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Backwash Optimization for HYDRAcap® Systems by Qualitative Analysis

This Technical Service Bulletin provides optimization information for the backwash process on HYDRAcap® systems.

Description of the Backwash Sequence

As solids accumulate on the membrane surface of a HYDRAcap® module, transmembrane pressure (TMP) will increase proportionally. In many cases this accumulation of solids or foulant can be removed physically and/or chemically. The physical process of removing foulants is known as backwashing. Backwashing is a multi-step sequence that may or may not include chemicals (i.e. chlorine, hydrogen peroxide, sodium hydroxide or citric acid) and air pressure. Often times overall system performance can be directly attributed to backwash cycle parameters. If any portion of the backwash sequence is not optimized or if backwash cycles are not frequent enough, then transmembrane pressure (TMP) will increase. This increase in TMP may be slow for a week or two (2 psi per week). But, after a certain duration, TMP will increase very dramatically, usually occurring after it reaches 15 psi. In order to maintain stable system performance and recovery, optimization of the following backwash steps will be required:

	Standard	AEB	CEB
Step 1.	Forward Flush	Forward Flush	Forward Flush
Step 2.	Backwash Top	Air Pressurization	Backwash Top (w/ chemical)
Step 3.	Backwash Bottom	Backwash Top	Backwash Bottom (w/ chemical)
Step 4.		Backwash Bottom	Soak
Step 5.			Rinse

Air Pressurization

Though air pressurization is listed as a step in the backwash sequence, no benefit will be obtained by prolonging air contact time. Air contact time is determined by the time required to drain feed header and pressurize the feed top header to 15 psi plus 5 seconds hold time. Hydranautics has determined that use of oil free pressurized air in various sections of the backwash sequence greatly enhances the efficacy of the overall backwash process. Some systems do not allow for air usage and reader may disregard subsequent references. It should be noted that systems which do incorporate air pressurization step(s) should ensure that the system design does not allow for water hammer to occur.

Forward Flush

During forward flush, water flows tangentially through the fibers from feed to concentrate. Forward flush typically uses feed water, though in some systems filtrate is used, at a flow of at least 40 gpm per module, to clear plugged fibers and create a shear effect that removes foulant residing on the membrane surface. Forward flush can be beneficial when filtering highly turbid waters where thick cake layers are typically formed during the filtration cycle.

Backwash Bottom and Backwash Top

The actual “backwash” occurs during the backwash bottom and backwash top steps.. During these two steps filtrate is pressurized from the filtrate side and permeates, at high fluxes (100-150 GFD), through the membrane to the feed side, basically reversing the processing flow and removing particles from inside the fibers. In backwash bottom, backwash retentate exits the feed bottom port, whereas in backwash top, backwash retentate exits the feed top port.

Soak

Soaking is used when chemicals are introduced into the filtrate backwash solution. This type of backwash is typically called a chemically enhanced backwash (CEB). The chemical solution that is present from the backwash steps, is allowed to reside in the idle module(s) for a defined duration. When fouling is severe, the rinse step is modified such that instead of having the solution remain idle in the module, the feed headers are drained and pressurized to 15 psi with oil free air. This time the beneficial effect of the air is the expansion of the fibers (2-3%) allowing lodged particles to be removed freely.

Rinse

The final step in the CEB sequence is a rinse step consisting of both a backwash bottom, and a backwash top. The duration of the rinse should be long enough to sufficiently remove the CEB chemical from the system. Residual chemical concentration, from a

CEB, will usually be quite small, but some applications may require removal of any residual chemicals.

Backwash Optimization

Processing time, backwash water volume and flux all have an overall effect on the system recovery and system size. An ideal system would operate at high fluxes with a low backwash frequency and use minimal filtrate for backwashing. It is possible to approach an ideal system by optimizing the backwash sequence. After optimizing the backwash, it is sometimes possible to significantly increase processing time, flux and thus system recovery.

Optimization of backwash sequences is an iterative process and can be time consuming. Many parameters must be altered in order to determine optimum backwash effectiveness. The optimum backwash parameters will vary from site to site and thus, the basis of this information is to provide a general strategy for optimizing the backwash sequence. If a pilot study has been performed, then the use of the optimized backwash parameters determined in the pilot study should be used as a starting point, otherwise review Hydranautics' System Design Table.

In order to perform the backwash optimization it is necessary that the following requirements are met:

1. Transparent PVC pipe connecting all feed and filtrate ports, on at least one module per rack, to each of their corresponding headers.
2. Ability to alter PLC or controller for backwash parameters.
3. Continuous system operation for at least 12 hours.
4. System operation only in feed bottom mode.

Listed below are steps that should be taken in optimizing the backwash sequence and thus enhancing plant performance.

Preliminary setup Procedure

Prior to optimization, a preliminary observation of backwash performance is necessary.

