Proceedings of International Conference on Heat Exchanger Fouling and Cleaning - 2015 (Peer-reviewed)
June 07 - 12, 2015, Enfield (Dublin), Ireland
Editors: M.R. Malayeri, H. Müller-Steinhagen and A.P. Watkinson

# MECHANICAL CLEANING IN PLACE OF HEAT EXCHANGERS USING THE COMPREX® PROCESS

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## ABSTRACT

The impulse flushing process Comprex® originates from pipe flushing in water distribution networks. In this process, a section of the piping is shut-off and cleaned by water and air blocks of high velocity without any chemicals. The same process allows cleaning technical equipment in industrial systems like heat exchangers including flow and return pipes without disassembling the system.

From economic point of view Comprex® is an efficient method to rehabilitate the heat transfer capacity by removing and discharging deposits.

This paper will describe the basic principle of the Comprex® process and some typical applications in industry from municipal water systems to different types of heat exchangers and other technical equipment. The focus will be laid on the presentation of an ongoing collaborative research project, which investigates the in-situ application of the Comprex® cleaning method to plate heat exchangers in the process industry. Promising results for the cleaning of biofilms and mineral deposits, as appearing in cooling water systems, show the potential of this cleaning technology.

## INTRODUCTION

During operation of technical water systems, deposits are formed by fouling processes according to the specific conditions of the system. Examples for these processes are crystallization fouling, particulate fouling and biofouling, see Müller-Steinhagen 2011. On the one hand, fouling affects hydraulic conditions. As cross sections are reduced, pressure drop and energy demand for pumping increase (Fig. 1). On the other hand, heat transfer performance of heat exchangers decreases due to deposits (Fig. 2). This correspondingly results in higher cost to maintain the system due to low in performance efficiency.

There are several methods to remove deposits formed due to fouling processes. For cleaning plate heat exchangers, chemical cleaning in place (CIP) is typically used in industry. Another common option is mechanical cleaning using high pressure cleaners after disassembling the heat exchanger. But these methods produce produce either chemical waste or require complex & time consuming procedures. Cleaning plate heat exchangers using the Comprex® process, both of these disadvantages can be avoided.

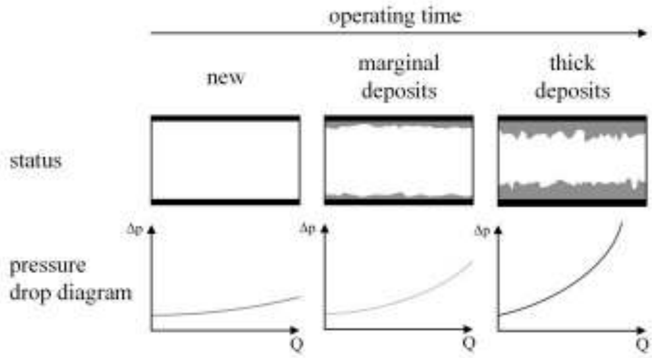

Fig. 1 Correlation between operating time, deposits and hydraulics using pressure drop.

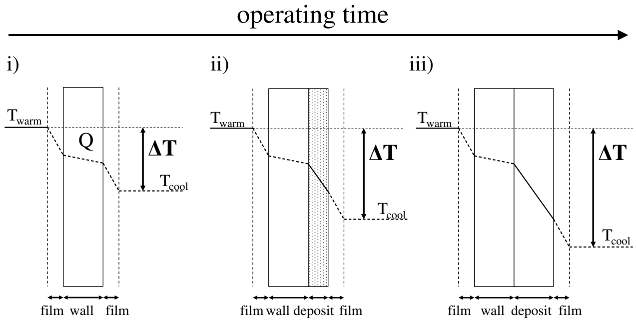

Fig. 2 Correlation between operating time, fouling and heat transfer: i) no deposits, ii) marginal deposits and iii) thick deposits.

### Principle of the Comprex® process

The Comprex® process is used for cleaning potable water pipe systems for nearly two decades. In this process, water and compressed air are used for cleaning, see Kuschnerow, 2015. Fig. 3 illustrates this process. During cleaning the Comprex® unit produces, controls and injects purified compressed air into the system. In special cases an inert gas like nitrogen can be used, e.g. to prevent an explosion hazard. Gas and water are injected into the system via adapters and hoses in defined quantities. During cleaning, the remaining parts of the system are isolated by closed valves.

