Research project REINER for energy efficiency in drinking water distribution

- Recognize existing savings potential and exploit it through cleaning

Energy efficiency has also played an increasingly important role in the drinking water sector in recent years. Initially, the focus was on water extraction, where well pumps become clogged during operation and have to be replaced for cleaning and overhaul. Raw water pipes also require cleaning measures (depending on the operating conditions), e.g. as a result of clogging, because deposits reduce the cross-section and at the same time increase the roughness of their inner surfaces, so that the pressure loss increases and pumps need more energy to pump the water. But what about the drinking water network? Is there also potential to save energy there? Against this backdrop, a completed research project is clarifying how much energy can be saved by cleaning pipes in drinking water networks.

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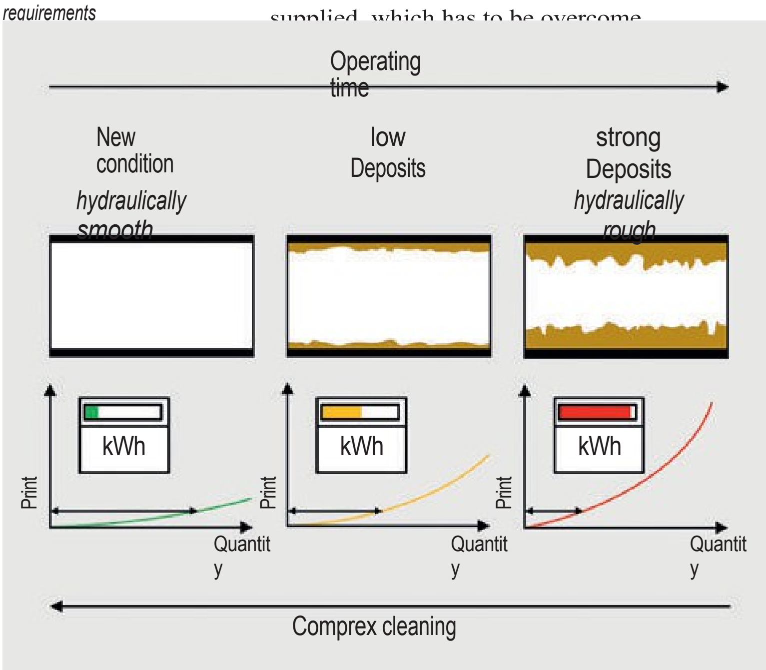
The pumps that transport the drinking water to the consumers require electrical energy. In Germany, this amounts to around half a percent of the total primary energy requirement and is primarily due to the volume of water to be supplied, which has to be overcome geodetic height and the water pressure required by the consumer. The hydraulic resistance of the pipes also has a decisive influence.

Fig. 1: Influence of deposits on pipe hydraulics and energy requirements



Source: Hammann GmbH

The project "Increasing energy efficiency in water networks through new assessment tools and optimized cleaning" (REINER) funded by the Federal Ministry of Education and Research (BMBF) was completed in April 2017. The research project was funded as part of the "KMU- innovativ: Ressourcen und Energieeffizienz" (SME innovation: resources and energy efficiency) funding measure in the technology and application area of "Sustainable Water Management (NaWaM)" [1] and dealt, among other things, with the improvement of hydraulics in existing water networks by means of Comprex cleaning. Newly developed assessment tools make it possible to evaluate existing energy-saving potential. New measuring methods and prototypes show the condition of the pipeline before and after cleaning; proof of the energy savings was provided in practical measurements.

Pipeline hydraulics and energy requirements

The assessment tools are based on piping curves. **Figure 1** shows schematically how the pressure, depending on the volume flow of the water (quantity), affects the pipe characteristic curve and thus the energy requirement of the pumps. The electricity meter symbolized in traffic light colors represents the electrical energy required to pump the water. During the operating time, substances are deposited in the pipes, making the pipe surface rougher and narrowing the pipe cross-section; this results in an increase in hydraulic resistance. The pipe characteristic curve also changes accordingly: **Figure 2** illustrates the relationship between the pipe characteristic curve, pump characteristic curve and the efficiency of the pump.

