Technical Service Bulletin

October 2013 TSB 139.03

Data Logging, Normalization and Performance Analysis for HYDRAcap® Systems.

This Technical Service Bulletin provides information for manual data logging, data normalization and HYDRAcap® performance analysis.

General

Most HYDRAcap® systems have supervisory control and data acquisition (SCADA) such that operating data is capable of being automatically acquired and stored at least every minute. Despite this technical convenience, manual data logging should be performed at every HYDRAcap® plant. Not only does the physical act of data logging allow operators to inspect their systems, but it also facilitates corroboration amongst transmitters and gauges. Data sheets are also a good backup source of data should the electronic data be lost.

Data Logging Sheet

A sample data logging sheet is provided below. This sheet lists all parameters that are necessary to determine HYDRAcap® performance. Some systems incorporate supplemental equipment as part of the ultrafiltration process, such as a screen filter, chemical injection, tanks, particle counters and pH probes. Data from each of these items should be logged, as well, to ensure proper plant performance and establish baseline characteristics.

A data set from each HYDRABLOC® or rack should be manually logged at least once per day (minimum), and preferably once per operator shift. A data set includes both data logged two minutes prior to backwash and two minutes after backwash. This allows for an accurate assessment of backwash efficacy and HYDRAcap® performance.

The following is a description of parameters used in the data logging sheet:

- Date – calendar date.
- Time – local time.
- Hour Meter –machine time, usually in hours.
- Temperature – feed water temperature in degrees Celsius, [^{o}C].
- Screen Filter Pressure In – water pressure entering the screen filter, [psi].

- Screen Filter Pressure Out – water pressure exiting the screen filter, [psi].
- Bottom Pressure – water pressure on the bottom feed side of the HYDRAcap® module, [psi].
- Top Pressure - water pressure on the top feed/top concentrate side of the HYDRAcap® module, [psi].
- Filtrate Pressure – water pressure on the filtrate effluent side of the HYDRAcap® module, [psi].
- Feed Turbidity – feed water turbidity, [NTU].
- Filtrate Turbidity – filtrate water turbidity, [NTU].
- Filtrate Flow – instantaneous filtrate flow, [gpm].
- Bleed Flow - instantaneous bleed flow, [gpm].
- Recycle Flow - instantaneous recycle flow, [gpm].
- Comments – time remaining until next backwash [minutes], type of backwash (i.e., high pH, low pH or oxidant CEB), chlorine concentration, or other notable events.

Data normalization is required to determine HYDRAcap® performance. As feedwater temperature changes, so does membrane permeability. Temperature change not only effects feed water viscosity, but also membrane permeability. Significant temperature fluctuations yields significant fluctuations in observed transmembrane pressure (TMP), and actual plant performance may not be determined. For this reason it is necessary to normalize operating data to a reference temperature. For simplicity, our reference temperature for normalization is 20º Celsius. The following equations should be used in determining HYDRAcap® system performance:

Flux is filtrate flow rate per unit area of membrane. Flux is a system design parameter that has a direct correlation with membrane fouling rate. As flux is increased, so is the fouling rate.

- Flux calculation:

$$J = \frac{1440 * Q}{A_m}, \text{ [gfd]}$$

where

J - filtrate flux, [gallons/ft^2/day].

Q - filtrate flow, [gallons/minute].

A_m - effective membrane area, [ft^2].

Trans Membrane Pressure (TMP) is the net driving pressure on the membrane. This is the effective pressure for forcing water through the membrane. A clean membrane will have a relatively low TMP, whereas a fouled membrane will have a relatively high TMP, depending on the severity of fouling. When TMP reaches 15-20 psi a chemical cleaning is recommended.

NOTE: TMP should never exceed 20 psi.

- Trans Membrane Pressure calculation:

$$TMP = \frac{(P_{bottom} + P_{top})}{2} - P_{filt}, \text{[psi]}$$

where,

TMP - trans membrane pressure, [psi].

P_{bottom} - bottom feed pressure, [psi].

P_{top} - concentrate pressure, [psi].

P_{filt} - filtrate pressure, [psi].

Temperature Compensated Specific Flux (TCSF), or permeability is an intrinsic property of the membrane and should be used to determine membrane performance. In relation to the startup, a significantly high TCSF may indicate chemical degradation of the membrane, whereas a low TCSF may indicate fouling. When the TCSF reaches 7-9 gfd/psi, a chemical cleaning is recommended.

NOTE: TCSF should never decrease below 7 gfd/psi.

- Temperature compensated specific flux calculation:

$$TCSF = \frac{J}{TMP} * e^{(-0.031*(T-20))}, \text{[gfd/psi]}$$

where,

TCSF - temperature compensated specific flux.

J - flux, [gfd].

TMP - trans membrane pressure, [psi].

T - water temperature, [°C].

Differential pressure or ΔP is the pressure drop across the fiber length on the feed/lumen side. ΔP is calculated from the difference between bottom feed and top feed pressure during processing. ΔP increases as the membrane fouls due to increased filtration resistance across the length of the fibers. Excessive ΔP (>6 psi) may cause fiber damage.

- ΔP calculation:

$$\Delta P = P_{bottom} - P_{top}, [psi]$$

where

P_{bottom} - bottom feed pressure, [psi].

P_{top} - concentrate pressure, [psi].

Note: P_{top} must be greater than P_{filt}

Instantaneous Recovery is the recovery of a HYDRAcap® system for one processing/backwash cycle. Actual daily recovery may vary from that calculated from a single processing/backwash cycle due to chemical cleaning, chemically enhanced backwashing (CEB), integrity testing or other occurrences that might alter the processing duration and net filtrate production. Instantaneous recovery is calculated based on the following formula:

- Instantaneous Recovery:

$$R = \left[\frac{V_{FiltGross} - V_{BW}}{V_{FiltGross} + V_{Bleed} + V_{FF}} \right] * 100, \quad [\%]$$

where

R - system recovery.

