Flanges in (plastic) pipeline construction: from the wooden to the high-performance solution

History

For thousands of years pipelines have been used for the defined supplying or discharging of fluids. In each era, the choice of material was determined by availability and the latest technology. There are plenty of examples: Findings of several underground masonry sewerage systems even date back to 3,800 BC, in the Antique period. Relics of the water supply systems of cities in the Roman Empire date back to the time before 500 BC. These can still be viewed today as brickwork aqueducts. A further development in piping technology for water supply systems was marked by the use of hollowed-out wooden trunks in the Middle Ages. Down to the present day, wooden water pipes or fragments of such pipes, which can be dated back to the 17th century, have been found repeatedly during civil engineering work. Due to the short life span of wood, these pipes had to be continually repaired and replaced. For this purpose, flanged pipe pieces had already been used earlier, as evidenced, for example, by a finding in the Thuringian town of Ronneburg, in the district of Greiz.[1]

Contemporaneously with these wooden supply lines, however, there existed cast iron pipes, which had been laid to channel water to various fountains as well as to supply manorial estates. Examples include the supply system for the Dillenburg Castle, dating from 1455, as well as the channelling system for the waterworks in the park of the Chateau of Versailles, which dates from 1668. This latter system was even made from cast iron piping with flange connections in the nominal pipe sizes DN 350 to DN 500, with an overall length of around 24 km.[2]

Over the course of the industrial revolution, the use of cast iron piping continually spread further: starting from 1885, it was produced industrially. This meant that the products of the different piping manufacturers had to be standardised to ensure compatibility. Cast iron pipes were standardised as early as 1873, and standard flange sizes were established as the "dimensional standards of 1882" shortly afterwards by the Association of German Gas and Water Specialists in cooperation with the Association of German Engineers. In 1926, it was established that the screw holes on flanges must be arranged symmetrically to both main axes irrespective of the material used, and their number must always be divisible by four. [3] This remains valid today and is currently determined in Europe by EN 1092[4] .

In the 1930s, the raw materials used until then, that is, cast iron, steel, stoneware etc., were supplemented on the market by the first artificially produced materials, that is, rigid PVC (unplasticised polyvinyl chloride) and PE-HD or PE-LD (= **h**igh **d**ensity or **l**ow **d**ensity polyethylene)[5]. Analogously to the known pipes, the dimensioning and quality criteria for these innovative pipes were then also gradually set out in standards to emphasise their importance for pipeline construction. For instance, the first standard for pipes made of rigid PVC (today PVC-U) dates from 1941. Polyethylene, whose importance grew more slowly, became interesting for pipe manufacturing in the 1950s and was then standardised for the first time in 1960 with pipe standards DIN 8074/8075[6] for PE-HD and DIN 8072/8073[7] for PE-LD.

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[1] Source: Publication commemorating 700-year anniversary of the town of Ronneburg in Türingen.
[2] Source: The Historical Development of Pipeline Technology, Harald Roscher and Ulf Herbig, Springer 2016
[3] Source: E-Book Cast Iron Pipes 05/2014
[4] EN 1092 Flanges and their joints
[5] Source: W. Müller und E. Ant, The History of Plastic Piping, Plastic Piping Manual, KRV
[6] DIN 8074 and DIN 8075 Pipes Made of Polyethylene (PE) – PE 80, PE 100
[7] DIN 8072 and DIN 8073 Pipes Made of Polyethylene plasticised (PE) – **NB: Document withdrawn**

Down through the years PE-HD was continually developed further. The material properties in terms of creep rupture strength were significantly improved in several steps, with the result that today PE-HD is one of the main materials in the municipal supply and waste management market.

The polyethylene material used can be divided into 3 types: PE 63 (first generation) with an MRS (Minimum Required Strength) of 6.3 MPa, PE 80 (second generation) with an MRS of 8.0 MPa, and PE 100 (third generation), which is the kind used most widely today, with an MRS of 10.0 MPa. The numeral after the acronym PE is a dimensionless number that is determined according to the creep rupture strength under internal pressure at 20°C after 50 years with water as the test medium.

