BACKWASH TESTING – TRUST BUT VERIFY

The functions performed by filter underdrains are fairly simple – support the media during filtration and evenly distribute air for air scouring and water for backwashing to clean the filter media and maintain proper filter operations. While the duties of filter underdrains are simple, the science behind accomplishing these tasks is not. There are a host of variables involved and numerous "rules of thumb" are often employed to simplify the process of granular media filter design. In the marketplace for filter underdrains, does everyone always get it right the first time? Unfortunately, the answer is "No".

IMPORTANCE OF BACKWASH FLOW DISTRIBUTION

In current filter designs that employ air scour, the introduction of backwash water to the filter following air scouring serves three primary objectives:

1. Enhance the cleaning process by introducing sufficient backwash water flow into the filter to expand the media bed while still air scouring until the level in the filter reaches the bottom of the troughs. Expansion of the media bed following vigorous air scouring allows the dirt to more effectively be flushed from the media bed.
2. Transport the dirt that air scouring has knocked loose from the filter media out of the filter via the backwash troughs.
3. Prepare the filter media bed for the next filtration cycle by insuring that the media is properly stratified and level so that the media can deliver optimum filtration performance.

Even distribution of backwash water flow is critical in order to meet the second objective. Uneven distribution of backwash water flow when more than one type of media is used will result in a poorly defined interface between the media types and the interface that exists will not be level.

More importantly, uneven distribution of backwash water flow will result in peaks and valleys throughout the media bed and this unevenness is exacerbated if filter gravel is used. As intuition suggests, a low point in the media bed yields a lower headloss than the surrounding media resulting in short circuiting through the media bed. Conversely, a mound in the media bed yields a higher headloss than the surrounding media leading to agglomerations of media and contaminants often referred to as "mudballs".

CONTROL OF BACKWASH FLOW

There are two commonly used methods for designing filter underdrains to insure even distribution of backwash flow:

1. Manifold Approach - The most commonly used control method involves using a comparatively large conduit to convey backwash water to the far reaches of the filter and a comparatively small orifice with substantial headloss to distribute that flow evenly. This is essentially treating the conduit as if it is a manifold.
2. Variable Orifice Approach - The second control method usually involves a smaller conduit to convey backwash water and a series of variably sized orifices that are tailored to deliver flow evenly through all of the orifices while using variable pressure drop across the orifices to account for a changing rate of flow and velocity in the conduit.

Both of these approaches can achieve even distribution if executed properly because they both use the same basis of design, the formula shown below:

$$h = \left(k_1 \frac{v_m^2}{v_o^2} + k_2\right)\frac{v_o^2}{2g}$$

Where:

h	=	headloss across the orifice
k_1 and k_2	=	constants associated with the physical characteristics of the manifold and orifices
v_m	=	the velocity in the manifold
v_o	=	the velocity through the orifice
g	=	gravitational constant, acceleration due to gravity

This is a version of the Darcy-Weisbach Equation tailored for the situation where you have a pipe or conduit with orifices. In the case of the manifold approach, the velocity through each orifice is presumed to be very high relative to the velocity in the conduit or manifold with the result that the term, (v_m^2/v_o^2), approaches 0 and the headloss for every orifice becomes essentially the same. The variable orifice approach changes the diameter of the orifices to account for changing velocities along the length of the conduit in an effort to maintain a constant rate of flow through all of the orifices.

The length of the conduit carrying the backwash flow is critical. As the conduit gets longer in an effort to provide backwash flow to more filter area, the rate of flow in the conduit increases and the velocity in the conduit increases commensurately. When using the manifold approach for filter underdrain design, the assumption that (v_m^2/v_o^2) approaches 0 ceases to be valid. When using the variable orifice approach, the orifices near the backwash water source must be comparatively large with orifices further from the source becoming progressively smaller. In either case, proper design is critical if the goal of even distribution of backwash flow is to be met.

Going back a number of years, a standard of ±5% was often used as to define even distribution of backwash flow. Variability of ±5% has not always resulted in optimum filter performance due to either actual variability in backwash flows or an inability to measure a tolerance of ±5% with a reasonable degree of precision. Over the last decade, more precise means of controlling backwash flows coupled with improved methodology for measuring those flows has led to an improved standard of ±2½%. Due to improvements in both flow control and measurement, AWI typically field verifies variability in backwash water flows in the significantly better than ±2½% at its filter underdrain installations.

