4. discontinuous processes (offline cleaning)

4.7 Flushing procedure (Offline/Online)

Cleaning heat exchangers with the Comprex process

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1. Introduction

This book distinguishes between off-line and on-line cleaning. The process described in the following article can be used both for off-line cleaning and for on-line cleaning of heat exchangers, including supply and return lines. The key question is how the rinsing water contaminated with deposit products can be disposed of. There are other variants between the two types of cleaning. For example, in some systems it may be possible to continue production in throttled operation for a short time if there is reduced heat transfer during cleaning or if parts of the system are taken out of operation for cleaning. Examples illustrate the cleaning procedure. However, they can also be helpful when planning new systems in order to provide for economical cleaning options in good time.

2. The Comprex process: from off-line to on-line

The pulse flushing process originates from pipe network flushing. In this process, a pipe section is taken out of operation, cleaned and put back into operation after microbiological testing. The task here is to restore the pipes to a perfectly hygienic condition. All mobilized deposits must be removed. The turbidity of the rinsing water serves as a criterion for cleaning. The turbidity level can be checked on the sight glass (Figure 1) during cleaning (Figure 2). This application is carried out off-line.

Fig. 1:
Cloudy rinsing water in the sight glass during Comprex cleaning

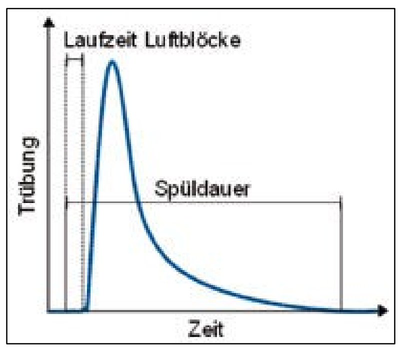

Fig. 2:
Principle turbidity progression during Comprex cleaning

1) Hammann GmbH, D- Annweiler

In recent years, more and more wastewater pressure pipes have been successfully cleaned using the process described below. Wastewater that is stored in basins or tanks upstream of the pumping station is primarily used for cleaning. After the line to be cleaned, the rinsing water relaxes, for example, in the gravity sewer or in the basin of the sewage treatment plant, so that the rinsing water can be disposed of like normal wastewater. The turbidity can serve as a criterion here using comparative samples. This application is an example of on-line cleaning.
Both applications also occur when cleaning heat exchangers. In the chemical industry, reactors are cleaned off-line during downtimes. Comprex is often the only process that can be used here to clean the system economically without very time-consuming dismantling.
One example of the on-line process is the cleaning of plate heat exchangers, which are used in the paper industry to cool wastewater prior to wastewater treatment. In contrast to wastewater pressure pipes, some systems in the control room constantly have measured values for temperature, pressure and flow rate so that cleaning and its effects can even be monitored online.

Some systems, especially in the chemical industry, cannot be taken out of operation between scheduled downtimes to clean clogged heat exchangers. The procedure described here can help here. The following examples serve to explain this. These applications are variants between off-line and on-line cleaning.

- Batching tank
  Heat exchangers with a redundant design are used for temperature control. Some of the heat exchangers can therefore be taken out of operation for a short time and cleaned using the Comprex process. The rinsing water can be pumped into a sedimentation tank to decant the deposits or disposed of via the wastewater treatment plant. As water also flows through the heat exchanger during cleaning, albeit at a reduced rate, the required cooling capacity is available.

- Gas cooler
  In distillation plants in the chemical industry, gas coolers separate condensates from gases. On the cooling water side, substances are deposited in the gas coolers and hinder heat transfer. Cleaning is possible during operation if the production output can be reduced. For safety reasons, an inert gas such as nitrogen is used instead of compressed air. The rinsing water cools during the cleaning process. The cooling capacity is reduced, but still sufficient to maintain production at reduced output.

- Cooling circuits
  Many consumers are integrated in cooling or cold water circuits. Consumers with their heat exchangers and supply lines are often divided into groups. This can be used for cleaning in such a way that these groups are briefly taken out of operation for cleaning while the rest of the production continues. Water and air can be fed in via rinsing inlets on the supply lines and rinsing water can be fed out via rinsing outlets on the return lines. Figure 3 shows a schematic diagram.

