipeline. Only part of it works on the surface of the pipeline. This means that the concentration of active substance decreases there, while it remains unused on the inside of the pipeline and then has to be disposed of. This disadvantage is ironed out by the dynamic disinfecting process. Here the disinfecting solution moves through the pipeline. In this way no differences in the concentration of active agent occur. With the dynamic disinfecting process, however, particular conditions are required, which are described in **Table 21.3**. With the plug method it is recommended that the disinfecting solution is moved slowly through the pipeline between two pigs.

Table 21.3:
Dynamic disinfection process

Process	Application	Effective use of the agent
Run-through method	Small nominal sizes, short pipe sections, Flushing with disinfecting solution	poor
Closed loop method	Double line or ring line, recirculation of the disinfecting solution	good
Plug method	Large nominal sizes, long pipe sections, plugging with disinfecting solution	good

Ingress of the disinfecting solution into the piping network still in operation is to be prevented by disconnecting the pipeline or by watertight shut-off devices. The shut-off devices must be checked for tightness and identified to prevent them being activated by mistake. The positive operating pressure in the section of pipeline to be disinfected must be considerably lower than that in the adjacent drinking water piping network.

21.9 Disinfection agent

A distinction is to be made between the following disinfection agents:

- commercial form,
- application form or dosage solution (stock solution),
- disinfection solution.

Chlorine and hydrogen peroxide are available as ready-to-use dosage solutions. Commercial chlorine bleaching agent has a chlorine content of 130 g/L to 150 g/L. Solutions of hydrogen peroxide often have a content of 30 % or 50 %. Chlorine bleaching agent and hydrogen peroxide solutions are to be stored in the dark, cool and tightly sealed. Light, heat and impurities accelerate deco position. Hydrogen peroxide solutions often contain stabilisers.

Chlorine dioxide solution can easily be produced on site with two components with good storage stability. The ready-to-use dosage solution usually has a chlorine dioxide content of 3 g/L. It is stable for weeks if stored correctly. Meanwhile single-component products are also available for producing chlorine dioxide solutions. Calcium hypochlorite and potassium permanganate are solids from which dosage solutions can be produced before use.

In recent years the use of disinfecting agents based on chlorine and hypochlorite has been decreasing. Reasons for this are, among other things, the restricted area of application, the production of undesirable by-products and the expense of disposal. Modern disinfecting agents are based on hydrogen peroxide or chlorine dioxide. Calcium hypochlorite and potassium permanganate do not play any significant role in pipeline disinfection.

DVGW worksheet W 291 [21.2] dedicates a special section to disinfection agents. Advice on the choice of disinfection agent and safe working practices can also be found there. The relevant table provides information on chemicals for disinfecting equipment and gives a summary of the commercial form, storage and application concentrations. Special sections deal with the individual disinfection agents including their chemical properties and fields of application. The application concentrations recommended in DVGW worksheet W 291 [21.2] for the major disinfection agents for pipelines are:

- chlorine/hypochlorite 50 mg/L
- hydrogen peroxide 150 mg/L
- chlorine dioxide 6 mg/L

The efficacy of the disinfection agent depends essentially on the pH value. With pH values < 8 the disinfection solutions with the concentrations recommended in DVGW worksheet W 291 [21.2] work well. However at higher pH values the effectiveness of chlorine/hypochlorite and hydrogen peroxide quickly subsides. Such conditions can arise with construction components in cementitious materials and/or soft water. DVGW worksheet W 346 [21.1] provides information in its Annex 2 on the efficacy of disinfection agents with pipelines lined with cement mortar depending on the type of water. In pipelines with untreated cement mortar lining the pH value can increase considerably with soft water of water types W_{KS}I and W_{KS}II and hence the efficacy of chlorine/hypochlorite and hydrogen peroxide decreases. **Table 21.4** provides information on essential content in a simplified form.

The redox voltage or oxidation-reduction potential (ORP) is often used for estimating efficacy. The ORP is the mixed potential of all oxidation and reduction reactions (redox reactions) occurring in the water, where the substances contained in the water and in the material as well as their possible chemical reactions are not known. Therefore the redox potential cannot be calculated from the concentration of disinfection agent alone. Added to this is the fact that many redox reactions are dependent on the pH value. **Figure 21.3** shows the correlation between redox potential and pH value for the major disinfection agents.

In order to achieve a germicidal effect there should be an ORP of $E_H > 800$ mV. These conditions apply not only to the water but they must also be ensured at the water/material phase interface. If soft, slightly buffered water is used for filling a pipeline which has a fresh, untreated cement mortar lining then, as a consequence of the increase in the pH value, the ORP required for disinfection of $E_H > 800$ mV cannot be achieved with many disinfection agents, or can only be achieved with high concentrations and long reaction times. Among these disinfection agents are, for example, the frequently used chlorine/hypochlorite which, at pH values above 8, increasingly causes difficulties with disinfection.

Table 21.4:
Efficacy of different disinfection agents with pipelines lined with cement mortar based on DVGW worksheet W 346 [21.1], Annex 2

Cement mortar	without pre-treatment			with pre-treatment [1]		
Water typw	W_{KS}I	W_{KS}II	W_{KS}III	W_{KS}I	W_{KS}II	W_{KS}III
$K_{S\,4,3}$ in mmol/L	< 0,5	0,5 bis 2	> 2	< 0,5	0,5 bis 2	> 2
Chlorine/hypochlorite	–	0 [2]	+	0 [2]	0	+
Hydrogen peroxide	– [2), 3)]	0 [2]	+	0 [2), 3)]	0	+
Chlorine dioxide	+	+	+	+	+	+

\+ good
0 adequate
– poor

1) If applicable water treatment with W_{KS}I and with W_{KS}II
2) High disinfection agent concentration and long working time
3) Improves efficacy with addition of 1 % phosphoric acid

To be recommended in these cases are disinfection agents with an ORP which has a zero or low dependency on the pH value, such as chlorine dioxide for example.

If a cement mortar lined pipeline is put into operation with sufficiently hard water, then surface layers are formed on the surface of the mortar.

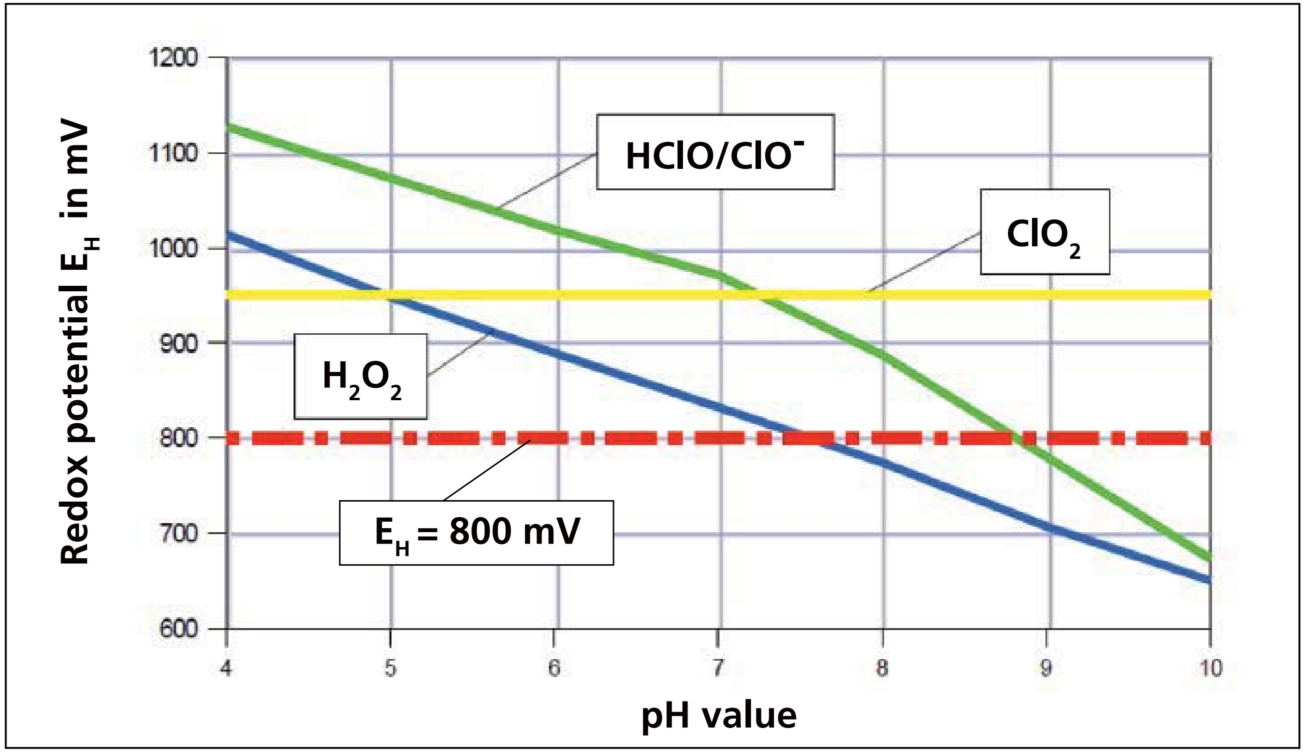

Fig. 21.3:
ORP of the disinfection agents chlorine (hypochlorous acid)/hypochlorite ($HClO/ClO^-$), hydrogen peroxide (H_2O_2) and chlorine dioxide (ClO_2) depending on pH value [21.23]

Good buffering of harder water alleviates the increase in the pH value. Accordingly, surface layers and good buffering of the water favour the achievement of the necessary redox potential.

21.10 Handling and disposal

Information on the storage, handling and disposal of disinfection agents can be found in the manufacturer's data sheets and safety data sheets. DVGW worksheet W 346 [21.1], Annex 2 offers advice here.

All disinfection agents have a tendency to decay, light and dust as well as heavy metal compounds and organic materials have an accelerating effect. Therefore disinfection agents, and above all their dosage solutions, must always be stored in cool and dark conditions. Only the equipment recommended by the manufacturer is to be used for handling them. If too much dosage solution is taken out of the storage container it must not be put back.

Dosage solutions should not be stored for too long. The manufacturer's instructions must be followed. The free chlorine content of commercially available chlorine bleaching agents diminishes constantly depending on temperature. DVGW worksheet W 229 [21.24] provides information on this correlation. This disintegration also produces undesirable by-products. Therefore it is essential that the content of free chlorine is checked after longer storage times.

In contrast to hydrogen peroxide and chlorine dioxide solutions, sodium hypochlorite solution is alkaline (chlorine bleaching agent) with pH values between 11.5 and 12.5. After it has been added, the pH value of the treated water inevitably rises. With soft water this affects the efficacy of the disinfecting solution and with very hard water it can lead to the precipitation of calcium carbonate. Reducing the pH value by mixing the solution with acids is to be discouraged because chlorine gas can escape and this may trigger an incident.

Disinfection solutions containing chlorine should basically be treated before they are introduced into the sewage system or into bodies of water. The possibilities here are dilution, chemical neutralisation with e.g. sodium thiosulphate or filtration through activated carbon filters.

Disinfection agents based on hydrogen peroxide are available under various trade names. As an dosage solution they have hydrogen peroxide concentrations of around 35 % or 50 %. For spray application there are e.g. pump sprays with hydrogen peroxide concentrations of around 3 %. These allow parts or joints to be disinfected on site.

DVGW worksheets W 291 [21.2] and W 346 [21.1], Annex 2, ÖVGW guideline W 55 [21.4] and SVGW guideline W 1000 [21.3] all provide information on the disposal of water containing disinfection agents.

21.11 Inspection and release of the pipeline

After disinfection, the disinfection solution is flushed out of the pipeline and it is filled with the water to be transported subsequently. No more disinfection agent should be able to be detected in the last filling of water. Approximately two to three times the pipeline capacity is necessary for the flushing. At the end of the flushing process water samples are to be taken from the pipeline for microbiological examination. This is done at the end of the pipeline or, with longer pipelines, also on partial sections. It is essential that the measures stated in e.g. standard ISO 5667-5 [21.25] – also included in the German standard method for the analysis of water, wastewater and sludge; general information (Group A); (A 14) – are taken into account when taking the samples. This includes run-out, cleaning and flaming of the extraction valves.

The success of cleaning and disinfection measures is to be checked by microbiological examinations. Basically, pipelines should only be put into operation once corresponding test results produce evidence of complete microbiological safety and the limit values specified for chemical substances are respected. Inspections with limit values and tests are based on the drinking water regulations. If the result is not satisfactory the measures must be repeated.

It should be mentioned that, on the basis of microbiological examinations after thorough cleaning, e.g. using the impulse-flushing method, there may be no need for disinfection [21.21]. This is of particular interest if there is not enough water available or there are large flushing volumes to be disposed of. The impulse-flushing method reduces the amount of water required for cleaning and can save the need for subsequent disinfection and rinsing of the pipeline.

21.12 Measures for existing cast iron pipelines

After repairs and other work on a pipeline, the sections of the pipeline need to be put back into operation as quickly as possible. Therefore there is no time left for standard disinfection and sampling with the issuing of a release. In this case it must be ensured by other means that the drinking water pipeline is in perfect condition from the hygiene viewpoint after completion of the work. Particular attention is to be paid here to clean practices when carrying out the work. It is recommended that the components are checked for cleanliness and disinfected with spray solution before their installation. After the end of the work the section of pipeline is to be thoroughly flushed through with water, if possible at high speed. By adding disinfecting agents, disinfection can be achieved if necessary during the flushing process. In all cases the instructions of DVGW worksheet W 291 [21.2] are to be observed.

It happens time and again that water quality is adversely affected by malfunctions, exceptional events or emergencies. Examples are failures in water purification, the ingress of impurities into the drinking water pipeline via leaks, or an unintentional connection with pipelines which do not carry drinking water. The Federal environmental agency gives recommendations on provisions for a sufficient disinfection capacity in such cases [21.26]. After disinfection of the specific area of drinking water using mobile equipment, it is above all essential to understand the cause of the problem. After remedial measures, the drinking water supply system in question must be thoroughly cleaned. As this normally involves impurities which are difficult to remove, highly effective cleaning measures are indicated. The impulse-flushing method has proved itself here. Its efficacy can be increased by the injection of solids.

