Back-pressure ball valves for contaminated liquids

Mirosław Szuster

1. INTRODUCTION. The unreal became possible

The introduction title refers to the first article (PP1 – February 2002) 'Back-pressure ball valves for contaminated liquids of the SZUSTER system. Unreal has become possible'.

As the objective of the article, we would like to lay emphasis upon a totally different approach to designing back-pressure valves for faecal sewage, which would be consistent with the new standards. The author pays particular attention to the **new possibilities** of further optimization of the mentioned valves in terms of complying with these standards, as well as designers' and waste water pumping station users' expectations.

Pic. 1. SZUSTER system valves: on the left – a valve with a long cover (previous construction model); on the right – new valve in a short cover.

2. Basis for review of selection and design of back-pressure ball valves estimations in terms of faecal sewage

2.1 Basis for review of estimations consistent with the new standards [1]:

- PN-EN 12050-1; *Waste water* ***pumping stations*** *in buildings and their surroundings****; Construction rules and examinations; Part 1: Pumping stations for faecal sewage.***
- **Minimum flow speed** in an outflow line working point – 0.7 m/s (point 5.4 pic. 1),
- **Minimum volume of outflow lines** in pumping stations for faecal sewage without a diluting device - DN 80 (if required, DN 50), while the clearance in a back-pressure valve should not be smaller than 60 mm (or, if required, 50 mm) (point 5.6),
- **Minimum outflow line volume and back-pressure valve size** in pumping stations for faecal sewage equipped with a diluting device - DN 32 (point 5.7).
- PN-EN 12050-4; ; *Waste water* ***pumping stations*** *in buildings and their surroundings****; Construction rules and examinations; Part 4:*** ***Back-pressure valves for waste water pumping stations for faecal and non-faecal sewage.***
- **Clearance for solids in a back-pressure valve** should not be smaller than 80% of the inner diameter of the outflow line, minus 4 mm; Ds = 0.8 x Di - 4 mm (point 5.2), where: Ds – clearance for solids provided in mm, Di – inner diameter of the outflow line provided in mm,
- **Examination of back-pressure valves at 0.2 bar in 10 minutes time** in the closing direction performed with clean water, while the leaks in the valve cannot exceed the values listed in table 1.

Table 1. Relation between the valve size and the maximum leak - PN-EN 12050-4, point 8.2.4

Valve size	Maximum leak during a 10 minute test (litres)
DN<32	0.5
32<DN<100	1
DN>100	3

- **Pressure test of back-pressure valves,** both open and closed, under a test pressure not smaller than 6 bar (in case of back-pressure valves not integrated with the pumping station, the test pressure should equal 1.5 of the maximum pressure of the pump used in the device), while in a test lasting 10 minutes, there should be no visible leakage (point 8.2.5).

2.2 Basis for review of estimations consistent with the expectations of designers and users of pumping stations for faecal sewage and other sewage water

a) elimination of constant movement of the closing element during the flow, especially of the *ball vibration in the entire scope of recommended flow speed values (from 0.7-0.8 m/s to 2.3-3 m/s), which, so far, has seemed to be 'unreal'*, so that the local resistance coefficient value ζ of the back-pressure valve for water is constant (ζ = constant) and comparable with the local resistance coefficient value ζ of the back-pressure valve for faecal sewage.

Attention: Local resistance of back-pressure valves meant for faecal sewage is tested with clean water, because the classic back-pressure ball valves working with undiluted faecal waste usually have a significantly higher local resistance coefficient ζ. This is caused by vibrations of the ball element due to incomplete opening of the valve and pressure pulse during the flow of solids through the pump. This can be caused by other factors, related to the Magnus effect and the bearing surface effect, while in the case of larger valve diameters, the G. Eiffel paradox can be in question (when the Reynolds number is approx. ok. 240000 - 300000).

