Cleaning as a measure for the safe operation of pipelines

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When renovating or renewing pipelines, the main focus is on technical and economic aspects. However, hygienic aspects should not be forgotten when recommissioning drinking water pipes and aspects relating to cleaning during the future operation of pressure pipes for raw water, process water and wastewater, which tend to form deposits and thus narrow the cross-section of the pipe. The article first provides information on cleaning measures to ensure that a renovated or renewed drinking water pipe is in perfect hygienic condition. It also explains cleaning options for returning pipes with a constricted cross-section to the hydraulically planned condition. This aspect has recently become increasingly important in order to ensure the demand for raw water in the summer months or the disposal of wastewater at peak times and also to keep energy costs in check.

REASONS FOR CLEANING

There are various reasons for cleaning pipes. Drinking water pipes must be in perfect hygienic condition in order to transport our No. 1 foodstuff. However, the drinking water pipe network also performs other tasks. In the event of a fire, it provides water to extinguish it. Faultlessly functioning fittings are a prerequisite for this. Newly built drinking water pipes contain construction-related additives and unavoidable impurities that must be removed by cleaning. Depending on the type of pipe, type of water and operating conditions, deposits and biofilms can form during operation. Cleaning is necessary to restore the hygienically and hydraulically perfect condition that existed after initial commissioning.

In many untreated water pipes, deposits of iron or manganese compounds form during operation and reduce the flow rate. Increased flow during periods of high water demand, for example in the summer months, leads to the mobilization of loose deposits. They cloud the water and lead to frequent backwashing of the filters in the waterworks. Regular cleaning during periods of low consumption prevents disruptions and helps to ensure sufficient drinking water even at peak times.

Rinsing process	Brief description
Rinsing with water	Simple conventional procedure
	Water suction rinsing
Flushing with water and air	Flushing with air/water mixture
	Impulse rinsing process
Rinsing with water and mechanical aids	Rinsing with water and sponge rubber balls
	Rinsing with water and plastic pigs
Special cleaning processes	High pressure cleaning
	Cleaning with scratches

***Table 1:** Mechanical flushing methods for pipes*

The water must be provided in perfect condition. Sewers and drains also require regular maintenance.

moderate cleaning measures to remove deposits of wastewater constituents and ensure wastewater disposal. In wastewater pressure pipes, deposits lead to an increase in flow resistance. Organic deposits and microbial gas development are particularly critical. This shifts the operating points of pumps. The consequences are longer running times, lower pumping volumes and ultimately increased energy costs, in extreme cases even the complete cessation of pumping.

The need for cleaning has been recognized in recent years and anchored in the regulations. While the title of the DVGW Code of Practice W 291 published in 1986 "Disinfection of water supply systems" [1], the current revised edition of March 2000 is entitled "Cleaning and disinfection of water distribution systems" to emphasize the importance of thorough cleaning before disinfection. In the worksheet itself, cleaning is given priority, while disinfection is to be regarded as an additional safety measure.

In January 2012, the draft of DVGW Code of Practice W 557 [4], which is analogous for drinking water installations, was published. The white print is expected in the second half of the year. This worksheet will go into more detail on cleaning and cleaning methods. Findings from the BMBF joint project "Biofilms in drinking water installations" underline the importance of cleaning. They have been published in the form of theses and are available on the Internet [6].

Cleaning is also increasingly mentioned in the DWA regulations for wastewater pressure pipes, for example in DWA A 116 [5] and other worksheets that are currently still being worked on. The causes of deposits, their consequences and cleaning measures are described here.

CLEANING PROCESS

Various mechanical flushing methods are available for cleaning pipes, depending on the task (**Table 1**).