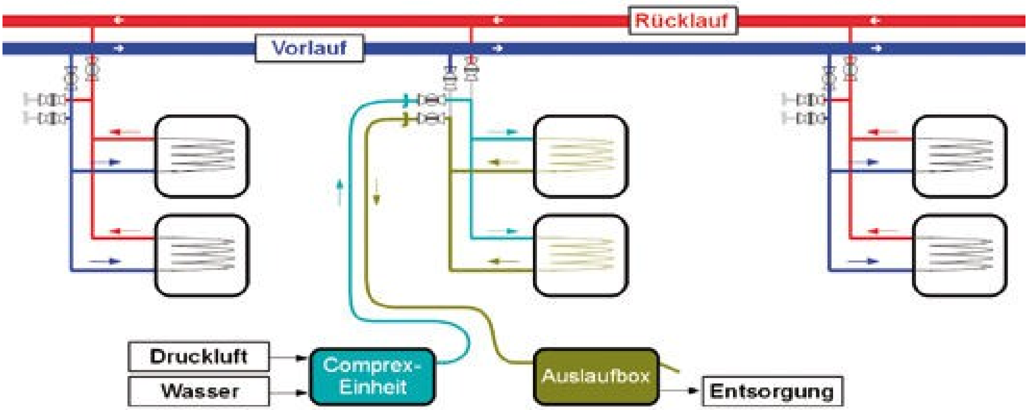

Fig. 3: Cleaning a group in the cooling circuit using the Comprex process

3. Functionality

This pulse flushing process is based on a controlled, pulse-like addition of compressed, filtered air from a Comprex unit into a defined flushing section of a system, shown as a pipe in Figure 4.

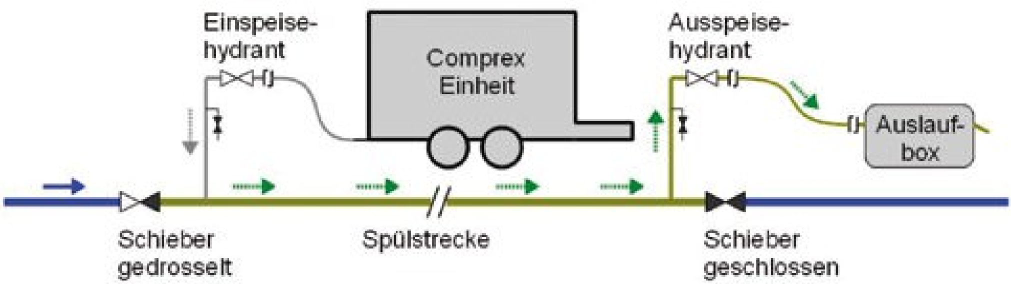

Fig. 4: Principle of the Comprex pulse flushing process

Based on the parameters nominal diameter of the pipe, length and course of the flushing section, pipe network resting pressure, the pipe network pressure is lowered and the impulse pressure of the air is set below the pipe network resting pressure. The air blocks that form at the feed point move alternately with water blocks through the flushing section. Mobilizable deposits are detached from the pipe walls and carried out with the flushing water (Figure 5).

Fig. 5: Mobilizing the deposits with air and water blocks

In contrast to rinsing with water, this cleaning process uses water sparingly and still achieves a more effective cleaning performance thanks to the air pigs [1]. These effects are shown as a model in Figure 6. In contrast to water flushing, where a continuous turbulent flow acts on the impurities and deposits, the flow velocity in the process described here changes depending on the air pulses [2].

