How SURE?

SUstainability and REsiliency for Conventional Filters

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For over a century, conventional granular media downflow filters have provided reliable, economic water and wastewater treatment. Even today, this type of filtration system provides proven treatment capabilities and long-term maintenance benefits. Though the process of granular media filtration is relatively well-understood, the long-term success of a filter may ultimately depend more on the filter underdrain design.

Conventional Filter "ABCs"

The filtration operation for conventional filters is comprised of two distinct phases: filtration and cleaning (backwashing). The filtration phase to remove particulate material is accomplished by passing the water downward through a filter bed comprised of one or more granular medias (e.g., sand, anthracite, GAC), with or without chemical addition. The solids removal process is accomplished by several removal mechanisms such as straining, sedimentation, impaction, interception, adhesion, and adsorption. The filtration phase must end once the suspended solids in the effluent increase to an unacceptable concentration or when a limiting headloss occurs across the filter bed. Backwashing cleans the filter media by reversing the flow through the media to send the solids-laden wash water for treatment elsewhere. Air is often used in addition to water, either sequentially or simultaneously, to provide enhanced media scouring.

All granular downflow filters must contain media and an underdrain that:

1) supports the granular media;
2) withstands maximum filtering headloss;
3) uniformly allows percolation of the filtrate across the media bed;
4) uniformly distributes backwash water across the entire bed at varying flowrates;
5) uniformly distributes the scouring air either separately or simultaneously with the backwash water;
6) withstands the upthrust created at the maximum rates of backwash and scouring air; and
7) resists corrosion.

Underdrain Types

Filter underdrains are principally comprised by one of the following: (a) suspended concrete slab or steel plate with integral filtration nozzles and plenum below; or (b) set of round-, triangular-, or block-shaped parallel pipes (laterals) containing holes, slots or nozzles and that connect into a main header pipe or duct (flume).

Suspended underdrains utilize an elevated floor, supported on columns or between dwarf walls, creating a plenum underneath. The plenum space, with at least 6'' to more than 30'' of vertical height, advantageously provides for inspection and service through an access hatch. Floors are constructed using steel plate (for small filters), from precast slabs, or by pouring a monolithic concrete slab on top of base form panels. Monolithic slabs minimize grouting (i.e., potential leakage points) and include reinforcement bars linked to the tank structure to create a robust design that withstands very high vertical forces. Nozzles sleeves are cast into the concrete floor, and once curing is finished, nozzles are quickly installed. Unlike nozzle-less lateral underdrains, suspended floors may be pressure-tested to ensure structural capability by inserting blanking plugs into the nozzle sleeves.

Lateral underdrains consist of a main header pipe or flume with several parallel laterals branched perpendicularly off one or both sides of the header or flume. The headloss in each lateral includes entry, friction, and discharge losses, the sum of

which vary water and air flowrates considerably under different operating conditions. Lateral underdrains are often fixed in place by grout or anchor bolts and buried in gravel to support and retain media and improve backwash performance.

Underdrain Design

Except in specific cases, filter underdrains must be level for uniform filtration across the bed and to evenly distribute the water and air fed during backwashing in a two-dimensional horizontal plane. Uneven, shallower parts of the media bed will create undesirable and increased filtering, backwash, and separate air scour flowrates. For simultaneous air-water cleaning, a zone of lower water flow may receive a higher proportion of air due to reduced water flow back pressure.

Filter underdrains must either have a fine straining method to hold back the media or have graded gravel to prevent media migration and loss. For underdrains requiring gravel, packing layers must remain stationary during backwash – if disrupted, the gravel must be re-laid.

Backwashing, particularly at increased rates, will not regrade the material, and instead will likely cause spouting through the media. Air scour and simultaneous air/water washing

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make problems from gravel layer undulations much worse. Suspended underdrains with large slot opening nozzles and gravel permit horizontal short circuiting, convergence of flow from several nozzles, and formation of a spout through the packing layer. Fine slot nozzles to retain media directly above the suspended underdrain eliminate horizontal short circuiting and also provide the advantage of a lower hydraulic filter profile.