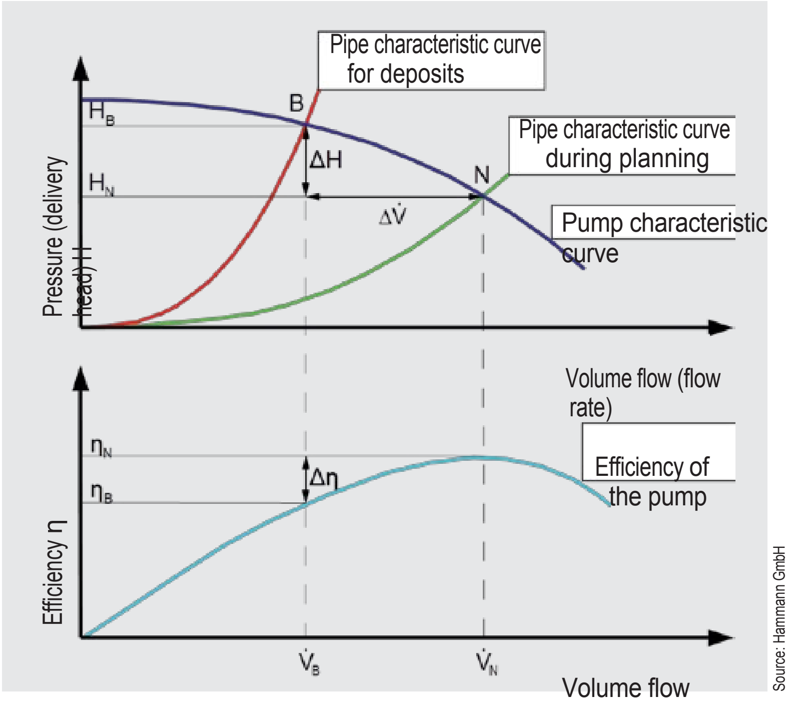


Fig. 2: Pipe and pump characteristics and pump efficiency

Effect of Comprex cleaning on the required pump performance ($_{PR}$)

Comprex cleaning removes deposits, which changes the pipe characteristic curve **(Fig. 1)**. The hydraulic resistance decreases again. This results in a lower pressure loss ($_{hv}$) between pump and consumer after cleaning than before cleaning. With the same pump performance, the customer will have

a higher supply pressure. The pressure regulators ensure, among other things, that sufficient water is available in the event of high demand, such as in the event of a fire (network safety). If the water pressure is already sufficient for pipes with a constricted cross-section, cleaning makes it possible to reduce the pump output and thus save energy.

Cleaning as an energy-saving measure

Cleaning should be effective, cost-effective and easy to carry out.

be. Comprex cleaning fulfills these criteria: All that is required is to pressurize cleaning sections between two shut-off valves at reduced water pressure using controlled compressed air pulses **(Fig. 3)**. Compact water blocks can thus be accelerated to speeds of more than 15 m/s. This results in the mobilization and subsequent discharge of deposits. Compared to conventional water flushing, it is more effective, as the drag force required to mobilize the deposits is greater by a factor of more than 100 and at the same time only around 10 percent of the water volume flows into the cleaning section for the cleaning process. How much can be mobilized depends on the type of pipe and the deposits: For example, a distinction is made between pipelines in their current state, for example plastic pipelines, steel or cast iron pipelines with cement mortar linings and old cast iron pipelines with linings made of bituminous materials. These often contain very hard