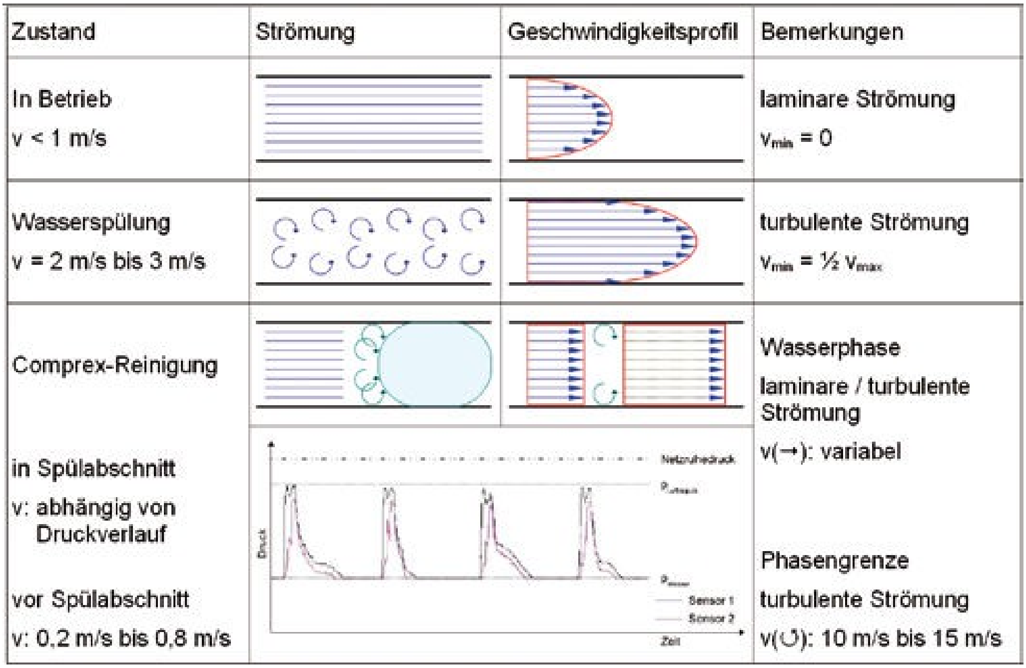

Fig. 6: Model representation during operation, water flushing and Comprex cleaning of a pipe

Figure 6 below shows the pressure curve during a cleaning process [3]. Two pressure sensors positioned at different distances are used to measure the pressures. Due to the buffering effect of air blocks (air pigs) already present in the pipe, the flow velocity of the water blocks changes. The water enters the flushing section at flow velocities < 1 m/s and has a laminar flow. The water blocks are accelerated by air pulses. Vortexes with flow velocities of 10 m/s to 15 m/s form in the water/air/pipe wall boundary areas. The intermittent flow velocities induce an extremely intensive drag stress. The turbulence at the phase boundaries between the water and air blocks continues to cause controlled cavitation. Impurities and deposits are mobilized. Table 1 describes the three phases of Comprex cleaning.

Phase	Work	Remarks
Running-in phase	Inserting the first air blocks	The first air blocks serve as a buffer for subsequent hard-dosed air blocks. blocks during the cleaning phase
Cleaning phase	Cleaning by pulsed setting of air blocks	Empirically determined cleaning programs
Conditioning phase	Purging the residual air from the system or drying the system	Conditioning depending on application, e.g. with cooling water, process water

Table 1: Phases of Comprex cleaning

Air pigs adapt to any geometry and do not get stuck, so that even complex systems such as networks with different nominal widths and branches or plate heat exchangers with flow and return pipes can be cleaned. Existing inlets and outlets can be used for the cleaning process. Adapters to standard connections are sufficient to feed in the air. While pipelines are designed for several bar of pressure, the load limits of heat exchangers are often only a few bar of pressure due to the large surface area for heat transfer. Cleaning processes must therefore also be effective at these low pressure ratios.

Unlike pipes, heat exchangers cannot be calibrated. It was therefore necessary to develop special flushing programs. Adapted to the respective system, it is possible to efficiently clean heat exchangers on both the medium side and the heat transfer medium side. All that is required are adapter connections at the inlet and outlet (Figure 7). Other costly and time-consuming separation points can be omitted, as can the subsequent leak tests of the system. The inlet and outlet of heat exchangers are not far apart. It has therefore proven to be advantageous to flush alternately in and against the flow direction via a changeover station (Figure 7).

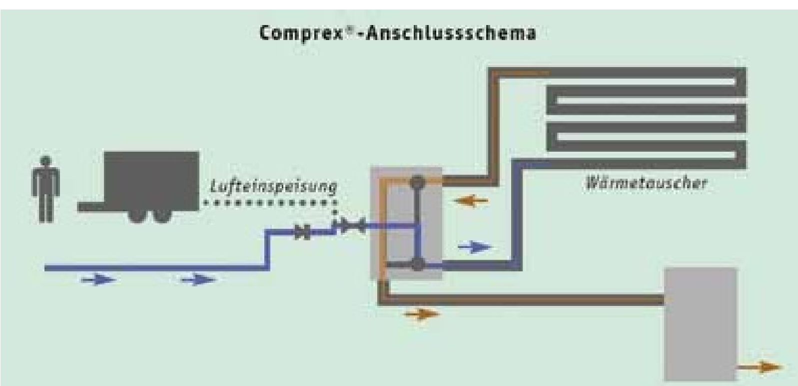

Fig. 7: Cleaning a heat exchanger using the Com- prex method via changeover station