Lateral systems (triangular or block with slots, round pipes with nozzles) that have openings fine enough to retain the media can block up if backwash water is not entirely free of grit. In contrast, because suspended underdrain velocities are relatively low, nozzles with very fine slots may be used without concern as grit particles in backwash water may settle in the plenum.

Backwash Method

Critical to a filter is the ability for its media to be effectively cleaned. With proper backwashing, conventional filters have many significant advantages over other filter types, to include much longer filter runs with smaller overall backwash volumes; however, not all conventional filter backwash capabilities are "created equal."

Velocities under a suspended underdrain are relatively low, which reliably leads to good backwash and air scour distribution. The large plenum area buffers changes and provides uniform water and air flowrates across the filter floor. Comparatively, underdrains with laterals produce higher velocities, friction loss, and the Bernoulli effect, resulting in limits of effective lateral length, additional filter design concerns, and increased maldistribution. The flow pattern down the length of a lateral forms an asymmetric "U" shape and changes significantly according to flowrate, leading to operational challenges and structural design concerns. When the air/water interface is created during air scour, without a sufficient lateral cross-section for the air to pass down the lateral length, waves are created that produce intermittent discharge and damage. As inferred previously, nozzle-less lateral systems cannot be pressure-tested following installation, introducing doubt of installed structural capability during these conditions.

Air is distributed through laterals using the orifices or slots located in the crown of a round pipe or triangular lateral, near the top of the primary duct of a block-shaped lateral, or through slotted nozzles mounted on a round pipe lateral. For triangular and nozzle-less round laterals, orifices must be engineered only for a specific set of flowrate conditions, which unquestionably change during backwash and air scour operation and lead to poor performance and orifice blockage.

Air is distributed through a suspended floor through precision-engineered nozzles/strainers. A nozzle has three main components – the strainer to retain media, a water control orifice, and a stem with air orifices. Nozzle stems include a top air bleed hole and lower air metering hole or slots. As scour air is supplied, air collects at the plenum top and depresses the plenum water to form a uniform air/water divide line across all filter stems. The air bleed hole triggers the flow of air and the resulting headloss causes depression of the plenum water interface. Once the air metering hole or slots are exposed, this larger orifice area stabilizes the water level; however, when air and water flows simultaneously, the driving head increases, forcing air into the stem, which raises the plenum water level. By correct selection of the stem bore and of the size and location of the orifices, a range of air/water interface level may be beneficially maintained under both air-only and simultaneous conditions. After air scour has ended, the air bleed hole allows venting of air from the underdrain.

Market Analysis

Though nozzle-based underdrains predominate the international municipal market, block-shaped lateral systems are prevalent in the United States. The molded block contains a triangular or semi-circular primary manifold that distributes into an outer pair of secondary ducts, which in turn feed an upper face (or cap). Multiple lengths of blocks are laid side-by-side and grout is placed between these laterals. Originally (late 1970s), the cap contained large perforations requiring gravel; however, to avoid the packing layer in the early 1990s, sintered polyethylene bead slabs were screwed onto the block top. Due to the numerous amounts of floor uplift events, resulting mostly from slab plugging, biological fouling, and grout leakage, manufacturers are currently discontinuing the beaded slabs, reverting to slotted caps, and providing a significant amount of supplementary hardware to hold down the blocks.

In response to the prevalent floor failures, stainless steel triangular laterals have recently increased in usage. Though having a low hydraulic filtering profile, maldistribution of triangular lateral systems is significantly higher than that of block or nozzle-based monolithic floors. Undesired outcomes resulted in poor media agitation and cleaning, shorter filter runs, increased backwash rates and volumes, and a reduction in filter capacity. Adding the recent increased cost of stainless steel, the life cycle benefit of triangular lateral systems over that of block style is questionable.

To fully capture the treatment capabilities and long-term maintenance benefits of conventional filters, prudent municipal filter design must include consideration of suspended monolithic floors. This type of nozzle-based underdrain system eliminates gravel, has excellent filter and backwash distribution characteristics, and is structurally superior to lateral systems. At end-of-life cycle, in contrast to a complete lateral underdrain overhaul, nozzles are simply replaced as the monolithic floor remains part of the civil structure. One monolithic underdrain manufacturer, Orthos Liquid Systems, boasts 200 installed filters, some with over 20 years of operation, without a filter underdrain failure. Lateral systems manufacturers with significant experience can make no such claim.