Rinsing with water

The simplest cleaning method is flushing with water. For flushing to be successful, it is essential that the water in the pipe reaches a sufficient flow velocity of between 2 m/s and 3 m/s to create turbulent flows. Flushing with water is possible in pipelines up to DN 150 via hydrants. Significant quantities of water are required for larger nominal diameters. **Figure 1** provides information on the flushing water requirement depending on the nominal diameter. The corresponding quantities of water must then be disposed of. Depending on the pipe cross-section, at least three to five times the pipe volume must be provided for flushing new pipes. Pipes are always to be flushed from top to bottom. Effects on the neighboring supply network must be taken into account. For example, the supply in neighboring pipes must not be impaired by a drop in pressure during flushing. The drinking water must not become cloudy if deposits mobilize in upstream pipes as a result of increased flow velocity. The local and statutory regulations must be observed when discharging the flushing water. When flushing via hydrants, the capacity of these fittings must be taken into account. In the case of conventional hydrants it is around 110 m³/h and for free-flow hydrants around 150 m³/h. Their capacity is not sufficient for nominal widths above DN 150. Therefore, especially for nominal widths larger than DN 150.

The effectiveness can be improved by flushing according to the flushing schedule. Water suction flushing enables a further increase. An effective suction pump with variable performance over a wide range is used at the outlet hydrant. This can increase the water withdrawal quantities by 50 % to 120 %. Furthermore, different flow velocities are possible intermittently. Both lead to increased drag or wall shear stresses and improve the discharge of easily mobilizable deposits.

Flushing with water and air

In contrast to flushing with water, this work has high procedural and safety requirements and can only be carried out by experienced specialists. Only purified air may be used in raw and drinking water pipes. It must be oil-free and low in particles and germs. The ratio of flushing water to flushing air is between 1:1 and 1:3.

The addition of air improves the cleaning performance. However, if air bubbles collect at the top of the pipe, this effect can only be limited to the