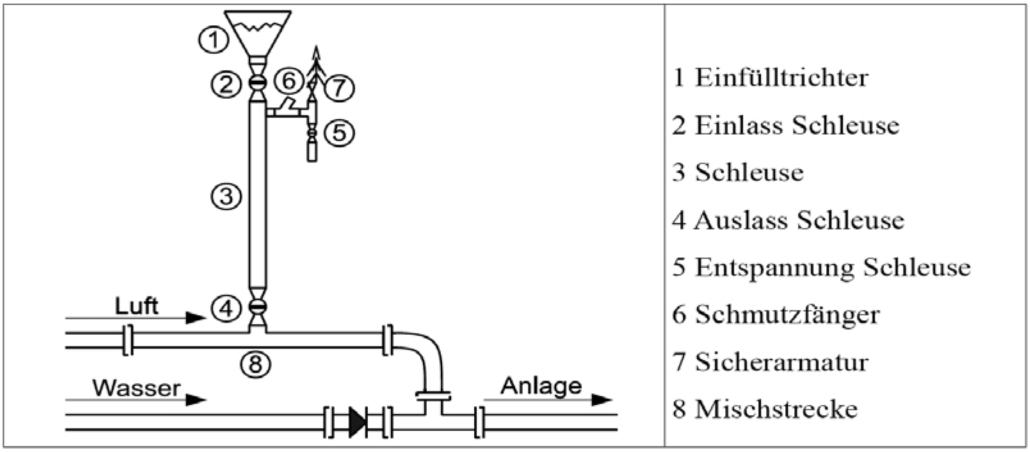

Fig. 8: Unit for introducing solids (solid injection) during Comprex cleaning

An interesting extension of the process is the injection of solids. Selected solids, for example, are injected into the supply line with the compressed air pulses (Figure 8). They have an abrasive effect on solid deposits and increase the effectiveness of the cleaning process.

Solids such as sand, plastic granulate or plastic bodies of various types can be used. In complex systems such as heat exchangers, however, there is a risk that a few parts may remain and impair subsequent operation. Solids that dissolve after a certain time have therefore proven to be advantageous. For example, coarse rock salt has proven effective in mobilizing solid deposits in well pipes or in tubular heat exchangers. Another variant of solid injection is the temporary sealing of areas in shell-and-tube heat exchangers that still have a good flow rate with slowly dissolving substances in order to clean the contaminated areas more intensively (Figure 9).

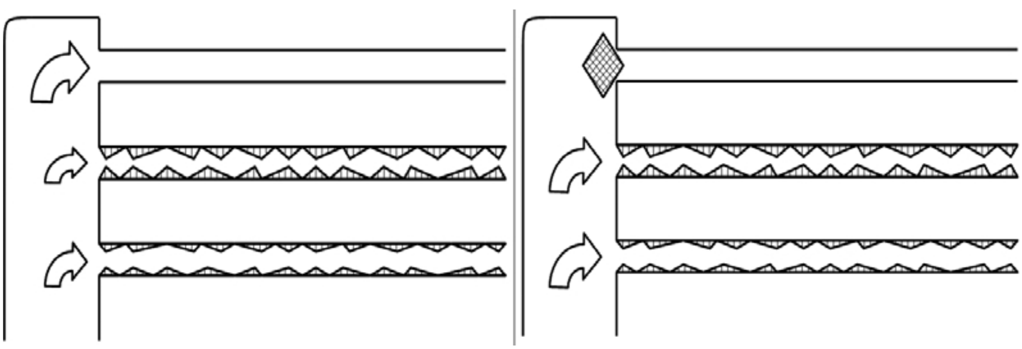

Fig. 9: Temporary sealing with introduced coarse solids for targeted cleaning

The aim is always to carry out cleaning efficiently with as little input material as possible. Table 2 shows a flow chart for Comprex cleaning in combination with solids injection.

Phase	Work	Remarks
Retract	Inserting the first air blocks	Setting up the buffer effect during cleaning
Pre-cleaning	Comprex cleaning	Mobilize easily adhering deposits
Intensive cleaning	Comprex cleaning + Solid injection	Mobilize firmly adhering deposits, Cleaning areas with poor flow
Post-cleaning	Comprex cleaning	Discharge of solid residues
Conditioning	Purging the residual air from the system or drying the system	Depending on application

Table 2: Flow chart for Comprex cleaning in combination with solid injection

4. Procedure

The tasks in the industrial sector are diverse. For complex systems, such as cooling circuits with many consumers, the procedure illustrated in Table 3 has proven its worth.