Raw water pipelines have a tendency to incrustation, particularly with high iron and manganese contents. Depending on the operating method and type of raw water it can happen that, because of traces of dissolved oxygen, oxidation and precipitation already occur before treatment of the water. It is currently being investigated whether and to what extent microbial iron ochre formation is a cause of the negative impacts [21.27].

In order to safeguard the performance capability of these pipelines, regular maintenance is necessary, for example by flushing with rubber balls or pigging. By contrast, compressed air “pigs” fit every pipe cross-section and reliably carry the mobilised deposits away. The causes of deposits in raw water pipelines as well as measures for avoiding and removing them, above all using the impulse-flushing method, are described in [21.28].

21.13 Summary

When planning, constructing and commissioning new pipelines, attention needs to be paid to aspects of hygiene. **Table 21.5** provides information on work before, during and after cleaning and disinfection. Preventive measures take account of sanitary aspects during the planning and construction of pipelines. After disinfection, arrangements need to be made for the proper elimination of the water containing disinfecting agent and for putting the pipeline into operational condition by flushing it with drinking water. Microbiological testing provides information on whether the measure was completed successfully. The pipeline may only be put into operation once the release has been given.

21.14 Closing comments, additional information and prospects

21.14.1 European rules and standards

In contrast to DVGW rules and standards, to date European rules and standards do not contain any particular standard for the commissioning or the cleaning and disinfection of pipelines.
EN 805 [21.11] only provides information on disinfection in Section 12. Here, flushing with drinking water without any disinfection agent with or without the addition of air is considered as part of disinfection. Annex A.28 together with Table A.3 offers advice on the selection of the disinfection agent.

21.14.2 Research projects

In recent years a number of research projects have helped with a better understanding of connections in terms of cleaning and disinfection. The results are published in the form of thesis papers [21.35], [21.36]. There is now some important new knowledge available about biofilms in systems carrying drinking water, in particular regarding the VBNC state of bacteria. VBNC means viable but not culturable. The disinfectant influences the transitions between the culturable and VBNC stages of certain bacteria. It can alter the populations and favour fast-growing bacteria. Cleaning does not mean the same thing as disinfection. Effective cleaning is a precondition for the success of disinfecting measures.

In the explanations it is clearly described what cleaning means – namely removing impurities, deposits and other undesirable substances from the pipelines. In this process all loose deposits are to be mobilised and carried away. In no case should they be deposited again elsewhere, thereby leading to further detriment to the drinking water. The removal of deposits reduces the possibility of the implantation of micro-organisms and optimises the operating condition of the drinking water system.

Table 21.5:
Sanitary aspects when planning, constructing and commissioning pipelines

Measure	Work	Standard work/reference
Preventive measures	Selection of materials according to generally accepted technical rules and standards	Guideline 98/83/EC [21.29], Deutsche TrinkwV § 17 [21.6], DIN 2000 [21.5], Section 6.6
	Use of tested materials	Federal environment agency guidelines [21.7], DVGW worksheets W 270 [21.30], W 347 [21.31] and W 348 [21.32] SVGW guideline W4-1 [21.8] OENORM B 5014-1 [21.9] and OENORM B 5014-2 [21.10]
	Use of tested aids; flushing-out capability	DVGW test specifications VP 641 [21.15] and W 363 [21.16], Annex A, plus [21.17], DVGW worksheet W 521 [21.18]
	Use of certified products when available	DVGW index of products for the water industry [21.33]
	Avoidance of impurities during production, storage and transport; closure with caps, packaging	EN 805 [21.11], Section 10.1.3, DVGW worksheets W 400-2 [21.12], Section 5, and W 346 [21.1], EN 1074-1 [21.13], Section 8 SVGW guideline W4-3 [21.19], ÖVGW guideline W 55 [21.4]
	Cleanliness during installation; avoidance of impurities e.g. mud, dirty rags	DVGW worksheets W 346 [21.1] and W 400-2 [21.12], Section 7.2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]

Continued on page 21/18

Measure	Work	Standard work/reference
Cleaning	Removal of unintentional foreign matters; removal of assembly agents	DVGW-worksheets W 291 [21.2] and W 346 [21.1], Annex 2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]
Disinfection	Killing/damaging micro-organisms; compliance with fields of application	DVGW-worksheets W 291 [21.2] and W 346 [21.1], Annex 2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]
Measures after disinfection	Flushing, taking water samples; disposal of water containing disinfection agents	DVGW worksheets W 291 [21.2] and W 346 [21.1], Annex 2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]
Inspection of measures	Microbiological testing; measuring the pH value	EN 16412 [21.34] Deutsche TrinkwV [21.6] SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]

Simulated calculations show areas where there is insufficient flow. Such areas in joints and components can result in an increased biofilm formation during operation and must be constructively minimised. Also the length of little-used outlets should be limited to a maximum of three times the internal diameter. In the event of contamination, areas of low flow can only be reached by means of intensive cleaning processes such as the pulsed impulse-flushing method. Simulated calculations have already helped with the optimisation of components with the aim of reducing problems with increased biofilm formation during operation, as well as improving cleaning and disinfection.

21.14.3 DVGW worksheet W 557 [21.37]

While DVGW worksheet W 291 [21.2] concerns water distribution systems, rules were needed for drinking water installations inside buildings as a result of different operating conditions, nominal sizes, materials, components and apparatus.

Based on DVGW worksheet W 291 [21.2] and as a supplement to EN 806-4 [21.38], DVGW worksheet W 557 [21.37] was produced. In fact pipes and fittings in ductile cast iron according to EN 545 [21.39] are normally only used outside buildings, but this worksheet nevertheless contains information on the operation of distribution networks of such outstanding importance that it is worth mentioning here.

DVGW worksheet W 557 [21.37] was published in October 2012 with the knowledge available at that time but it did not yet take account of the results of the latest research project [21.36]. In its structure it reflects the three themes of DVGW worksheet W 291 [21.2]:

- preventive measures,
- cleaning,
- disinfection.

DVGW worksheet W 557 [21.37] emphasises the importance of cleaning before disinfection. This advice applies equally for water distribution, in particular for impurities and contamination.

The first step in eliminating impurities is always cleaning. This also applies for microbial contaminations. Microorganisms embedded in particles or corrosion products are not really killed with the help of disinfection agents as these do not reach the microorganisms. Therefore the particles or corrosion products have to be removed by flushing or other cleaning measures. System disinfection may be necessary as an additional safety measure. Deposits favour the growth of microorganisms, which can then result in adverse microbial effects. In order to prevent this, cleaning is necessary whenever there is a presence of deposits. Where the quality of the drinking water has been adversely affected by microbial action, cleaning must be carried out as the first measure. In these cases, additional disinfection of the system may be necessary after cleaning.

The worksheet refers to the stress on materials due to disinfection. Each system disinfection places stress on the materials and components of the drinking water installation, meaning that damage may occur to the drinking water installation. Repeating system disinfection at regular intervals in order to prevent contaminations is not to be recommended for this reason.

21.14.4 Revision of DVGW worksheet W 291 [21.2]

After more than 15 years the revision of DVGW worksheet W 291 [21.2] is pending. Work begins in 2015.

21.14.5 Cleaning and maintenance

Cleaning is not only necessary at the time of commissioning in order to expel impurities and assembly agents but also plays a major role in the maintenance of pipelines. It ensures a hygienically impeccable condition and security of supply. Particularly with raw water pipelines, regular cleaning is necessary if, for example, the pipeline is affected by iron ochre formation [21.23].

The new DWA rules take account of the maintenance of wastewater pressure pipes. Here cleaning is possible by means of pigging, flushing with compressed air or the impulse-flushing method. The corresponding insertion equipment or pigging traps need to be envisaged during planning and construction. Static compressed air flushing should prevent deposits while the impulse-flushing method can target the cleaning to sections of the pipeline where it is needed. Both processes normally work online and use accumulated water for cleaning.

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22 Use of ductile iron pipes for trenchless installation techniques

22 Use of ductile iron pipes for trenchless installation techniques

22.1 General

22.1.1 Historical development

The roots of the construction method known as the trenchless installation technique lie in soil displacement hammers. The burst lining technique was developed from this at the beginning of the 1980s. British Gas was already using modified soil displacement rockets for the trenchless replacement of pipelines on a large scale in the early eighties. Burst lining was developed further over the years. Then, in 1990, Berliner Wasserbetriebe in collaboration with the Karl Weiss company introduced the press/pull or Hydros technique. This in turn was later developed into the auxiliary pipe technique. Since then both techniques have been applied by Berliner Wasserbetriebe with ductile iron pipes. In Berlin alone, around 10,000 m of pipelines in nominal sizes of DN 80 to DN 500 are replaced in this way each year.

In parallel with this method of replacing pipes along the same route, additional techniques were developed for the trenchless installation of ductile iron pipes. First and foremost here is the horizontal directional drilling (HDD) technique. The first successful example of directional drilling was the roughly 180 m long crossing under the Pajaro River in the vicinity of the Watsonville (California) in 1972. The essential details of this technique were taken from the deep drilling process for oil, for example, and then further refined. In the years which followed, up to 1980, the controlled horizontal directional drilling technique progressed rapidly. At this time the first projects using the HDD technique were also being carried out in Europe.

In addition to this classic trenchless technique, another possibility had been established for the trenchless replacement of old pipelines – so-called pipe relining. This method consists of pulling a smaller

As time went on, further techniques were developed which are more or less widely used. A few examples of these processes are cutting or ploughing in or the pulling (relining) of ductile iron pipelines.

Ductile cast iron is a tough iron-carbon material in which the carbon element is predominantly present as graphite in free form. Pipes and fittings in ductile cast iron are structurally treated as flexible pipes. Pipes produced in rigid materials were scarcely able to safely cope with the mechanical tensile and bending loads produced during trenchless installation.

So the development of trenchless pipe installation techniques is inseparably linked with ductile iron pipes, their push-in joints and their external protection techniques. Soon the potential of restrained push-in joints developed as a substitute for concrete thrust blocks was recognised for the first trenchless installation techniques. Since then ductile iron pipe systems have come to represent the benchmark in terms of reliability and efficiency in trenchless installation techniques.

In 2012 a summary of current installation techniques was published in ISO 13470 [22.1].

22.1.2 Efficiency aspects of trenchless installation

These days it is generally understood that a process for installing pipes is usually considered efficient if it means that the pipeline constructed in this way can be quoted and completed at the lowest price. This approach seldom considers the operating and maintenance costs of the pipeline, let alone the costs of replacement once its normal working life has come to an end.

Until now no account has generally been taken of the costs incurred by the construction of the pipeline in its surroundings and factors concerning the general public in the form of traffic hold-ups, noise nuisance and pollution of the environment have been tacitly put up with without prospect of compensation. In this respect it is hardly possible to make a fair financial comparison between trenchless and open techniques because the "social" costs borne by the public at large, although perfectly capable of being estimated, are not taken into account when contracts are awarded.

Nevertheless experience is gradually showing that trenchless installation and replacement techniques can generally be more cost effective than conventional open technique. For example, a regional gas and water supply company has published a comparison between open and closed construction methods as shown in **Table 22.1**.

Table 22.1:
Overall comparison of the open and closed construction techniques [22.2]

	Conventional technique	Closed technique
Line length	100 %	100 %
Civil engineering on surface restoration	100 %	15 %
Construction time	100 %	30 %
Costs	100 %	50 – 70 %
Working life	100 %	70 – 100 %
Conserving resources	20 %	80 %
Noise, damage to the environment	100 %	Ideal gain

Table 22.2:
Rough cost comparison of construction techniques [22.2]

Open technique	Closed technique					
	Bursting	Soil displacement hammer	Press/pull technique	Relining		
				with annular gap	without annular gap	flexible pipe
100 %	70 %	70 %	80 %	60 %	70 %	60 %

An estimated comparison of the costs of closed replacement techniques with those using the open method also shows clear potentials for savings with the closed technique **(Table 22.2)**.

In order to safeguard the workmanship of drinking water pipelines installed or replaced using the trenchless technique, over recent years the DVGW in Germany, for example, has produced a comprehensive set of rules (series commencing GW 320-1) which takes account of precisely this requirement [22.3 to 22.8]. This describes the quality parameters for current trenchless installation and replacement techniques and determines limit values and measurement specifications for them. DVGW worksheet W 400-1 [22.9] emphasises the predominant influence which the choice of piping system has in connection with the choice of construction technique.

The key areas for the choice of piping system are given as the following [22.9]:
1. Bedding and conditions of use (e.g. diffusion characteristics, capacity reserves),
2. Features of the corrosion protection system and joint technology,
3. Positive experiences found with particular systems,
4. Appropriate availability (delivery times, stocks, system continuity).

22.1.3 Ecological aspects of trenchless installation techniques

In the development of trenchless installation techniques, first of all it was economic considerations which were in the forefront in order to emphasise advantages as compared with conventional techniques using open trenches, making their use possible with most public pipeline projects. Once the trenchless technique had become established and was being widely used, its positive influence on ecological considerations became clear. It is to the credit of the GSTT (German Society of Trenchless Technologies) that the beneficial effects of trenchless techniques on the reduction of CO_2 and fine particulate matter emissions in the construction, renovation and replacement of pipelines was investigated and published (www.gstt.de).

22.1.4 Sustainability with ductile iron pipe systems using trenchless techniques

The sustainability criteria of ductile iron pipe systems in combination with trenchless installation techniques are summarised below.

