

VI. Preventive Measures for Mitigation of Fouling for Compact Heat Exchangers

VI.2 Filtration/Micro Filtration

Eliminating Contamination Problems in Processes and shortening maintenance Loops in Plate and Tube Bundle Heat Exchangers

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1. 200 μ mainstream filtration at a rate of up to 10,000 m³/h using wedge wire filter tubes – preventing impurity in heat exchangers

1.1 200 μ mainstream filtration with automatic KAF Bernoulli filters

Automatic self-cleaning process filters with continuous filtration

Industrial procedures and processes require clean water or process liquids that are free of solids and contaminants. Open water systems place particularly high demands on filtration in terms of separation quality and process safety under continuous operating conditions.

The filter described here operates on the Bernoulli principle, which is well-known in the field of hydromechanics. Over 250 years after the physical processes were discovered by Daniel Bernoulli (1700 – 1782), his discovery is being utilized in the filtration process used in systems under continuous operation.

However, ever increasing importance as an effect of the filter system described here is being attributed to the discovery that not only particles and contaminants are captured and filtered out from a specific slot width/filtration level upwards, but also that mussel and snail larvae that are smaller than the slot width are destroyed, thus significantly reducing their population.

The automatic filter operating on the Bernoulli principle is distinguished by its simple, compact design and can be installed in any mounting position. Using corrosion-resistant materials ensures reliability, minimal maintenance costs and a high level of plant safety, even in salt water systems or when corrosive media are used.

1) Krone Filtertechnik, D- Bremen

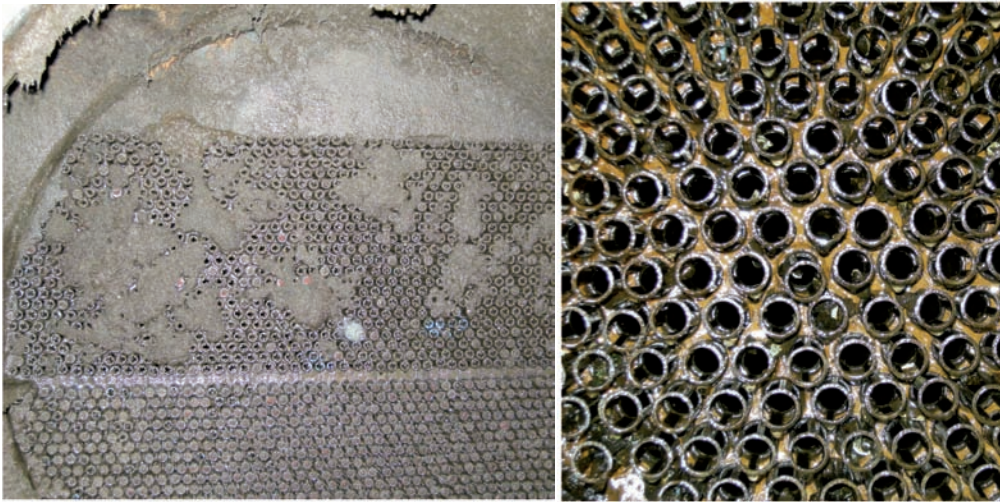


Fig. 1: Operation without filter

Fig. 2: Operation with 300 μ filtration

Acknowledgement:

Fig. 1: Tube bundle - blockages and fouling - inspection/cleaning required every 3 months

Fig. 2: same tube bundle heat exchanger with filter located after the inspection hole – no cleaning required

1.2 Improving heat transfer in plate and tube bundle heat exchangers

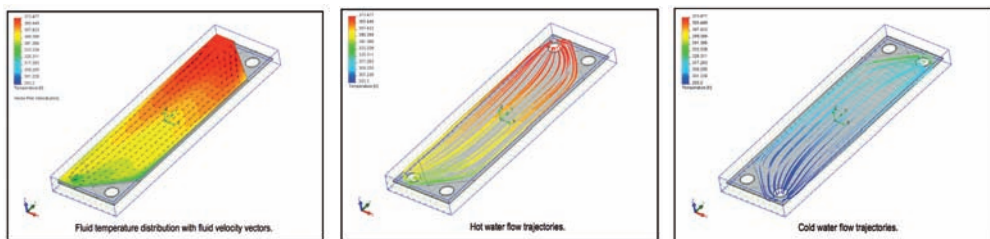


Fig. 3: Evaluating heat transfer coefficients

Evaluation of the durability of heat exchanger systems utilizing a filter system with filtration steps from 1 mm - 500 μ shows that the performance of these systems over time is significantly better than that of unprotected systems. The filter system pays for itself very quickly due to considerably reduced maintenance requirements.



