

# Filter nozzle and underdrain systems used in rapid gravity filtration

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## Abstract

Inadequate understanding of the basic hydraulic principles is often the cause of malfunctioning filter underfloor systems, which will eventually lead to inefficient filtration. To achieve a successful end result, it is imperative that certain fundamental principles are considered and adhered to in the planning and construction of filtration systems. Therefore, this paper:

- Provides the theoretical background to enable designers to check the adequacy of water and air flow distribution.
  - Contrasts the essential differences between filtration systems, to assist clients and process designers in the selection of an appropriate filtration system.
  - Provides practical guidance to supervisors on the pitfalls and precautions to be heeded during construction and commissioning.
- The following aspects contribute towards an efficient filtration system:
- Fundamental hydraulic principles are essential towards understanding the behaviour of underfloor systems.
  - Even distribution of air and water is ideal, but variations in water and air discharge will inevitably be encountered in filter underfloor manifolds. Careful manifold design and analysis are essential to limit these variations to within acceptable limits.
  - Diligent care in design, manufacture, installation and supervision together with rigorously controlled testing is of decisive importance.
  - Correct operational procedures by operators are critical.

## Introduction

Rapid sand filtration is encountered at the vast majority of water treatment plants in South Africa. Despite the impressive track record of this old and well-established unit process, problems with filtration systems are routinely encountered. In the majority of the cases, the problems can be traced to malfunctioning underfloor and media support systems. In the authors' opinion, many of these problems could be avoided if the relatively simple hydraulic principles of water and air distribution, as well as the numerous practical constructional pitfalls were recognised by designers, contractors and operators. This paper, therefore, deals with the following:

- The elements of filter nozzle design and specification
- Flow of water and air through nozzles
- Flow of water and air through manifolds
- The merits of different backwash systems
- Precautions to be heeded to ensure an effective filtration system, illustrated by numerous practical examples of failures encountered by the authors.

## Underfloor systems

### Nozzle support systems

There are two common nozzle support systems in use in South Africa; the false floor system and the pipe lateral system. Hydraulically, the essential differences are:

- In the case of the false floor system, rectangular slabs with an evenly spaced matrix of nozzles overlie the underfloor plenum. As a result, the flow of water in the underfloor plenum is directionally unrestricted.
- In the case of the pipe lateral system, nozzles are evenly spaced on the lateral pipes, and the pipes are laid out parallel to each other. This causes unidirectional flow along the lateral pipes, and also increases the flow velocity in the underfloor volume compared to the false floor system due to the smaller underfloor volume.

This pipe lateral system thus requires more stringent hydraulic analysis than the false floor system in terms of the underfloor flow, but otherwise the systems are identical in terms of all other requirements.

Filter backwash rates (and the resulting underfloor flow velocities) are considerably higher than filtration rates. Nozzles and their support systems are therefore designed for effective distribution during backwash.

### General hydraulic relationships

The discharge per nozzle is calculated from the following:

$$q = \frac{v}{3600.n} \quad (1)$$

where:

$$\begin{aligned} q &= \text{flow per nozzle (m}^3\text{-s}^{-1}\text{)} \\ v &= \text{backwash rate (m-m}^1\text{)} \\ n &= \text{nozzle density (\#-m}^2\text{)} \\ \# &= \text{number of nozzles} \end{aligned}$$

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