1. First, allow the system to operate for 3 to 4 hours and monitor color and solids in each of the transparent pieces of PVC pipe upon the next backwash. As this is a qualitative approach to optimization, it is necessary to create a reference point or baseline value for the color shade and quantity of solids at the end (when there is no flow in the pipe) of each of the backwash sequence steps. An arbitrary scale

of 1 to 5 (1 is zero color/solids and 5 is very colored and many solids), for example, should be designated to the color and amount of solids. After each optimization attempt, it will be necessary to qualitatively determine the relative removal of color and solids in each of the backwash steps. Using the arbitrary scale, record a value of "clarity" for each of the following backwash steps.

2. Calculate the TMP two minutes after the backwash cycle. Though TMP is a quantitative approach for determining effectiveness of the backwash sequence, it is often not accurate enough, in this short time span, to make necessary adjustments to optimize backwash parameters. It is calculated strictly for reference, though may be useful in severe fouling situations.

Backwash Optimization Procedure

1. Observation of the backwash cycle in the Preliminary Setup Procedure should have given some insight into which steps in the backwash sequence need to be optimized. Upon observing the transparent piping during each backwash step, color change and decreased amount of solids should be apparent. Goals in backwash optimization are:
    a. Optimize forward flush by ensuring that residual amounts of color and solids at the end of the forward flush step is relatively low. If air pressurization is used prior to the forward flush step, then it is necessary that no air remain in the modules upon completion of forward flushing.
    b. Optimize remaining steps in the backwash sequence. Since these remaining steps are similar in their mechanism of removing the foulant, the technique for optimization should be such that each of these remaining steps should have an equal contribution on foulant removal. This means that no one step should be optimized to removing all of the foulant such that color and solids in the transparent PVC tube is completely clear. These steps should work jointly such that only at the end of the backwash process should there be no remaining material in the clear PVC pipe. If not optimized in this manner, recovery will be unnecessarily reduced. An ideally optimized system would have values of:

        Forward Flush = 1
        Backwash Top = 3
        Backwash Bottom = 3, 2 or 1
        Soak = NA
        Rinse = 1

2. Based on "clarity" values assigned to each backwash step, in step 2 of the Preliminary Setup Procedure, increase the duration of each step that does not "appear" to be optimized. If one step appears to have a high "clarity" value (i.e., four) then increasing the time (20-50%) of that step should reduce it's clarity value. The typical range of time for each step is as follows:

   Air Pressurization = 30 – 50 seconds
   Forward Flush = 6 – 20 seconds
   Backwash Top = 6 – 10 seconds
   Backwash Bottom = 6 – 16 seconds
   Soak (CEB) = 40 – 300 seconds
   Rinse = 12 – 30 seconds

3. Once all backwash steps, which require optimization, have been changed to the new time values, then repeat the steps in the Preliminary Setup Procedure through the Backwash Optimization Procedure until all backwash steps have been optimized.
4. Once all backwash steps have been optimized, allow the system to operate for 12 hours and review each backwash sequence again by noting "clarity" in the clear PVC pipes. Typically a second optimization will be required. If a second optimization is required follow the Backwash Optimization Procedure steps 1-3.

Processing Duration/Backwash Frequency Optimization

Optimizing the processing duration, or backwash frequency, is a quantitative process that requires careful monitoring of the TMP. At this point the backwash sequence has been optimized and, in most cases, regardless of the fouling, system performance (i.e. TMP or specific flux) should return to original startup values or other stable values. If this is not the case then the fouling is beyond the capabilities of the determined operating parameters. This may occur when the processing durations are too long and the build-up and compression of the foulant is such that regular backwashing interval is not fully effective.

At this point it will be necessary to perform manual backwashes. A manual backwash should be performed when the calculated TMP, after a backwash, has increased more than 0.5 to 0.7 psi for a 12 to 24 hour period. If manual backwashes do not restore performance then a chemically enhanced backwash or chemical cleaning may be required.

1. Once TMP has been restored to its' baseline value then the processing duration should be decreased (i.e., increase the backwash frequency) by 5 minutes and

allowed to operate for 12 to 24 hours with the new processing time. Continue this iterative process of lowering the processing time until the value for the processing duration produces stable operation for a few days. Meaning, the backwash cycles are completely or nearly completely restoring the TMP after two days of operation.

2. Conversely, if the system has been steadily operating since optimizing the backwash sequence, then increase the processing duration until a noticeable (0.5 psi) increase in TMP for a 12 to 24 hour period (measuring 2 minutes after a backwash). When this point is reached, reduce the processing time to the previous value (subtract 5 minutes).

It should be noted that the fouling mechanism characteristic may vary significantly from site to site and season to season. System stability is defined by minimal change in TMP, after a backwash, for extensive periods of time. For a given process cycle, TMP may increase 2 psi from the beginning of the processing cycle to the end of the processing cycle, but as long as the backwashes are capable of restoring TMP to the starting value of that process cycle, then the system is considered stable.

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