Fig. 4:
Plate heat exchanger with blocked surface



1.3 Filter design/filtration degree



Fig. 5: Installed and ready for operation, e.g. 16" unit/400 mm nominal diameter for a capacity of 1800 m³/h (EExd design). Can be installed in any position in the piping system. The units is in operation in a seawater system for QAFCO in Qatar.

The filter installed will be a stainless steel filter element made from perforated plate or a wedge wire strainer/wedge wire tube, depending on the filter mesh required and the type of contamination expected. When the wedge wire tube is used, the destructive effect on larvae (dissipation rate) is observed at filtration mesh sizes of 200 - 700 μm (0.2 - 0.7 mm). Special inserts make filtration steps as fine as 100 μm (0.1 mm) possible.

1.4 Principles of operation and cleaning process

The medium flows axially against the filter. Filtration takes place from the middle outwards. After filtration, the medium exits the filter through the radially mounted outlet flange. A piston with a flushing disk is located at the upper end of the filter housing opposite the inlet. During reversible flow, the piston is driven axially up and down in the filter element by a pneumatic cylinder or linear electric motor. There is also a flushing valve located above the strainer insert in the upper part of the filter housing. The flushing process is triggered by a differential pressure measurement system. All stages of operation are monitored by the control unit. The serial interface makes it possible to transfer the data recorded directly to the main control and communications system. Of course, the filtration and cleaning processes can also be controlled and monitored by the dedicated control room.

Fig. 6: Principles of operation and cleaning process



1.5 Overview of operation/physical principles

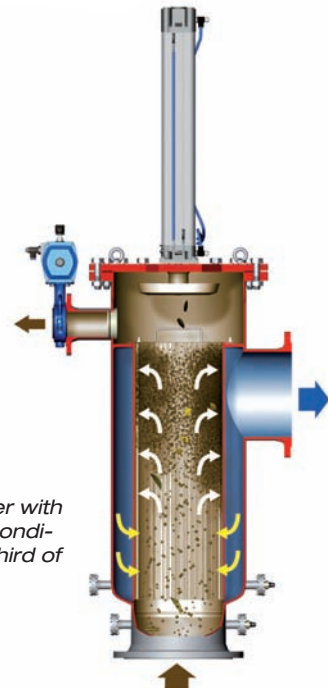
The filter is used for the filtration of liquids in pressurized systems, meaning that it cannot be used in suction lines. The flushing valve is closed during filtration. In its initial position, the pneumatic piston with flushing disk installed in the housing cover is outside the filter element. The filtered solids accumulate on the inner surface of the filter element.

Expressed in simple terms, this means that static pressure increases as flow velocity falls. As flow velocity increases, static pressure drops. The special geometry within the KAF-type filter and the positioning of the flange result in

$$\frac{1}{2} \rho v^2 + p + \rho gh = \text{const.}$$

Formula: According to Daniel Bernoulli, following applies

Fig. 7: Bernoulli filter with post-flushing the conditions in the lower third of the strainer



pressure conditions, which cause the contaminants to follow a defined process as they accumulate on the inner side of the strainer. The end of the strainer insert is the first part of the strainer to become coated after a purification process. As operating time progresses, the inside of the strainer becomes coated from the end of the strainer to the inlet.

The strainer becomes increasingly clogged from the top end to the bottom. As the filter becomes dirtier, the pressure within the strainer at the filter inlet continues to increase, and becomes greater than the pressure outside the strainer.

1.6 Using the principles of physics in the filter – only 0.3 bar operating pressure required

The solution to this problem is based on a discovery which is over 200 years old. The physicist Daniel Bernoulli discovered in the 18th century that the velocity plus the pressure in flowing liquids is constant in relation to the total pressure.

If velocity falls, static pressure increases, while if velocity increases, static pressure falls. Among other things, this discovery explains the underlying principle by which aircraft can fly - due to reduced pressure beneath the wing creating lift (in this case, this principle naturally operates in conjunction with other factors).