Expansion of compressed air in the system effects an acceleration of water blocks, which pass the system with high velocity. Typical velocities found in piping systems are about 15 to 20 m/s. This high flow velocity results in removal of fouling material of the system using high shear forces. After passing the system, water containing mobilized deposits is discharged via adapters, hoses and a special discharge unit. Frequently discharged water can be treated by sedimentation of deposits in a tank. In special cases the Comprex® process can even be applied online while continuing operation of the system, e.g. for cleaning municipal water pipelines, see Immel 2014. The pressure of the impulses is kept below the pressure of operation of the pipe of heat exchanger.

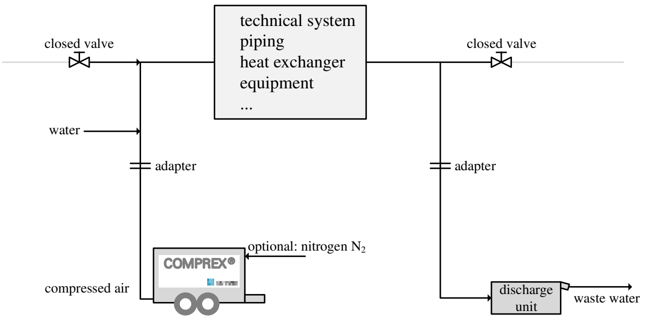

Fig. 3 Basic principle of the Comprex® process in technical systems using water and compressed air or nitrogen.

### Cleaning strategies

There are several possible cleaning strategies to maintain technical systems. Typically three cleaning strategies are employed:

i) preventive cleaning,
ii) cleaning based on the actual condition of the system,
iii) cleaning due to breakdown.

In many cases cleaning based on the actual condition of the system using indicator parameters is the most efficient strategy. But complex and time-consuming cleaning methods which come along with disassembling the system are difficult to handle and expensive. Hence, cleaning activities are often delayed until damage occurs.

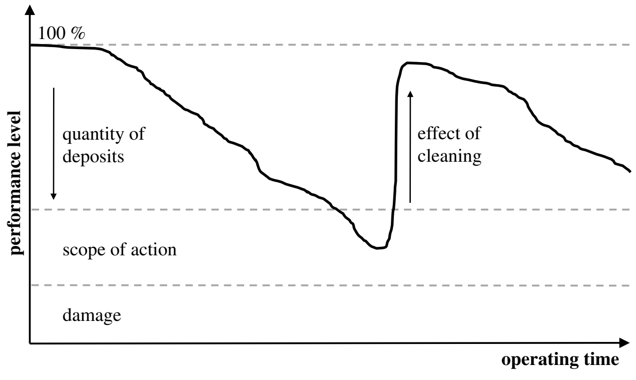

Fig. 4 Cleaning strategy based on the actual condition of the technical system.

Cleaning a system using the Comprex® process, it is possible to keep all system parts in place. There is no necessity to disassemble the system. Shutdown times can be minimized. With this process, it is efficient to clean systems preventatively or according to the actual conditions. Fig. 4 shows a cleaning cycle of a technical system based on the actual condition of the system. First due to fouling the performance level decreases during operating time until a defined performance level is reached. Continuing operation of the system would result in damage. By a short-time cleaning of the system, the performance level can be restored close to the reference value.

### Research project “WÄRMER”

This paper presents first results of an ongoing collaborative research project called “WÄRMER”, see “WÄRMER-website”. This project investigates the cleaning of plate heat exchangers in the process industry aiming on the development of a service package for cleaning plate heat exchangers in place without any chemicals. Co-operation partners are the Institute for Chemical and Thermal Process Engineering, TU Braunschweig (www.ictv.tu-bs.de), the IWW water centre, Mülheim (www.iww-online.de) and the Hammann GmbH, Annweiler. The research project is promoted by the German Federal Ministry for Economic Affairs and Energy.