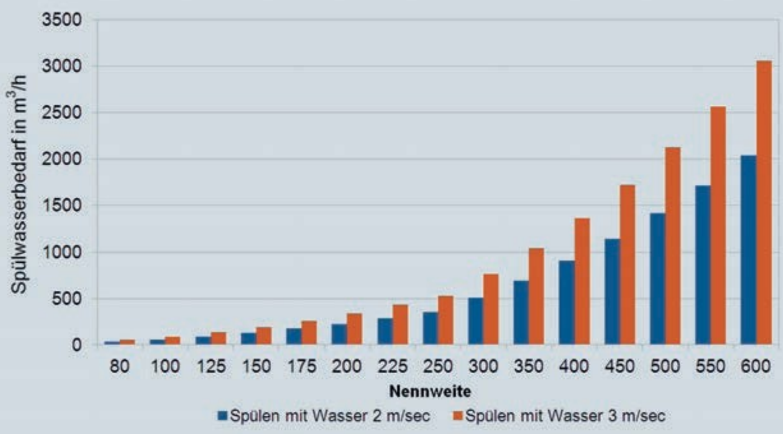


***Figure 1**: Water requirement for rinsing with water*

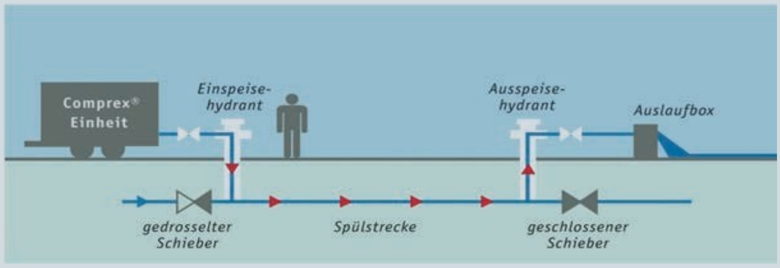


***Fig. 2**: Principle of the pulse flushing process for existing pipes < DN 400*

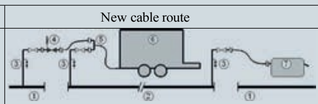
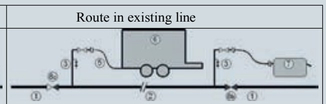
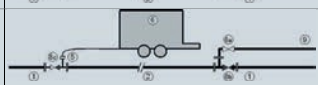
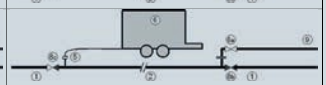
Impulse flushing technology	New cable route	Route in existing line
Small nominal diameters (DN ≤ 400) Inlet and outlet via hydrants Outlet via outlet box or rinsing bag		
Large nominal widths (DN 400) Inlet and outlet via T-pieces Free outlet		
Legend	1 Water pipe in operation 2 Pipe section to be cleaned 3 Standpipe with tap 4 Fuse fitting 5 Air feed 6 Compressor with air treatment	7 Outlet box/rinse bag 8 Shut-off valve 9 free outlet a) open b) Closed c) throttled

***Fig. 3**: Pulse flushing technology for new and existing pipelines*

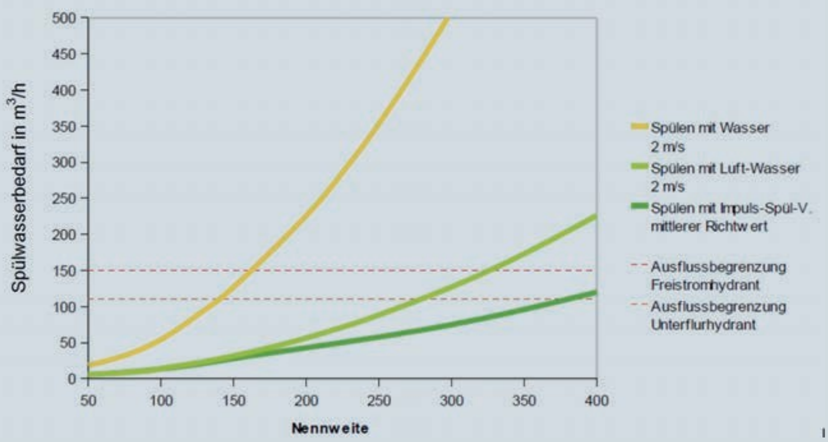


***Figure 4**: Comparison of the rinsing water requirement*

Figure 5: Feed-out during cleaning with the pulse flushing process

be limited to the pipe invert. Uncontrolled pressure surges can cause pipe bursts.

Impulse rinsing process

A variant of flushing with water and air is the pulse flushing method. In this process, processed compressed air is added in pulses within a defined flushing section without exceeding the resting net pressure (**Fig. 2** and **Fig. 3**). Air bubbles of a defined size are formed, which form a chain of space-filling water and air blocks in the water flow. The space-filling turbulent flow causes locally high forces to mobilize deposits.

Compared to flushing with water, the water requirement is drastically reduced (**Fig. 4**). As a result, the impairment of neighboring networks and upstream pipelines can be largely avoided.

The impulse flushing process was initially used to clean drinking water distribution networks. It has the following advantages over conventional water flushing:

- More intensive cleaning
- Up to 90 % less water required
- No turbidity and pressure drops in the upstream network
- Maintaining the water supply outside the flushing section
- Improving the function of fittings

Rinsing with water and pigs

As shown in **Table 1**, sponge rubber balls or plastic pigs are used. In both cases, equipment is required for feeding and discharging the pigs. Hydrants, preferably free-flow hydrants, are suitable for sponge rubber balls. For pipelines that need to be cleaned frequently, e.g. for raw or process water, sluice fittings are recommended. Sponge rubber balls are used for cleaning pipes up to DN 150.

While loosely adhering deposits and sediments can be mobilized and removed when rinsing with sponge rubber balls, special pigs can also be used to remove firmly adhering deposits.