1.7 Incorporation into the piping system

The filter's design makes it light – it can often be installed in the pipeline without any additional mountings and in any position. One arrangement that is particularly space saving is to install the filter “on its side” as a replacement for a 90 degree pipe bend in the existing piping system.



Installation of a filter on its side as a replacement for a 90 degree pipe bend in the existing piping system. (Figure 8a+b)

Fig. 8a: Filter with a nominal connection diameter of 600 mm in the cooling loop of a biomass power plant.



Fig. 8b:
manufacturing of a
Krone KAF 24" Car-
bon Steel Unit

1.8 Physical principles according to Daniel Bernoulli -
utilized in the KAF filter

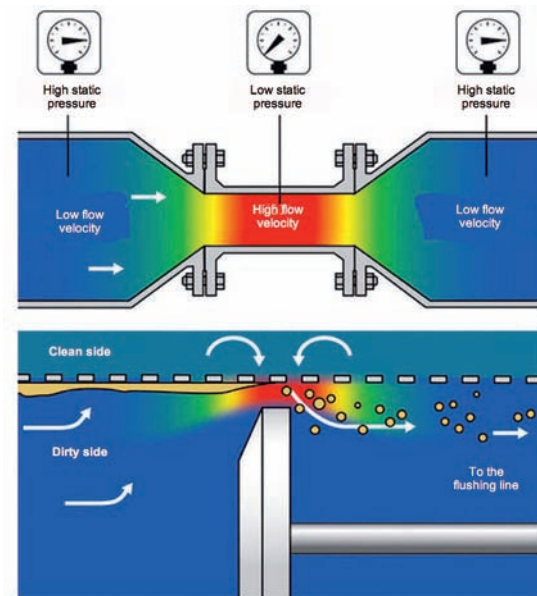


Fig. 9: The Bernoulli principle based
on the example of reduced cross
section/ increased velocity/reduced
pressure in the pipe and strainer

$$p \cdot v + \frac{mc^2}{2} = \text{const.}$$

$$p + \frac{Q}{2} c^2 = \text{const.}$$

1.8.1 Operation – continuous filtration in the filter

The filter operates on the same principle, using what is known as the flushing disk mounted on a moving piston to reduce the cross section in the strainer insert within the filter.

This results in a major increase in velocity in the gap between the flushing disk and the strainer. The slow-flowing clean liquid outside the strainer has a higher static pressure, resulting in a partial flow reversal around the flushing disk. This and the high flow velocity together with cavitation (behind the flushing disk) in the reduced cross section effectively tear and suck the contaminants away. At the same time, the control system opens a flushing valve with a nominal diameter considerably smaller than the nominal diameter of the piping system; the contaminants are carried out by the pressure gradient. The removal of the contaminants is absolutely reliable with only minor losses of pressure and with the filtration phase continuous; there is no need for maintenance or for any interruption to the process.

Normal filtration initially only takes place in the upper two thirds of the filter. During normal filtration, constant post-flushing conditions predominate in the lower third of the strainer due to the high flow velocity at the strainer inlet.

During filtration the filter strainer slowly becomes clogged from the area around the filter outlet downwards, toward the inlet.

Thus, filtration also gradually starts to occur in the lower third of the strainer. The top end of the strainer becoming coated causes a change in the pressure conditions.

This increasing contamination in what is termed the “lower third of the strainer” triggers the fully automatic self cleaning of the filter. This self cleaning is triggered from differential pressure measurement points in the lower end of the filter, one in inlet and the other in the third of the strainer containing the inlet/at the filter inlet, but on the clean side of the filter. The self cleaning is triggered when this point measures an increase in pressure.

A pneumatic flushing valve then opens for about five seconds in the cool outlet of the filter. Since the valve is opened to atmospheric pressure and because the pressure is lower than the system pressure, even large particles are removed at this point.

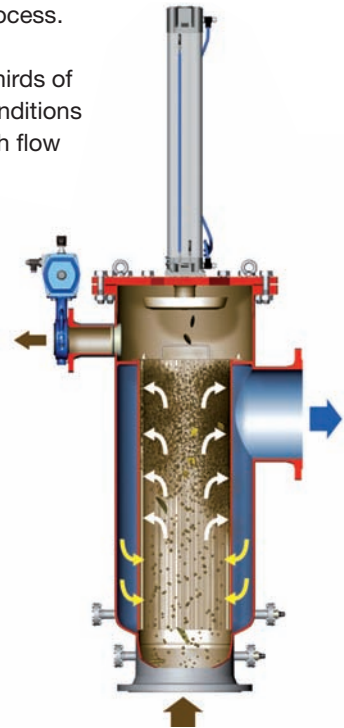


Fig. 10: Filtration in the upper two thirds of the filter. Due to the constant post-flushing in the lower third due to the flow velocity, no filtration or depositing takes place in the strainer inlet during the normal filtration phase.

