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Flow inverted filtration (FIF) innovative filtration technology

M. Rognoni*, F. Volpe

SWS-Saline Water Specialists Srl, Via Pio La Torre, 14/c, 20090 Vimodrone (MI), Italy
Tel. +39 02 27401426; Fax +39 02 27409452;
email: swsinfo@swsonweb.com

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Abstract

The FIF technology of fine filtration was studied, tested and patented by the engineers of SWS as an appropriate method to most conveniently replace sand filtration, under a large number of working conditions.

1. Introduction

This new technology is based on filtration through a bed of floating grains, typically polypropylene of specific gravity ~0.9 kg/l (~0.65–0.70 bulk). This new technology is named flow inverted filtration (FIF). The filtrating bed naturally floats and the raw water flows upward, thus compacting the bed for the most effective filtration. The capacity of filtration is the same as achieved in sand filtration, because the size of the grains is approximately the same. A large number of valuable advantages are however ensured by FIF mainly in the backwash as detailed in the paragraphs below and summarized as follows:

- No air consumption is necessary during the backwash and therefore no blowers need to be installed and maintained.
- The consumption of backwashing water is very limited, with up to a 90% reduction of water use. Therefore no additional sedimentation tank is necessary for the eventual recovery of the excess of backwashing water.
- No forced water flow is necessary for backwash and therefore no backwash pumps need to be installed.

2. Design parameters

SWS proposes the following typical design parameters for filters and fully automatic filtration systems:

*Corresponding author.

Propylene (PP) grains: The PP grains are selected in a range of dimensions Ø = 0.6–5.0 mm.

Filtration velocity: The filtration velocity is in the range 20–25 m/h/m^2

Filtrating nozzles: The grains of PP are retained by filtrating nozzles typically made of PVC with 250 μ mesh. The nozzles are positioned in a triangular pitch ($\sim$60 m^2) each standard sized Ø = 58 mm and adequate for $\sim$0.40 m^3/h flow (Fig. 1).

Bed depth: The depth of the bed is typically 400 mm. During backwash, the dimensions of grains (see 2.1) are naturally selected by gravity and the smallest grains are positioned in the lower part of the bed. During the filtration, the bed is naturally shrunk by $\sim$5% and filtration efficiency is accordingly improved.

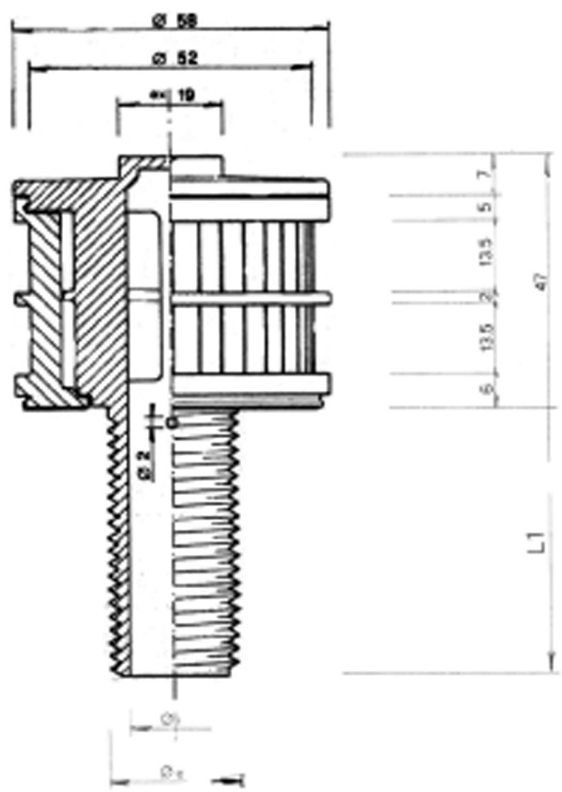

Fig. 1.

2.1. Backwash

The backwash requires a very limited amount of water, varying from:

- Min: m^3 = 0.01 per m^3/h of filtrated water (low velocity backwash)
- Max: m^3 = 0.025 per m^3/h of filtrated water (high velocity backwash)

2.1.1. Low velocity backwash: The total requirement of water is provided in two pulses, as necessary to expand the bed and release the filtrated particles. The filtrated particles shall sedimentate by gravity on the bottom of the filter (see construction details at 3) and be extracted after sedimentation.

The recommended sedimentation time is $\sim$1–3 h depending on the dimensions of the filter and accordingly is to be based on the total backwash time.

2.1.2. High velocity backwash: The total requirement of water is provided by the continuous flow of the backwash water, as appropriate to enable the bed to float and not be ejected out with the turbid water reject.

The total backwash time is planned for 4–5 min (typically and velocity is progressively increased 0 to 7–10 m/h).

