# Tailoring flushing procedure to modern Pods systems

## Introduction

Millistak+® HC, Millistak+® HC Pro and Clarisolve® clarification filters are widely-used disposable depth filters, suitable for a broad variety of applications and sizes due to their broad range of pore sizes and easy to use format (Pod). Millistak+® HC, Millistak+® HC Pro and Clarisolve® filters may be assembled together in parallel to scale up the clarification process by equally distributing the flow between the modules. Incorporating multiple grade-density layers and adsorptive positively charged filter media, made of natural materials (Millistak+® HC, Clarisolve®) or fully synthetic components (Millistak+® HC Pro), MilliporeSigma's depth filters provide unique filtration performance.

For optimal filtration performance, it is necessary to wet the filter media adequately prior to using for several reasons:

- Removing excess air entrapped in-between the media layers. This ensures complete utilization of the filtration area. During processing, a pressure increase in the Pods can lead to degassing on the downstream side of the filter, resulting in foaming which may affect product quality (aggregates have a propensity to form at air-liquid interfaces) and reduce the overall capacity of downstream bioburden reduction filters.
- Ensuring an even flow distribution among the filters.
- Reducing the level of leachables from the media.

MilliporeSigma recommends flushing the Millistak+® HC and Clarisolve® filters with 100 L/m$^2$ purified water (WFI or equivalent quality) at a flow rate between 270[1] and 600 LMH (L/(m$^2$.h)), and 50 L/m$^2$ at 300 LMH for Millistak+® HC Pro devices. However, depending on the total filter area installed, it can be difficult to achieve sufficient flow rates needed with existing pump capacities for large system installations or smaller systems with single-use flow path. Consequently, MilliporeSigma has evaluated the possibility of performing a reduced flowrate flush on the clarification media and developed an alternative procedure for flushing the filters at a lower flowrate.

## Definition of wetting targets

Process scale Pod filters are composed of different surface areas (each filter being made of several media layers) installed together in parallel to obtain the final filtration area (**Figure 1**). To estimate the efficiency of the pre-use RO water flush, the filters were first flushed with water according to the experimental parameters and afterwards stained with a solution of water/Ponceau Red. Staining was performed until the outflow was visually similar to the staining solution. The filters were then drained and transversally cut (**Figure 1**), and each media sheet colored area was quantified using a 10 x 10 units grid. The number of units colored gave a percentage of staining within the device. The final wetting score was calculated by averaging the wetting percentage of each sheet of the device. The total media surface was considered as adequately wet when reaching an average of 90 % or more, partially wet between 50 and 90 % , and not wet when less than 50 % of the full surface was stained.

**Figure 1:** Cross sectional cut of a Pod showing the multilayer structure (Left) and dissection of colored pods by transversal sectioning (Right)

