The Bernoulli Filter

Simple and ingenious filtration

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1. The Bernoulli history
Mr. Ulf Steiner, with a passed within the Heat exchanger business founded Bernoulli System in the mid 1986. During his years within PHE business he had gathered an extensive know-how within design of Plate Heat Exchangers (PHE) and the problem with clogging of PHE’s.

In the late 80:es Ulf Steiner and his research team started to develop an automatic and self-cleaning filter for protection of PHE’s.

The very first Bernoulli Filter was installed at Leine Smolt, Bodø Norway in 1990. The first Bernoulli Filter was of model BSS 200 and has been in operation 24 hours 7 days a week since 1990.

With many years of extensive filtration experience, engineering knowledge worldwide installations in more than 70 countries since its launch in 1990, we at Bernoulli are confident that we know how a seawater filter system should perform.

2. Introduction of the Bernoulli Filter
The Bernoulli Filter is a fully automatic self-cleaning filter for continuous filtration of water in pressurized systems. It removes debris from natural water sources such as sea, lake and river water but can also be used for removing particles in process liquids.

The main application is protection of plate heat exchangers. The Bernoulli Filter has a simple but ingenious cleaning operation. A special designed disc creates a velocity increase between disc and filter basket, which results in a local pressure reduction which “vacuum cleans” the basket. The filter is designed for good corrosion resistance and low maintenance with few moving parts and experienced choice of material.
3. The target application, protection of PHE
The most common application for the Bernoulli Filter is protection of PHE (Plate Heat Exchangers). The Bernoulli Filter shall preferable be installed as close as possible to the PHE, which reduces the risk for pipe growth to enter the PHE.

The cleaning function of the Bernoulli Filter is independent of the position of the filter. Meaning that the filter can be installed in any position, horizontal, vertical, leaning or even upside down. The Bernoulli Filters are pipe mounted and special filter support is normally not needed for small and medium sizes of Bernoulli Filters.

10 x Bernoulli Filter BSG 350 installed directly in front of PHE’s at QAFCO (fertilizer) in Qatar. The Bernoulli Filters have been in operation since 1995 on a seawater application.

The Bernoulli Filters are designed to filtrate all kinds of debris in natural water including sea grass and sea mussels. The picture below shows an intake pipe for cooling water. The amounts of sea mussels are considerable. Sooner or later the sea mussels will come loose from the pipe walls and enter the down stream system. A system without Bernoulli Filters will rather quick lead to clogged PHE and reduced heat transfer.

Submersible picture of an in take pipe for cooling water.
The purpose with the Bernoulli Filter is to prevent the inlet ports in a PHE from clogging. Without the Bernoulli Filter the inlet ports will be blocked with debris, which reduces the flow rate between the plates. Further on this leads to a biological fouling on the plates with the final consequence that the PHE has to be open up and cleaned. The Bernoulli recommendation is to use a filter basket with a filtration degree corresponding to 20-50% of the plate gap. The most common filtration degree for protection of PHE is 1,0 or 2,0 mm filtration.
4. Bernoulli recommendations for protection of PHE

The Bernoulli Filters are developed to protect narrow plate heat exchangers working in polluted sea and river water. Early tests showed clearly that surface deposits could not be prevented by over sizing of the heat exchangers. Attempts were made with a simple back flushing systems (flow reversal) combined with chlorination to protect the sensitive plate heat exchangers from fouling up at the heating surface. During the test attempts it was discovered that solids could not settle on the plate surface if the shear rate at the wall of heating surface was sufficiently high. The required shear rate corresponds to about 0,8 bar pressure drop for a normal plate type. Further on chlorination is today for environmental reasons prohibited in Europe.

One problem remained. The narrow gap between the plates makes them sensitive to clogging. The gap between plates may be as narrow as 2 mm for some types. A plate heat exchanger could clog up in minutes. The flow rate dropped due to the clogging then resulting in surface deposits as the shear rate became too low.

Designing philosophy of cooling plants using natural water such as sea or river waters.
1. Use automatic filters such as Bernoulli Filters and locate them close to the exchangers.
2. The filtration shall be 20 - 50 % of the plate gap.
3. Use wedge wire screens if the water contains sand.
4. Design plate heat exchangers for a minimum pressure drop of 0,8 bar. This corresponds approximately to 70 Pa shear rate.
5. Operate the heat exchanger at full flow rate. Speed up pumps during flushing if pumps with speed control are used.
6. Use the same standby philosophy for pumps, filter or heat exchangers.