Procedure	Work	Remarks
Preliminary planning	Determining the flushing sections with feed-in and feed-out points and any conversion measures for adapter connections	Organization of sample cleaning during a plant shutdown or in the operational process of an installation
Sample cleaning	Adjusting the cleaning parameters to the system, optimizing the cleaning process	Checking cleaning performance, checking time requirements, organizing basic cleaning
Basic cleaning	Mobilization and removal of deposits	Verification of cleaning performance, verification of time requirements

Table 3: Procedure for Comprex cleaning of complex systems

Since in most cases the operating conditions do not change after the basic cleaning, regular maintenance cleaning must be scheduled. For economic reasons, the time interval between cleaning actions and the amount of work required for cleaning must be weighed up. For recurring maintenance cleaning, it is advantageous to permanently install suitable entry and exit points and, if necessary, other devices such as enclosures. This reduces the amount of work required before and after the actual cleaning.

5. Application examples

Examples are used to illustrate the areas of application of the Comprex process. After describing specific problems, measures show how the Comprex method can be used effectively to clean heat exchangers and supply and return pipes. New fields of application for the Comprex process are constantly emerging in the industrial sector. The examples described here show the current status and are intended as suggestions for further possible applications.

5.1 Shell and tube heat exchanger

5.1.1 Problem definition

Tubular heat exchangers are used as reactors in the chemical industry. Certain reactions only take place at a few hundred degrees. Steam is used to supply heat, which - directed via the shell tube of the tubular heat exchanger - starts the reaction of the reaction mixture in the inner tube and allows it to take place in a controlled manner. Over time, deposits grow on the separating wall between the inner and outer tube, increasing the heat transfer resistance and thus the energy requirement. The deposits must be reliably removed during regular maintenance work. In the past, this was only possible after dismantling the system parts. After cleaning, the parts had to be reassembled with the help of expensive special seals.

5.1.2 Problem solution

Cleaning using the process shown here only requires adapter connections at the inlet and outlet of the heat exchanger. As shown in Fig. 7, it is advantageous to flush in and against the flow direction with coordinated flushing programs. Heat exchangers connected in series can be cleaned together in some cases. If the heat exchangers are designed for high pressures, it is possible to use the water pressure specified by the existing network in order to intensify cleaning with a corresponding increase in compressed air. In the meantime, there is also experience of using solid injection to increase the cleaning work.

5.2 Spiral heat exchanger

5.2.1 Problem definition

Spiral heat exchangers are often used in industry as coolers. Well or river water, for example, is used for heat dissipation. These cooling waters deposit deposits on the surface of the heat exchanger. In the case of well water, this is iron or manganese sludge. In the case of river water, layers of turbidity and biofilm form. Up to now, the deposits have mainly been removed using chemical cleaning agents. The contaminated rinsing water had to be disposed of properly.

5.2.2 Problem solution

Cleaning using the process described is characterized by the fact that it removes the deposits in a short time without the need for additional aids. The rinsing water can be disposed of via the sewer after the removed solids have settled in decanting tanks or containers. The deposited solids are of natural origin and therefore easy to dispose of.

In many cases, it is possible to clean the spiral heat exchangers together with the supply and return lines (Figure 7). This is another advantage of Comprex cleaning. As air pigs adapt to the nominal diameter of the pipes and heat exchangers, even in complex systems several spiral heat exchangers can be flushed one after the other by controlling the shut-off valves without loosening the connections.

5.3 Plate heat exchanger

5.3.1 Problem definition

Plate heat exchangers are often used in industry in either welded or bolted form. They are often designed for low pressures. Various cleaning methods have been used to date. Chemical cleaning agents are normally used. In the bolted form, the partition walls can be dismantled and sometimes cleaned with high pressure. If refrigerants such as ammonia are used in plate coolers, the corresponding chambers must be dry after cleaning, which in turn means extra work.

5.3.2 Problem solution

The Comprex process can also work at low pressures [3]. It is important to ensure that the pressure permitted in the heat exchanger is not exceeded. The flushing program must be adapted accordingly. It has been shown in many cases that deposits can be effectively removed from well and river water.