## EXPERIMENTAL SETUP AND PROCEDURE

### Experimental plate heat exchanger

For experimental evaluation, a gasketed plate heat exchangers (model: GEA Ecoflex® NT 25 M CDS-16) are used. These heat exchangers have a maximum working design pressure of 10 bar. Fig. 5 shows a photograph of the experimental heat exchanger. Using this standard type of gasketed plate heat exchanger brings numerous advantages. The heat exchanger is easy to handle due to its size and weight. As the heat exchanger can be simply disassembled, the cleaning efficiency can be evaluated by visual control of plates. Furthermore the modular design allows variation of plate number and blocking degree.

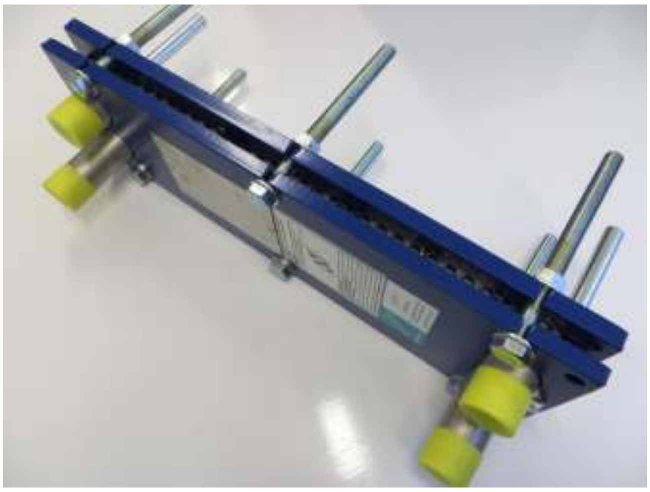

Fig. 5 Gasketed plate heat exchanger for experimental use.

### Testing plant for experimental purpose

To realize cleaning and optimization experiments, a custom-built testing plant was developed. Fig. 6 shows a simplified scheme of the testing plant. A picture of the constructed testing plant is illustrated in Fig. 7. The testing plant allows cleaning experiments using experimental heat exchangers of different sizes. Flow direction and Comprex® parameters can be varied by newly developed software. Sensors monitor the pressures of the inlet and outlet of the heat exchanger and volumetric flow rate. The inlet of compressed air is indicated ("air"). Pressure is delivered in bar with an uncertainty of ± 0,1 bar. Volumetric Flow is delivered in Litre per min with an uncertainty of 0,1 L/min. All experiments are done at room temperature.

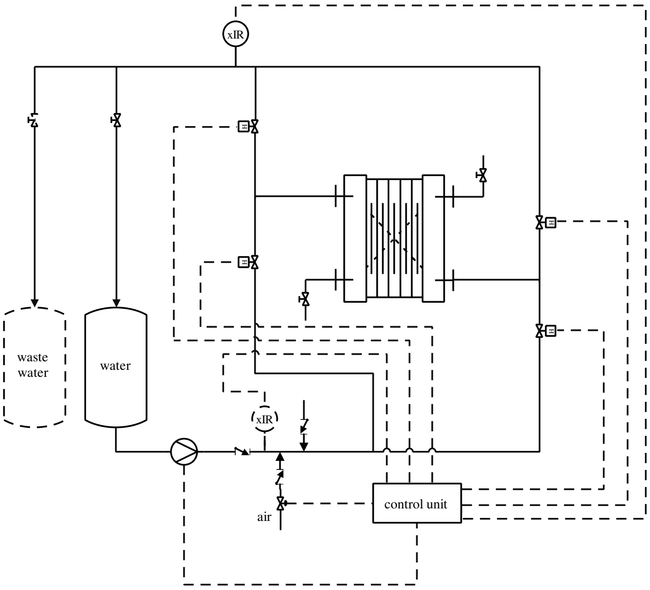

Fig. 6 Simplified flow diagram of the testing plant for the experimental cleaning of plate heat exchangers.

Fig. 7 Testing plant for cleaning plate heat exchangers.

### Model deposits and configurations

There are multiple requirements for model deposits to replicate real deposits occurring in heat exchangers. This include: should be easy to produce and to handle, mechanically stable (adhesion, cohesion and hardness), reproducible concerning composition (water content, organic matter), non-hazardous to prevent waste problems and able to be discharged.

Taking all these aspects into consideration, several model deposits were produced and tested. The model deposits consisted of clay, gypsum, gelatin and water in different contents. The properties of these model deposits were first tested by simple methods based on the experience gained in in water piping systems to estimate the cleaning efficiency (Fig. 8). Further analytics of the model deposits will be realized in the next step.