V_{BW} – volume of water used for single backwash cycle.

$V_{FiltGross}$ – volume of filtrate water produced for single processing cycle.

(processing cycle is the time between two backwashes).

V_{Bleed} – volume of bleed water wasted durring single processing cycle.

V_{FF} - volume of feed water used for forwardflush step during single backwash process.

or if the bleed and forwardflush are equal to zero, the formula simplifies to :

$$R = \left[1 - \frac{V_{BW}}{V_{FiltrGross}} \right] * 100, \quad [\%]$$

V_{BW} – This is the total volume of filtrate used during a single backwash sequence. This volume may vary depending on the type of backwash (i.e., standard or CEB). To accurately calculate the instantaneous recovery, it is important to include the water consumed for the backwash bottom, the backwash top, and when chemical enhanced backwash is performed, the rinse.

V_{Filt} – The gross amount of produced filtrate from a single processing cycle. Unless a totalizer is available on the SCADA or flow transmitter, it will be difficult to obtain accurately the volumes used to calculate recovery. This reason is due to the fluctuation in flow, due to temperature changes, fouling and the frequency drives on the pumps.

V_{Bleed} – When system works with cross flow, part of the water stream can be directed to the waste as reject. Such flow is called bleed. In UF systems, for efficiency purposes, only small part of the cross flow is sent to drain as bleed. This value is usually 5-25% of the feed flow. Feed water quality (TSS, TOC, BOD) greatly impacts bleed volume. It is trade off between recovery and system fouling ratio. Because fouling usually produces difference in flow distribution in the system (relation between bleed and filtrate flow), the net bleed flow can vary substantially in single processing time duration. Totalizer installed in the bleed effluent line allows system operators maintain stable conditions using closed loop control system complemented with flow control valve on bleed line.

Recovery, ΔP, TCSF and TMP are the minimum parameters that should be calculated and monitored to determine HYDRAcap® performance. For a complete assessment of the HYDRAcap® system performance, other parameters should be monitored as well (i.e., turbidity rejection, TOC rejection, TSS rejection etc.)

HYDRAcap® Performance Analysis

Recovery

Unless HYDRAcap® optimization is to be performed or system feedwater conditions change, each HYDRABLOC® and HYDRAcap® module should operate at constant recovery. Assuming the system is currently in equilibrium, this will ensure good and predictable performance. Increasing recovery may cause the system to operate erratically. Signs of unstable operation are increasing TMP and decreasing specific flux. As a result, previously determined chemical cleaning schedules will change and cleanings frequencies will increase.

Flux

Similar to recovery, the temperature compensated flux should be kept constant. As the temperature of the feed water changes, the instantaneous flux may need to be changed accordingly. If possible, flux should be monitored and controlled by the SCADA. Any change on the flux should be accompanied with the appropriate adjustment of the backwash frequency and sequence durations.

ΔP

Differential pressure is important for analysis only when cross flow or bleed flow is utilized. In direct or “dead end” filtration the ΔP is low, and in most cases will not be beneficial in determining the degree of membrane fouling inside the fiber lumen. However, crossflow or bleed flow will yield much information about fiber plugging or cake layer build-up. Fiber plugging is a potential hazard to hollow fibers integrity. It is of the utmost importance that, at a minimum, a 150μm screen filter be incorporated to condition feed water prior to HYDRAcap® modules. As fibers become plugged, effective membrane area decreases. Once a significant number of fibers have been plugged, localized flows become excessive and fiber breakage or rapid fouling may occur. Should a significant increase in ΔP occur (also an increase in TMP) then a module should be taken off-line and feed end fibers inspected. If there is no observable blockage over the fibers, then most likely a thick cake layer has formed and the backwash frequency should be optimized and a chemical cleaning should be performed.

Trans Membrane Pressure (TMP)

When flux and temperature are constant, the TMP is indicative of the degree of fouling on the membrane. A clean membrane will have a constant TMP, assuming the previous conditions are met. However, water viscosity and membrane resistance are dependent on temperature. When water temperature changes, TMP changes as well. This effect is common for every membrane process. In some cases when water temperature fluctuates significantly, TMP fluctuations will occur. This is also true when flux varies. Thus, an increasing TMP does not necessarily indicate fouling, only the possibility of fouling. Care should also be taken to ensure that the TMP during backwash does not exceed 20 psi.

CAUTION: TMP should never exceed 20 psi (1.4 bar) or fiber damage may occur.

Permeability or Temperature Compensated Specific Flux (TCSF)

For any HYDRAcap® system it is critical that the TCSF be monitored. Being an intrinsic property of the membrane, TCSF will represent the condition of the membrane regardless of the changes in temperature or flux. The benefits of properly maintaining TCSF will translate into the energy usage as well. As the membrane fouls, and the TCSF decreases, energy requirements will increase (if system operating parameters remain constant).

CAUTION: TCSF should never decrease below 7 gfd/psi (172 lmh/bar) or fiber damage may occur

Useful Tips:

1. Take data daily and if possible once per shift. Keep on-line data as a more reliable information source and record a complete data set at least every minute.
2. Plot each parameter versus time in such scale to observe sudden spikes on data trends.
3. Log graphs in journal and keep them available at operator control room.
4. Log events of errors in control on the UF system as well bad service and operation.
5. Try to analyze every upset in data trends (especially TMP, Flux and Permeability).
6. Trace water quality and its relation to system performance.
7. Trace the effect on water temperature to fouling ratio.

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