Economic sustainability criteria:

– push-in joints make for highly productive installation	▶ reduces labour costs
– no welding needed	▶ reduces labour costs
– installation in all weathers	▶ reduces labour costs
– sand bedding often not required	▶ reduces materials and logistics costs
– concrete thrust blocks not needed when joints are restrained	▶ reduces materials and logistics costs
– joints can be deflected angularly	▶ saves on fittings
– wide range of fittings and valves available so no need for specials	▶ reduces materials and labour costs
– extremely low damage rates	▶ reduces operating, energy, repair and maintenance costs
– operating life of up to 100 years or more	▶ keeps renovation budgets to a minimum

Ecological sustainability criteria:

– impermeability to diffusion	▶ safeguards drinking water in all soil and installation conditions, protects against environmentally harmful hydrocarbons, protects groundwater in sewage transport
– linings approved to food hygiene standards	▶ ensure hygienic and environmentally safe transport of drinking water
– scrap as the raw material	▶ minimises the consumption of primary and fossil raw materials and reduces CO_2 emissions
– ductile iron can be recycled	▶ saves resources for present and future generations
– low expenditure on maintenance and repair expenses with long operating working life	▶ avoids waste, minimises the consumption of resources and reduces CO_2 emissions

Technical sustainability criteria:

– material strength	▶ allows operating pressures up to 100 bars
– effective external protection	▶ shields against mechanical and chemical attack
– static load-bearing capacity	▶ allows very high loads in the transverse and longitudinal directions
– joints	▶ allow operating pressures up to 100 bars; are resistant to root penetration
– ductile iron	▶ is non-combustible
– installation	▶ is possible with no special equipment
– restrained joints	▶ allow very high tractive forces and are therefore ideal for trenchless installation
– the material has superior properties	▶ which allow special applications in mountainous regions and for fire-fighting pipelines, snow-making systems and hydroelectric power stations

22.2 Coatings of ductile iron pipes for trenchless pipe installation

Dctile iron pipes are basically supplied with factory coatings. Coatings need to be selected so that the durability of the pipeline is guaranteed. For this it is important to know in what types of soil the pipelines are to be installed. The limits for the use of different coating systems for pipes, fittings and accessories are stated in product standards EN 545 [22.10] and EN 598 [22.11] with reference to relevant soil parameters in Annex D (EN 545 [22.10]) and Annex B (EN 598 [22.11]).

With the trenchless installation of pipes the coatings of ductile iron pipes are exposed to a variety of external mechanical loads. In order to avoid damage to the coatings applied in the factory during trenchless installation, the use of coatings which can resist high mechanical loads is recommended. Two important examples of such heavy-duty iron pipe coatings are cement mortar coating to EN 15 542 [22.12] **(Figure 22.1)** and polyurethane coating (PUR) to EN 15189 [22.13] **(Figure 22.2)**. They have thoroughly proved their credentials for the trenchless installation technique.

22.3 Joint technology

With push-in joints for ductile iron pipes a distinction is basically made between non-restrained and restrained constructions.

22.3.1 Non-restrained push-in joints

Among the non-restrained push-in joints there is for example the TYTON® push-in joint **(Chapter 8)** to DIN 28 603 [22.14]. This kind of joint is only suitable for trenchless installation techniques to a limited extent. The only method which comes into question here is the push-in technique in pipe relining. As the pipe is pushed in the axial force is transmitted from the spigot end across the root of the socket to the next pipe **(Figure 22.3)**. Permissible pushing-in forces are stated further on in this chapter.

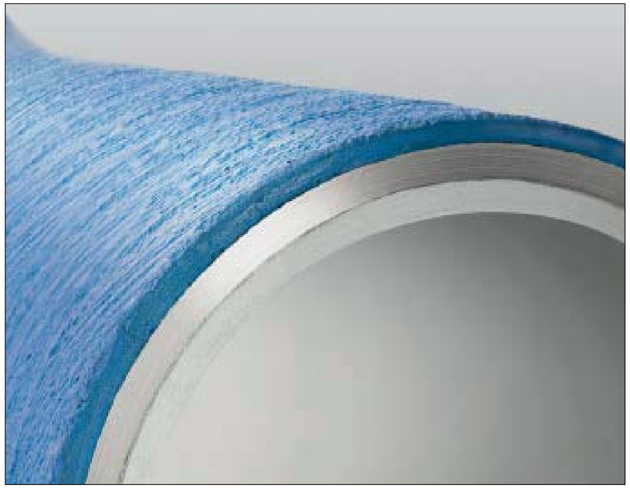

Figure 22.1:
Cement mortar coating
to EN 15542 [22.12]

Figure 22.2:
Polyurethane coating
to EN 15189 [22.13]

Figure 22.3:
Pipe relining –
pushing in ductile iron pipes

Figure 22.4:
Friction locking push-in joint
Fig. 2807A

Further details and conditions of use for this process can be requested from the manufacturers.

22.3.2 Restrained push-in joints

Restrained push-in joints are divided into friction locking and positive locking push-in joints **(Chapter 9)**.

22.3.2.1 Friction locking push-in joints

With friction locking constructions the traction forces are transmitted via the contact surface, e.g. toothed elements which grip onto the surface of the spigot end **(Figure 22.4)**.

22.3.2.2 Positive locking push-in joints

With positive locking push-in joints the forces are transmitted across shaped elements (e.g. welding beads) to the spigot ends in combination with force transmitting elements (e.g. locks or segments) and cast-on or pre-fixed thrust resistance chambers **(Figures 22.5 and 22.6)**.

22.3.3 Fields of use for restrained push-in joints

Opinions differ in the individual countries of Europe as to which type of restrained push-in joint should be used or is best recommended for which installation technique. So for example in Germany, according to the DVGW worksheets GW 320-1 [22.3], GW 321 [22.4], GW 322-1 [22.5], GW 322-2 [22.6] and GW 324 [22.7] on the subject of trenchless installation of ductile iron pipes, it is predominantly positive locking restrained push-in joints that are recommended. For burst lining, according to DVGW technical information sheet GW 323 [22.7], only positive locking joints are permissible.

In other European countries friction locking restrained push-in joints are also permitted. They should be used in consultation with the pipe manufacturer.

Technical data on positive locking restrained push-in joints (traction forces, curve radiuses etc.) according to DVGW Worksheet GW 320-1 [22.3] are given in **Table 22.3**.

Figure 22.5:
HYDROTIGHT positive locking push-in joint

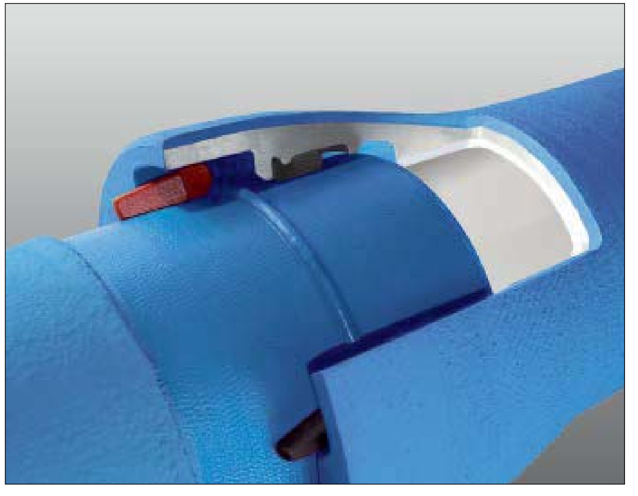

Figure 22.6:
BLS®/VRS®-T positive locking push-in joint

Table 22.3:
Technical data on positive locking restrained push-in joints according to Table A.6 – Allowable traction forces, angular deflection and curve radiuses for pipes in ductile cast iron with BLS® [1)] joints (incl. VRS®-T for DN 80 – DN 500 and TKF for DN 600 – DN 1000) and TIS-K (type pressure testing P_{typ} = PFA x 1.5 + 5 bar, reduced by the safety factor S = 1.1 for construction condition) [22.2]

Nominal size DN	Wall thickness class	Allowable operating pressure [2)] PFA [bar]	Allowable traction force [2), 3)] F_{zul} [kN]	Angular deflection / minimum curve radius [°/m]
80	10	64	70	3/115
100	10	64	100	3/115
125	9	60	140	3/115
150	9	50	165	3/115
200	9	40	230	3/115
250	9	35	308	3/115
300	9	30	380	3/115
400	9	25	558	3/115
500	9	25	860	2/172
600	9	25	1200	2/172
700	9	25	1400	1.5/230
800	9	16	1350	1.5/230
900	9	16	1700	1.5/230
1000	9	10	1440	1.5/230

[1)] From DN 80 to DN 250 BLS® - joints with high pressure lock must be used.
[2)] Higher pressures and traction forces are to be agreed with the pipe manufacturer where necessary.
[3)] Where the route of the pipeline is in a straight line (max. 0.5° deflection per joint) allowable traction forces may be increased by 50 kN

Individual manufacturers and utility companies allow higher allowable traction forces and smaller curve radiuses in their own works standards.

22.4 Trenchless installation techniques

With trenchless installation techniques we will now be making a basic distinction between:

- Processes for replacing existing pipelines along the same route:
  This includes the burst lining technique, the press/pull technique and the auxiliary pipe technique. With these techniques the existing route of the pipe is used for installing a new pipe of the same or a different dimension.
- Trenchless laying of new pipelines:
  The usual techniques for ductile iron pipes are horizontal directional drilling (HDD), cutting in, ploughing in and guided pilot jacking.
- Relining technique:
  Relining is understood to be the pulling or pushing of a new pipe into an old, larger carrier pipe. This produces a reduction of the cross-section of the new carrier pipe.

22.4.1 Burst lining technique

22.4.1.1 General

Burst lining is used for the trenchless replacement of pipelines along the same route. To do this the existing old pipeline is destroyed by means of a bursting head while simultaneously being pushed into the surrounding soil by an upsizing element **(Figure 22.7)** and the new pipe string is drawn in (**Video 22.01**). The old pipe material remains in the ground. Depending on the material this offers advantages as regards disposal, but also disadvantages as regards the point loading of the new pipes. When ductile iron pipes with mechanically resistant coatings are used, however, it can be assumed that the body of the pipe and the coating will not be sensitive to the loads produced (e.g. by fragments of old rigid pipes).

Figure 22.7:
Bursting head with ribs,
upsizing element and traction head

Video 22.01:
Burst lining, DN 200, Vienna

Burst lining is particularly well suited to old pipes in brittle materials such as asbestos cement, vitrified clay or grey cast iron. But pipes made of steel or ductile cast iron can also be “burst” using the static technique with the help of special cutting heads. The newly inserted pipe can be in the same nominal size as the old pipe or, depending on the size of the upsizing head used, in larger dimensions [22.15].

Enlarging the nominal size by up to three stages is possible. If the new pipeline can be smaller than the old pipeline, pipe relining is an available alternative.

With ductile iron pipes, an upsizing dimension **(Figure 22.8)** which is larger than the diameter of the socket is to be selected. Based on DVGW technical information sheet GW 323 [22.7], the required distance to adjacent supply carriers and the depth of cover are to be determined according to the upsizing dimension (UD). The following minimum distances are to be observed:

- parallel line: > 3 x UD, min. 40 cm,
- parallel fragile lines < DN 200: > 5 x UD, min. 40 cm,
- parallel fragile lines from DN 200: > 5 x AM, min. 100 cm,
- crossing lines at critical distance open wherever possible,
- pipe cover: > 10 UD.

Another advantage of burst lining old pipes in asbestos cement can be seen in the fact that the problematic processing and disposal of the old pipes, which

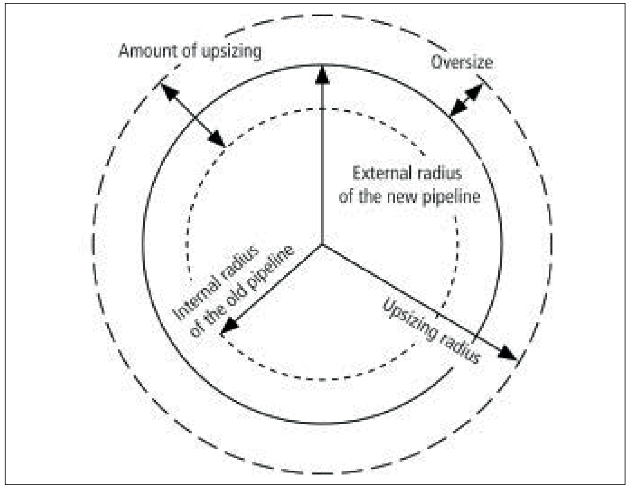

Figure 22.8:
Definition of the upsizing dimension UD

is difficult from a work safety point of view when replacing pipes in open trenches does not apply here.

In the area of distribution networks the use of burst lining (or any trenchless replacement) is above all dependent on the number of intermediate installation pits necessary. Intermediate installation pits have to be created for house connections, valves, changes of direction and cross-section and branch pipes. Bends up to 11° can usually go through. With a tighter series of house connection pipelines replacement using the open trench technique may be more cost effective [22.16].

Of equal importance is the accuracy of the documentation on the existing old pipeline. Among other things the following points are to be documented:

- Diameter and material of the old pipe,
- Change of nominal sizes and materials,
- Cover depth,
- Changes of direction,
- Horizontal and vertical offset sections,
- Branch pipes or connections,
- Condensate drains,
- Valves,
- Concrete thrust blocks,
- Fittings, clamps, etc.,
- Parallel and crossing line equipment.

22.4.1.2 Description of technique

With burst lining a distinction is made between dynamic and static processes. With both techniques forces are introduced into the old pipeline to destroy it when the bursting head is used. Brittle materials are burst into fragments **(Figure 22.9)**, all others are cut open **(Figure 22.10)**. The fragments or cut pipes are pushed into the surrounding earth.

Figure 22.9:
Grey cast iron fragments

Dynamic burst lining

The force needed for bursting is introduced in the longitudinal direction of the pipe by a kind of soil displacement hammer. This is driven by compressed air from a compressor. In order to guide the bursting head it is winched from the target pit by a traction cable pulled through the old pipe. The dynamic technique is above all suitable for highly compacted and stony soils and brittle old pipes. It is not suitable for laying new ductile iron pipes.

Figure 22.10:
Steel pipe cut open

Static burst lining

With this technique the force is introduced through a traction rod in the bursting head which is run from the target pit through the old pipeline from the traction unit to the bursting head **(Figures 22.11 and 22.12)**.

During the pulling process the traction unit is supported against the wall of the target pit. The traction rod is successively dismantled. The static technique is suitable for easily displaceable, homogeneous soils and is suitable for laying new ductile iron pipes.

22.4.1.3 Advice for users

The largest nominal size of ductile iron pipes inserted to date using the burst lining technique is DN 600. But in principle any nominal size, including DN 1000, is possible. The tractive power of the machine used is to be designed according to the nominal size to be burst and the upsizing expected.