5.4 Cooling water pipe in closed circuit

5.4.1 Problem definition

Cooling circuits often contain components made of different materials. While the main lines in larger nominal diameters are mainly made of welded steel pipes, the distribution lines contain components made of other materials, such as stainless steel or copper pipes and brass or gunmetal fittings. The heat exchangers are normally made of stainless steel.

The cooling water in industrial cooling circuits is often treated well water and contains corrosion inhibitors. The temperatures vary depending on the application, but are often between 10°C and 30°C. The pressure can be kept constant via expansion tanks. If necessary, treated water is added. In many places, important parameters such as temperature, pressure and flow rate are monitored at machines and other important points.

In terms of the behavior of the materials towards the cooling water, closed cooling circuits are comparable to heating circuits in buildings. Corrosion products form during operation. The water in steel pipes is often greenish or contains black turbidity caused by divalent iron ions. After taking water samples, the color changes the color on contact with air. The divalent iron ions oxidize to form brown trivalent and poorly soluble iron compounds.

Corrosion products can impair the function of cooling circuits. As deposits on the heat exchangers, they restrict heat transfer and as plugs they block critical supply lines. Filters are of little help. They reduce the volume flow with the load and are difficult to clean in closed circuits.

5.4.2 Measures

Corrosion cannot be completely avoided in closed cooling circuits, but measures can be taken to significantly reduce the processes. For example, certain treatment substances with a biocidal effect reduce microbiological corrosion. The use of gas-tight materials in components and connections reduces the corrosion rate due to oxygen permeation. Certain plastic parts, rubber seals or rubber hoses should be viewed critically.

As the risk of corrosion cannot be ruled out in practice, cleaning measures are required for the maintenance and, if necessary, upgrading of the cooling water pipes. The Comprex process has proven its worth in this application and enables cleaning at fixed intervals, for example during maintenance work on the units or also during the cleaning of the cooling water pipes. if necessary, whereby the necessity and urgency of the cleaning measure can be recognized by checking the temperature, pressure and flow rate.

Fig. 10: Rinsing water discharge via rinsing boxes during Comprex cleaning of DN 250 supply and return pipes

This process can be used to clean the main pipes first (Figure 10) and then the distribution pipes and finally the heat exchangers quickly and effectively. Coordinated flushing programs are used for these applications. Work instructions are provided if required.

Sampling during flushing provides information on the type and quantity of turbidity and deposits. Further investigations of the samples aim to determine their composition and obtain information on necessary water treatment or remediation measures.

5.5 Cooling water pipe in open circuit

5.5.1 Problem definition

In contrast to closed cooling circuits, cooling towers in open circuits allow the entry of atmospheric oxygen, dust and other particles. The consequences are corrosion and the proliferation of microorganisms. Finally, deposits and biofilms impair the function of the systems and the emission of microorganisms into the environment.

5.5.2 Measures

As with closed cooling circuits, these processes cannot be completely avoided. Although they can be significantly reduced by treatment measures and controlled by modern analysis methods, e.g. on the basis of bioluminescence [4], cleaning measures are necessary at some point. While the cooling towers are accessible for these measures, the pipelines require other cleaning strategies. The process described here offers decisive advantages here. In addition to mobilizing and removing the deposits and biofilms from the supply and return lines to the cooling tower, areas with poor flow, for example at shut-off valves, can also be cleaned. The air pigs do not get stuck in the pipes. The entrained solids can be collected, the microorganisms from the exhaust air can be retained by filtering and disposed of properly.

6. Conclusion

The Comprex process offers new possibilities for efficiently cleaning both heat exchangers and the associated pipework. All that is required are adapter connections at the inlet and outlet. Other costly and time-consuming disassembly and assembly work can be omitted, as can the subsequent leak tests of the system. The cleaning process is not only applicable off-line. Some systems also allow cleaning to be carried out on-line or at least only parts of the system can be taken out of operation for cleaning [5].

The diverse applications in the industrial sector sometimes require adjustments to the process. For example, heat exchangers with supply and return lines in production lines with nominal diameters smaller than DN 80 require small and flexible Comprex units in order to be able to carry out cleaning in a given time window. If cleaning is required very frequently, adapted small stationary units can be used.

The application examples described show possible uses of the Comprex process
on. Further information on the process in the industrial sector can be found in [6].

Literature

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