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Umwelt- und Fluid-Technik
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Waste water technology
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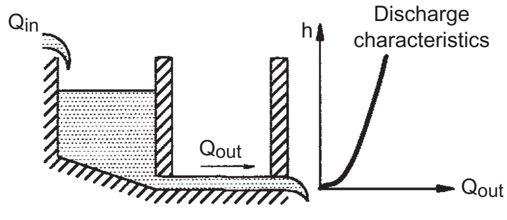
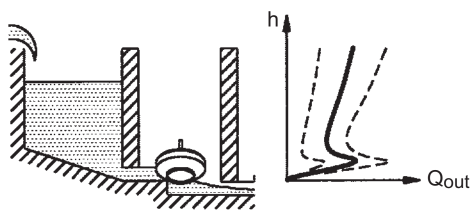
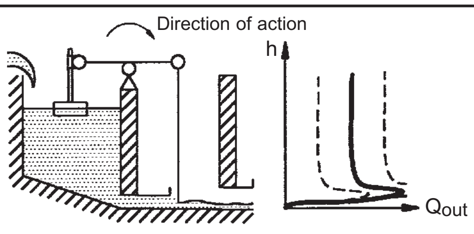
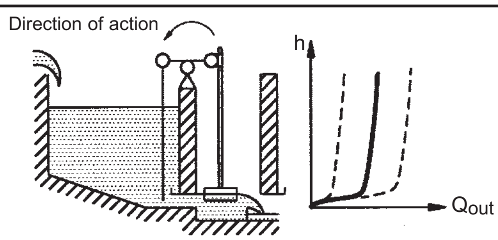
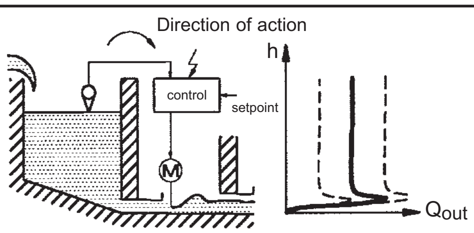
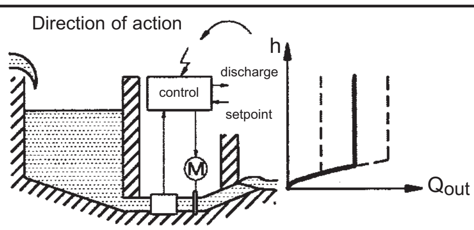
Technical Note

Flow control devices for low and very low flows from storm water tanks

Qmin
0098 E

		open loop flow control	closed loop flow control	
without external power requirements	passive	 Throttle pipe	not possible	without moving parts
without external power requirements	active	 Vortex valve	not yet possible	without moving parts
without external power requirements	active	 Upstream water controlled unit	 Downstream water controlled unit	with moving parts
with external power requirements	active	 Upstream water controlled unit with motor drive	 Throughflow-controlled unit with motor drive	with moving parts
		$Q_{out,min}$ > 25 l/s	$Q_{out,min}$ > 10 l/s	
		Classification of flow control devices as per DIN 19 266 part 1. Minimum discharges as per ATV-A 111 and ATV-A 166		

1 What is the problem?

As manufacturers of all types of flow regulating device, we often face the question "How does one control the discharge reliably with low flows on combined sewer overflows (CSOs) and combined sewer overflow tanks (CSO-tanks)?". The background for the question, are often small catchment areas or new building areas which are to get a new storm water treatment facility. If the rain reservoir is sized according to ATV-worksheet A 128 /1/, under average conditions, e.g. with a population of 3300 connected, a control flow of 25 l/s is obtained during wet weather. With 1300 resident equivalents it is only 10 l/s.

Fig. 1: Evangelista Torricelli (1608 - 1647)

Throttling to such low and very low discharges in the sewer network, far from the wastewater treatment plant, would have been unthinkable prior to 25 years ago when the throttle pipe was the usual method. Experience from 120 years of sewage technology prohibits throttle pipes under 8 inch inner diameter due to risk of blockage, corresponding to metric DN 200, an old English sewer tradition which was adopted by Germans late 1800. This old "magic" and still important lower limit may still be found today in standards and ATV-worksheets (see box).