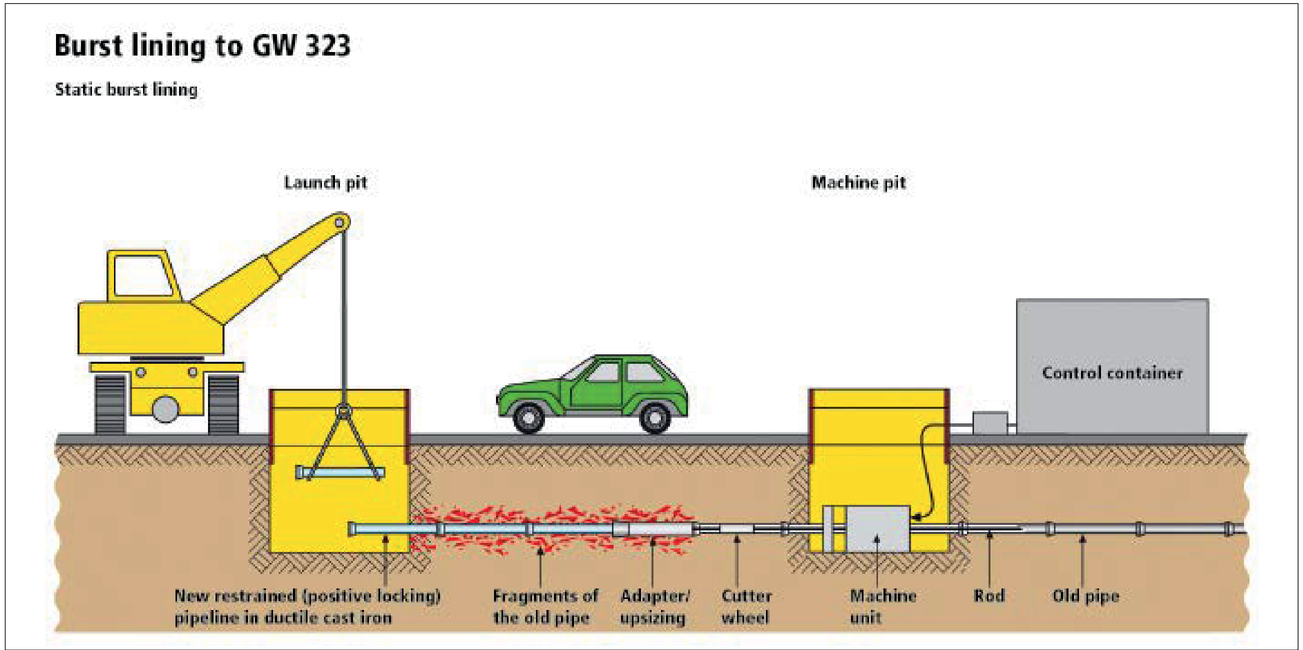

Figure 22.11:
Diagram of static burst lining-technique

Figure 22.12:
Traction rod with bursting head

As a rough classification, the following tractive power levels can be assumed depending on the diameter of the old pipe; refer to [22.17]:

- ≤ DN 250 → 400 kN,
- > DN 250 ≤ DN 400 → 770 kN,
- > DN 400 ≤ DN 600 → 1250 kN,
- > DN 600 ≤ DN 1000 → 2500 kN.

However, the traction forces to be expected are also still dependent on a few other factors, such as e.g. the upsizing dimension, the type of soil to be found and pipe lengths. The major part of the tensile forces is produced by the breaking of the old pipe and the upsizing. Added to this is a relatively small proportion from surface friction with the new pipe.

The usual pipe lengths are between 50 m and 200 m. Longer lengths are also possible theoretically as in fact only a small part of the tensile force is due to the pipe material and its length and consequently to surface friction. But pipe lengths are usually limited by local circumstances such as changes in direction or other components.

The lengths which are actually possible and practicable are to be determined individually for each project.

Meanwhile there are also practical experiences with the replacement of ductile pipe materials (spheroidal graphite cast iron and steel) with ductile iron pipes. Here the old pipes are cut open with special perforating and cutting wheels **(Figure 22.13)** and then bent open with the upsizing head until the new pipe can be drawn through. Use up to nominal size DN 400 has been tried and tested [22.18] **(Video 22.02)**.

Figure 22.13:
Cutting whell for old pipes in steel

Video 22.02:
Burst lining, demo site in Lennestadt

22.4.2 Press/pull technique

22.4.2.1 General

The greatest innovative boost in the domain of trenchless replacement came from Berlin. The oldest grey cast iron network of water pipes in Germany, dating back more than 120 years, is in operation here and in urgent need of replacement. The ambient conditions in Berlin make replacement more difficult, mainly because of the following two requirements:

1. The pipelines lie in the area of the roots of trees lining the street pavements. The trees are under strict protection and the roots may in no case be damaged. The use of pipe trenches and conventional installation is not permitted.
2. Replacement techniques in which the old pipes, either whole or in fragments, remain in the trench, cannot be used because of the Berlin street regulations. All unused construction materials have to be completely removed.

Hence the development of two special pipe replacement techniques – the press/pull technique and the auxiliary pipe technique – was almost inevitable. With both techniques pipelines can be replaced along the same route without digging trenches with new pipelines of the same or larger nominal sizes, e.g. new DN 125/150 for old DN 100 **(Table 22.4)**, where the pipes of the old pipeline are salvaged, either in fragments or in whole pipes. This offers the following advantages:

- Valuable raw materials are put back into the cycle,
- Surfaces and nature are only affected to a minimum extent,
- the underground space is not obstructed by additional pipelines.

Table 22.4:
Maximum nominal size enlargement with trenchless replacement

Nominal size of old pipe	Maximum nominal size of new pipe
DN 80	DN 150
DN 100	DN 200
DN 150	DN 200
DN 200	DN 300
DN 300	DN 400
DN 400	DN 400

Additional plus points of the two techniques are:

- There is no need to move bus stops or reroute bus services.
- Delivery traffic in shopping streets is hardly affected at all.
- Other utility lines are not put at risk by excavations.
- Depending on the machine technology used, with a max. noise emission of < 54.5 dB(A) a particularly "quiet" and dust-free site is possible. In fact in residential areas it is possible to work without night-time interruptions.

Above all in inner-city construction projects with extremely densely laid piping networks, lines running parallel or crossing lines are at high risk when heavy civil engineering equipment is used in open trenches. This risk is minimised with the use of trenchless replacement techniques.

Both techniques (press/pull and auxiliary pipe techniques) are used with supply pipelines in the nominal size range DN 80 to DN 400.

Requirements:

- a machine pit to take the machine technology,
- an assembly pit for the new pipes (about 7 m long),
- intermediate pits for house connections and branch pipes.

The distance between the intermediate pits depends on the nominal size of the old pipes and its condition, the nominal size of the new pipe, the machine technology, the type of soil, the status of trees and roots and, naturally, traffic conditions and the presence of utility lines. Depending on technique and location, the distance between the intermediate pits should not exceed 25 m to 50 m. In normal cases, where the route runs in a straight line or there is a minimum curve radius of 170 m, there is a distance of 100 m to 180 m between launch and target pits. Before the replacement process, the old pipeline is taken out of operation. Residents continue to be supplied by temporary water pipelines, where the water is fed into the disconnected house connection pipelines in the house connection pits.

22.4.2.2 Description of technique

In the press/pull technique (**Video 22.03**) the old pipe is pushed onto a splitting cone, broken up and removed in fragments from the machine or intermediate pit **(Figure 22.14)**. The new pipes with restrained joints are attached to the end of the traction rod via the pull/push head and drawn into the space as it is freed. Both stages take place simultaneously. In this way, as already described, there is still a stage for upsizing behind the traction head, allowing for widening of up to three nominal sizes **(Table 22.4)**.

Once the necessary launch, target and intermediate pits have been created and installed, the old sections of pipeline are removed and dismantled. When doing this, the old pipe must not be removed from the ground all at once along its whole length but only between the individual pits. This means a lower traction force. Specially prepared assembly/launch pits make pipe assembly easier and avoid the ingress of contamination **(Figures 22.15 and 22.16)**. Because of the overall length of ductile cast iron pipes, they should not be less than 7 m to 8 m long.

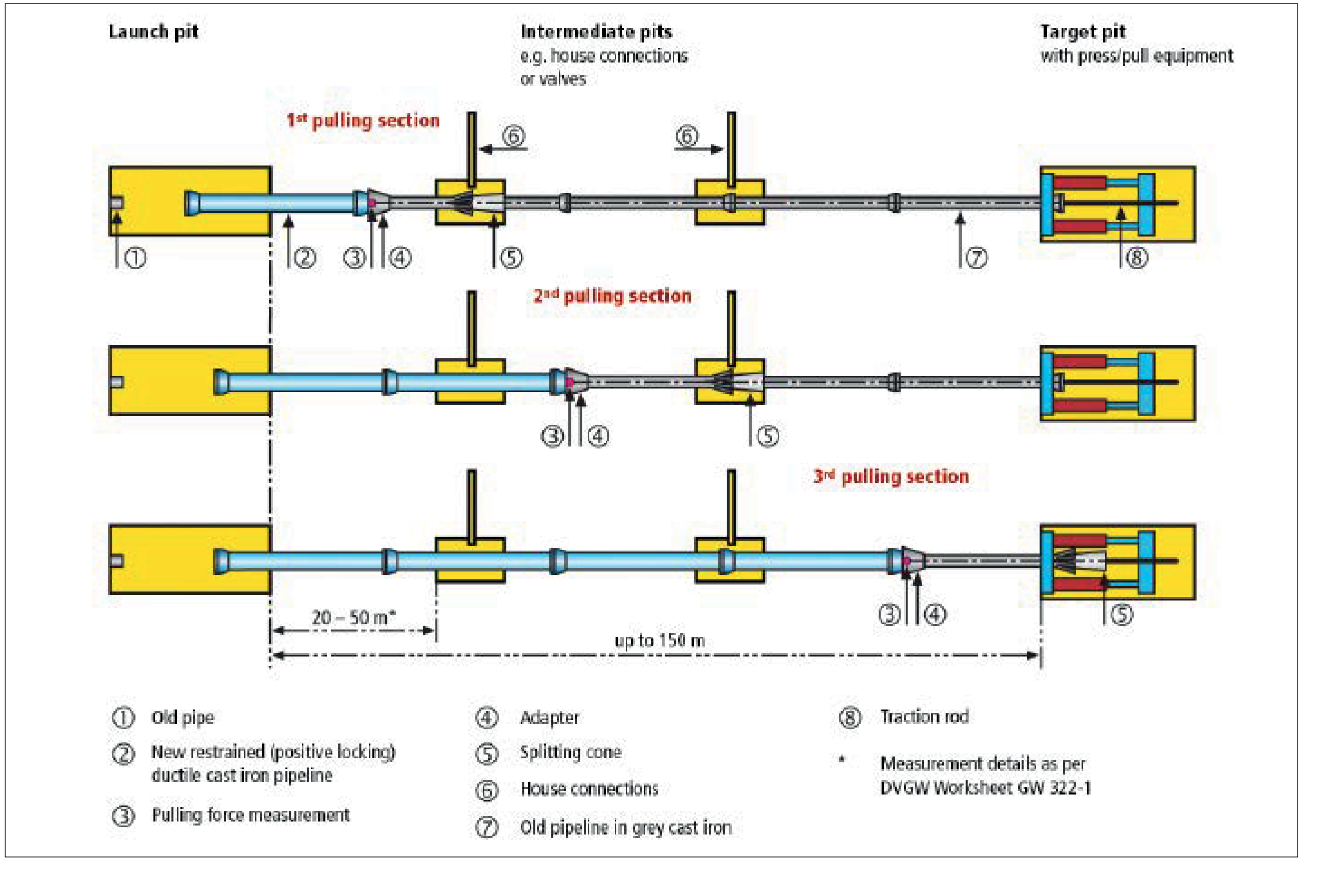

Figure 22.14:
Diagram of the press/pull technique for the trenchless replacement of grey cast iron pipelines

Video 22.03:
Presentation of the press/pull technique – Example in Switzerland

Figure 22.15:
Launch and assembly pit

Figure 22.16:
Assembly accessories

Firstly a coupling traction rod is inserted into the old pipeline and anchored onto a transition adapter at the end of the old pipeline **(Figure 22.14)** so that the old pipe is pushed out of the ground in the replacement process. No fragments remain in the bedding zone of the new pipeline. The new pipe is also attached to the transition adapter and simultaneously drawn along afterwards as the pipe is removed.

The traction forces are introduced across the traction rod at the transition adapter as axial compressive forces in the end of the old pipeline. In some cases it can happen that the old pipe is already so weak that it cannot take up the axial forces occurring and thus cannot be pushed out of the ground. In such cases the old pipe must be reinforced in advance. This can be done for example by pulling in an empty pipe and then filling the empty gap between the old pipe and the empty pipe with concrete.

It is only the traction forces of its own weight and surface friction which act on the new pipe string to be pulled in.

As the socket acts much like an upsizing element, in general only forces from surface friction are produced here, while the 6 m long barrel of the pipe, which is smaller in diameter, makes no contribution to the production of surface friction forces.

At the back wall of the target pit, the hydraulic press/pull equipment (traction unit) is supported e.g. by a steel construction as a thrust bearing **(Figure 22.17)**.

The thrust bearing is calculated according to the reaction forces and the nominal size and only allows for a small overlap with the pipe so that as far as possible no earth is pushed into the pit. The hydraulic piston of the press/pull equipment allows the old pipe to be pushed out without vibrations and jolting. In the intermediate construction pits the old pipe is pushed across a splitting cone or shattered with an automatic pipe cracker **(Figure 22.18)**.

Figure 22.17:
Traction unit and thrust bearing

Figure 22.18:
Hydraulic pipe cracker

In this way it is always only the old section of pipe which is pushed out in front of the splitting cone, which results in a not inconsiderable reduction in the traction forces required. The position and size of the intermediate pits is determined in situ on the basis of e.g. house connections, branch pipes and components. Usually the distance between them is 20 m to 50 m. The fragments in the intermediate and target pits are taken to the surface in containers. With the last section drawn, the old pipe drawn into the target pit is generally crushed by the return stroke of the piston.

Just as with burst lining **(Chapter 22.4.1)** here again an upsizing dimension is to be selected which is greater than the diameter of the socket. On top of the upsizing dimension UD **(Figure 22.8)** the necessary distance from adjacent utility carriers and the cover depth are to be determined.

The following minimum distances are to be observed according to [22.7]:

- parallel line: > 3 x UD, min. 40 cm,
- parallel fragile lines < DN 200: > 5 x UD, min. 40 cm,
- parallel fragile lines from DN 200: > 5 x UD, min. 100 cm,
- crossing lines at critical distance open wherever possible,
- pipe cover: > 10 UD.