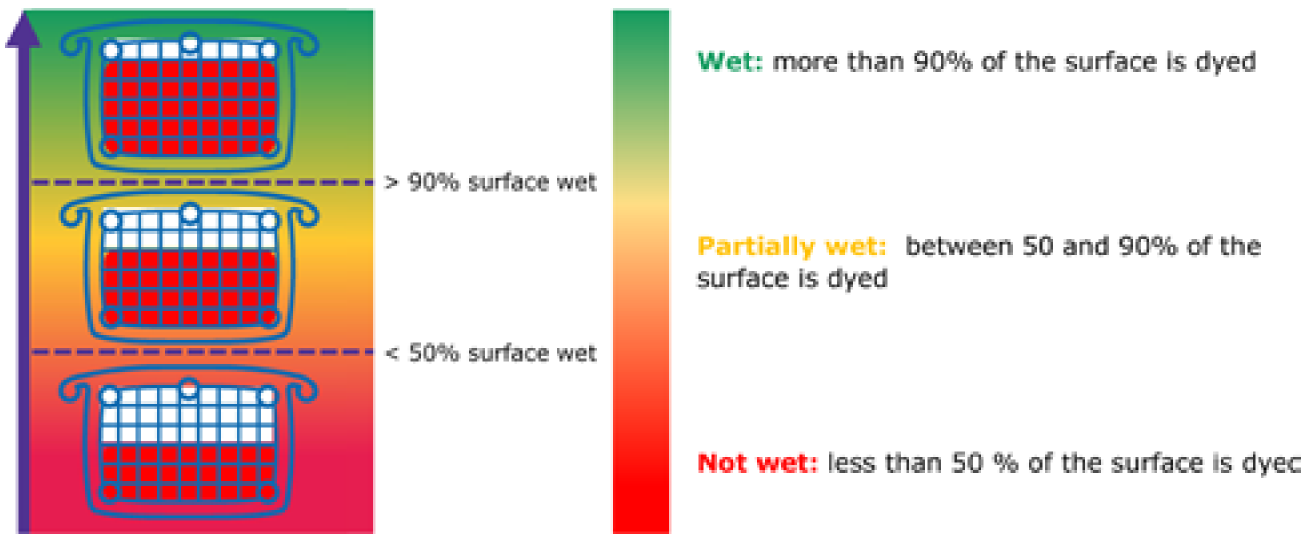



**Figure 2:** Definition of media wetting targets

## Experimental procedure

The study was performed on process scale Pods to bracket the overall range of the Millistak+® / Clarisolve® filters used in manufacturing processes. A sampling of different media grades was selected based on their filtration material (type and media density) as well as on their ratio internal void volume / filtration area.

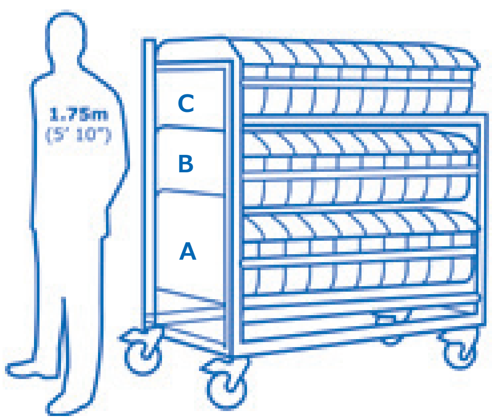
### Table 1: Properties of tested devices.

| Encapsulated media grade | Family | Structure | Nominal retention rating | Effective area of one manuf. scale device | Ratio pod void volume / filtration area |
|---|---|---|---|---|---|
| 40MS | Clarisolve® | Polypropylene and cellulose fibers combined with an inorganic filter aid | 0.6-40 µm | 0.55 m² | 2.7 |
| D0HC | Millistak+® HC | Multiple layers of cellulose fibers and diatomaceous earth | 0.6-8 µm | 1.10 m² | 1.0 |
| D0SP | Millistak+® HC Pro | Nonwoven, Silica filter aid/Polyacrylic fiber pulp | 0.6-8 µm | 0.77 m² | 2.0 |
| X0HC | Millistak+® HC | Multiple layers of cellulose fibers and diatomaceous earth | 0.05-0.1 µm | 1.10 m² | 1.0 |
| X0SP | Millistak+® HC Pro | Silica filter aid/Polyacrylic fiber pulp | 0.05-0.1 µm | 1.10 m² | 1.0 |

All tested devices were filled with purified water at a flow rate of 85 LMH, with outlet port closed and vent port open. After complete filling, the outlet port was opened, then the media flushed up to 120 L/m² with RO water. Filtrate conductivity was monitored in-line. Media was then stained with a Ponceau Red solution and the devices were cut open to measure the colored area.

Flushing flow rates were calculated based on a pump able to deliver a flow rate up to 3600 L/h but only 2870 L/h (80 % of its full capacity) was used, filling a full three-level holder with all three racks being flushed in parallel. In this configuration, a worst-case scenario would be flushing a holder filled with 30 x 1.1 m² Millistak+® Pods, resulting in a flushing flow rate of 87 LMH (rounded to 85 LMH for ease of calculation).