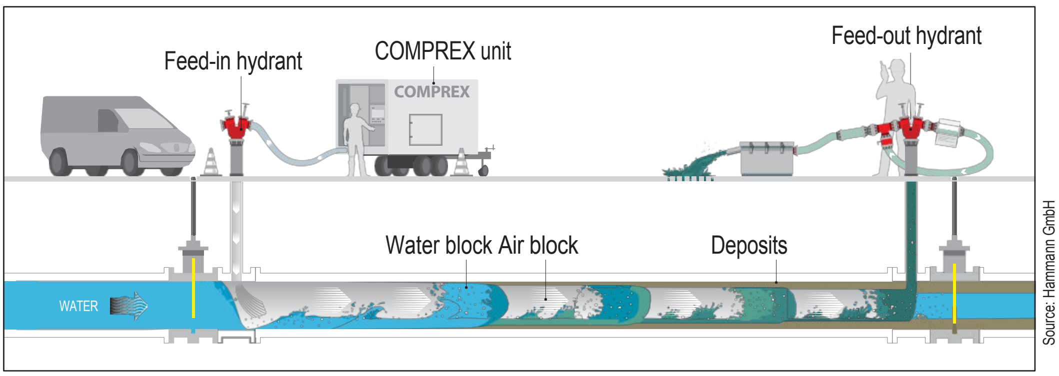
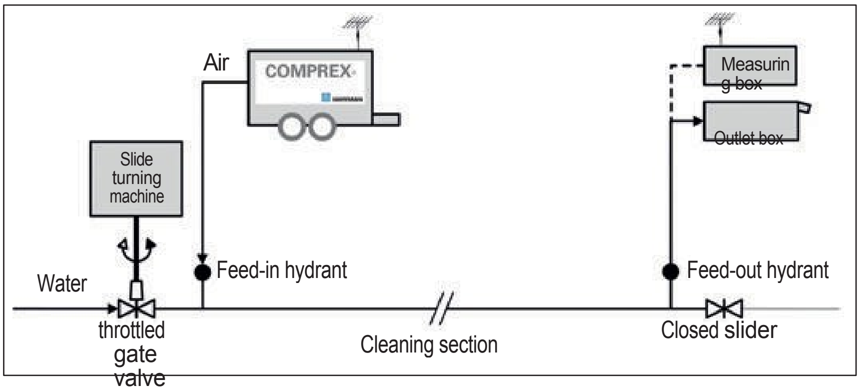


Fig. 3: Scheme of Comprex cleaning in the drinking water network



Source: Hammann GmbH

Fig. 4: Schematic representation of Comprex cleaning in combination with slide lathe and measuring box

corrosion products that cannot be completely removed using the Comprex process. This is why the energy savings are greater with the first-mentioned pipes than with the old cast iron pipes. The calculation tools for evaluating the energy savings take different materials into account.

Calculation tools and numerical simulations

The aim of the REINER research project was to develop calculation tools and the measurement procedure for determining the hydraulic characteristics of the cleaning sections before and after cleaning.

Data determination

In practice, the inlet and outlet hydrants are often several hundred meters apart. In built-up areas, real-time data transmission is only possible wirelessly. This was the reason for developing a measuring box for the real-time transmission of data from the outlet point to the Comprex unit and, if necessary, back **(Fig. 4)**. It turned out to be an advantage that in order to create the pipe characteristic curve, the volume flow must be set upstream of the outlet box. Otherwise, a volume flow-dependent pressure loss occurs, which influences the pressure conditions in the entire downstream system. Furthermore, when the valve is closed at the end of the section upstream of the outlet box, the geodetic height difference is determined directly by the pressure difference between the outlet and feed hydrant.

Calculation tools

First of all, the energy required to convey water through this section had to be determined for the energy assessment of the pipe sections. This ultimately led to the allocation of energy to individual pipe sections. Based on these considerations, the development of the assessment tool could begin. This was initially tested in a first rough version and then gradually developed further. For this purpose, the results of the tests at the Hammann GmbH test facility and the measurement data were analyzed.