22.4.2.3 Latest developments

During the Baustellentag der Wasser Berlin 2011, a further development of the press/pull technique was presented as a world premiere. Together with the Tracto Technik company from Lennestadt, the Berlin branch of the Josef Pfaffinger company developed the possibility of also replacing larger nominal size differences based on the press/pull technique, even with shallow depths of cover (**Video 22.04**).

This is made possible by removing soil between the press/pull head and the new pipe. The soil removed is carried away by means of a feed auger (**Figure 22.19**) through a steel pipe running inside the utility pipe (**Figure 22.20**) into the launch pit. At the same time the old pipe is pushed into the target pit where it is burst. In this way, with a pipe cover of only 1.5 m, an old DN 300 grey cast iron pipe can be replaced with a new ductile sewage pipe of nominal size DN 500. The lengths tested here were around 50 m. Ductile sewage pipes to EN 598 [22.11] with positive locking restrained BLS®/VRS®-T push-in joints and ZM-U-Plus cement mortar coating were used. The cement mortar coating and the very low overcut of approximately 15 mm meant that subsequent settlement was reduced to a minimum [22.19].

Figure 22.19:
Traction head with internal feed auger

Figure 22.20:
ZM-U-Plus cement mortar coated sewage pipe fitted with feed tube and string of auger sections

Video 22.04:
Press/pull technique with soil removal

22.4.3 Auxiliary pipe technique

22.4.3.1 General

The auxiliary pipe technique has been developed out of the burst lining and press/pull processes. Basically, the same principles apply as already described in **Chapter 22.4.1 and Chapter 22.4.2**.

In contrast to the press/pull technique the auxiliary pipe technique is used for replacing pipes in ductile materials – i.e. those which cannot be burst in target or intermediate construction pits (e.g. steel pipes) along the same route. If such materials are to be removed from the ground, without excavation and without leaving residues, and replaced by a new pipe along the same route, the auxiliary pipe technique can be used. Cross-section enlargements of up to three nominal size stages are also possible with this technique (**Table 22.4**).

As regards the upsizing dimension and the minimum distances to adjacent utility carriers and to the surface which are closely related to this, the statements made in **Chapter 22.4.1.1** apply accordingly.

22.4.3.2 Description of technique

With the auxiliary pipe technique the replacement process is divided into several working stages. Just as with the press/pull technique described in **Chapter 22.4.2** here again a machine pit and an assembly pit are needed as well as the intermediate pits for house connections and branch pipelines. The distances between the individual pits are also similar. In the first stage of the work the house connections are disconnected and connected up to the temporary supply pipelines **(Figure 22.21)**.

Parts of the old pipe which are missing because of the removal of house connections or other fittings are replaced by transition pieces.

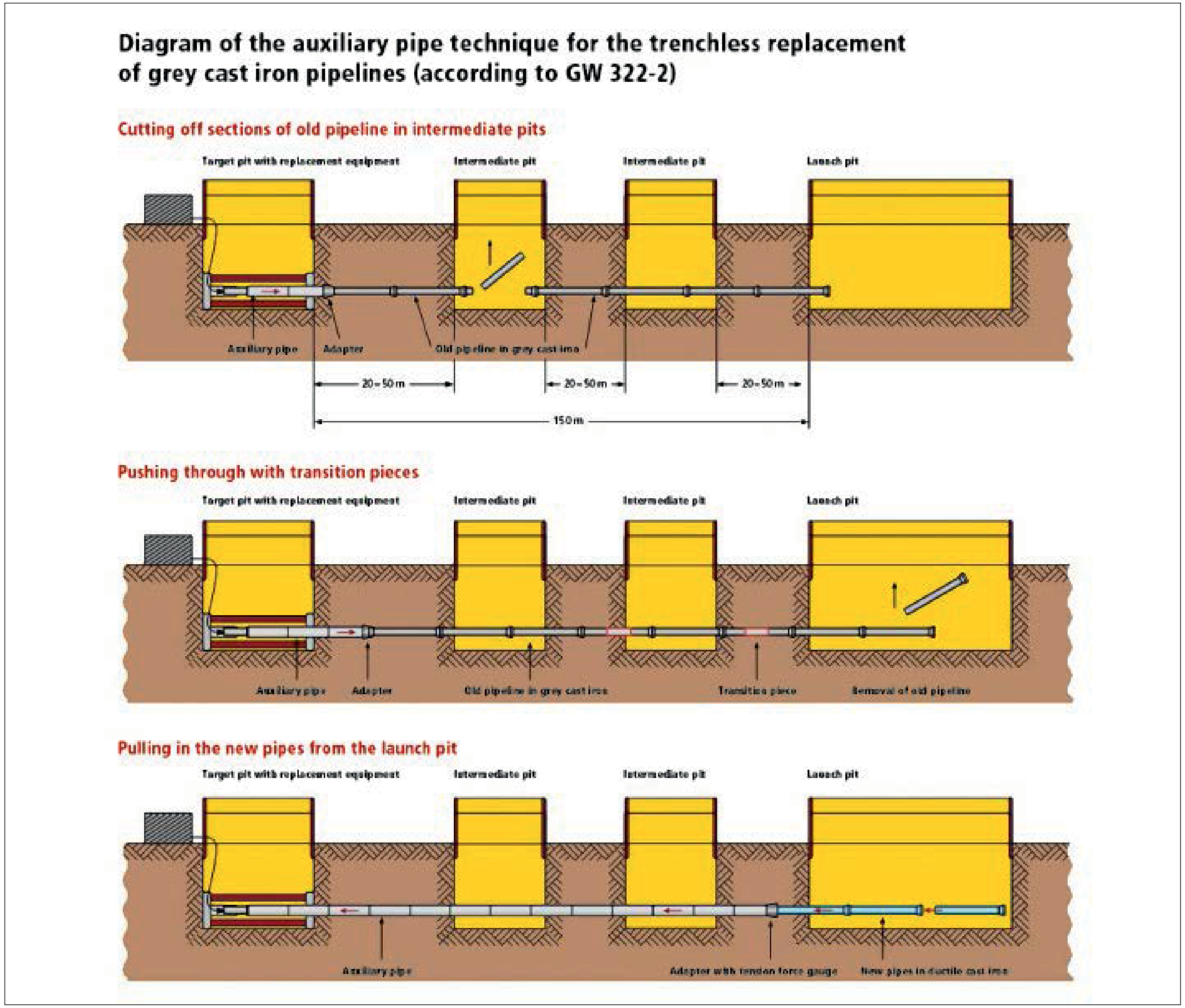

Figure 22.21:
Diagram of the auxiliary pipe technique for the trenchless replacement of grey cast iron pipelines according to DVGW Worksheet GW 322-2 [22.6]

Figure 22.22:
Steel pipes pushed out

Then the mechanical press pushes the old pipes out into the assembly pit by means of restrained auxiliary steel pipes until they have been completely removed **(Figure 22.22)**.

If the old pipe cannot take the high pressing forces to be expected, it is cut in the intermediate pits and removed in shorter pieces of pipe.

After complete removal of the last of the old pipes the route is now occupied by the reusable auxiliary pipes **(Figure 22.21)**. These now take up the loads of the cover and the traffic and so secure the sewage channel.

In the last stage of the work, the new pipe is connected up to the auxiliary pipes in the pipe channel by means of a traction head with an integrated tension force gauge. The auxiliary pipes are drawn back into the machine pit and with them the new pipeline is pulled into the existing pipe channel **(Figure 22.21)**. As the auxiliary pipes are being dismantled and removed in the machine pit, the assembly of the new pipes is taking place in the pipe installation pit. If an upsizing traction head is used, larger dimension new pipes can also be pulled in. Usually a small overcut of 10 % to 15 % more than the external diameter of the socket is used.

22.4.4 Horizontal directional drilling

22.4.4.1 General

In contrast to the techniques described in **Chapters 22.4.1, 22.4.2 and 22.4.3** for replacing existing pipelines using the same route, the following technique for the trenchless installation of a new pipeline of ductile iron pipes is now described. This includes horizontal directional drilling (HDD), cutting in, ploughing in and guided pilot jacking. While the last-named techniques play a rather subordinate role, the HHD technique practically represents an everyday form of trenchless installation of ductile iron pipes.

Since the beginning of the nineties the development of this technique has been closely linked with ductile cast iron pipes. As early as 1993, in experimental tests Nöh [22.20] installed 60 m long DN 150 pipelines with positive locking push-in joints and extracted them from the pipe channel again to assess the surface stresses. The excellent results formed the basis for a double culvert of 2 x DN 150 of around 200 m in length which was installed in 1994 near Kinheim under the River Mosel, partly through rocky ground.

22.4.4.2 Description of technique

The horizontal directional drilling technique is by far the most widespread trenchless technique for the installation of new pressure pipelines for water supply the [22.21]. Examples of execution can be seen in **Videos 22.05 and 22.06**.

The process of the horizontal directional drilling technique is divided into three consecutive working stages as follows **(Figure 22.23)**:

- Pilot boring,
- Upsize boring,
- Pulling in.

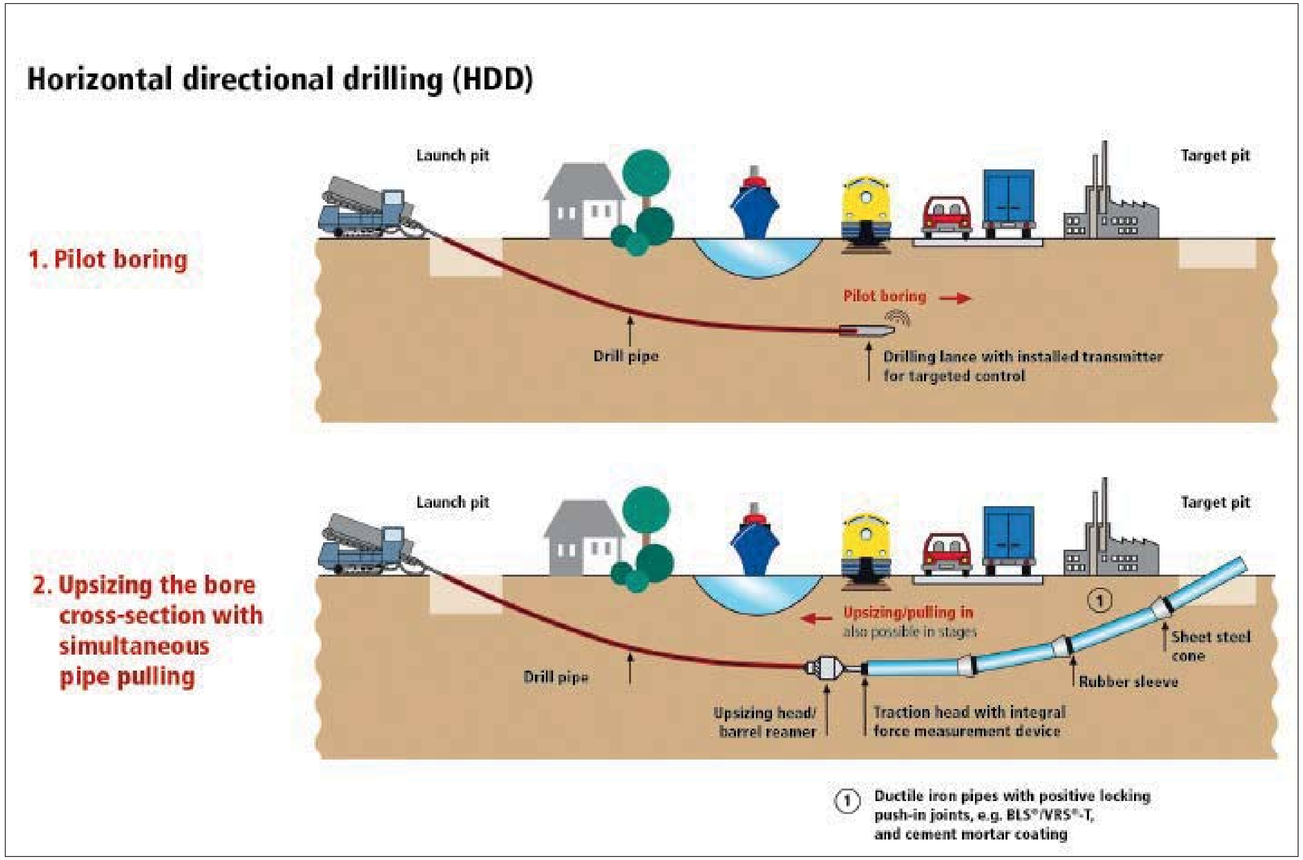

Figure 22.23:
Diagram of the horizontal directional drilling technique

Video 22.05:
HDD for a DN 500 culvert at Geel in Belgium

Video 22.06:
HDD for a DN 900 culvert at Alzira in Spain

1. Pilot boring

This is the first stage of producing a drilled channel from the starting point to the target pit into which the pipe string can be drawn. The pilot hole is driven in a controlled way using a drill head on the end of a drill pipe. In this process a watery bentonite suspension, the so-called drilling fluid, escapes under high pressure at the drill head which is pumped through the drill pipe by the drilling machine to the drill head. The drilling fluid serves the dual purpose of transporting the detached material away and supporting the drill hole. The drill head is designed differently for different soil types. With sandy soils the outlet nozzles are generally sufficient for loosening and carrying away the drilling spoil. In rocky ground drill heads equipped with roller chisels can be used.

The pilot boring is guided by controlled rotation of the bevelled control surface of the drill head, the swerving movement of which can be pushed by rotation in the desired direction **(Figure 22.24)**. The actual position of the drill head is located by radio signals from a transmitter housed in the drill head above the route of the pipeline. Deviations from the target pipeline are corrected by steering movements. The precision of steering is so high these days that it is possible to have pilot bores arrive in a target area of only 1 m^2 after lengths of more than 1,000 m.

Figure 22.24:
Drill head for pilot boring

2. Upsize boring

The purpose of upsize boring is, where necessary, to enlarge the pilot bore to a diameter sufficient for the insertion of the utility pipe in a number of stages by the use of appropriate tools. To do this an upsizing head is mounted on the pilot drill string, the size and design of which are based on the soil conditions in each case and the dimension of the pipe to be pulled through subsequently **(Figures 22.25 and 22.26)**.

The upsizing head is drawn through the borehole under constant rotation and so widens the pilot bore. The soil removed is carried away with the drilling mud, which simultaneously supports the channel bored.