Sponge rubber balls are made of a soft, fine to medium-pored material with a density of around 0.16 g/cm³. The diameter of the rubber ball is matched to the diameter of the pipe section to be cleaned. Cleaning is achieved by friction on the inner wall of the pipe, high flow velocities in the annular gap and turbulence in cavities that are difficult to access, e.g. socket connections, over-slides, valve domes. In contrast to sponge rubber balls, plastic pigs can be designed in such a way that they remove firmly adhering deposits and incrustations. Internal surfaces become bright and usually require corrosion protection for metallic materials.

During cleaning, precautions must be taken to ensure that the pigs do not get stuck in the cleaning section, for example by using pigs with diameters smaller than that of the pipeline. As a result, water flows through the intermediate space and serves to remove the mobilized deposits.

from the pipe section to be cleaned. Cleanliness must be ensured when handling and storing pigs and sponge balls for drinking water pipes.

Special cleaning processes

In special cases, high-pressure cleaning and cleaning with scrapers are used.

High-pressure cleaning can be used regardless of the surface finish. However, the cleaning nozzle, the pressure and the distance to the wall must be adjusted to the type of surface in order to avoid damage. Warm water can improve cleaning. Disinfectant can also be used selectively and sparingly. In particular, measures must be taken to dispose of or treat the rinsing water properly. Flushing lances with a backward jet and free outflow of flushing water are used for non-accessible pipes. In accessible pipelines, short sections can be cleaned manually. It is possible to clean particularly heavily soiled areas in a targeted manner. The safety regulations must always be observed. Cleaning with scrapers removes adhering deposits.
incrustations and corrosion products. This cleaning process is used, for example, before renovating old cast iron or steel pipes with cement mortar. The DVGW worksheet W 343 [2] provides instructions.

New developments in the impulse flushing process

Hammann developed the even more powerful Comprex process from the impulse flushing process. It is now also possible to clean large transport pipes of several kilometers in length and nominal diameters up to DN 1200. The impulse flushing process has also proven itself in drinking water installations. Here, unwanted biofilms and deposits can be mobilized and removed. In circulation pipes, this is the only way to achieve hydraulic balancing so that the required hot water temperature can be reached again at the taps. Thus, in the event of contamination with legionella, the pulse flushing process can reduce the possibility of the microorganisms becoming established and restore the system to the condition required by the regulations. Further developments, often as part of research projects, aimed to increase cleaning performance, use less water and at the same time reduce the amount of flushing water required. Improved process control has now made it possible to shoot water blocks through pipe sections at flow rates of 15 m/s to 20 m/s and to significantly increase the drag stress on the inner surfaces. Tests on a test system confirm this optimization of the cleaning performance. In the case of stubborn impurities, the cleaning performance can be further increased by adding pieces of ice or inert solids.

Recent experience shows that the design of the feeding has an influence on the effectiveness of the cleaning has. While a flushing box is used for pipelines with small nominal diameters
performs its service, it is more efficient for pipelines DN 250 to DN 400 to be discharged via several hydrants and flushing boxes (**Fig. 5**). A free outlet is required for pipes over DN 400 (see also "Fascinating technology" on page 882).

Biofilms can provide shelter and food for multicellular animals such as water lice. Initial cleaning measures using the impulse flushing method show the effectiveness of efficiently removing biofilms from pipes together with the animals and thus sustainably reducing the population of metazoans [7].

In raw water pipes, the pulse flushing process not only serves to create hygienically perfect conditions, but also opens up potential savings for the operator [8, 9]. Deposits and clogging lead to reduced pipe cross-sections and irregular or rough surfaces. Increased pressure means that pumps need more power. The pumping time takes longer due to the reduced flow rate. Finally, the efficiency of the pumps decreases,
because they are not designed for this situation (**Fig. 6**).

The impulse flushing process restores the raw water pipe to the condition for which the pumps were designed. The cost of cleaning is quickly amortized by significant energy savings. Similar tasks have to be solved in wastewater pressure pipes. Cleaning can be carried out online here. While the wastewater is being pumped at a throttled pump capacity, the control system of the pulse flushing technology ensures compressed air blocks in the pipe. The loosened deposits are either discharged directly into the sewage treatment plant or into a sewer for disposal. Flow measurements show that the cleaning process enables considerable energy savings to be made on the one hand and, on the other, that disposal reliability can be restored in the event of increased wastewater volumes.