2 What are low and very low discharges?

It is indisputable that the risk of blockage of a throttle system increases when the throttle discharge gets smaller. This may be demonstrated by a simple hydraulic calculation. The control cross-section of a throttle system on which a huge pressure drop occurs, e.g. at an orifice or a gate valve, conforms to the Torricelli Formula:

$$Q = A \cdot \mu \cdot \sqrt{2g \cdot h}$$

Extracts from standards and German ATV-worksheets on the subject of minimum diameters and discharges

EN 752-3, Section 8.7:
Minimum dimensions of pipes:
*The **pipes** are not only to be dimensioned while considering the hydraulic requirements, but also the risk of blockage needs to be reduced [...].*

ATV-A 118, Section 3.4:
*For operational reasons [...] it is recommended […] that in public **drains with free level flow** generally widths must not fall below the following minimum nominal diameters:*
Sanitary sewer DN 250
Storm and combined sewer DN 300
In justified cases (e.g. small discharge in rurally structured areas [...]), smaller cross-sections, however, if possible not below 200 mm, may be chosen.

ATV-A 111, Section 4.1.1:
***Throttle pipes** are arranged only behind CSOs, not behind storm water tanks. The following constructional marginal values must be observed:*
- Minimum diameter 200 mm [...]

ATV-A 111, Section 4.1.2:
Regulating gate valves
[…] with this additional throttling, the minimum opening height must not fall below the value of 20 cm.

ATV-A 111, Section 4.1.3:
***Vortex devices** […] as a minimum control flow, the value of Q_{min} = 25 l/s must be observed.*

ATV-A 111, Section 4.3:
Closed loop flow control units
[…] as a minimum control flow, the value of Q_{min} = 10 l/s must be observed.

ATV-A 111, Section 4.4:
Open loop flow control units
[…] as a minimum control flow, the value of Q_{min} = 25 l/s must be observed. For control units which, when blocked, open automatically, a minimum flow of Q_{min} = 10 l/s is applicable.

ATV-A 128, Section 10.1.1:
Combined sewer overflow (CSO)
In order to design hydraulically perfect CSOs, the discharge remaining in the duct must be at least 50 l/s.

ATV-A 128, Section 10.2.1:
Combined sewer overflow tanks (CSO-tanks)
The consequences of backpressure (from the outlet flow control) in the feeder duct must be noted. The flow velocity in the feeder should if possible be greater than 0.80 m/s in the dry weather discharge peak in order to remedy deposits again.

ATV-A 128, Section 10.2.4:
*The discharge cross-section in the unregulated **gate valve** must be at least 0.06 m² and exhibit a minimum opening height of 0.20 m.*
[…] With lower control flows (e.g. below 30 l/s), the risk of depositions should be noted.

ATV-A 166, Section 7.2:
Flow control units
[…] Practice has shown that, for reasons of operational safety of storm water reservoirs in the sewage network, minimum conditions must be observed with the control flow. Due to blockage risk, irrespective of flow control type, the nominal width must not be smaller than DN 200.

If the free cross-section A is sought, the formula is resolved to

$$A = \frac{Q}{\mu \cdot \sqrt{2g \cdot h}}$$

If a typical CSO-tank filling height of h = 2.5 m and a usual control orifice throughput coefficient of μ = 0.7 is assumed, a free cross-section of 0.005 m² results for a control flow of 25 l/s. That's 50 cm². With 10 l/s control flow, the sickle-shape opening gap of a gate valve DN 200 is reduced to 10 mm or just the area of a match box, see Fig. 2. Every other advanced type of discharge regulator having a single control cross-section, must reduce the throttle cross-section to this extent. The only exception to this principle are vortex throttles and vortex valves, because they do not use not the cross-sectional constriction, but the centrifugal force for regulating.

It is obvious to anyone, that waste water from a population of 1300, apart from rainwater discharge from roads and roofs, cannot be forced through a 10 mm gap without particular measures against blockage. For this reason we term control systems in the sewage network, which must operate in the 10 to 25 l/s range as regulators for *"very low"* discharges. These systems require a certain amount of effort in planning and in installing and *in the long term they need maintenance.*

The ATV-worksheet A 166 /5/ requires that only "true closed loop flow control units" may be used in storm water reservoirs with very low discharges from 10 to 25 l/s, see title picture. True closed loop flow control units are regenerative systems, DIN 19 226 /6/, and can therefore recognize blockages by the flagging discharge and automatically remedy them and regenerate themselves. Despite this, the operational risk is still not small.