General pipe parameters								
L	1,2	[m]	Medium	Drinking water	[-]	Average flow rate of the line	10	[m³/h]
DN	80	[mm]	Material	5) Insulated cast iron pipe	[-]			
Δh geod.	0,000	[m]						

Pump parameters					
Average pump efficiency	0,6	[-]	average performance		[kW]
			Funding level		[m]
			Flow rate		[m³/h]

Source: RWW mbH

Fig. 5: Data entry of the general parameters for the simplified piping analysis; fields with a gray background must be filled in, fields with a white background are calculations/defaults

Data input before cleaning																	
1. pressure measurement before cleaning			2. pressure measurement before cleaning			3. pressure measurement before cleaning			4. pressure measurement before cleaning			5. pressure measurement before cleaning			6. pressure measurement before cleaning		
v_0	0,0	[m/s]	v_1	0,7	[m/s]	v_2	1,2	[m/s]	v_3	1,7	[m/s]	v_4	2,2	[m/s]	v_5	2,6	[m/s]
Q_0	0,0	[m³/h]	Q_1	12,5	[m³/h]	Q_2	21,0	[m³/h]	Q_3	30,2	[m³/h]	Q_4	39,6	[m³/h]	Q_5	47,6	[m³/h]
Pressure on Feed point	37,31	[m]	Pressure on Feed point	33,02	[m]	Pressure on Feed point	30,83	[m]	Pressure on Feed point	26,72	[m]	Pressure on Feed point	21,1	[m]	Pressure on Feed point	14,82	[m]
Pressure on Outlet point	37,31	[m]	Pressure on Outlet point	32,73	[m]	Pressure on Outlet point	30	[m]	Pressure on Outlet point	25,01	[m]	Pressure on Outlet point	18,16	[m]	Pressure on Outlet point	10,54	[m]

Data entry after cleaning																	
1. pressure measurement after cleaning			2. pressure measurement after cleaning			3. pressure measurement after cleaning			4. pressure measurement after cleaning			5. pressure measurement after cleaning			6. pressure measurement after cleaning		
v_0	0,0	[m/s]	v_1	0,7	[m/s]	v_2	1,2	[m/s]	v_3	1,7	[m/s]	v_4	2,2	[m/s]	v_5	2,7	[m/s]
Q_0	0,0	[m³/h]	Q_1	12,2	[m³/h]	Q_2	21,5	[m³/h]	Q_3	30,6	[m³/h]	Q_4	39,0	[m³/h]	Q_5	49,0	[m³/h]
Pressure on Feed point	37,31	[m]	Pressure on Feed point	33,06	[m]	Pressure on Feed point	30,59	[m]	Pressure on Feed point	26,48	[m]	Pressure on Feed point	21,49	[m]	Pressure on Feed point	13,35	[m]
Pressure on Outlet point	37,31	[m]	Pressure on Outlet point	32,96	[m]	Pressure on Outlet point	30,27	[m]	Pressure on Outlet point	25,85	[m]	Pressure on Outlet point	20,46	[m]	Pressure on Outlet point	11,72	[m]

Source: RWW mbH

Fig. 6: Data entry of the pressure measurement, before and after cleaning; fields with a gray background must be filled in, fields with a white background are calculations/specifications