For transitions to another pipe material as well as detachable connections between these pipes, the flange connection was the only option available at that time. Standardised loose flanges that enabled pairing with corresponding counterflanges of the same size, analogously to those used in steel piping systems, were developed. The polyethylene welding stub required for usage with loose flanges was then also developed, for example, according to the standard for steel flanges (see Fig. 1 "Welding stub based on steel flange").

Flange and pipe dimensioning

Flange connections are used to create tight but detachable joints between pipe sections. The correct contact pressure of the annular sealing surfaces of the flange on the interjacent gasket ensures the tightness of the system. The flange is usually attached by screws that are inserted through bore holes in the flange faces. A flange connection is to be regarded as a system consisting of two flanges, a gasket matching the sealing surface, and a certain number of screws with nuts and washers. We make a distinction between two versions: the fixed flange and the loose flange. As its name indicates, the loose flange lies loosely on the pipe and requires an additional component, the stub end or welding neck, so that a flange connection can be created. Unlike the fixed flange, it can be positioned in line with the hole pattern on the counterflange for assembly. Fixed flanges are either included in the casting during the manufacture of cast iron pipes (flanged pipes: F pieces or FF pieces) or can be welded to the front end of the pipe as separate fittings.

In designing a pipe system, factors such as pressure, temperature, medium and mass flow must be taken into account, with the mass flow and the maximum acceptable pressure loss basically determining the required pipe cross section. Since at that time, as is the case today, a pipe could not be manufactured for every calculated internal pipe diameter, nominal pipe sizes were set out in the standards. Based on these nominal pipe diameters, both the pipes and flanges were then designed according to pressure levels that were also pre-defined. This means that the connecting dimension of a flange can be clearly determined according to the nominal pipe size DN and pressure level PN. In Germany, DIN EN 1092 sets out dimensions and designs for flanges of nominal pipe sizes DN 25 to NPS 4,000 and for pressure levels PN 2.5 to PN 400 with respect to the largest outside diameter D, the pitch circle diameter K, and the number of screw holes and their diameters.

DN (Diameter Nominal) and PN (Pressure Nominal), followed by a dimensionless number, are alphanumerical parameters of a piping system component that are used for reference purposes. They are indirectly related to the physical size of the bore hole or to the outside diameter of the connections in millimetres or to the maximum permissible pressure in bar, with respect to a combination of mechanical and dimensional characteristics of a component.

The manufacture of PE-HD pipes according to standard DIN 8074/8075, for instance, generally takes place using the vacuum extrusion process. Here the plastic mass of the PE-HD produced in **the** annular extrusion process is shaped by means of vacuum calibration to obtain the outside diameter. The desired wall thickness of the pipe is obtained via a precisely coordinated interplay between material addition and haul-off speed. The outside diameters set out in this standard follow certain preferred numbers, known as the Renard series according to ISO 3[8] or ISO 4065[9] or DIN 323[10]. In this way the appropriate wall thicknesses of the pipes can be determined via the defining of pipe series S, which stands for a certain outside diameter / wall thickness ratio (SDR = Standard Dimension Ratio) in each case. Taking into account the respective material properties and a total operating (calculation) coefficient (safety factor), assignment to the pressure classes is then carried out. In conformity with the standard, the designation of a PE-HD pipe must contain at least information on the material used (strength value) and the corresponding standard as well as the outside diameter and the pipe series S or the outside diameter / wall thickness ratio (SDR). Thus the internal diameter or the actual nominal pipe size is defined only indirectly. This must be taken into account when calculating pipe networks and especially when selecting flanges.