Fig. 8 Removal of model deposit by simple finger test.

To investigate geometrical effects on cleaning efficiency, different deposit geometries can be realized on plates of the experimental heat exchanger. Fig. 9 illustrates some examples for geometrical structures on heat exchanger plates. Fouling layers with a thickness of 3 mm are indicated in dark grey, and with a thickness of 1 mm in light grey.

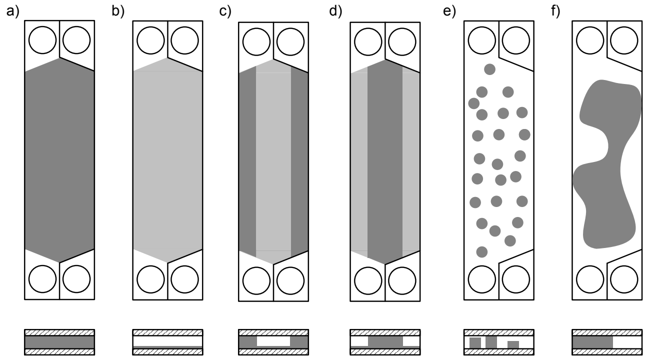

Fig. 9 Different types of deposit geometries on plates of the experimental heat exchanger.

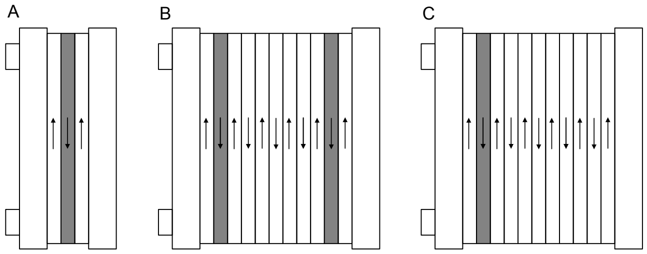

Fig. 10 Different plate configurations with charged plates (Fig. 9) in the experimental plate heat exchanger.

Another option for variation is the plate configuration, which means the amount of plates and the location of the charged plates inside the heat exchanger. Some plate configurations are shown in Fig. 10. Case A uses four plates to realize only one charged cross section within the heat exchanger while case B and C result in multiple parallel charged cross sections. By varying location and amount of charged plates, different blocking degrees can be simulated.

## RESULTS AND DISCUSSION

### Model deposits and configurations

Developing a reproducible model deposit was one of the very first steps on investigation of cleaning plate heat exchangers. Different model systems were tested. Table 1 shows qualitative properties of different model deposits formed of clay, gypsum, gelatin and water.

Table 1 Qualitative properties of different model deposits for heat exchanger fouling. (below average: - average: O above average: +)

| model deposit | adhesion | cohesion | hardness |
|---|---|---|---|
| clay-water | - | - | O |
| clay-gypsum-water | - | O | + |
| gelatin-water | O | + | O |
| clay-gelatin-water | + | O | O |

As a result of examining different model deposits, clay-gelatin-water-mixtures showed the best compliance to typical soft deposits found in heat exchangers running with untreated river water. These mixtures are easy to produce and reproduce, easy to handle and show good adhesion and cohesion. The material is non-hazardous and easily disposable. It is insoluble in cold water and stable in water flow but dischargeable by hot water.

### Cleaning experiments using model deposits

An example for the cleaning experiments using the developed model deposits is shown in Fig. 11. For this experiment the plate was charged with deposits using the geometry shown in Fig. 9 c). The plate was placed in the heat exchanger using the configuration according to Fig. 10 A. The first picture (Fig. 11a) shows the charged plate with deposits before cleaning. On the outside of the plate, thick deposits are visible which block nearly two thirds of the cross section. The second picture (Fig. 11b) was taken after a Comprex® cleaning phase using standard settings. After this standard cleaning, just a thin layer of deposits is remaining on the plate. The third picture (Fig. 11c) was taken after an additional Comprex® cleaning phase using optimized settings. As potential customers have different expectations on cleanliness of heat exchangers, it is necessary to figure out the best cleaning performance which can be reached without dismantling the plant. The amount of remaining deposits on the plate could be reduced significantly. As evident in these photographs, the potential of the Comprex® cleaning system is clearly visible. Further optimization experiments will be realized during the ongoing research project “WÄRMER”.