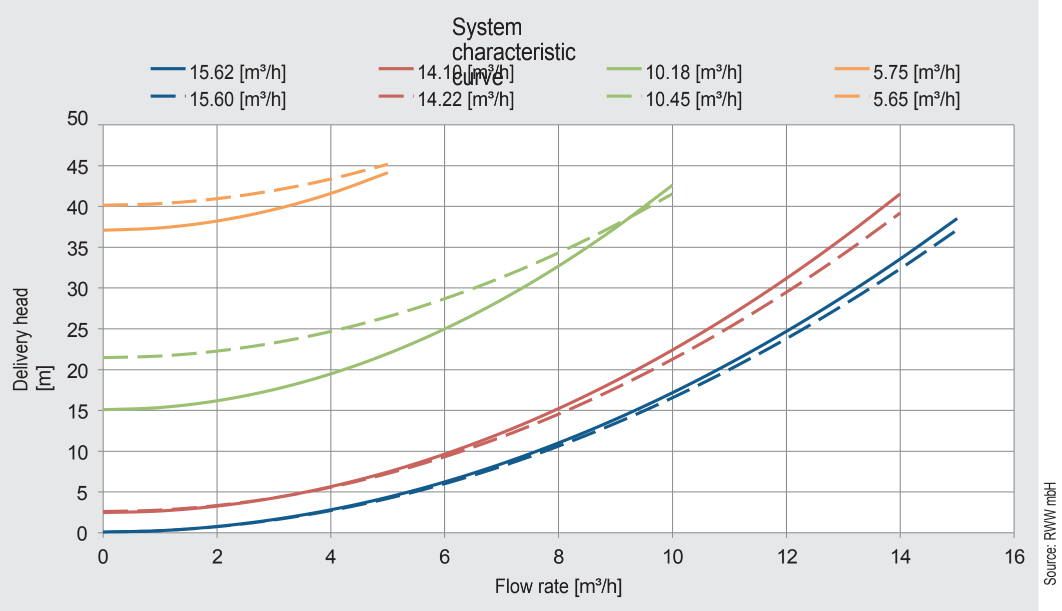


Fig. 7: System characteristic curve at different flow rates before (solid lines) and after (dashed lines) cleaning

cleaning measures on real pipe sections. Furthermore, the tool also includes a measurement schedule so that this information can be accessed when entering data. **Figures 5** and **6** show the contents of the data entry spreadsheet; **Figure 7** shows an example of the results output by the assessment tool.

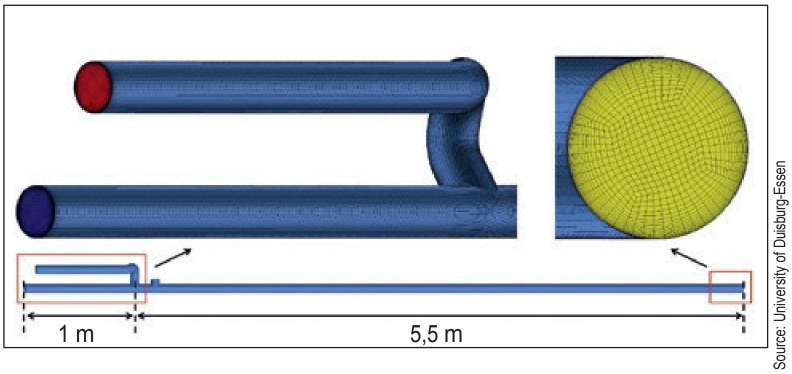
Numerical simulation

In order to visualize the highly dynamic processes during a cleaning pulse independent of time and location, the University of Duisburg-Essen's Department of Mechanics and Robotics has developed a numerical simulation model for multiphase flow analyses. **Figure 8 shows** the modeled geometry of the existing Hammann GmbH test plant in order to validate the knowledge gained in practice. As the cleaning result depends decisively on the drag stresses occurring on the pipe wall, high-resolution discretizations were used in the area close to the wall. Block-structured meshing and extensive test series on the required element fineness ensured both the quality of the results and the feasibility of the computer-aided analyses with regard to the available computing resources on several high-performance clusters [2].

The pipe model designed for compressible media made it possible to investigate the behavior of the turbulent flow under the influence of installations (such as partially closed gate valves or butterfly valves). Furthermore, conclusions could be drawn regarding dead spaces or a possible risk of cavitation. Extensive parameter studies made it possible to analyze possible optimization potentials in the configuration of the cleaning impulse. Based on the original standard parameters of the Comprex process, the cleaning success could be significantly increased with identical energy input and optimized parameters. Comparisons of the maximum average drag stresses across all relevant wall surfaces show an improvement of around 200 to 500 percent, depending on the intensity of the compressed air pulse **(Fig. 9)**.