In both cases of 2.1.1 and 2.1.2. the necessary amount of backwash water is available in the volume of the upper part of the filter and therefore the backwash can be achieved by just letting some atmospheric air enter the top of the filter. The reduction of the water level shall provide the necessary backwashing flow.

2.1.3. Friction losses: The friction loss along the typical 400 mm bed is $\sim$0.1–0.15 bar for a clean bed condition. A range of ΔP = 0.4–0.45 bar is recommended for the backwash.

For the design conditions of the filtration system, the total friction loss has to include the inlet outlet flange ($\sim$0.25 further bar). In dirty conditions, the total ΔP of the filter is to be considered typically 0.70 bar, to be checked under actual working conditions.

2.2. Operation mode (Fig. 2).

2.2.1. Filtration: Valves V1, V2 opened, Valves V3, V4 closed, ΔP increasing 0.2–0.45 bar

2.2.2. Backwash: Valves V1, V2 closed, Valve V3 opened, Valve V4 intermittently opening as per the requested sequence according to modes 2.1.1. or 2.1.2.

a) Slow backwash

Valve V4 is opened twice of the time necessary for the flow of the requested backwash water. The bed is expanded downwards and the filtrated particles released. Time is to be provided to allow sedimentation in the cone lower head of the filter. After sedimentation, a limited outlet flow shall evacuate the sediment by opening the V4 valve.

b) Fast backwash

Valve V4 is opened progressively, as necessary to let the bed float again and not be draught out from the bottom. The total backwash flow is to be equal to the total value of the bed and lower come, such as to replace the volume of turbid water with the equivalent volume of filtrated water (available in the upper part of the filter).

Note: In many cases, the value V3 can be replaced by a floating (breathing) valve that naturally allows for air entrance and air outlet, but stops any outlet of liquid. Therefore no automatic operation is necessary when changing the operation mode between filtration and backwash or visa versa.

2.3. Operating conditions

2.3.1. Temperature: Temperature is a critical factor for the thermal resistance of the polypropylene.

Max. temperature allowed for continuous operation is 60°C

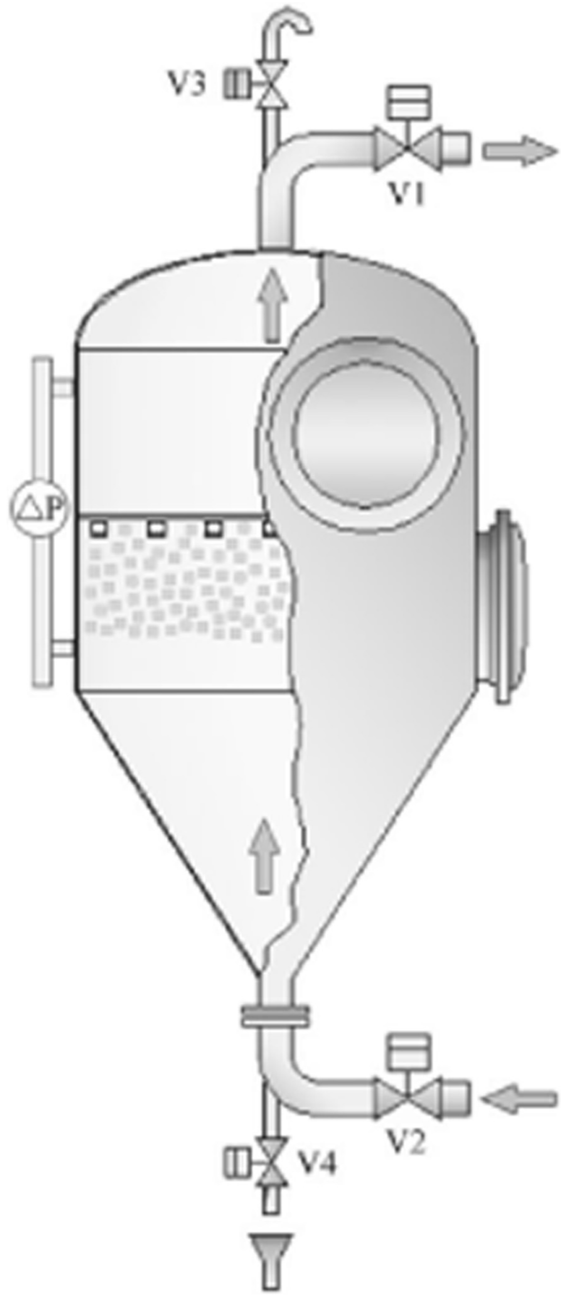

Fig. 2. Typical filter arrangement.