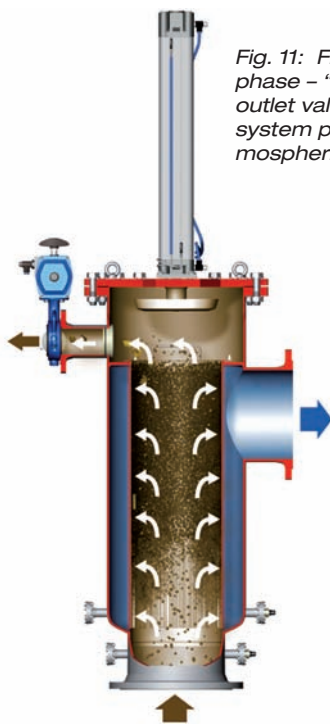


Fig. 11: Filter flushing phase – “opening the outlet valve to lower system pressure/atmospheric pressure”

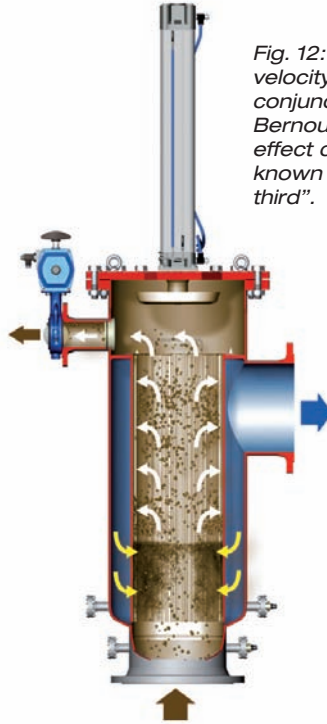


Fig. 12: The high flow velocity at the inlet in conjunction with the Bernoulli post-flushing effect cleans what is known as the “lower third”.

The flushing disk remains in its initial position in the upper third.

The filtration flow remains uninterrupted and continuous during this cleaning process phase. When the piston starts to move at this point, the Bernoulli principle takes effect. The flushing disk reduces the cross section and causes a partial increase in flow velocity in the gap between the flushing disk and the contaminated surface of the strainer.

The flushing disk never travels along the entire length inside the strainer because if it did, it would block or minimize the filtration flow.

The lower area is cleaned due to the pressure conditions that soon predominate once again in this area. As the flushing disk travels upwards again, the conditions change back in the now clean upper two thirds of the filter housing. Filtration once again takes place at the top, with post-flushing taking place again at the bottom.

1.9 Use of GRP/FRP (glass reinforced polyester/fiber reinforced polyester) as a material for the filter housing

Corrosion problems in salt water and systems with corrosive media solved.

Major chemical companies around the world not only have to combat contaminants in their systems, but also a resource shortage of titanium. This is the only material in the field of plate heat exchangers that can protect your cooling system against rapid corrosion. In most cases, it has not been possible to use alternative materials such as Hastelloy or Inconel due to addi-

tional proportioning of chlorine and fluorine, as these combine with oxygen input carried in through the open cooling towers to turn the cooling water into a highly corrosive medium. The extent to which reducing the additional proportioning of these elements by fine-mesh filtration can in the end make it possible to use alternatives to titanium which is currently being investigated in studies.