**Table 2: Flow rates calculation based on maximum filtration areas.**




| | | Clarisolve® 40MS | Millistak+® HC Pro D0SP / C0SP | Millistak+® D0HC / X0HC Millistak+® HC Pro X0SP |
|---|---|---|---|---|
| One-level Rack A | Number of modules | 7 | 7 | 10 |
| | Total area | 3.85 m² | 5.39 m² | 11.00 m² |
| | Flushing flux (@ 80 % full pump) | 780 LMH | 557 LMH | 272 LMH |
| Three-Levels Racks A + B + C | Number of modules | 21 | 21 | 30 |
| | Total area | 11.55 m² | 16.17 m² | 33.00 m² |
| | Flushing flux (@ 80 % full pump) | 260 LMH | 185 LMH | 87 LMH |

## Influence of flushing flow rate on media wetting

Effective wetted surfaces were measured for each Pod type after completion of the trial flushes. The resulting heat-map of wetting efficacy revealed that wetting is sufficient for Millistak+® HC and Millistak+® HC Pro at the minimum flow rate of 270 LMH, in-line with current User Guide recommendations. At the same time, it demonstrated limited efficiency of low flow rate flushing, especially on the filters with the highest ratios void volume / area (namely Millistak+® D0SP and Clarisolve® 40MS).

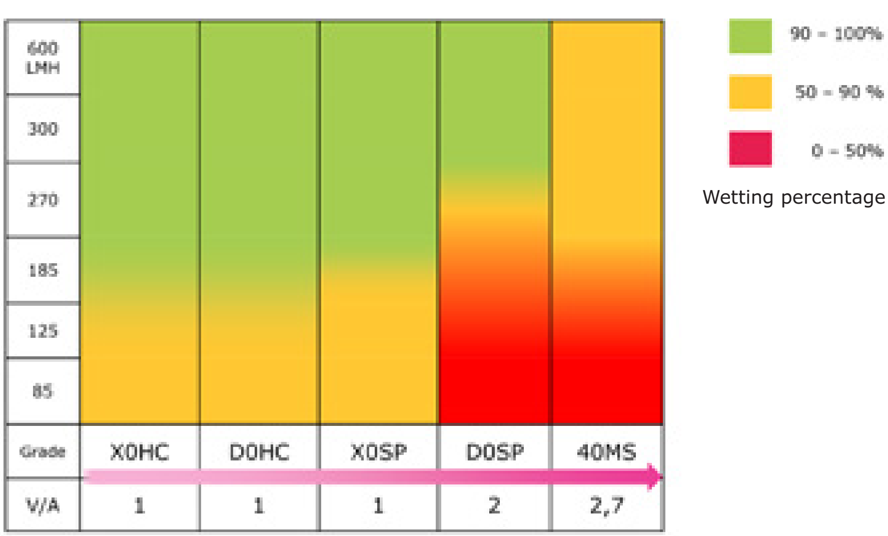



**Figure 3:** Heatmap of Pod wetting after flushing with current recommended procedure (Left). On the right, flushing Millistak+® X0HC at 600 LMH (up, 100 % wetting) and Millistak+® HC Pro D0SP at 85 LMH (Down, 45 % wetting).

For devices with low media density, permeability is relatively high. The media does not exhibit sufficient resistance to the passage of the fluid, and this prevents a complete filling of the upstream chamber. Additionally, the large void volume to area ratio (V/A) indicates the presence of large chambers upstream of the media that can easily be drained under gravity drain. At low flushing flow rates, filter draining occurs faster than filling. This results in incomplete wetting of the media surface with the upper half still being dry.

## Improvement of media wetting at low flow rate

To achieve a complete wetting of the media surface, it is key to remove air pockets entrapped in the Pod modules, both upstream and downstream of the filtration media. At low flow rates, due to the very high permeability of open media – i.e. Clarisolve® 40MS or Millistak+® HC Pro D0SP – even restricting the outlet port does not provide enough back-pressure.

Alternatively, air bubbles can be chased by pulse pressurizing each side of the media (inlet and outlet), then releasing quickly. Using the following protocol led to a significant improvement of media wetting for flow rates lower than 270 LMH:

### Wetting procedure at low flow rate

1. Outlet port closed and vent port open. Fill the pod with RO water at 50 - 150 LMH
2. Pump still operating , close vent port and let inlet pressure increase up to 10- 15 psi (0.7 - 1.0 bar). Then open vent port valve to release pressure.
3. Repeat step 2 once.
4. Pump still operating , close vent port and let inlet pressure increase up to 10 - 15 psi (0.7 - 1.0 bar). Then open outlet port valve to release pressure.
5. Close outlet port again and let inlet pressure increase up to 10 - 15 psi (0.7 - 1.0 bar). Then open outlet valve to release air bubbles.
6. Repeat operation five additional times, or until no more air can be seen at the outlet port.
7. Finalize flushing by pumping the appropriate volume of water.