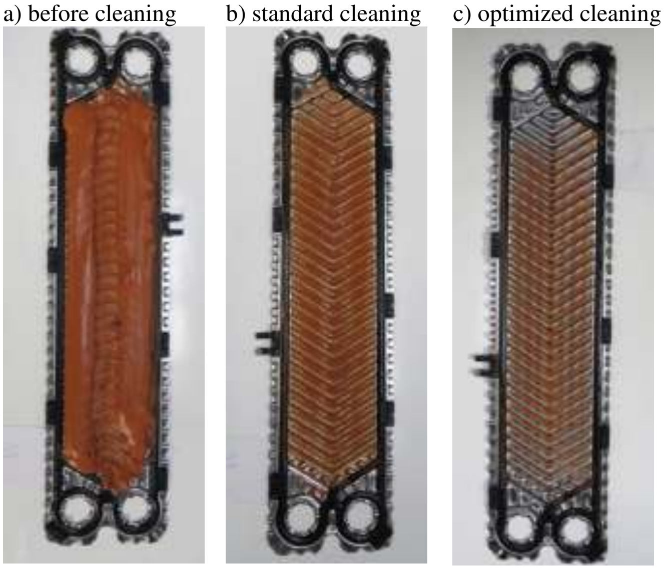
a) before cleaning b) standard cleaning c) optimized cleaning

Fig. 11 The effect of cleaning a gasketed plate heat exchanger with standard Comprex® and optimized Comprex®.

### Cleaning experiments using real deposits

Another example shows the effect of cleaning a welded plate heat exchanger taken from a real world system charged with real deposits. These heat exchangers are of a size which is similar to our laboratory equipment. Investigations on heat exchangers of industrial size are described in the next section. As it is a welded plate heat exchanger, disassembling the plates was not possible. For this reason, only a visual control at the feed inlet was possible combined with hydraulic measurements of the heat exchanger to determine the effectiveness of cleaning. Fig. 12 shows the effect of cleaning on the basis of visual control at the feed. Efficiency is defined as the maximal cleaning performance realized by the lowest effort (time, number of impulses…).

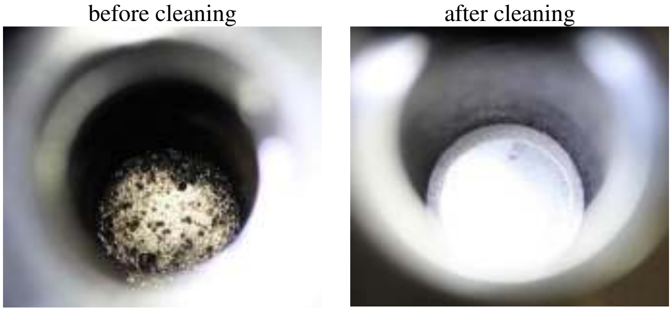
before cleaning
after cleaning

Fig. 12 The effect of cleaning a welded plate heat exchanger with Comprex® on the basis of visual control at the feed of the heat exchanger: before cleaning (left) and after cleaning (right).

Fig. 13 illustrates hydraulic properties of the welded plate heat exchanger. Pressure drop diagrams were measured before and after cleaning with Comprex®. At a volume flow rate of approx. 3.5 m3/h the pressure drop reached more than 0.7 bar before cleaning. After cleaning, the pressure drop at the same volumetric flow rate was reduced to approximately 0.35 bar. circa an almost 50% reduction in the pressure drop. Combined with visual control, this shows the significant effect of cleaning the heat exchanger using Comprex®.

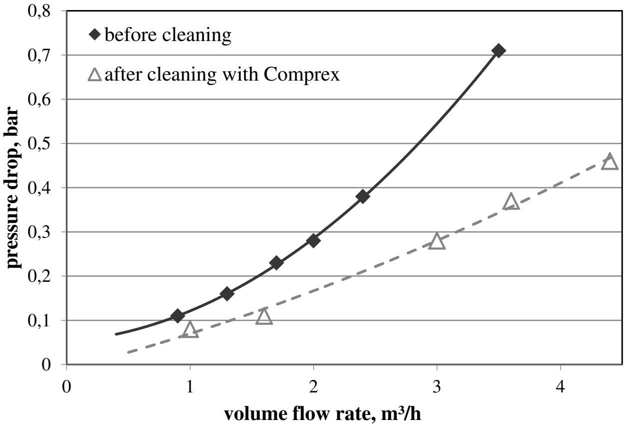

Fig. 13 The effect of cleaning a welded plate heat exchanger with Comprex® on the basis of pressure drop.