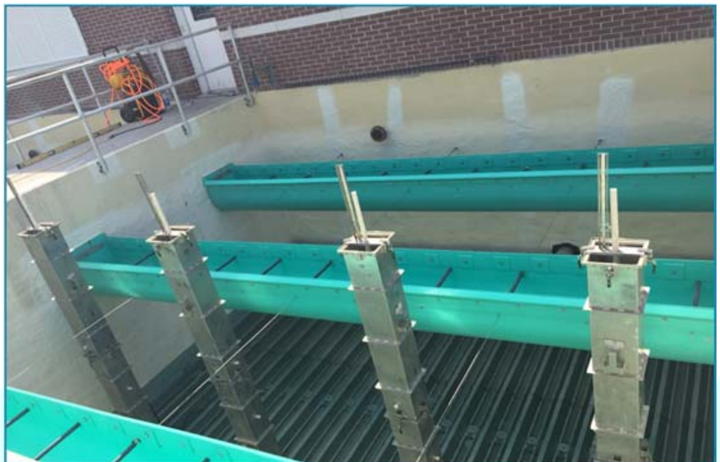
Using either the manifold approach or the variable orifice approach, a host of assumptions must be met in order for backwash flow to be evenly distributed. This is the reason AWI uses its in-house test tank to validate its orifice sizing for projects before a project's underdrain laterals are manufactured and shipped to a jobsite. Unfortunately, factory testing is not an absolute guarantee of success in the field due to quirks in how filters are laid out and particularly variations in how the backwash water is fed to a filter underdrain system.

BACKWASH TESTING

Backwash testing of an installed filter underdrain system in the field is the only way to positively ascertaining whether or not the underdrain system is properly distributing backwash water.

AWI uses a "box test" approach to directly measure backwash water flowrate at various points in a filter. A vertical "box" with a standard cross-section is attached to a lateral isolating a fixed point and capturing the backwash flow entering the box. A measuring float within the box to gauges the rising water level in the box. By using a stopwatch in conjunction with measuring the liquid level in the box, the backwash flowrate in the filter can be directly and accurately measured. Multiple boxes are distributed about the filter so that flowrates can be directly measured and verified at multiple points against the specified tolerance for distribution of backwash flow.

A photograph of an ongoing box test is shown below.



UNIFORM DISTRIBUTION – FIELD VERIFIED

A virtue of the box test is that flow is measured and compared throughout the period when the level in the backwashing filter rises prior to reaching the bottom of the filter troughs. Imbalances in flow during the period when backwash water is filling the filter will indicate areas where the media may not be getting properly cleaned or areas that will require extended backwashing to be effectively cleaned. If backwash flow imbalances exist during this portion of the backwash cycle, backwashing must continue for a prolonged period under steady state conditions with the backwash overflowing into the filter troughs in the hope that the fluidized media will restratify and level itself. When air scouring, the filter design philosophy is to use air scour to loosen the dirt attached to filter media and then use backwash water primarily as the means to transport the dirt out of the filter. Prolonged backwashing under steady state conditions to level the media bed needlessly wastes backwash water.

The box test is a significant improvement in field filter underdrain hydraulic performance validation because it directly measures flow. In the past, measuring pressure has been used to indirectly infer flow measurement. There are three primary shortcomings when using pressure as a surrogate for flow:

1. Valid pressure measurements can only be made after backwash has begun overflowing into the filter troughs and steady state has been reached. When using pressure as a surrogate, flow distribution can only be assessed during the least desirable and most wasteful portion of a backwash cycle.
2. Measuring pressure using manometers attached to multiple pressure taps in an underdrain system, termed piezometer testing, is far less precise. Though the headloss in the tubing used to attach the pressure taps to the manometers

dampens the changes in pressure read at the manometer greatly, manometer liquid levels still bounce around a great deal. Accurately determining whether backwash flows at different points in a filter are within a tolerance of ±2½% or even ±5% when the liquid levels in the manometers being used as measuring devices are moving is a near impossibility.

3. Pressure transients that commonly occur when backwash pumps surge create pressure waves that propagate across a filter. When using manometers to measure pressure as a surrogate for flow, these pressure waves are impossible to segregate from the actual static pressure beneath the underdrain system. This pressure “background noise” can actually be greater than the pressures you are attempting to measure during testing.

CONCLUSION

Proper distribution of flow during backwashing is key for successful long-term filter performance. Field testing needs to be done to verify even distribution because there is tremendous variability in filter design when it comes to size, shape, and means of introducing the backwash flow into the filter.

Predictive models used in filter underdrain design and even use of computational fluid dynamics (CFD) modeling greatly improve our ability to achieve better backwash performance. Nonetheless, each filter is unique and models are only as good as the information entered into them. For the foreseeable future, field testing to validate performance will be a key element used to insure that the filter underdrain designer got it right or to direct corrective action in the event the designer got it wrong.

The box test is a significant advancement in field testing to assess backwash performance because the box test uses direct and accurate measurements taken during the most critical portion of the backwash cycle.