The upsizing process is repeated with ever larger drill heads until the desired internal diameter of the channel is achieved. With ductile iron pipes the diameter of the bore is based on the outside diameter of the sockets. Usually an overcut of 20 % to 30 % larger than the socket is necessary.

Figure 22.25:
Examples of upsizing heads

Figure 22.26:
Reamer with swivel and traction head

3. Pulling in

Once the drill hole has reached its final diameter, the pipe string can be pulled in. A reamer **(Figures 22.26 and 22.27)** is fitted to the drill pipe which is still inside the bored channel, followed by a swivel, which prevents the pipe string from rotating, and a traction head suitable for the piping material to be pulled in **(Figure 22.28)**. The traction head has a positive locking to the pipe string. The maximum possible length of the pipe string to be pulled in depends on local circumstances.

Depending on the space available, with ductile iron pipes, the horizontal directional drilling technique can be carried out with a completely pre-assembled pipe string **(Figures 22.29, 22.30 and 22.31)** or for individual pipe assembly **(Figure 22.32)**.

Figure 22.27:
Positioning the swivel between reamer and traction head

Figure 22.28:
Traction head with sheet steel cone

Figure 22.29:
HDD – pipe string pre-assembled in the trench

Figure 22.30:
HDD – elevated pre-assembled pipe string

Figure 22.31:
HDD – pre-assembled pipe string floating in the bentonite suspension

Figure 22.32:
HDD – individual pipe assembly using an assembly ramp

22.4.5 Cutting in

22.4.5.1 General

According to GW 324 [22.8] the soil is loosened, broken up and conveyed by a cutting tool (chain, wheel). It is deposited beside the trench or carried away **(Figure 22.33)**. A distinction is made between cutting in without installation box and cutting in with installation box For the installation of ductile iron pipes, the cutting in process with installation box (e.g. sliding formwork) is used **(Figure 22.33)**.

Figure 22.33:
Cutting in – individual pipe assembly in sliding formwork

22.4.5.2 Description of technique

The cutting and installation unit cuts the trench. The installation box is set up and the ductile iron pipes are assembled inside the box on the bottom of the trench. The filling and compacting unit moves the backfilling material deposited on the side into the pipeline area in layers and compacts it.

22.4.6 Ploughing in

22.4.6.1 General

For a long time cables and plastic pipelines have been ploughed in in rural areas and along routes without pre-existing infrastructures or other obstacles. This mainly happens along service tracks at the edge of land used for agricultural purposes. In 2000 the technique was successfully trialled for the first time with pipes in ductile cast iron in the context of a research project and since then it has been further developed to become a standard technique. DVGW Worksheet GW 324 [22.8] is applicable for the planning and construction of underground pressure pipelines for public water supply in Germany.

22.4.6.2 Description of technique

A hollow is produced by an upsizing unit shaped like a rocket head on the bottom of a ploughshare. In the same stage of the work, the pipe string which is attached to the upsizing unit via a traction head is pulled into this hollow space (**Video 22.07**). **Figure 22.34** shows the principle of the technique.

So far the technique has been used with nominal sizes DN 80 to DN 300.

The machine technology required consists of a towing vehicle **(Figure 22.35)** and a plough **(Figure 22.36)** with a ploughshare. For vertical consistency of the pipe route in an undulating topographic profile, the insertion depth of the ploughshare can be controlled hydraulically.

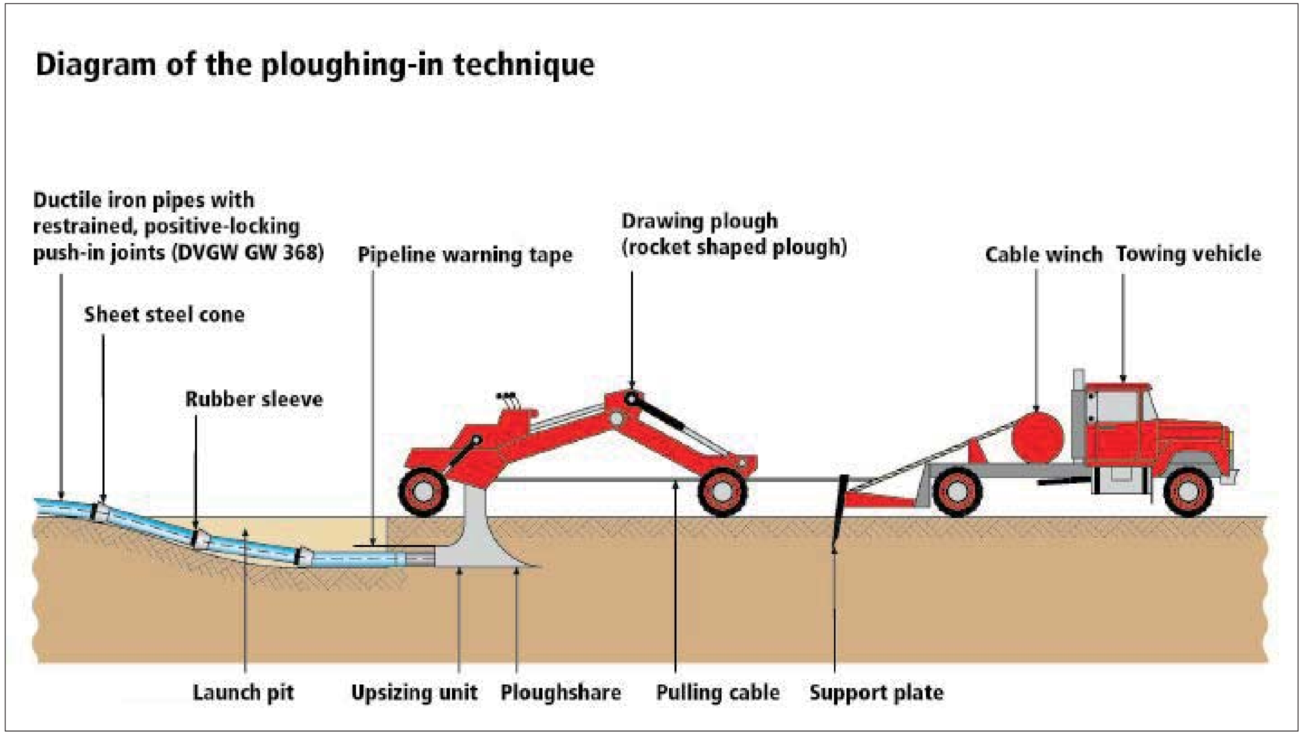

Figure 22.34:
Diagram of the ploughing-in technique

Figure 22.35:
Towing vehicle

Video 22.07:
Ploughing in DN 150 ductile iron pipes

Figure 22.36:
Plough

The plough is attached by a steel cable **(Figure 22.37)** to the towing vehicle, which can be supported by a plate on the ground to transmit the traction forces into ground.

The pipeline of ductile iron pipes with positive locking restrained joints is laid along the route. The pipe string is then attached to the upsizing unit **(Figure 22.38)** and ploughed into the soil via a launch pit with a sloping ramp **(Figures 22.39, 22.40 and 22.41)**. The length of the launch pit depends on the angular deflection capacity of the restrained push-in joints.

Figure 22.37:
Steel cable to the towing vehicle

Figure 22.38:
Plough with upsizing unit

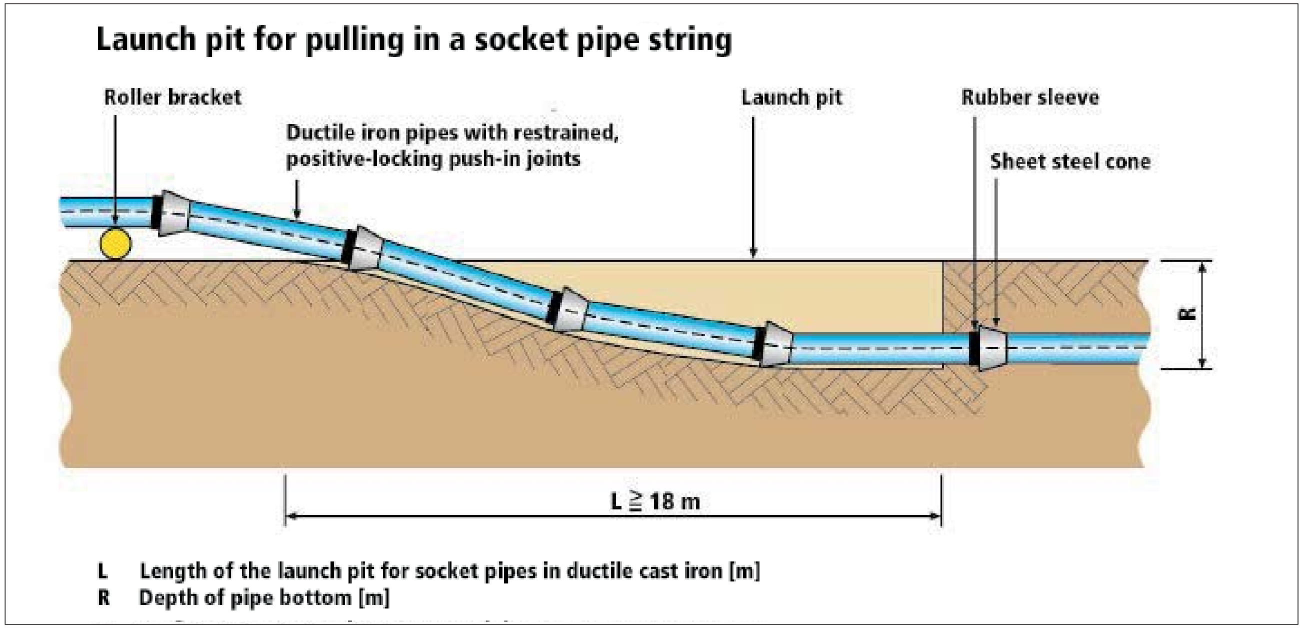

Figure 22.39:
Launch pit with sloping ramp

Figure 22.40:
Launch pit

Figure 22.41:
Pipeline ploughed in

As the pipeline is pulled in, additional protection tubes, cables and warning tape can be installed at the same time. In order to fill the annular space or to reduce friction forces a bentonite suspension can be introduced. Individual pipeline strings are connected one beneath the other with collars. Any surface distortions existing after the installation of the pipeline are then evened out by running the excavator over them.

22.4.7 Guided pilot boring

22.4.7.1 General

An interesting variation of the trenchless installation of new pipelines in ductile cast iron is so-called guided pilot boring. Using a pipe boring machine for micro-tunnelling, a guided pilot bore is driven for about 70 m to the target pit. In a second stage, this bore is widened by removing soil using auxiliary pipes with feed augers. The third stage consists of withdrawing these auxiliary pipes while simultaneously pulling in the individual ductile iron pipes **(Figure 22.42)**. The precision which can be achieved with this version of the technique is so high that even the high requirements for gravity sewers can be met.

Basic conditions for guided pilot boring are displaceable soil, piping lengths < 120 m, no stones > 80 mm in the route and a groundwater level above the pipe of less than 3 m. The available machine technology currently allows the installation of pipes with a maximum outside diameter of 1,000 mm. This approximately corresponds to a ductile iron pipe with positive locking restrained push-in joints of nominal size DN 800.

The essential advantage of this technique lies in the fact that even pipe materials which are not normally available as jacking pipes can be very accurately installed as new using a trenchless technique.

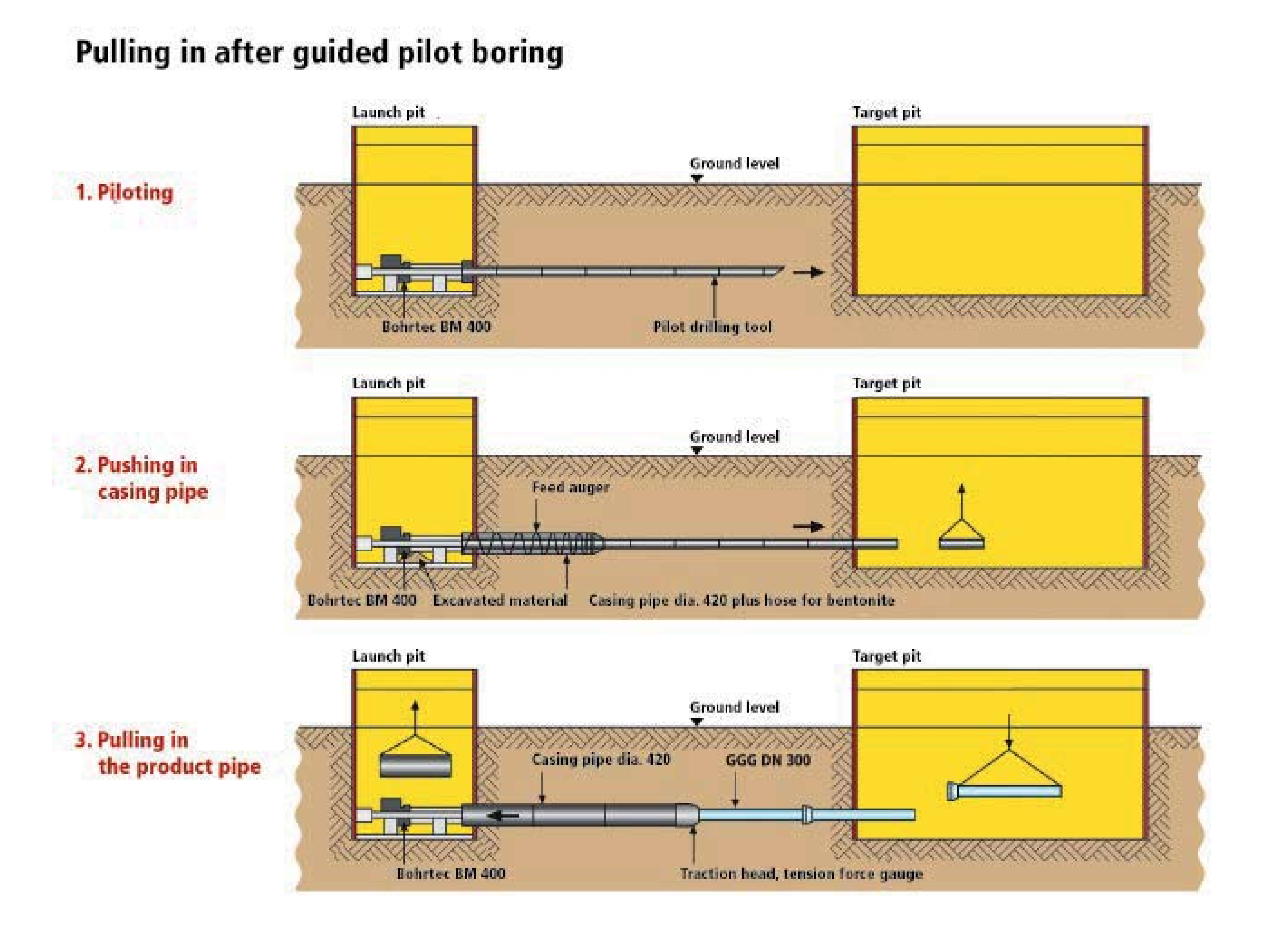

Figure 22.42:
Pulling in after guided pilot boring

22.4.7.2 Description of technique

The first stage is the pilot boring. The pilot pipe is pushed out from the launch shaft into the target pit through the displaceable soil. With the help of an optical path, a control head, a theodolite with CCD camera and monitor it is possible to guide the equipment precisely to target with constant control of direction and inclination **(Figure 22.42)**.