Discharges between 25 l/s and 50 l/s are termed as *"low"* control flows. Vortex throttles and vortex valves can easily handle these discharge ranges with a free spherical

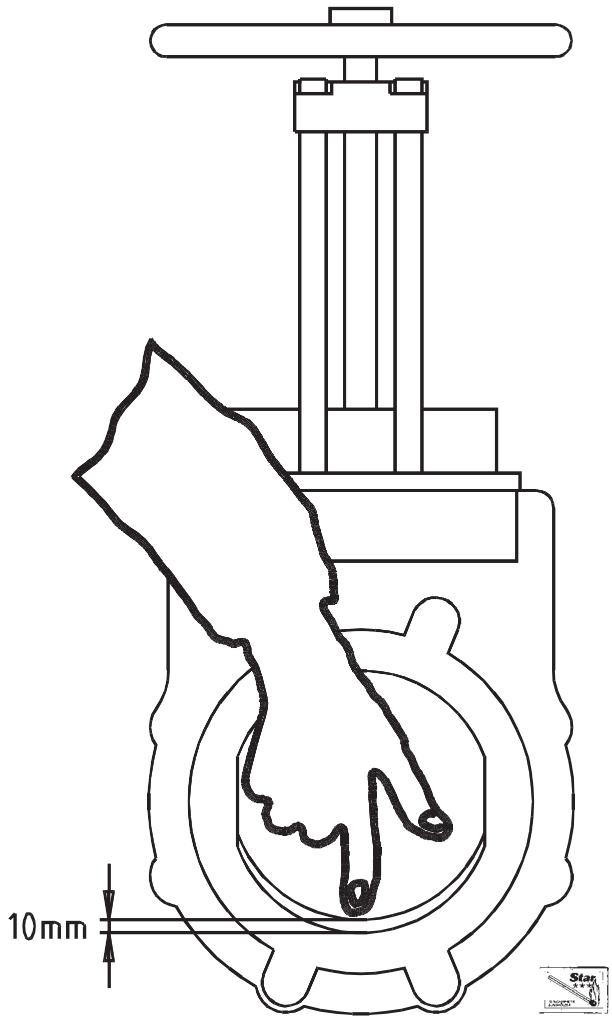


Fig. 2: A knife gate valve DN 200 must be closed to 10 mm gap to throttle the discharge to 10 l/s with a pressure head of 2.5 m. The free flow cross-section is 20 cm². That corresponds to the size of a match box.

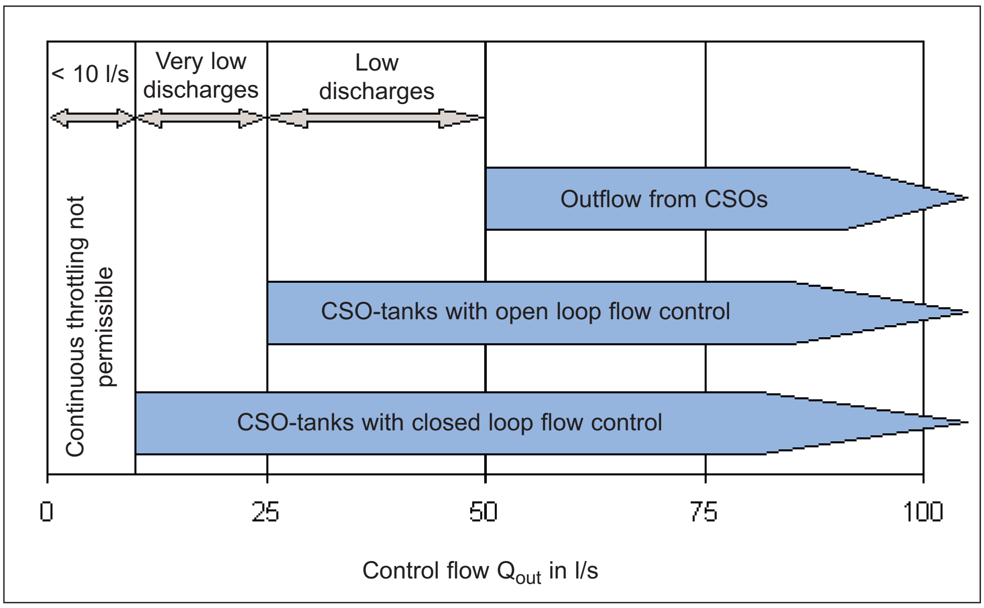


Fig. 3:
Definition of the regulator discharges and permissible operating ranges of various regulating systems for flow control in combined sewer systems.

passage of 200 to 250 mm. Hydromechanical discharge controls have control cross-sections between 50 and 100 cm². That corresponds to a free spherical passage of 80 to 113 mm. The risk of blockage is reduced, but not entirely removed.