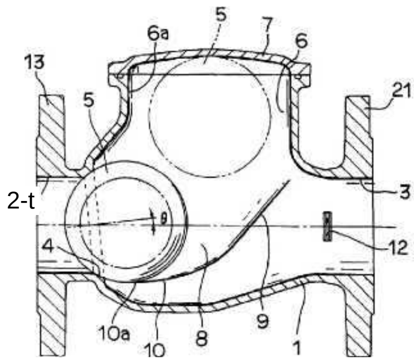
Example 1

Operation of DN 150 back-pressure ball valves of two renowned foreign companies was observed in a dry pumping station located in the municipal waste water plant. During the flow of raw waste water through these valves, regular ball vibrations were audible at a certain distance and palpable after putting a hand against the valve. Their frequency reached 2 to 3 ball beats per second, equaling approx. 7,000 – 10,000 ball beats per hour.

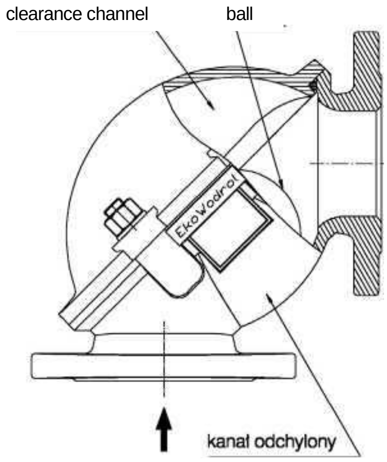
Attention: Having excluded in this case the possible increased wearing out of the ball, it is necessary to consider higher flow resistance caused by the vibrations. If the effect of increased flow resistance at the pump is added to this, not predicted by the designer, then in some situations the flow speed in the line can drop below the rate of its self-purification. The more variables of this type, the more difficult it is for a designer to estimate the possible flow speed reduction while using the pipeline.

Example 2

At the municipal waste water pumping station in Koszalin, which is equipped with immersible pumps and back-pressure inclined ball DN80 valves with long covers (L = 3 x DN = 240 mm), opening completely at a flow reaching



Pic. 2. Valve compatible with patent USA[2]

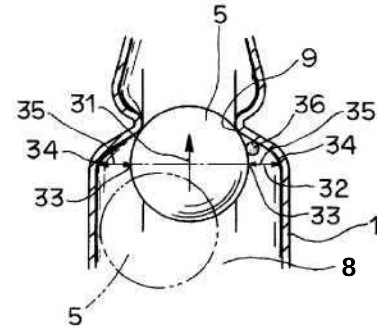


Pic. 3. The new valve of the SZUSTER system

approx. 1.0 m/s, one of the valves was replaced with a DN 80 new ball valve from the SZUSTER system with a short cover (L = 2 x DN + 5 mm =165 mm) - pic. 1. While the estimated flow speed in a pumping pipeline reaches v = 0.75 m/s, the valve vibration caused by the ball occurred only in the valve with a long cover, but it was not observed in the valve with a short cover. Elimination of the valve local resistance coefficient variability ζ in relation to flow speed of faecal waste water in the pumping pipeline (recommended flow speed from 0.7 m/s to 2.3-3.0 m/s) and the ingredients of the faecal waste water, which facilitates calculation of the local flow resistances, without employing diagrams not always giving a true picture of the situation;

a) possibly movement of the closing element from the completely opened position to the completely closed position, which reduces strong and uncontrolled hydraulic shocks;

b) possibly large impact of the returning current on the closing element,



which also reduces strong and uncontrolled hydraulic shocks and enables, for example, the application of a back-pressure ball valve in water systems where quick reduction of water flow speed occurs in a pumping vertical line (pipelines from deep water intakes);

c) possibly short cover of the back-pressure L-angled ball valve (concerns the back-pressure ball valves of the SZUSTER system in particular).