In the second state the pilot bore is widened by pushing through a restrained steel casing **(Figure 22.42)**. If necessary the bore can now be widened to the final dimension required. With the steel casing, the pieces of pipe are pushed through the pilot bore to the target shaft where they are dismantled and salvaged. The excavation material produced by widening the borehole is conveyed back to the launch shaft with a feed auger consisting of 1 m long part sections. Here the soil is taken up in a container, lifted out with the site lifting gear and collected in containers for disposal.

In the third stage of the work the ductile iron pipe with positive locking restrained push-in joint is released into the target shaft and connected to the traction head of the foremost casing pipe. The friction-locked casing pipes are now drawn back to the launch shaft. Here they are retrieved together with the feed auger **(Figure 22.42)**.

All further product pipes are connected to the pipe previously pulled in very quickly. The traction head carries a tensile force gauge with which the pulling forces working on the pipe string can be measured and documented.

As an alternative to the pulling head a so-called hole opener **(Figure 22.43)** can also be used with a connection for ductile iron pipes **(Figure 22.44)** [22.22]. This has the advantage that the utility pipe to be laid can be installed to millimetre precision, which is particularly important when installing gravity sewers. The frictional forces produced on the casing can be reduced by lubrication with bentonite.

Figure 22.43:
Hole Opener

Figure 22.44:
Coupling for ductile iron pipes

If necessary the bentonite mixture can be pushed through a feed pipeline which runs through the new pipe in the area of the hole opener between pipe and soil.

22.4.7.3 Coatings

Basically, for this technique, pipes with cement mortar coating to EN 15542 [22.12] or polyurethane coating to EN 15189 [22.13] are used. The area of the joint is protected with a protective rubber sleeve and/or a sheet steel cone.

Many innovations are based on proven products where skilful adaptation and reorientation has developed them further for new conditions of use and basic requirements. This is also the case with the ZM-U-Plus pipe which has been in use in Berlin for a number of years.

Initially developed and successfully because of the desire of Berliner Wasserbetriebe (BWB) for a trenchless pipe replacement technique in the domain of drinking water which could keep to the track in coarse-grained and loose soils containing gravel, the technique of trenchless laying of new pipelines opened up an entirely new area of use.

With the ZM-U-Plus cement mortar coated pipe **(Figure 22.45)** ductile iron pipes are so thickly coated with cement mortar up to the outside contour of the socket that externally they have a cylindrical contour without any recognisable socket. The cement mortar coating is extremely mechanically robust. It resists enormous friction forces over the entire circumference of the pipe barrel. Once the joints are assembled the gap between the end face of the socket and the spigot end is closed with flexible material and then sealed with special tape.

22.4.7.4 Push-in joint

As the utility pipe is pulled in by guided pilot boring, here again the use of positive locking restrained push-in joints is necessary. Allowable traction forces and operating pressures for the positive locking restrained push-in joints are given in **Table 22.3**.

Figure 22.45:
ZM-U-Plus pipe

22.4.7.5 Miscellaneous

As a result the individual pipeline sections can be conventionally assembled in the installation pits (previously launch and pulling pits) with the help of standard fittings. For pipelines to be fully locked, restrained fittings are to be used. By using these fittings, with pressure pipelines the ends of the pipeline can also be closed for pressure testing before connection.

Shoring of the ends of the pipeline is not necessary in this case.

An advantage of guided pilot jacking is the low overcut. Therefore there is no or only a little amount of settlement as a result. The technique is technically mature. It combines the known technique of guided pipe jacking which has been tried and tested in the field of sewer construction with the pull-in technique for restrained ductile iron pipes. Traffic and environment are only affected to a slight extent.

22.4.8 Relining technique

22.4.8.1 General

When replacing pipelines using the relining technique a new pipeline is drawn or pushed into an existing pipeline. This always results in a reduction of the clear inside diameter. When relining with ductile iron pipes the reduction of the cross-section of the pipeline depends on the diameter of the sockets of the new pipeline. As a rule this is two nominal size stages. The hydraulic efficiency of the pipeline is reduced. However this is in part compensated by the smoother internal surface (lower wall roughness) of the new pipeline. Old pipelines are often incrusted on the inside und therefore have a high wall roughness. The relining technique can be used for drinking water pipelines, industrial water pipelines and pressurised and gravity sewage pipelines. Pipe relining is based on DVGW Worksheet GW 320-1 [22.3].

In Germany the consumption of drinking water by the public and by industry has been declining for some years. According to information from the German Federal Statistics Office the per capita consumption in 1990 was still around 145 L/(i · d); by 2007 it had dropped to around 120 L/(i · d). It has a very strong regional variation between 90 and 135 L/(i · d).

Therefore reducing the hydraulic cross-section of a pipeline often brings advantages for the operator because the speed of flow of the water is raised again and the drinking water spends less time lying idle in the pipeline, which means that hygiene problems can often be avoided.

With sewage pipelines too, the speed of flow increases with relining, which in many cases means that sedimentation of the solids carried in the wastewater is avoided. It is because of the solids deposited that wastewater pipelines often have to be cleaned at relatively short intervals by high pressure flushing or pigging. In some cases this may be unnecessary with the use of a smaller diameter. With all pipelines where the distance is not too short between changes of direction or side connections, replacement using the relining technique is always more cost effective than laying a new pipeline in open pipe trenches. This applies in particular where pipelines run under hard surfaces (e.g. road surfaces) or in built-up areas.

In the relining technique with ductile iron pipes, depending on the conditions locally, section lengths of far more than 1,000 m can be renovated in one process. All that is required for this is one launch pit and one target pit. As regards the nominal size of the new pipe, there are no limits.

22.4.8.2 Description of technique

With the relining technique, pipes in ductile cast iron to EN 545 [22.10] or EN 598 [20.11] are pulled or pushed into the old, existing pipeline sliding on the socket and protected with a sheet steel cone **(Figure 22.46)**. Because of the high longitudinal bending resistance of ductile iron pipes, only one support per pipe (in this case the socket) is necessary. Additional supports/skids are not normally required. **Figure 22.47** shows a special relining measure in which the new pipes have been provided with skids. The very small annular gap has not been filled.

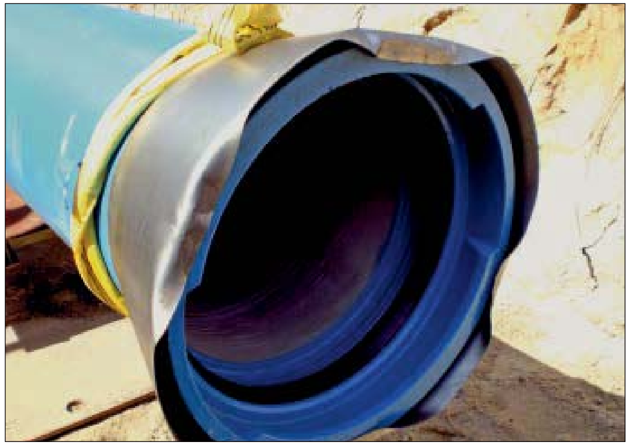

Figure 22.46:
Sheet steel cone for protecting the socket

Figure 22.47:
Relining DN 200 (new) cast iron pipe in an old DN 300 cast iron pipe

In the first stage, launch pits **(Figure 22.48)** and target pits **(Figure 22.49)** are set up along the pipeline to be renovated. Their position depends above all on points of constraint such as changes of direction and, of course, the beginning and end of the pipeline. The size of the pits depends on the machine technology used and the new pipe material. For ductile iron pipes, their length of about 6 m is crucial, entailing a construction pit size of around 8 m. the size of the assembly pit is based on the nominal size to be installed.

The old pipeline is then cut off in the construction pit. Good preparation of the old pipeline will be important later. From measures carried out in the past it has been shown that, with good preparation of the old pipeline, removal of incrustations **(Figure 22.50)**, closing of joint gaps in the pipe invert, application of a lubricant in the invert of the pipe, etc. a friction coefficient of $\mu \leq 1{,}0$ can always be achieved. This means that only part of the actual pipe weight is pulled.

In particular cases, such as the simultaneous inclusion of additional empty pipes or supply carriers, rolling brackets are also used **(Figures 22.51 and 22.52)**. These have the additional advantage that, compared with customary methods, the trasction forces are considerably reduced. Because of the high longitudinal bending resistance of ductile iron pipes, only one bracket per pipe is necessary, just behind each socket.

With the simultaneous pulling/pushing of a number of pipelines, at least one guide rail should be provided in order to prevent the twisting of the pipe string.

In almost all cases pipelines are put together using the single pipe assembly technique. Even here, the short assembly times **(Table 22.5)** allow for fast progress.

Figure 22.48:
Launch pit

Figure 22.49:
Target pit

Figure 22.50:
Tool for removing incrustations

Figure 22.51:
Sewage pipeline – guided roller brackets

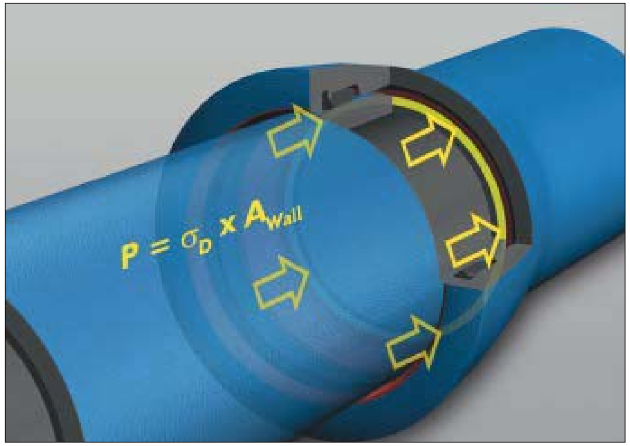

Figure 22.53:
Transmission of forces on pushing in

Figure 22.52:
Sewage pipeline –
assembling the roller brackets

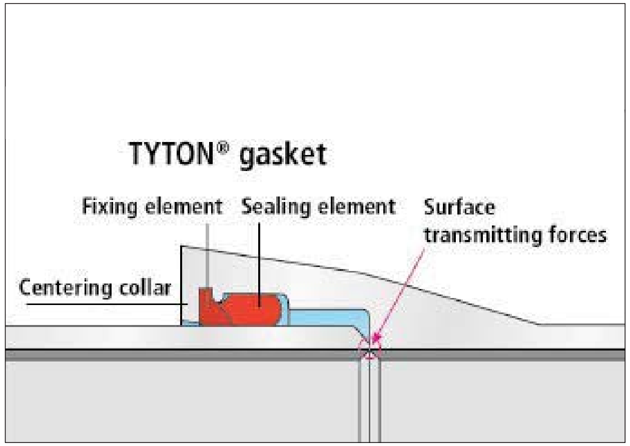

Figure 22.54:
Transmission of axial forces
when pushing in the pipe

As a rule, the remaining annular gap between the old pipe and the new pipe is filled with an alkaline insulator. However this is dependent on local conditions such as the type of operation, the exterior coating, the size of the annular gap and the static load capacity of the old pipe. The last stage consists of testing tightness, connecting the individual renovation sections and backfilling the construction pits.

22.4.8.3 Pushing in

With the pushing in technique, ductile iron pipes with the non-restrained TYTON® push-in joints are pushed into the old pipeline. Here the axial thrust force is transmitted across the front of the spigot end into the ground of the TYTON® socket **(Figure 22.53)**. As the spigot ends of the pipes are bevelled (chamfered), not the entire cross-section of the pipe wall is available for the transmission of the axial thrust force **(Figure 22.54)**. In addition the smallest possible outside diameter of the pipes and the minimal wall thickness according to EN 545 [22.10] and EN 598 [22.11] must be taken into consideration.

Table 22.5:
Individual pipe assembly – Assembly times for pushing in/pulling

Nominal size DN	Number of installation engineers	Assembly time without joint protection [min]	Assembly time using a protective sleeve [min]	Assembly time using shrink-on sleeves [min]
80	1	5	6	15
100	1	5	6	15
125	1	5	6	15
150	1	5	6	15
200	1	6	7	17
250	1	7	8	19
300	2	8	9	21
400	2	10	12	25
500	2	12	14	28
600	2	15	18	30
700	2	16	–	31
800	2	17	–	32
900	2	18	–	33
1000	2	20	–	35

Table 22.6:
Allowable pushing-in forces according to DVGW Worksheet GW 320-1, Table A.7 [22.3] for ductile cast iron pipes (depending on joint, without safety factor – the safety factor must be adapted to local circumstances, i.e. in particular curve radiuses and angular deflection, and correspond to the pipe manufacturer's application technology)

Nominal size DN	External diameter (DN/OD) d_a [mm]	Wall thickness class	Wall thickness s_{min} [mm]	Allowable compression strength σ_{zul} [N/mm²]	Allowable pushing-in force F_{zul} [kN]
80	98	10	4.7	550	138
100	118	10	4.7	550	168
125	144	9	4.7	550	206
150	170	9	4.7	550	244
200	222	9	4.8	550	339
250	274	9	5.2	550	513
300	326	9	5.6	550	723
350	378	9	6.0	550	968
400	429	9	6.4	550	1246
500	532	9	7.2	550	1912
600	635	9	8.0	550	1085
700	738	9	8.8	550	1767
800	842	9	9.6	550	2595
900	945	9	10.4	550	3561
1000	1048	9	11.2	550	4669

The compressive strength of ductile cast iron is σ_D = 550 N/mm². Without taking account of a safety factor, therefore, a pressing force of $P = \sigma_D \times A_{Wall}$ is possible where A_{wall} represents the cross-section surface of the cast iron wall transmitting the force.