The optimization potential discovered by simulation with regard to the Comprex control system could also be demonstrated on the test system. In future, these will therefore contribute both to reducing the energy required for cleaning and to increasing cleaning performance.

Fig. 8: Geometry and meshing of the simulation model



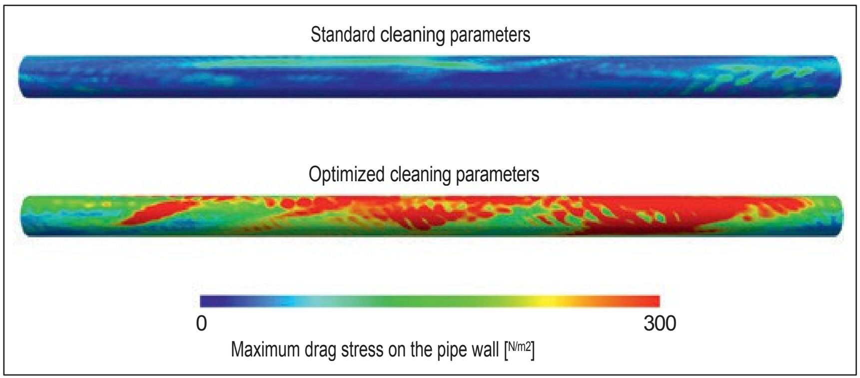


Fig. 9: Improving cleaning success by optimizing the operating parameters

Fig. 10: Real pipe sample in the test facility

Fig. 11: Pressure measurement of a pipe section using a measuring box in practice

Cleaning to improve hydraulics: test system

As part of the project, an existing Hammann GmbH test system was converted and expanded for cleaning and hygiene tests. Pressure and flow measurements as well as the integrated Comprex control system now allow questions from practice to be simulated and investigated. Using an integrated gate valve and hydrant, it was possible to initially test the measuring arrangement for hydraulic measurements in the technical center. At the same time, the prototypes of the gate valve turning machine and measuring box were subjected to an extensive testing phase. The test facility made it possible to further optimize Comprex cleaning and to investigate flow conditions in the area of valves. With the help of the BMBF research project "Microbial clogging in technical systems", cleaning and hydraulic tests can be carried out under reproducible conditions. Pipe samples from the RWW network also made it possible to optimize cleaning using real deposits and to compare hydraulic parameters before and after cleaning **(Fig. 10)**. This ultimately led to the fine-tuning of the calculation tools.