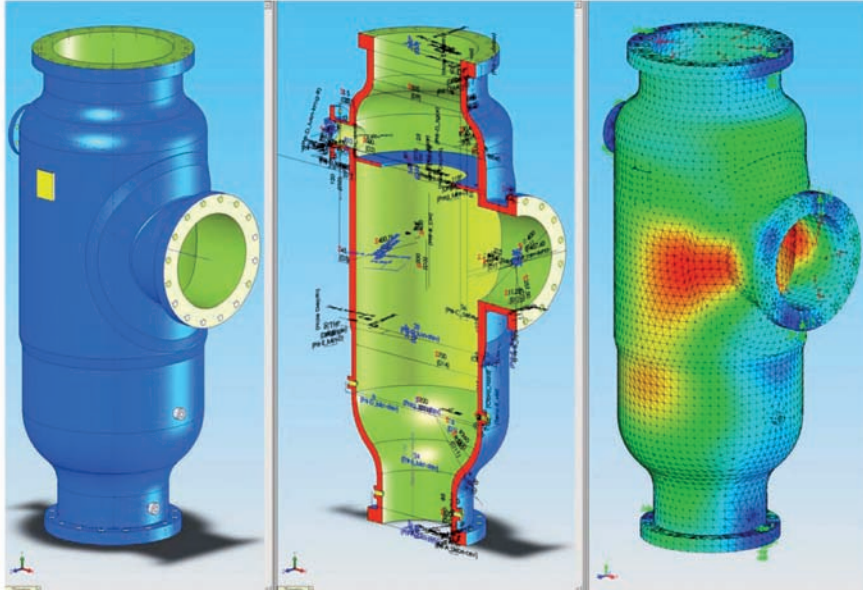


Fig. 13: Design and finite element modeling for GRP housings

After the expenditure of considerable resources on durability analyses, research and development, it was finally possible to safely use the corrosion resistant materials GRP and FRP in tank and filter designs.

The material permits the installation of the filter in environments such as those containing brackish water or highly corrosive cooling waters in the Persian Gulf or the Red Sea, for example.

Fig. 14: 24" GRP filter with a total flow capacity of 12,800 m³/h, designed for a seawater desalination plant in Jeddah (Saudi Arabia)



2. 50 μ side stream filtration of cooling tower water and cooling water with filter skids arrayed in multiple stages (flow capacity up to 1000 m³/h)

2.1 Reducing levels of chemicals and abrasive particles reduces corrosion in piping and maintenance intervals in the plant

By reducing turbidity and solid content it is possible to achieve a highly effective reduction in the amount of the otherwise necessary permanent/periodical chemical additional proportioning – this is an important factor in the reduction of corrosion in the pipe network and the protection of heat exchangers from contamination and fouling. Open cooling tower cooling loops are also subject to penetration by particulate contaminants and evaporative densification, which are both factors in the abrasion of system components.

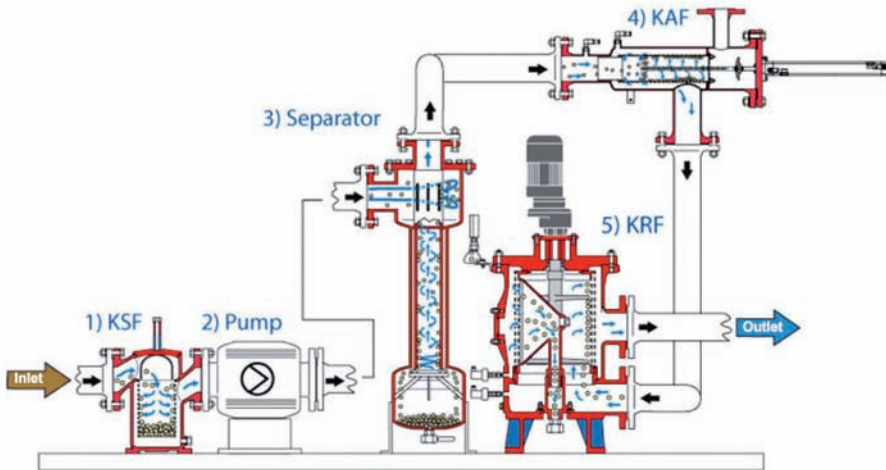
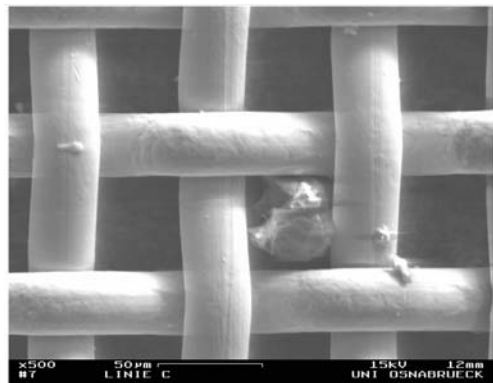


Fig. 15: a multiple-step system consisting of the following optional elements (from left to right): 1) filter with a 2 – 5 mm strainer on the pump inlet side; 2) pump; 3) centrifugal separator; 4) 200 μ automatic filter; 5) 40 – 80 μ automatic filter.