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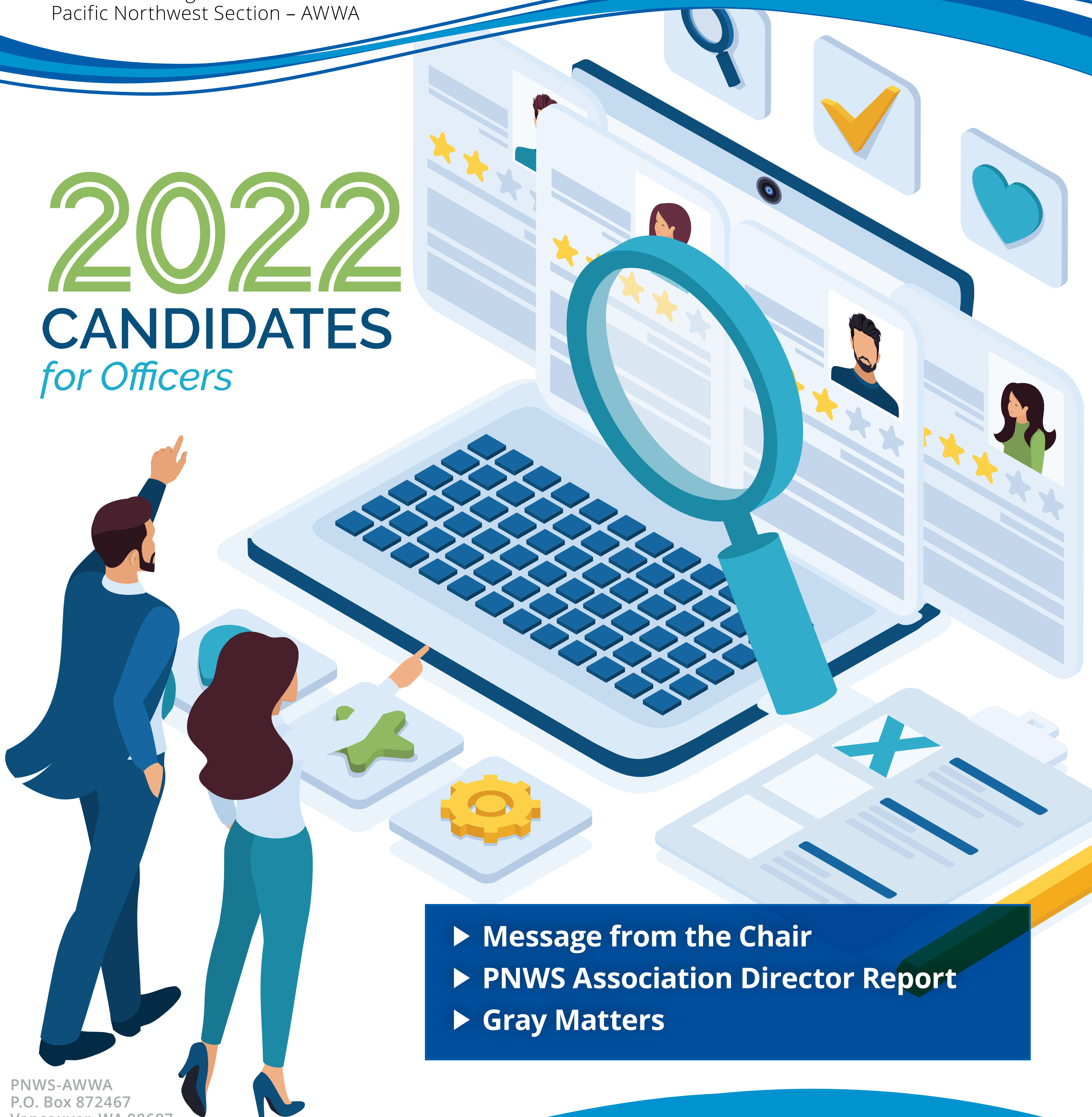

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