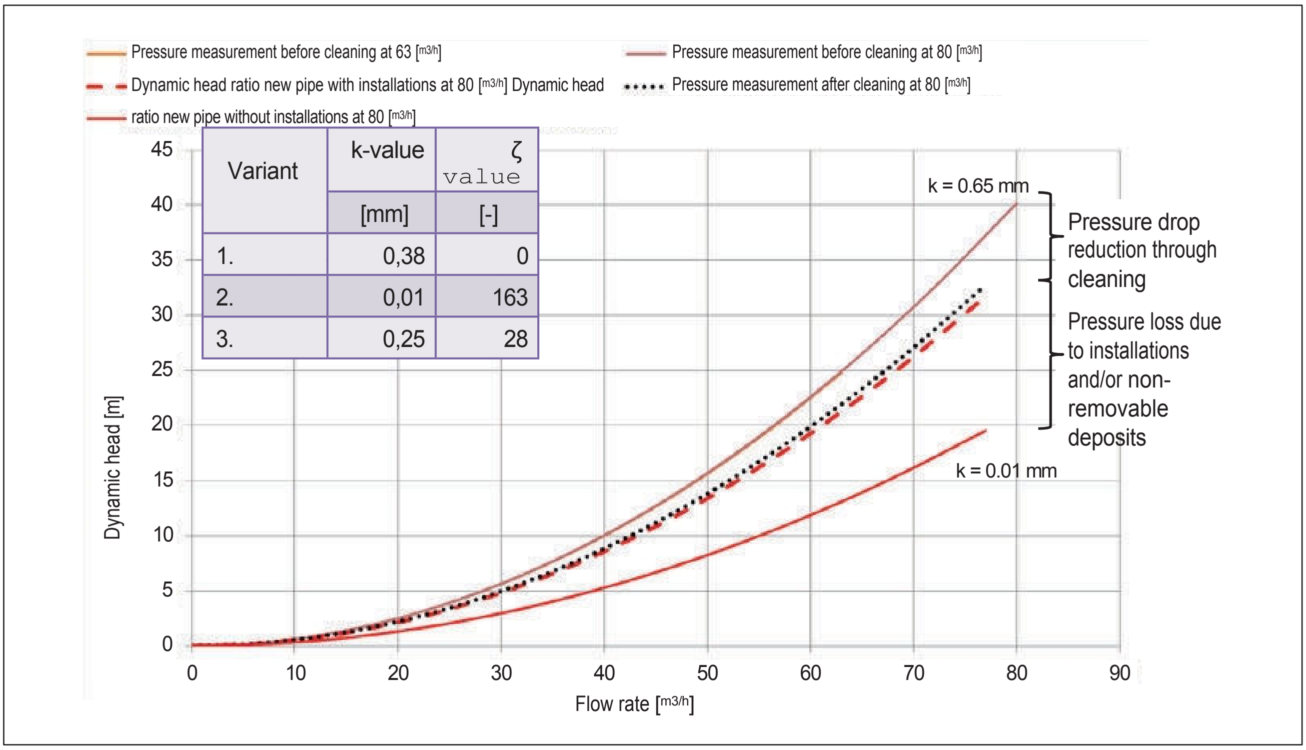
Practice

In addition to tests in the technical center, practical investigations during cleaning measures provided new findings. Measurements before and after cleaning were used to validate and adapt the calculation tools on the one hand and to optimize Comprex cleaning on the other.

Figure 11 shows the practical use of the measuring box developed in the project to determine the hydraulic characteristics. The measured values determined in the process served as the data basis for the calculation tools. **Figure 12** shows the results obtained during a practical test.

Prototypes

The new slide valve turning machine is used to precisely control the water flow during cleaning in order to carry out cleaning even more efficiently. However, only a prototype could be developed as part of the research project. In the process It turned out that multi-level safety devices are essential for both the operator and the valve. These are built into the hardware and software. The software also has the option of saving the data and preparing it for documentation.



Variant	k-value	ζ value
	[mm]	[-]
1.	0,38	0
2.	0,01	163
3.	0,25	28

Source: RWW mbH

Fig. 12: Example of the system characteristic curve of a real pipe section before and after cleaning and in comparison to the theoretically calculated characteristic curve

graphically: The graph shows the pipe characteristics before and after cleaning as well as the theoretically calculated characteristics. The measurements after cleaning show good agreement with the predicted cleaning result.

Conclusion

The completed BMBF research project REINER has shown that the condition of pipes in the drinking water network has an influence on energy requirements. Using the newly developed calculation tools for the hydraulic and energetic analysis of pipe sections, it is now possible to identify potential energy savings. Numerical simulations provided optimization approaches for cleaning. With optimized Comprex cleaning, existing savings potential can be exploited. In combination with the calculation tools, newly developed components provide proof of the hydraulic and energy improvements resulting from cleaning. ■

Literature

[1] Klein, N., Immel, S., Kowalczyk, W., Westermaier, S., Plath, M., Kaschulla, D., Fischer, S.: Reinigung 2.0: Energieeinsparung durch geringere Druckverluste in der Wasserverteilung, in: DVGW energie | wasser-praxis, Issue: 11/2016, p. 42-48.

[2] The computing resources for carrying out the simulations were provided by the University of Duisburg-Essen - CCSS mangiTUDE (ZIM) - DFG INST 20876/209-1 20876/243-1 FUGG, University of RWTH Aachen - Compute Cluster - Project <rwth0197>

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