3. New estimations for designing back-pressure ball valves of the SZUSTER system

3.1. Minimum clearance for solids in back-pressure valves

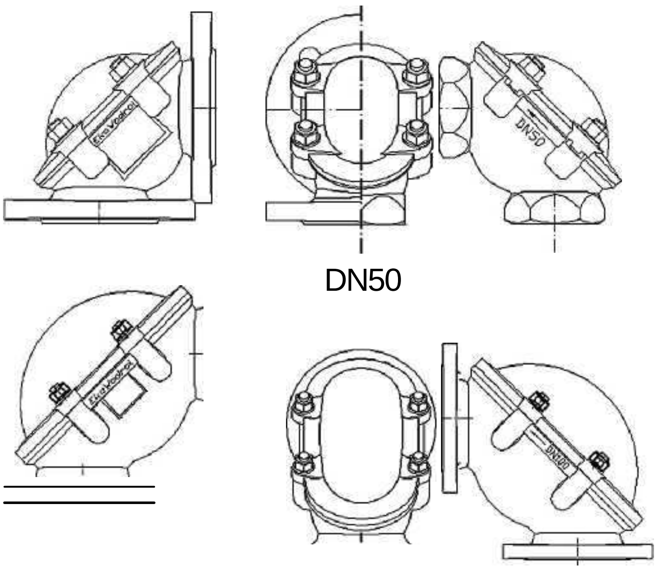
(estimations compatible with standard PN-EN12050-4)

Ds = 0.8 x Di - 4 mm)

DN 32 -» 32 mm x0.8-4 mm = 21.6 mm; DN 40 -> 40 mm x 0.8 - 4 mm = 28 mm; DN 50 -» 50 mm x0.8-4 mm = 36 mm; DN 65 -> 65 mm x 0.8 - 4 mm = 48 mm; DN 80 -» 80 mm x0.8-4 mm = 60 mm; DN100^> 80 mm x0.8-4 mm = 76 mm; DN 125 -»125 mm x0.8-4 mm = 96 mm; DN 150^ 150 mmx0.8 = 116mm; DN 200 -» 200 mm x 0.8 - 4 mm = 156 mm;

3.2. Real clearance for solids

(according to the author, this is the optimal clearance due to full opening of the valve at minimum flow speed and high contamination resistance) for DN 32 to DN 50 back-pressure valves, it is close to the minimum (as in point 3.1); for the DN 80, DN 100 and DN 150 valves, from 0.9 to 0.85 x DI; whereas in the case of waste water containing a high percentage of solids passing through DN 65 valves,



Pic. 4. The new valves of the SZUSTER 2system, DN50, DN 80, DN 100, DN 150

the clearance cannot be smaller than 50 mm (PN-EN 12050 – point 5.6). Therefore, a combined back-pressure ball valve could be suitable here – with a DN 50 inlet and DN 65 outlet, fulfilling both the conditions of a minimum 50 mm clearance and full opening for flow speeds beginning from 0.7 m/s;

3.3 New construction of the ball valve has more elastic and springy properties, namely it is more amenable to elastic and springy shaping which enables complete fitting of the ball to the valve ring seat at a pressure of 0.2 bar (PN-EN 12050-4, 8.2.4 and 8.2.5), and is more durable in terms of persistent pressure in the closing position on its ring seat - minimum 6 bar.

Attention: Development of sewage systems and their specific requirements have forced standardization of waste water pumping stations and back-pressure valves, being an important part of their equipment. Changes introduced in the new standards seem to be logical, especially in terms of clear definitions of the clearance of solids in back-pressure valves, as well as leakage and pressure tests. Only a minimal narrowing of the valve clearance for solids (which excludes entirely back-pressure poppet valves, as unsuitable for faecal sewage) and minimal leakages in the closing position, but at a 2.5 smaller pressure than the minimum tightness test pressure of the closed back-pressure waterworks system (PN-EN 1074-1, point 5.2.2.2).

4. Technology level analysis

Solutions of Japanese companies in the two latest patent descriptions prove that the problem of ball vibration during flow through a ball valve has been noticed.