That particular attention must be paid to the designation of the pipes (and fittings) during planning is shown by the naming of PE-HD pipes according to DIN EN 12201-2[11] or DIN EN 1555-2[12], for example. Herein the nominal outside diameters d_n of the pipes are assigned to a nominal pipe size DN/OD. The nominal pipe size DN/OD is a numerical figure for the size of a pipeline part, except those that are characterised by a thread. It corresponds approximately to the manufacturing size in millimetres and is related to the outside diameter. Example: The nominal outside diameter d_n 250 mm corresponds to the nominal pipe size DN/OD 250 with a calculated internal diameter or the nominal pipe size 204.6 mm in the version according to SDR 11. It is therefore important to know which “nominal pipe size” is being discussed.

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[8] ISO 3 Preferred numbers; Series of preferred numbers
[9] ISO 4065 Thermoplastics pipes. – Universal wall thickness table
[10] DIN 323 Preferred numbers and series of preferred numbers
[11] DIN EN 12201 Plastics piping systems for water supply and for drainage and sewerage under pressure - Polyethylene (PE)
[12] DIN EN 1555 Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE)

Plastic pipe-flange connections

As mentioned above, the first flange connections for plastic pipes consisted of accordingly designed loose flanges and weld stubs. This combination is still used extensively today. At the same time the loose flanges are of varying design. There are, for example, loose flanges made of galvanised steel, those made of stainless steel, those with a plastic sheathing (PP-St) and plastic coating, or those consisting entirely of plastic with or without fibre reinforcement. Each pipe or welding stub dimension can only be paired with a loose flange of a certain dimension (nominal pipe size DN). Example: Pipe DN/OD 250 or d_n 250 mm with a corresponding welding stub for a pipe d_n 250 mm requires a loose flange DN 250. With this flange, a flange transition to a valve or a flange of a steel or cast iron pipe with the nominal pipe size DN 250, for example, could be created. That the hole patterns must be identical in accordance with the pressure level of both flange partners is self-evident. The figure "Nominal diameter dilemma" shows that the flange dimension DN 250 corresponds but the internal diameters of the two system components are very different and jumps in the internal diameter of the nominal pipe size occur. In addition to this particularity, the PE welding stub was designed in accordance with the steel flange and, due to the mechanical properties of PE-HD, displays different behaviour under stresses in the limit range, especially in the case of dimensions from d_n 200 mm or DN/OD 200 (flange size DN 200) upwards. In the case of piping systems under internal pressure in the permissible component operating pressure PFA (French: pression de fonctionnement admissible) range, failures therefore frequently occur in the case of welding stub - loose flange combinations. The forces generated by the high internal pressure cause deformation of the stub (see Fig. "Buckling of the welding stub under stress"), which results in displacement of the stub and inevitably a reduction in the sealing surface. The special arrangement of loose flange and welding stub with a correspondingly small contact surface for force transmission favours this effect. Precise information on when a failure of the loose flange / welding stub combination occurs under the above-mentioned conditions cannot be found. Even in the DVS 2210-1 Supplement 3 [13]Part 2.1 Welding stubs, all that is found is the notice that the dimensioning of the welding stub allows no conclusions to be drawn as to its strength or the strength of the flange connection.

This "nominal pipe size dilemma" was constructively tackled many years ago by Karl-Albert Reinert, the founder of Reinert KG (later Reinert-Ritz GmbH), and resolved specifically for plastics. The result was the so-called special flange, a drilled-through PE stub with a steel backing flange (see Fig. 3 "Special flange"). Europlast in Oberhausen, a plastic pipe manufacturer and pioneer of that time, listed a special flange of this type in its technical catalogue for the first time in 1980. Special flanges are still widely used today.