## APPLICATION EXAMPLES

There are many possible application of the Comprex® process in technical systems. Basic requirement for applying the Comprex® process are simple adapters for connection to the system (Fig. 14). As these connectors exist, cleaning the system using Comprex® is usually easy to handle. This section will deal with three application examples of Comprex® in the field of cleaning heat exchangers.

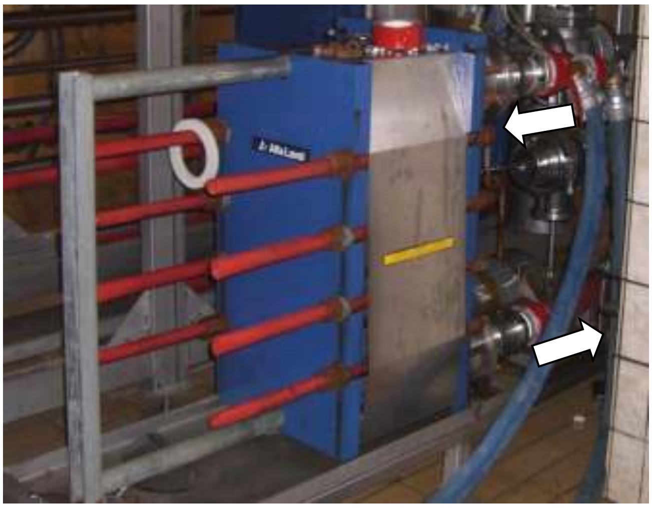

Fig. 14 Example for cleaning in place of a gasketed plate heat exchanger using the Comprex® process: water and air feed at the top; waste water and air outlet at the bottom of the heat exchanger.

**Example 1: steel work**

Steel works use large heat exchanger cells for cooling the furnace. In these heat exchanger cells, fouling and corrosion products reduce volumetric flow of the cooling medium and heat transfer performance. For this reason, the cells are shut down and cleaned at frequent intervals however the time frame for maintenance is very short.

By cleaning the cooling plant using the Comprex® process, the time for cleaning can be relatively short. The Comprex® process needs simple adapters as connection to the system (Fig. 15). Water needed for cleaning can easily be supplied externally. The compressed air is produced and injected by the Comprex® unit. A specially designed discharge unit is used at the outlet of waste water and discharged deposits.

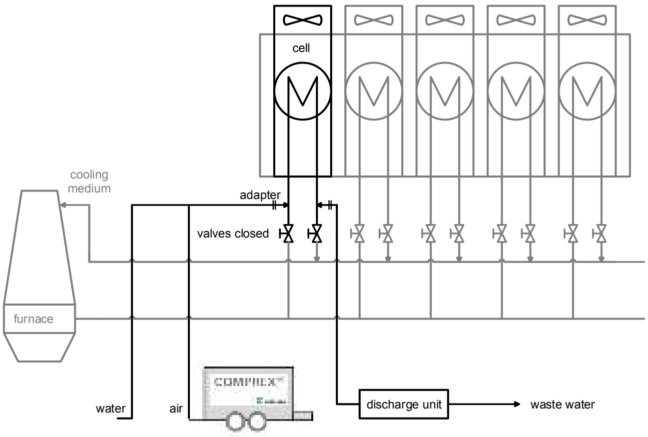

Fig. 15 Procedure of cleaning a cooling plant consisting of several cells in a steel work.

Turbidity of waste water at the point of discharge is used as indicator for the efficiency of cleaning. During cleaning, the specific cleaning parameters (e.g. length and pressure of impulses …) of the Comprex® process are varied depending on the turbidity. The total time for cleaning one heat exchanger cell consisting of four heat exchangers is about 10 hours. Fig. 16 shows the result of cleaning by means of the coarse particles within the discharge unit.