In the industrial sector, the impulse rinsing process impresses with its simplicity and effectiveness. In addition to the areas of application already mentioned, there are also cleaning tasks for heat exchangers. Complex cooling or heating systems can be cleaned without dismantling [10].

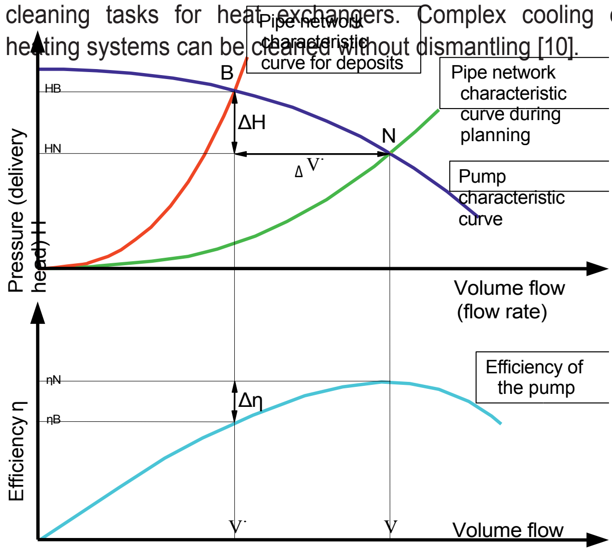


***Figure 6**: Pipe and pump characteristic curve and efficiency*

Deposits can also be efficiently removed from product lines by adding solids. The cleaning of fire extinguishing pipes serves to ensure safety in the event of a fire. Another development is the inspection and upgrading of valves in combination with pipe network cleaning [11, 12]. In this way, the costs for pipe network cleaning can be offset by extending the service life of the upgraded valves. This results in further advantages:

- » Hygienically and hydraulically perfect condition of the pipe network
- » Checking the function of all valves in the pipe network
- » Upgrading of poorly closing or non-closing gate valves by 50 % to 70 %
- » Increased safety in the event of incidents by cordoning off affected areas
- » Documentation of defective gate valves and labeling on site
- » Reduction in the number of gate valves to be replaced
- » Reduction in civil engineering measures as a result of the Valve replacement
- » Further valve inspection in accordance with DVGW Code of Practice W 392 [3] possible
- » Small repair measures possible during cleaning and valve inspection
- » Cost optimization by extending the service life of the pipe network including fittings, in particular the gate valves

CLEANING AND DISINFECTION

Cleanliness is the top priority, especially when constructing drinking water pipes. If all requirements regarding preventive measures are met, flushing with water is often sufficient to pass the microbiological test and the pipeline can be put into operation. In these cases, disinfection can be dispensed with. However, it can happen that sludge or other contaminants inadvertently get into a pipe section during construction. In this case, only intensive cleaning, for example using the impulse flushing method, will help [13]. Disinfection without prior cleaning is not effective. Disinfection cannot replace cleaning. This is shown not only by years of experience, but also by studies carried out as part of research projects. Repeated disinfection measures, where possible with increased disinfectant concentrations, damage many materials and lead to a shorter service life. The new technical regulations such as DVGW worksheet W 557 also refer to this [4].

PLANNING CLEANING MEASURES DURING PLANNING AND CONSTRUCTION

In many pipelines and especially systems, the focus during planning is on operation. Cleaning for maintenance is often forgotten. During operation, feed-in and feed-out options are very difficult to install, often only during downtimes. It is much easier to maintenance should be planned before the construction of new pipelines and systems or before renovation. This enables cleaning as a measure for safe operation either at regular intervals or as required.

LITERATURE

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