5. Added value for PHE's

World wide Engineering companies involved in the design of cooling water supply require today a complete package where automatic and self cleaning filters protects PHE from clogging. With the Bernoulli Filter we can offer an added value for PHE companies and the plant owner. The investment in Bernoulli Filters will in a few years be paid off by reduced maintenance and minimizes risks for cost full breakdowns in production.
6. The Bernoulli cleaning principle

The filter basket is cleaned by a disc, which enters the basket. During the cleaning operation water is passing through a defined gap between the disc and the basket. Flow velocity increases locally around the disc and in accordance with the principle of Daniel Bernoulli the static pressure is reduced. The lower static pressure around the edge of the disc has a “vacuum cleaning” effect on the basket. This is the key-factor, which makes the Bernoulli Filter totally unique on the filter market.

The Bernoulli Filter itself has a very simple and genius cleaning system with few moving parts and is designed to ensure high operational reliability with simple maintenance. The simple cleaning system together with filter bodies in GRP offers an outstanding corrosion resistance for seawater filtration.

The Bernoulli Filter has a double supervision system. A flushing operation is primarily started by a timer. As an extra safety the Bernoulli Filter has a differential pressure switch which sense the degree of clogging and if needed starts an additional flushing.

Normal operation
The flushing valve is closed and the piston mounted in the end cover remains outside the filter basket.

Flushing phase one
Cleaning is initiated either through increase in differential pressure or after a preset time interval. The flushing valve opens and large matters are flushed out.

Flushing phase two
The piston moves twice into the basket. The increased flow velocity between basket and the piston creates a reduction in pressure that “vacuum” cleans the inside of the basket. This reverses the flow direction locally into the basket and removes particles adhering to the basket.
7. The Bernoulli cleaning principle with pressure charts

7.1 Clean filter basket
At clean conditions the pressure inside the basket will be greater than the outside pressure. Therefore debris particles start to build up at the outlet end of the filter basket. To be noted is the parallel flow outside the basket and the counter flow at the inlet zone of the filter. During a cleaning operation the cylinder with its disc makes 2 strokes into the basket. The disc turns at about 2/3 of the height of the basket, which is equal to the point where the counter flow starts.

Pressure situation at clean conditions.

Water and pressure situation at clean conditions.
7.2 Dirty filter basket
The Bernoulli Filter has a double supervision system. A flushing starts either by a timer or by a differential pressure switch. The below picture shows the pressure situation just before the differential pressure switch starts a flushing. The debris has built up to about 2/3 of the height of the filter basket. Note that there is no longer a counter flow at the inlet of the filter.

Pressure situation just before flushing caused by too high differential pressure.
7.3 Cleaning of filter basket
The cylinder with its disc has entered the filter basket. When water is pressed into the narrow gap between filter basket and disc the flow velocity increases which generates an increased dynamic pressure. According to the Bernoulli principal the increased dynamic pressure leads to a reduced static pressure. Altogether it generates a “vacuum cleaning” effect, which removes debris from the basket.

During a flushing operation the differential pressure switch is inactivated.

Pressure situation during cleaning of filter basket.
8. Parallel Flows and counter flows
A small counter flow is generated in the inlet zone of the Bernoulli Filter. The appearance of the counter flow can be explained with the Bernoulli Principle.

The Bernoulli Principle: Static pressure + Dynamic pressure = total pressure = constant

Pressure and flow conditions for Z-configuration
At position 1a in the inlet pipe there is a high dynamic pressure and a low static pressure. Further to the right, at the end of the inlet pipe the relations are the opposite. A velocity close to zero leads to a low dynamic pressure and a high static pressure, position 1b. Due to the higher static pressure at the end of the inlet pipe larger volumes of water will flow through the connecting pipes to the right, all according to the Bernoulli Principle. This is also the reason why debris starts to collect at the outlet end of the filter basket in the Bernoulli Filter.

The outlet pipe has the same pressure situation as the inlet pipe, but opposite. At position 2a there is a high flow velocity, which generates a high dynamic pressure and a low static pressure.

For pipes connected in a Z-configuration the high static pressure in position 2b leads to a counter flow towards the inlet pipe. In the Bernoulli Filter this counter flow is generated in the inlet zone of the filter. With the counter flow the disc do not have to do full strokes. The non-full stroke gives a non-interrupted flow through the filter during the flushing operation.