Fig. 16 Discharged fouling material in discharge unit (left) and in detail (right).

**Example 2: petrochemical plant**

This example shows the special case of cleaning a heat exchanger online without shutting down the plant. The valves have been kept open and the water flow of the process is used for the cleaning procedure. It is a large shell and tube heat exchanger in a petrochemical process with a length of about 5 m and a diameter of about 1 m. The reason for cleaning is a strong drawback of thermal performance due to fouling. A system shut down is not viable. Fig. 17 shows the procedure of cleaning the shell and tube heat exchanger online.

To realize the online cleaning of the heat exchanger, control of system parameters like temperature, pressure and mass flow are essential. To prevent system damage, the Comprex® cleaning is regulated due to the system reaction in collaboration with the operator of the plant. That means the cleaning intensity is adjusted according to the behavior of system parameters, especially temperature. For explosion hazard reasons, the cleaning is realized with an inert gas instead of air, in this case nitrogen is used.

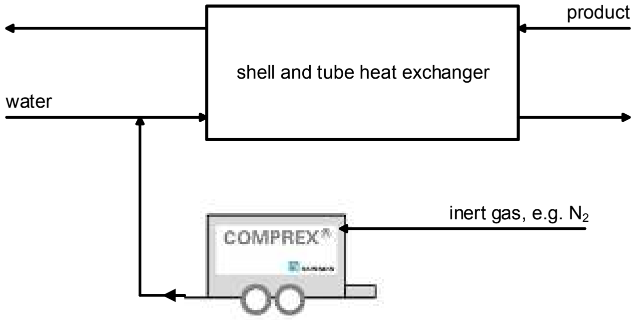

Fig. 17 Scheme of online cleaning a shell and tube heat exchanger in a petrochemical process.

Mass flow and temperature difference as a function of time is shown in Fig. 18. The Comprex® phases are clearly visible, as the mass flow fluctuates during cleaning. This fluctuation is caused by the simultaneous presence of water and air which disturbs the measurement. Simultaneously the temperature difference increases due to increased heat transfer performance by discharged deposits. The temperature difference increases from 9 K to 14 K during Comprex® cleaning while mass flow does not change. That means the heat transfer performance of the shell and tube heat exchanger is increased by 44 % as result of Comprex® cleaning. The waste water is discharged in the waste water system of the customer.

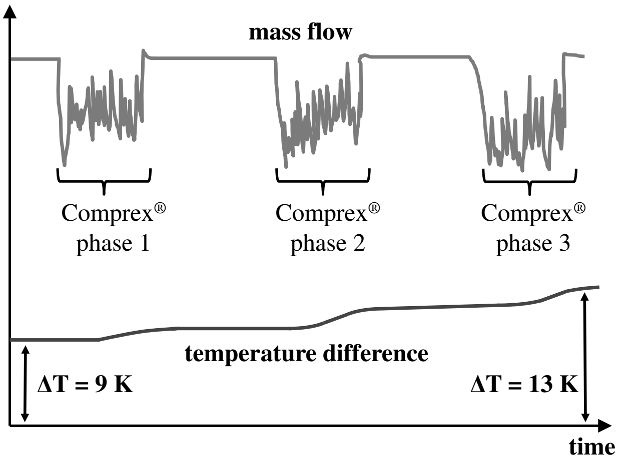

Fig. 18 Mass flow and temperature difference of process water vs. time during online cleaning using the Comprex® process.

**Example 3: biogas treatment**

To supply biogas into gas distribution networks the raw gas needs to be treated by certain processes. One of these processes is the amine gas treatment to remove carbon dioxide and hydrogen sulfide. In this process a special shell and plate heat exchanger is used to heat amine solution (Fig. 19).

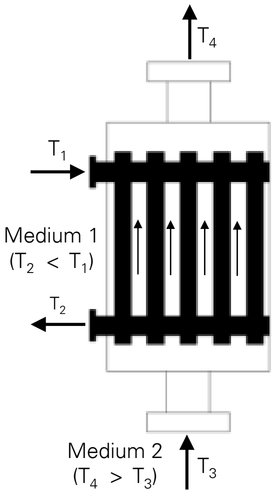

Fig. 19 Sketch of shell and plate heat exchanger.