The particularity here is that the same flange size as that of the corresponding loose flange is not used for this pipe dimension, with the result that only a fixed flange would result from the loose flange connection, but the nominal pipe size is one step smaller. The hole circle K is thus closer to the outer pipe diameter. To distribute the bolting forces over the rear side of the stub and therefore ensure the strength of the flange solution, a special steel flange with the same hole pattern is used. At the same time, this solution prevents the other deficiency of the loose flange /welding stub combination, namely the buckling of the stub. This means that not only a pressure class-compatible flange connection but also the connection of PE pipe to cast iron or steel valves and flange pipes of the same nominal size (related to the internal diameter) is possible and this enables the use of smaller valves. Example: To a pipe DN/OD 250 or d_n 250 mm SDR 11 with an internal diameter (nominal pipe size) 204.6 mm a valve DN 200 can be connected using a special flange DN 200/d 250

[13] DVS Guideline 2210-1 Supplement 3 Industrial pipelines made of thermoplastics. Planning and implementation – Aboveground pipe systems – Flange connections: Description, requirements, assembly

SDR 11. Here the choice of a loose flange-welding stub combination only allows a valve of the dimension DN 250 (see Fig. 4 “Nominal pipe size dilemma” and Fig. 5 “Smaller valve through use of special flange or VP flange”).

However, in the event that a pressure-class compatible, permanently tight flange connection is required, for which a special flange solution is not possible dimensionally or the degree of freedom of a loose flange connection is necessary, Reinert Ritz has a plastics-compatible solution in its product range. Since the end of the 1990s there has existed an HP flange variant that can even be designed for certain applications up to 25 bar and other applications up to DN/OD 2000. The particularity of the plastics-compatible HP flange consists in the fact that the PE stub and the backing flange are delivered as a single unit and are exactly attuned to one another. The specially designed backing flange interlocks in a positive fit with the back of the stub over an enlarged contact surface directly at the outer pipe diameter and also supports the stub at the outer diameter (see Fig. 6 “Comparison of welding stub with HP flange surface”). This counteracts deformation of the PE stub through generally high stress and, with the appropriate gasket, provides for a reliable and tight flange connection. Incidentally, influences of the sealing surface, gasket, screws and the flange in itself apply for all transitions produced with flanges. They are essential elements of the “flange connection” system (see Fig. 7 “Flange connection system”). The pressure-class compatibility, that is, the high performance of the HP flange solution then also led to the choice of the name: In this context, “HP” stands for high performance.

A new, future-oriented variant of the backing flange for both special flanges and HP flanges from Reinert-Ritz is becoming increasingly popular: the extremely lightweight version made of fibre-reinforced plastic (see Fig. 8 “HP flange” and Fig. 9 “VP flange”). Due to the low weight, handling and further processing are – depending on the size – significantly reduced. Another major advantage is the complete noncorrosiveness of the flange, which means that it can be used without difficulty even in an aggressive environment.

The combination of plastic flange and further constructional enhancements forms the basis for the VP (valve performance) flange, which has elongated holes in the PE stub that greatly facilitate alignment of the valve or the stub during professional assembly. After installation the VP flange offers continuous bolt preload thanks to the design of its backing flange with a disc spring effect (see Fig. 10 “Disc spring effect”). This bolt preload still predominates after the tightness test.

Permanently tight flange transitions in plastic piping systems to valves and flanges of other pressure pipe systems can be implemented safely and reliably with sophisticated solutions from Reinert-Ritz. Here you will find reliable components for your flange challenge too.

About Reinert-Ritz GmbH

Since 1970, Reinert-Ritz GmbH has focused on developing high-quality products for pipeline construction that are sold worldwide. Hollow bars and solid rods extruded from polyethylene and polypropylene with diameters of up to 1,200 mm or 2,400 mm are Reinert-Ritz’s core expertise. They form the basis for semi-finished products and fittings – which are built by more than 120 employees at the Nordhorn headquarters – for their application in pressure pipeline systems of up to 25 bar nominal pressure deployed in gas, oil and water distribution systems as well as in the chemical industry.