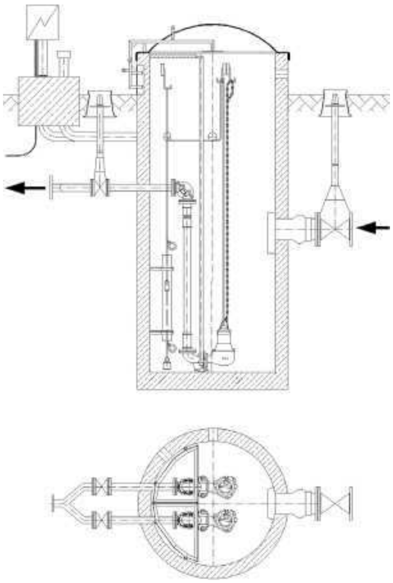
Modified structures of back-pressure valves were presented in patent descriptions [2, 3], which enable ball seating without any or minimal vibrations. Reduction of ball vibration or its elimination during the flow of faecal sewage was achieved thanks to extended space behind the ball seating, which in turn provided an appropriate pressure difference behind and before the ball in the opened position. Nevertheless, such a solution is not appropriate for faecal sewage, because solids existing in the waste water can easily block the ball in the position of incomplete opening, as it is intensively washed by them on each side. Due to the fact that the ball is not subjected to vibrations, it can be blocked in the incomplete opening position of the valve by obstacles of different sizes. This can delay or totally obstruct the return of the ball under the influence of the reverse flow. In this case, the missing ball vibration is not necessarily an advantage. Possible improvements like increased clearance between the ball and valve body do not guarantee a reliable solution, as it was estimated that the solids appearing in the network have a diameter of 5-10mm. Therefore, in the case of bigger solids occurring in waste water, the ball can be blocked anyway.

In the new solution for the back-pressure ball valve of the SZUSTER system, the ball is positioned open on the resisting seat (already at v = 0.7 m/s of flow speed), closing the angled valve channel and forcing the liquid to wash the ball only from one side (the side of the clearance channel).

5. Summary

A certain opinion has been preserved, claiming that back-pressure valves (especially ball valves) used for faecal sewage have a significantly lower local resistance coefficient ζ than when used for clean water. However, in relation to the new SZUSTER system back-pressure ball valve with a short cover, this opinion seems to refer only to the classic models of ball valves, as the mentioned valve opens fully already at v = 0.7 m/s of flow speed and, therefore, the local resistance coefficient ζ of the valve is actually constant, both for water and faecal waste water (in the entire scope of flow speeds recommended for the pipeline). Moreover, at its full opening, the ball tightly closes the inclined channel of the valve, which guarantees:

- Very high resistance to solid contamination by the valve, as during flow the valve actually works as a typical joint,
- Free clearance for solids already at 0.7 m/s of flow speed, without causing ball vibration, which is impossible in classic valve structures.
- In this way, the **UNREAL** has become **POSSIBLE**.



Pic. 5. Pumping station with new L-valves in pumping pipelines.

It is also hard to resist the impression that new harmonized standards concerning back-pressure valves for faecal sewage will cause serious production difficulties for typical companies in the plumber equipment field, due to quite complicated and new product compatibility assessment procedures, including type examinations and production quality control, as well as in terms of creation of new workstations for research of back-pressure valves and their costs. Besides, these standards favor the back-pressure hatch valves (especially with rubber discs), to be covered in a horizontal position as opposed to classic back-pressure ball valves, because at lower flow speeds they have better hydraulic parameters and do not make any noise due to closing element vibration. However, the recommended positioning of back-pressure hatch valves in a horizontal pipeline (for example, sewage presses), causing extension of hydrotechnical facilities (capacities of wet containers and dry cells of a pumping station), significantly increases the chances to use back-pressure knee-shaped ball valves of the SZUSTER system at any place where a 90° joint is used in a pipeline, especially because these valves do not cause vibrations of the closing element (the ball). In addition, they are also significantly more durable and resistant to contamination, and they react more quickly to reverse flow, as the returning way of the ball is short, and the current strikes against almost its entire surface.

The new reverse knee-shaped back-pressure valve is the only worldwide known angle valve, which works as, and simultaneously instead of, a joint in the scope of the recommended flow speeds.

LITERATURE:

1. Standards: PN-EN 12050-1; PN-EN 12050-4; PN-EN 1074-1,
2. American patent description no. US 6,267,137 B1,
3. American patent description no. US 6,510,869 B1,
4. M. Szuster, Polish registration description of events and a European registration description, which are a common property of M. Szuster and the EkoWodrol Sp. z o. o. Company of Koszalin.

AUTHOR:

MA Mirosław SZUSTER is the owner of the SZUSTER TECHNICAL WORKSHOP and an engineer for production and development in the EkoWodrol Sp. z o. o. Company of Koszalin.

Contact:

e-mail: miroslaw@szuster.pl;

mobile: 0607266751