Max. peak temperature is 80°C

2.3.2. Pressure: Pressure can be operated without limits according to the materials and design condition of the filter.

Table 1
Comparison of FIF sand filters. The advantages of FIF against sand filtration are quite remarkable under the largest range of working conditions and therefore the FIF system is to be preferred whenever applicable

Issue	Sand filters	F.I.F.
Working temperature	Unlimited	T<60°C
Filtration efficiency	Unlimited	T<60°C
Water pH	Critical	Quite unlimited
Backwash air	Yes: blowers to be provided	Not required (no electrochemical compactation)
Backwash water	100%	10–30%
Cycle duration (set by DP)	100%	120–150%
	Friction losses are increased also by the compactation of sand because of Van Der Wools forces	Friction losses are only due to the filtrated turbidity collected in the bed, and not to compactation of the bed
Purity of filtrated water	Risk of release of compounds by the sand (ex. SiO_2)	Excellent
Oil retention	Achieved by adding anthracite (dual media service)	Not yet available
Investment cost	100%	90–95%
Maintenance cost	Replacement of sand	Long life of P.P.
	Maintenance of blowers	No blowers installed
	6 automatic valves	4 automatic valves (3 in some cases)
	Maintenance of pumps	No backwash pump

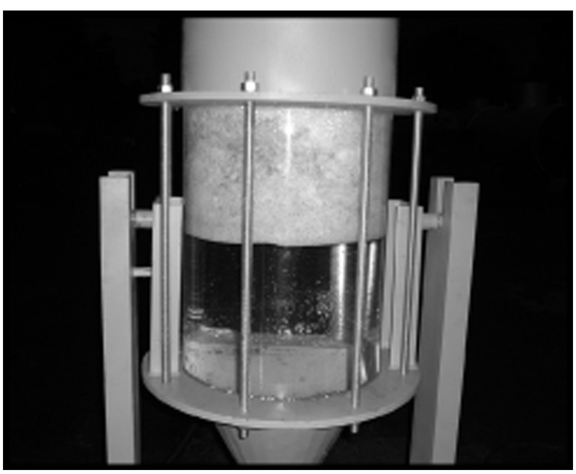

Fig. 3. Pilot filter.

2.3.3. Chemical content: Polypropylene is resistant to a large variety of alkaline and acid compounds. The material of the filter is to be checked accordingly.

2.3.4. Oil content: Oil can adhere to the polypropylene grains and stick to the bed. Therefore the absence of oil is required. Some studies and tests are now in progress aimed to add anthracite to the bed and ensure dual media service. However at this time the oil, if any, is to be removed in a separate pre-treatment section.

2.3.5. Erosion: In the case of a painted steel filter, the erosion of the paint by PP is negligible and the life of the filter is therefore remarkably longer than for sand filters (where the paint is subject to erosion by sand particles) during backwash.

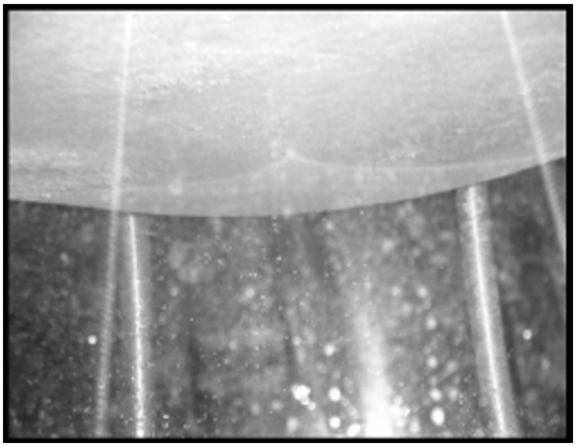

Fig. 4.

Fig. 5.

3. Pilot tests

The working and the design conditions were assessed in a number of tests made by SWS engineers at a pilot plant from May 2004 to December 2004.

The pilot filter (see Fig. 3) was constructed with the shell in a transparent material for full visibility of the filtration and backwash. The filter is sized Ø = 500 mm and filled with 85 l of PP grains.

P.P. filling was tested in the following two arrangements:

Arrangement 1

- 150 mm=grains 5 mm
- 150 mm=grains 0.9 mm
- 100 mm=grains 0.6 mm

Arrangement 2

- 200 mm=grains 5 mm
- 200 mm=grains 0.9 mm (Fig. 4)

The turbidity in the water was made in two different arrangements

Arrangement 1: Agricultural humus (commercially available). Dosing up to 10 l/m^3

Arrangement 2: Precoat (cellulose calibrated 13 μ). Dosing up to 5 l/m^3

The degree of filtration was assessed as excellent with the entirety of turbidity filtrated in both arrangements (see 3). The procedures of initial stratification of the PP grains according to the dimension of the grains (see 1.4) were carefully studied, and the procedures of backwash were assessed (See 2) (Fig. 5).