The permissible pushing-in forces are given in DVGW Worksheet GW 320-1, Table A.7 [22.3] **(Table 22.6)**. The values stated there do not include any safety factors. Before planning or starting construction, it is recommended that contact is made with the manufacturer's technical service department to determine the relevant values. Depending on how the route runs (gradient, radiuses) and the condition of the old pipelines, different safety factors are to be selected.

There is a report in [22.23] and [22.24] on relining measures according to this technique.

When pushing in **(Figure 22.55)** the spigot end is always first pushed into the socket of the last pipe installed. The spigot end of the first pipe installed is to be provided with a centering head **(Figure 22.56)**. This can be made available on loan by manufacturers.

As with the pulling process, at least two construction pits are necessary. The size of the pushing and assembly pit depends on the pipe length (usually 6 m), the pushing equipment used and the nominal size of the pipes to be installed. The size of the target pit depends on nominal size and any other components.

Figure 22.55:
Pushing in a pipe

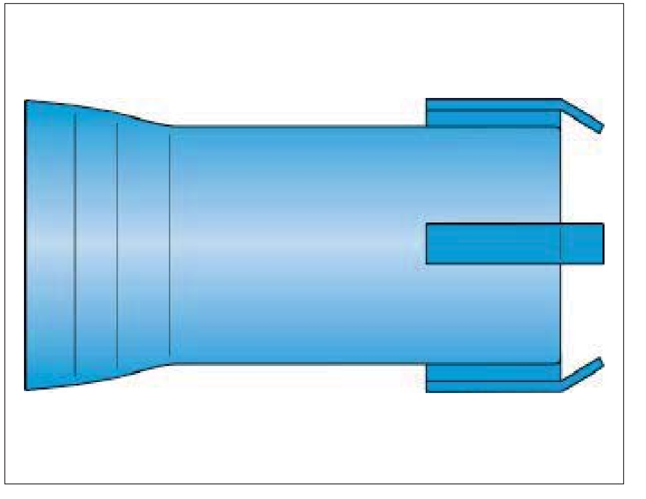

Figure 22.56:
Centering head

22.4.8.4 Pulling in

A positive locking restrained push-in joint is usually used for the pulling in technique. The permissible traction forces, the maximum possible angular deflection and the minimum possible radius can be found in **Table 22.3**.

Pulling in the new pipe string with tie rods has proved to be effective **(Figure 22.57)**. There is a report on this in [22.25]. The use of a cable winch and steel cable is not recommended for pulling in and nor is the use of friction locking restrained push-in joints.

A traction head is always required for pulling in the new pipe string. This is produced from a positive locking restrained push-in socket **(Figure 22.58)**. Traction heads can be made available to firms carrying out the work by the pipe manufacturer.

Figure 22.57:
Traction unit with rods

22.4.8.5 Coating

If the annular gap remaining between the old pipe and the new pipe is filled with an alkaline insulator, the pipes only require zinc or zinc aluminium coating. The socket is protected with a sheet steel cone for the pulling or pushing in process.

If the remaining annular gap is not filled, ductile iron pipes with cement mortar coating to EN 15 542 [22.12] or with polyurethane coating to EN 15189 [22.13] will be used. The push-in joints

Figure 22.58:
Pipe with traction head and sheet steel cone

of cement mortar coated pipes are protected with rubber sleeves or PE shrink-on material to DIN 30 672 [22.26].

The socket joint protection will be given additional mechanical protection during pulling and pushing in processes with a sheet steel cone **(Figure 22.59)**.

Figure 22.59:
Fitting the sheet steel protective cone

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23 Some new main applications for ductile iron pipes

23 Some new main applications for ductile iron pipes

This chapter is being prepared.

24 Standards, directives and technical rules

24 Standards, directives and technical rules

The Standards Database linked to this chapter is constantly updated.

Given below are details of the types of standards, directives, technical rules and other codes which are of significance to ductile iron water, wastewater and sewage pipelines, i.e. to pipes, fittings and valves, and which are listed in a Standards Database.

24.1 General

The standards, directives, technical rules and other codes which are of significance to ductile iron pipelines, some of which are referred to in this E-Book, are covered by a Standards Database. The standards and draft standards listed in the Standards Database are not only national standards such as German DIN standards, Austrian OENORM standards, Swiss SN standards und Italian UNI standards, but above all European standards (EN) and also international standards (ISO).

For the field of ductile iron pipe systems, national rules are also included in the listing to supplement the above.
The listing of standards and other documents contained in the Standards Database does not claim to be complete. When applying the standards, directives and technical rules listed in the Standards Database, it is essential to use the version with the latest date of issue (the latest edition).

24.2 The Standards Database

The Standards Database gives the numbers, titles and dates of issue (editions) of the standards, directives and technical rules listed in it.

On the search template, you can optimise your search for a standard, directive or technical rule, and can find the result of the search quickly, by entering search criteria. Some of these are preset. The preset search criteria also include the options of selecting the country in which documents apply and their language.

The results of a search are shown in the form of a table and can be printed out. Clicking on the „Details" button will show you all the stored information on the standard or other document selected, source of supply included.

Clicking on the link below will take you to the EADIPS®/FGR® Standards Database:
eadips.org/normen/

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25 Index

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26 Imprint

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Doncaster-Platz 5
45699 Herten
Germany
Phone: +49 (0)2366 9943905
Telefax: +49 (0)2366 9943906
E-mail: info@eadips.org
www.eadips.org

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Full members

Düker GmbH
Hauptstrasse 39–41 · 63846 Laufach/Germany
Phone: +49 (0)6093 / 87-0 · Telefax: +49 (0)6093 / 87-246
E-mail: info@dueker.de
Website: www.dueker.de

Duktus Rohrsysteme Wetzlar GmbH
Sophienstrasse 52–54 · 35576 Wetzlar/Germany
Phone: +49 (0)644 / 49-2401 · Telefax: +49 (0)6441 / 49-1455
E-mail: info@duktus.com
Website: www.duktus.com

ERHARD GmbH & Co. KG
Meeboldstrasse 22 · 89522 Heidenheim/Germany
Phone: +49 (0)7321 / 320-0 · Telefax: +49 (0)7321 / 320-491
E-mail : info@talis-group.com
Website: www.talis-group.com

Keulahütte GmbH
Geschwister-Scholl-Strasse 15 · 02957 Krauschwitz/Germany
Phone: +49 (0)35771 / 54-0 · Telefax: +49 (0)35771 / 54-220
E-mail: keulahuette@vem-group.de
Website: www.keulahuettekrauschwitz.de

Ludwig Frischhut GmbH & Co. KG
Franz-Stelzenberger-Strasse 9–17 · 84347 Pfarrkirchen/Germany
Phone: +49 (0)8561 / 3008-0 · Telefax: +49 (0)8561 / 3008-105
E-mail: frischhut@talis-group.com
Website: www.frischhut.de

TIROLER ROHRE GmbH
Innsbrucker Strasse 51 · 6060 Hall in Tirol/Austria
Phone: +43 (0)5223 / 503-0 · Telefax: +43 (0)5223 / 43619
E-mail: info@duktus.com
Website: www.duktus.com

vonRoll hydro (deutschland) gmbh

vonRoll hydro (deutschland) gmbh
Ferdinand-Lassalle-Strasse 16 · 72770 Reutlingen/Germany
Phone: +49 (0)7121 / 4347-49 · Telefax: +49 (0)7121 / 4704-33
E-mail: info@vonroll-hydro.de
Website: www.vonroll-hydro.de

vonRoll hydro (suisse) ag

vonRoll hydro (suisse) ag
von roll-strasse 24 · 4702 Oensingen/Switzerland
Phone: +41 (0)62 / 38811-11 · Telefax: +41 (0)62 / 38811-77
E-mail: info@vonroll-hydro.ch
Website: www.vonroll-hydro.ch

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Akzo Nobel Powder Coatings GmbH
Markwiesenstrasse 50 · 72770 Reutlingen/Germany
Phone: +49 (0)7121 / 519-197 · Telefax: +49 (0)7121 / 519-199
E-mail: resicoat@akzonobel.com
Website: www.resicoat.com

Friedrichshütte GmbH
Friedrichshütte 11–13 · 35321 Laubach/Germany
Phone: +49 (0)6405 / 826-0 · Telefax: +49 (0)6405 / 826-260
E-mail: info@friedrichshuette.com
Website: www.friedrichshuette.com

Rhein-Ruhr Collin KG
Geschäftsbereich HTI
Collinweg · 47059 Duisburg/Germany
Phone: +49 (0)203 / 28900-105 · Telefax: +49 (0)203 / 28900-103
E-mail: gsl.rrc@gc-gruppe.de
Website: www.hti-handel.de

Saint-Gobain Building Distribution Germany GmbH
Hanauer Landstrasse 150 · 60314 Frankfurt/Germany
Phone: +49 (0)69 / 40505655 · Telefax: +49 (0)69 / 40505565
E-mail: mario.hinz@saint-gobain.com
Website: www.sgbd-Germany.de

SATTEC DBS GOMMA SRL
Via E. Mattei, 12 · 33080 Prata di Pordenone (PN)/Italy
Phone: +39 (0)434 / 620100 · Telefax: +39 (0)434 / 610055
E-mail: commerciale@sattecgomma.it
Website: www.sattecgomma.it

TMH Hagenbucher AG
Friesstrasse 19 · 8050 Zürich/Switzerland
Phone: +41 (0)44 / 3064748 · Telefax: +41 (0)44 / 3064757
E-mail: info@hagenbucher.ch
Website: www.hagenbucher.ch

Tröger + Entenmann KG
In der Gabel 22 · 69123 Heidelberg/Germany
Phone: +49 (0)6221 / 825-0 · Telefax: +49 (0)6221 / 825-225
E-mail: info@tue-hd.de
Website: www.tue-hd.de

Vertriebsgesellschaft für Tiefbau und Umwelttechnik mbH + Co. KG
Wackerstrasse 7 · 85084 Reichertshofen/Germany
Phone: +49 (0)661 / 286-399 · Telefax: +49 (0)661 / 286-210
E-mail: martin.schulze@rf-tbu.de
Website: www.richter-frenzel.de

Woco IPS GmbH
Business Unit Pipe System Components
Hanauer Landstrasse 16 · 63628 Bad Soden-Salmünster/Germany
Phone: +49 (0)6056 / 78-7229 · Telefax: +49 (0)6056 / 78-57229
E-mail: ruwerner@de.wocogroup.com
Website: www.woco-psc.de

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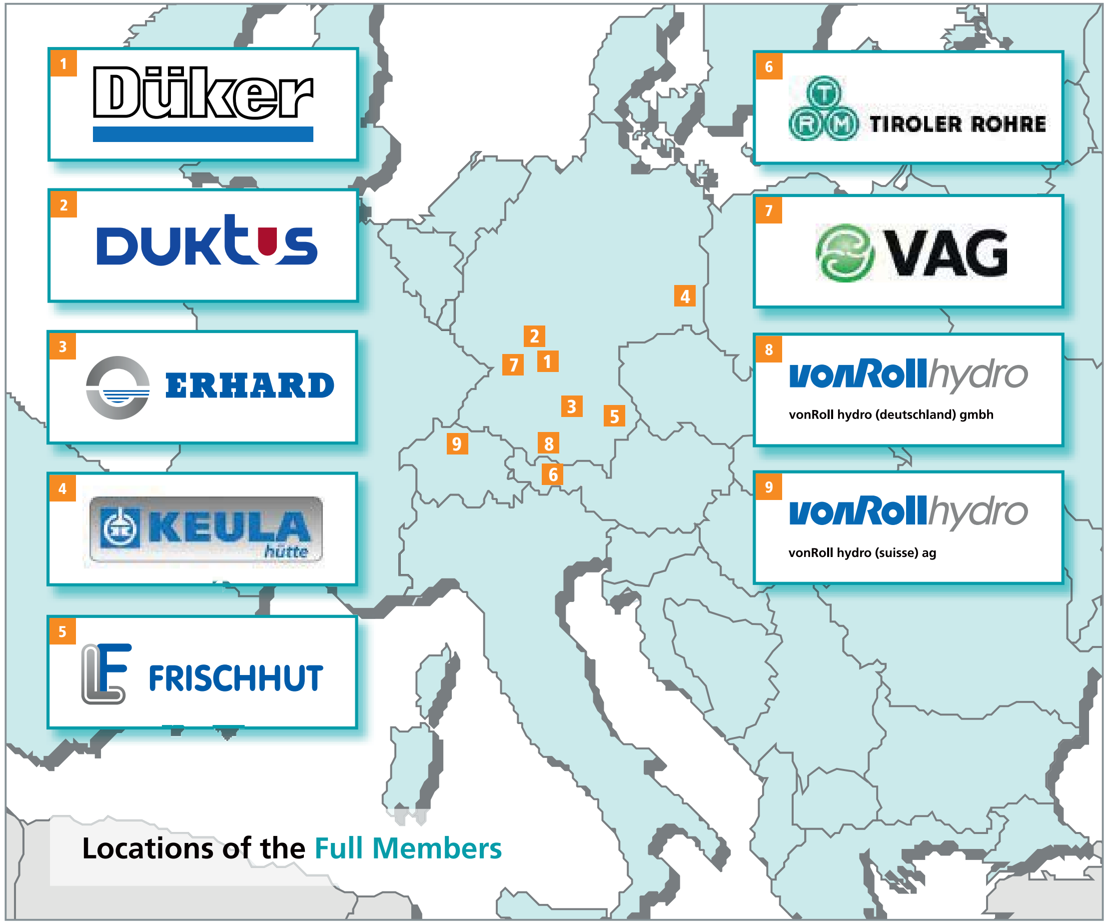

Sustainably superior – ductile iron pipe systems

Ductile iron pipe systems

Pipes, fittings and valves of ductile iron