In one concrete study, the use of this type of multiple-step filtration system resulted in a reduction of the corrosion rate from 0.095 mm/a to 0.005 mm/a. In addition, the filterable solid content was permanently reduced from between 2.2 and 1.9 mm/kg to below 0.4 mg/kg.

Fig. 16: Microscopic examination of filtration behavior according to particle composition (mesh size: 34 μ absolute/20 μ nominal).



Like cooling water taken from flowing water for direct cooling, cooling tower water is an environment to itself. Sometimes, this water also has other problems due to densification and increased conductivity.

Filterable solids and turbidity are also indicators that are important for membrane filtration systems. Today, they offer a maximum membrane area while minimizing space requirements. This means that the distances between the individual filter surfaces in the membranes can be reduced. This effect is quantified by very small clearances between spacers in the spiral-wound modules or the smallest capillary diameters in capillary pore membrane modules. The dimensions of these smallest open cross sections require filter meshes of ideally between 40 and 150 μm even for the pretreatment of inflow water. At the same time, increasingly large populations of microscopic life forms are observed in the untreated water in flowing water bodies in Europe. These present a major hazard for downstream systems as they remain viable even under very adverse conditions. For membrane filter system operators, this means that very small filter meshes need to be designed for a comparatively high particle load. The illusion that this can be implemented effectively and reliably using a single filter step usually disappears after a short amount of time.

2.2 Beneficial solution

In many cases, it is therefore better to use multiple-step automatic filtration. Any higher purchase costs are generally justified by the improved availability and lower maintenance costs and will generally repay themselves after the system has been in operation for a short time.

2.3 Avoid the error of side stream filtration

Side stream filtration is frequently used as a solution in cooling water processes. This is often ineffective, depending on hydraulic parameters. This is because all filter systems use differential pressure for filtration, but hydraulic factors mean that differential pressure can only be present in a side stream under certain conditions. If there is any flow resistance in the side stream, this will immediately cause the flow rate to break down or the flow to pass through the main line, meaning that it is not filtered at all. Operators are even frequently highly impressed by the technical reliability and durability of the side stream filter, even though it does not possess any great functionality as a filter.

2.4 Reliable operation

If it is not possible to integrate the filters into the existing network, the filter units can be delivered with dedicated pumps, thus guaranteeing optimal flow rates along with the required operating pressures.

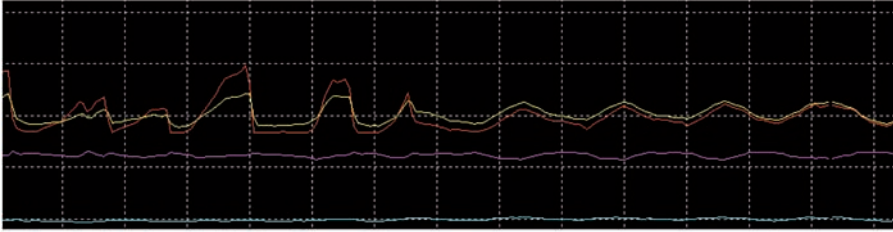


Fig. 17: Monitoring the filter system through the process control system shows that reliable cleaning is achieved by reaching “normal” operating pressure and flow rates after “cleaning processes” throughout the time axis.

2.5 Flexible construction

The required components can be assembled according to analysis of the water and particle distribution. What elements will be included in the system will also depend on the water medium, as well as on the hydraulic conditions and the location (e.g. use of an additional pump or a sludge separator).

The number of filtration steps is determined based on the composition of the “water” and numerous tests performed on-site. The most important steps in this filtration system are a centrifugal separator (advisable if there is a high sludge content) and a self-cleaning filter to remove impurities based on the Bernoulli principle. The prefilter step is envisaged as a 100 – 200 μm filter mesh. The second filter step consists of an automatic reversible flow filter capable of filtration qualities of 120 μm to 40 μm (25 μ in individual cases). Due to the benefits in terms of processing offered by the filter in the first step, water quality is also improved for the finer-mesh filter downstream, ensuring that this filter will operate reliably and uninterrupted over a long period.