The ATV-worksheet A 166 /5/ allows for CSO-tanks with open loop flow control units for throttle discharges from 25 l/s upwards. Open loop flow controls, by nature, are unaware of the current discharge, see DIN 19 226 /6/. Thus they cannot regenerate themselves automatically from blockages. Therefore, *regular monitoring and maintenance* is necessary with hydromechanical discharge controls.

3 Technical progress in flow controls

With pressurized pipes DN 200 no discharges under 60 l/s may be achieved with conventional filling heights in storm water tanks of 2.5 m.

In 1977 we entered the market with the vortex throttle. The completely new regulating principle at the time allowed discharge control to 25 l/s with a free spherical passage of 200 mm and a pressure height of 2.5 m. In this way, the 8-inch requirement was satisfied and great progress towards small discharges was achieved. Today our company alone has a dozen different regulating methods in its range which are very successful throughout the world in great numbers.

4 What to do in the case of low control flows?

What can be done if low or even very low control flows are to be dealt with? Here are some proposals.

4.1 Increase discharge

The ATV-worksheet A 128 does not compulsorily prescribe that discharge from CSO-tanks must be regulated to $2Q_{sx} + 1Q_f$ (twice the peak sanitary flow plus the flow of parasite water). There are many wastewater treatment plants, which at wet weather tolerate discharges up to $5Q_{sx}$. In many situations, increased flow rate may be released from a CSO-tank if it is ensured that, e.g. by long-term quantity-quality simulation, the water is collected further down the system harmlessly.

4.2 Interval operation

In special cases, interval operation may be considered, in which water is accumulated and yielded in pulses alternately. Impulse-pause-mode operation is also possible with wastewater pumps.

4.3 CSOs instead of CSO-tanks

At the edge of catchment areas, it is often more useful to arrange a combined sewer overflow (CSO) instead of a combined sewer overflow tank (CSO-tank). CSOs have a 5 to 10 times larger outflow than CSO-tanks and are also much cheaper.

4.4 Careful construction and explicit dimensioning

If all abovementioned alternatives are dropped and flows below 25 l/s must be regulated, the increased operational risk must be covered by careful construction and thorough hydraulic sizing, in particular by drag tension verifications for the pipework upstream and downstream of the flow control unit.

Discharges below 10 l/s on CSOs and CSO-tanks are a massive and multiple infringement against the rules of technology, which should be prevented wherever possible.

4.5 Regular maintenance

All flow controls with discharges below 25 l/s lead to an increased operational risk due to blockage, jamming, power failure etc. This increased risk may only be compensated by regular monitoring and maintenance work. The planner should inform the subsequent operator about this.

Literature:

/1/ Worksheet ATV-A 128: Standards for the Dimensioning and Design of Storm water Structures in Combined Sewers. German Association for Water, Wastewater and Waste e. V., St. Augustin: GFA, Apr. 1992.

/2/ Worksheet ATV-A 111: Standards for the Hydraulic Dimensioning and the Performance Verification of Storm water Overflow Installations in Sewers and Drains. German Association for Water, Wastewater and Waste e. V., St. Augustin: GFA, Feb. 1994.

/3/ Worksheet ATV-A 118: Standards for the Hydraulic Calculation of Wastewater, Storm water and Combined Wastewater Sewers. German Association for Water, Wastewater and Waste e. V., St. Augustin: GFA, Nov. 1999.

/4/ Brombach H.: Pressurized pipes and vortex throttles at storm tanks. In: Swiss Engineer and Architect, book 33-34 (1982) p. 670-674.

/5/ Worksheet ATV-A 166: Structures of Central Storm Water Treatment and Retention: Structural Design and Equipment; German Association for Water, Wastewater and Waste e. V., St. Augustin: GFA, Nov. 1999.

/6/ German Standard DIN 19 266 Part 1: Open loop and closed loop control technology: General Principles, Berlin: Beuth, 1994.

/7/ European Standard DIN EN 752 Part 3: Drain and sewer systems outside buildings: Planning, Berlin: Beuth, Sept. 1996.