9. Pressured drop across the Bernoulli Filter and the DP-switch
The pressure drop across the Bernoulli Filter is flow related and generated by the 90-degree turn of the water stream, inlet to outlet. The DP-switch in the Bernoulli Filter measures a degree of clogging which is equal to a basket clogged to 2/3 of the height. The pressure drop across the whole filter body stays the same at clean and dirty conditions provided that the filter basket is cleaned before it is clogged to more than 2/3 of its height.
10. Principle of Daniel Bernoulli

Daniel Bernoulli (1700 – 1782)
Between 1725 and 1749 Daniel Bernoulli was awarded no less than ten different prices for his work in fields like astronomy, gravity, magnetism, ocean currents and ship movements. His most famous work is Hydrodynamica, 1738. It comprises fundamental facts on the pressure, density and velocity of fluids and their relations, today known to the world as Bernoulli’s equation or the Principle of Daniel Bernoulli.

Bernoulli’s equation or the Principle of Daniel Bernoulli
Total pressure = static pressure + dynamic pressure = constant

An increase of flow will lead to a decrease in static pressure.

Total Pressure = $H_1 + \frac{u_1^2}{2g} + \ldots + H_2 + \frac{u_2^2}{2g} + \ldots$ = Constant

Bernoulli principle.

Bernoulli Filter cleaned with Bernoulli principle.
11. Materials and sizes of the Bernoulli Filter
The Bernoulli Filters are manufactured in plastic materials for seawater applications and in AISI 316L for fresh water applications, with connection sizes from 2½” till 28”.

<table>
<thead>
<tr>
<th>Filter model</th>
<th>Sizes</th>
<th>Filter body material</th>
<th>Capacity (m³/h)</th>
<th>Design Pressure</th>
<th>Design temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSC</td>
<td>DN 65</td>
<td>C-PVC (Chlorinated PVC)</td>
<td>0-60</td>
<td>PN 10</td>
<td>70</td>
</tr>
<tr>
<td>BSP</td>
<td>DN 80-100</td>
<td>PVC (Poly Vinyl Chloride)</td>
<td>0-130</td>
<td>PN 10</td>
<td>40</td>
</tr>
<tr>
<td>BSG (small)</td>
<td>DN 100-250</td>
<td>GRP (Glass fiber Reinforced polyester)</td>
<td>0-846</td>
<td>PN 10</td>
<td>60 (standard) 75 (high temperature)</td>
</tr>
<tr>
<td>BSG (medium)</td>
<td>DN 300-400</td>
<td>GRP</td>
<td>0-2090</td>
<td>PN 6, PN 10</td>
<td>60 (standard) 75 (high temperature)</td>
</tr>
<tr>
<td>BSG (large)</td>
<td>DN 450-700</td>
<td>GRP</td>
<td>0-6370</td>
<td>PN 6, PN 10</td>
<td>60 (standard) 75 (high temperature)</td>
</tr>
<tr>
<td>BSS</td>
<td>DN 80-400</td>
<td>Stainless Steel (AISI 316L)</td>
<td>0-2090</td>
<td>PN 10</td>
<td>80</td>
</tr>
</tbody>
</table>

12. Filter baskets and filtration degrees
The Bernoulli Filter can be equipped with filter baskets from 0,1 mm as finest filtration degree.

<table>
<thead>
<tr>
<th>Filter model</th>
<th>Sizes</th>
<th>Perforated filter baskets in AISI 316L (mm)</th>
<th>Wedge wire baskets in AISI 316L (mm)</th>
<th>Perforated filter baskets in Titanium (mm)</th>
<th>Expanded filter basket in AISI 316L (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSC</td>
<td>DN 65</td>
<td>-</td>
<td>0,3 1,0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BSP</td>
<td>DN 80-100</td>
<td>1,0 2,0</td>
<td>0,2 0,3 0,5 1,0</td>
<td>1,5 2,0</td>
<td>0,1</td>
</tr>
<tr>
<td>BSG (small)</td>
<td>DN 100-250</td>
<td>1,0 2,0</td>
<td>0,2 0,3 0,5 1,0</td>
<td>1,5 2,0</td>
<td>0,1</td>
</tr>
<tr>
<td>BSG (medium)</td>
<td>DN 300-400</td>
<td>1,0 2,0</td>
<td>0,2 0,3 0,5 1,0</td>
<td>1,5 2,0</td>
<td>-</td>
</tr>
<tr>
<td>BSG (large)</td>
<td>DN 450-700</td>
<td>2,0</td>
<td>0,6 1,0</td>
<td>2,0</td>
<td></td>
</tr>
<tr>
<td>BSS</td>
<td>DN 80-400</td>
<td>1,0 2,0</td>
<td>0,2 0,3 0,5 1,0</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
13. Bernoulli advantages