Fouling on the “amine side” results in a strong drawback of thermal performance. For this reason it is necessary to clean the heat exchanger during regular shutdown of the plant. In order to connect Comprex® equipment to the system two adapters are used (Fig. 20). The remaining system is separated by closing valves. Water supply for cleaning is realized with a well close to the plant.

During Comprex® cleaning fouling material is mobilized and discharged. The thermal performance of the heat exchanger was optimized, energy efficiency was increased and altogether process safety was ensured.

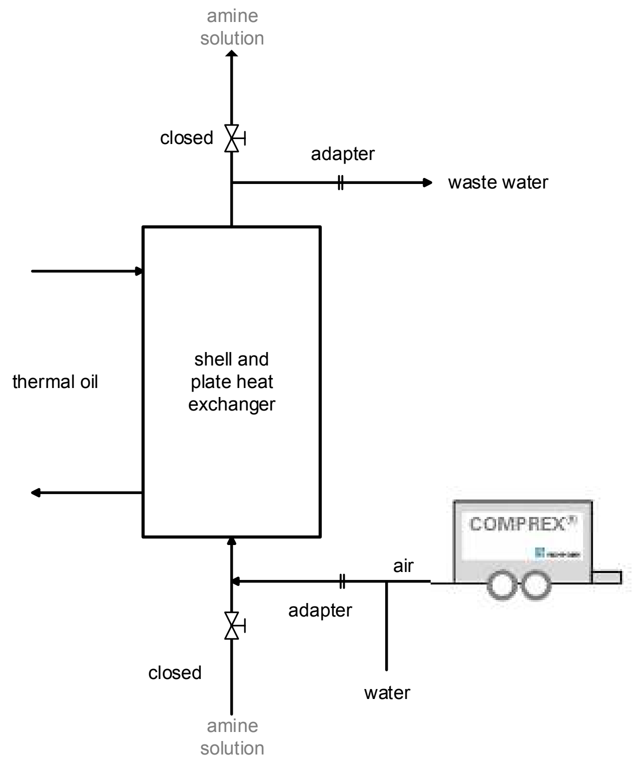

Fig. 20 Scheme of cleaning a shell & plate heat exchanger using the Comprex® process.

## CONCLUSIONS

The Comprex® process is an innovative method for mechanical cleaning of heat exchangers in the process industry without disassembling the heat exchanger. Comprex® can be applied to different types of heat exchangers. This paper presents first results of an ongoing collaborative research project called “WÄRMER” using the Comprex® process which has demonstrated the improved efficiency of this type of cleaning method.

## ACKNOWLEDGEMENTS

The authors acknowledges the Federal Ministry of Economic Affairs and Energy (BMWi) for funding within the scope of the Central Innovation Programme for SMEs (ZIM).

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

## NOMENCLATURE

| | |
|---|---|
| A | area, m² |
| $\Delta p$ | Pressure drop, bar |
| n | number, dimensionless |
| p | pressure, bar |
| Q | volume flow rate, $m^3 h^{-1}$ |
| t | time, s |
| T | temperature, K |
| $\Delta T$ | temperature difference, K |

### Subscript

| | |
|---|---|
| cool | cold side |
| v | volume |
| warm | warm side |

## REFERENCES

Müller-Steinhagen, H., 2011, Heat Exchanger Fouling – Mitigation and Cleaning Technologies, 2., revised and enlarged edition, *PP Publico Publications*, ISBN 3-934736-20-3

Immel, S., Schimmelpfennig, S., Klein, N., Utke, C. and Gnirss, R., 2014, Brunnengalerien und Rohwasserleitungen online reinigen, *wwt wasserwirtschaft wassertechnik*, 01-02/2014, pp. 15-19.

Website of research projekt „WÄRMER“: http://www.comprex.de/waermer

Website of Institute for Chemical and Thermal process Engineering (ICTV), TU Braunschweig: http://www.ictv.tu-bs.de

Website of IWW Water Centre, Mülheim; http://www.iww-online.de

Kuschnerow, J.C., Immel, S., Klein, N. and Hammann H.-G., 2015, Energieeffizienz durch gezielte Reinigung von Wärmeübertragern und Kühlkreisläufen, *Wümek Kongress Würzburg 2015*.