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Images

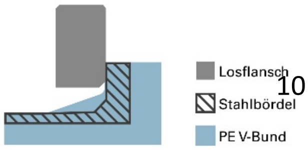

Fig. 1: Welding stub based on steel flange

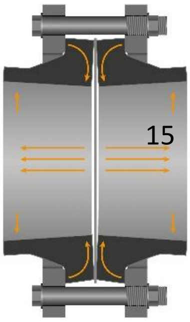

Fig. 2: Buckling of the welding stub under stress

Fig. 3: Special flange

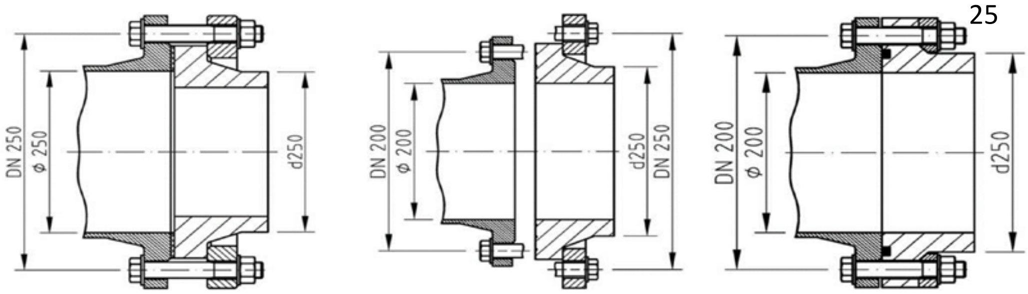

Fig. 4: “Nominal pipe size dilemma” steel / cast iron: DN = nominal pipe size = internal diameter = flange size

PE-HD: d = DN/OD = nominal pipe size related to outside diameter; internal diameter calculated; flange size = f (flange solution)

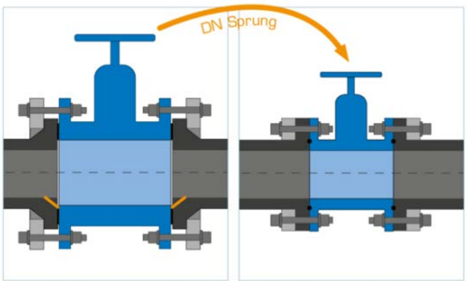

Figure 5: Smaller valve through use of special flange or VP flange

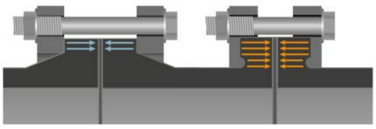

Figure 6: Comparison of welding stub with HP flange surface

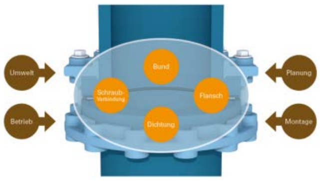

Figure 7: Flange connection system

Figure 8: HP flange with fibre-reinforced plastic backing flange

Figure 9: VP flange

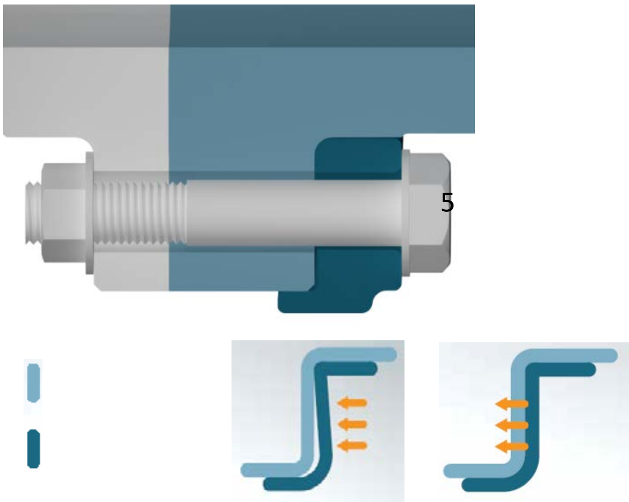

Figure 10: Disc spring effect VP flange

Figure 11: HP flange section