1. The Bernoulli Filter itself has a very simple and genius cleaning system with few moving parts and is designed to ensure high operational reliability with simple maintenance.
2. The Bernoulli Filter offers continuous operation without interruptions in flow during flushing.
3. The Bernoulli Filter has a low and constant pressure drop, the same pressure drop at clean and dirty conditions.
4. Low flushing pressure, only 0.3 is required.
5. The filter basket is easy to take out of the filter body, fixed with stabilization bolts.
6. The Bernoulli Filter are manufactured in either AISI 316L or Glass fibre Reinforced Polyester (GRP).
7. The combination of few moving parts and materials in GRP and titanium offers an excellent corrosion resistance for seawater applications.
8. We offer a wide range of filter sizes, from DN 65 up to DN 700 with a maximum capacity of 6.300 m³/h.
9. Maximum size of removable particles 40 mm.
10. The Bernoulli Filter can be equipped with filter baskets from 100 microns to 2.0 mm.

Most colleagues on the market are mainly working with rubber lined carbon steel. Carbon steel filters are about 3-times heavier than GRP filters which makes them harder to install and maintain.

With light weighted GRP the Bernoulli Filter can be pipe mounted without any filter body supports. There is always a risk for leakage in the rubber lining and in case the rubber lining gets damage the carbon steel filter must be taken to a workshop for hot vulcanization. If the rubber lining isn’t repaired the carbon steel filter will start to corrode.

The Bernoulli Filter has a very simple and reliable cleaning mechanism. A disc mounted on a pneumatic cylinder does all the work. Competing brands usually have a much more complicated cleaning mechanism. Sometimes flow diverters and axis are made of AISI that after a while starts to corrode.

The filter basket in the Bernoulli Filters is fixed with stabilization bolts and can easily be removed from the filter body. Competing brands sometimes have a flow diverter mounted through the filter basket, which makes it more complicated to release the filter basket during maintenance or clogging problems.
14. Application for the Bernoulli Filter

**Cooling water systems**
The Bernoulli Filter is an excellent choice for protecting heat exchangers in cooling systems. Bernoulli provides technical solutions for sea-, brackish- or fresh water applications. Typical customer groups for this application are Chemical-, Steel-, Power-, Food-, Mechanical-, Paper- and Petrochemical industries.

**Intake water – Pre Filter**
The Bernoulli Filters has a great record of installations as pre filter before UV-sterilizing, Ultra Filtration and Reverse Osmosis plants. These installation will be found in for example land based fish farms, mussel production plants, public aquarium or zoo’s and of course in drinking water production plants.

**HVAC**
The Bernoulli Filter is commonly used for protection of heat exchangers in heat pump systems (cooling or heating). Different kinds of water are used for example sea-, brackish-, lake-, pond or river water. Typical buildings are offices, congress centers, concert halls, government buildings, museums and other public buildings.

**Desalination plants**
The Bernoulli Filter is widely used in desalination plants both as pre filters before membranes and in distillation processes. In the distillation process are the Bernoulli Filters made of high-temp polyester to withstand the high temperature and salinity.

**Cooling tower systems**
The Bernoulli Filter can in cooling tower systems be used in three different applications, full stream filter and side stream filter and as make up water filter. We have experience both from fresh water and seawater systems.

**District cooling**
District cooling has in cities and larger industrial areas become a popular way to solve the need of cooling in a more environmental friendly way. Different water sources are used for example deep wells, lake water or seawater. The Bernoulli Filters are normally installed to protect the main heat exchangers.

**Wastewater**
The Bernoulli Filter can in some cases be suitable for applications with wastewater. The main application is protection of heat exchangers for heat recovery from processed wastewater but also protection of spray nozzles can be a suitable application.

**Irrigation**
The Bernoulli Filter can successfully be used in larger irrigation systems. Greenhouses and golf courses are two customer groups.