The fine filtration step utilizes a simple cleaning process principle: During filtration, the medium flows through the filter strainer from the inside outwards, with the solid particulates thus deposited on the inner surface of the strainer. If the strainer becomes dirty, the cleaning process is triggered either by the differential pressure defined in advance by the operator (this is mostly set within a range of 0.25 to 0.5 bar) or by an integrated timer control.

2.6 Positive effects on maintenance

The corollary effects of the cooling water filtration process are particularly evident when maintaining components in plate and tube bundle heat exchangers. The side benefit will be evident in the form of long intervals between cleaning and reduced spare part costs.



Fig. 18: Unprotected plate heat exchanger

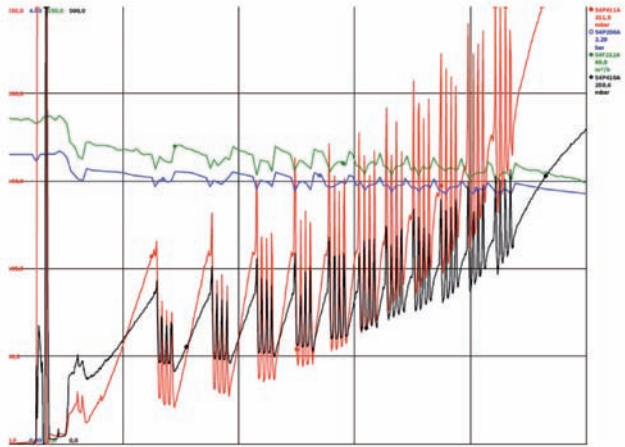


Fig. 19: Durability and cleaning process evaluations (partial view)

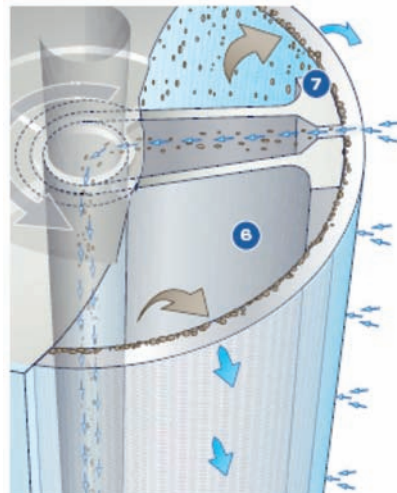
2.7 Using the downward pressure gradient principle to clean the strainer in the KRF fine-mesh filter

A pressure gradient principle is used for the actual cleaning of the filter surface in the fine-mesh filter. A reverse flow nozzle driven by a motor passes down the inside of the filter insert and the dirty side. A pressure gradient is created across an electro-pneumatic contaminant outlet valve in the flushing line which opens at the same time. This causes the dirt to be forced away from the dirty side of the strainer as the flow reverse in the area of the reverse flow nozzle and removes the contaminants through the nozzle opening.



Fig. 20: Cross section view of the so-called reverse flow filter

Fig. 21: detailed view of the use of the nozzle (6) to clean the strainer; the nozzle does this thanks to the reversed flow in (7) of the strainer



The distances between the nozzle and the filter mesh play an important role in this process. The smaller the distance, the more effective the flushing. Fine filter grades ranging from 25 to 50 µm are in particular need of very small clearances between nozzle and filter (once again, for these effective prefilters) – this is also achieved practically and reliably with multi-step systems. [sic]

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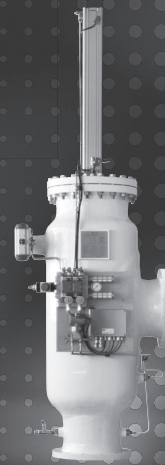
SEAWATER STRAINERS

APPLICATIONS

- Plate heat exchanger protection
- Cooling water filtration
- Rawwater filtration
- Power plants, HVAC, petrochemical, offshore, shipbuilding
- Since 1991 used all over the world
- For LNG or LPG Vessels
- FSRU
- Regasification Plants
- Platforms
- Reliquifaction
- Boil off Gas

ADVANTAGES

- Touchless cleaning
- Continuous flow
- Seawater resistant materials
- No maintenance
- High flowrates
5 m³/h -10000 m³/h
- Low dp (pressure loss)
- ATEX/EX
- Certification
Lloyds, DNV, ABS, ASME
VIII, X, PED



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