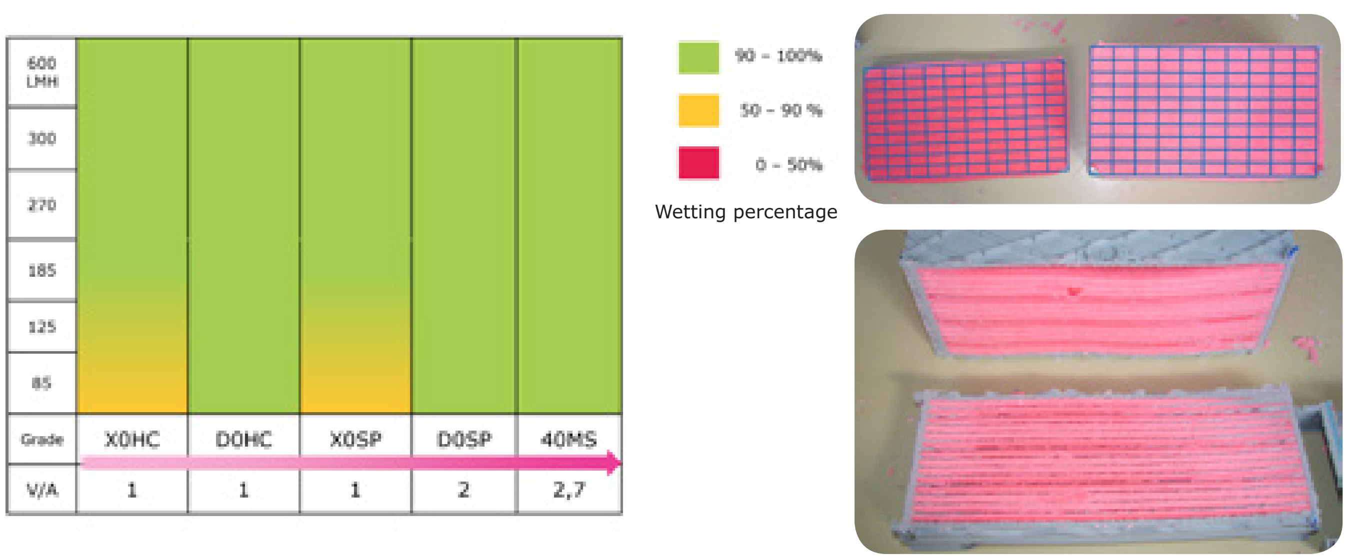



**Figure 4:** Heat map of Pod wetting with modified flushing procedure (Left). Right, Millistak+® HC Pro D0SP flushed at 85 LMH with modified procedure (including pressurization/pressure release).

## Flushing Pods in series

When processing direct harvest feed streams, depth filtration can be performed by using two grades in series (I.e. Millistak+® HC D0HC followed by X0HC) . Usually, this is performed with a ratio of 2:1 (primary open clarification grade: secondary tighter clarification grade). Large installations, i.e. a 3-level holder can be used, with two racks in parallel loaded with the coarse grade, their outlet feeding the 3rd rack loaded with the tighter grade. This installation has been simulated at smaller scale, as depicted in **Figure 5**, and evaluated for efficient wetting at low flow rate.

Working flow rates were set at 3.1 L/min, which corresponds to 85 and 170 LMH on D0HC and X0HC respectively. D0HC were filled with water with outlet O1 closed and vent V1 open and pulse pressurized twice up to 10-15 psi by closing the V1 vent port. Then the O1 outlet was open and water sent to X0HC (V2 vent open, O2 outlet closed). The D0HC was pressurized five times by closing/opening the V2 valve. Eventually, V2 was closed and O2 alternately closed/opened five additional times to pulse pressurize the X0HC device. After a flushing with 120 L/m$^2$, both filters were colored and cut for analysis.

This experience led to a complete wetting of both devices, with more than 99 % of the total filtration area colored, demonstrating the efficiency of the flushing procedure for common installations at low flow rate.

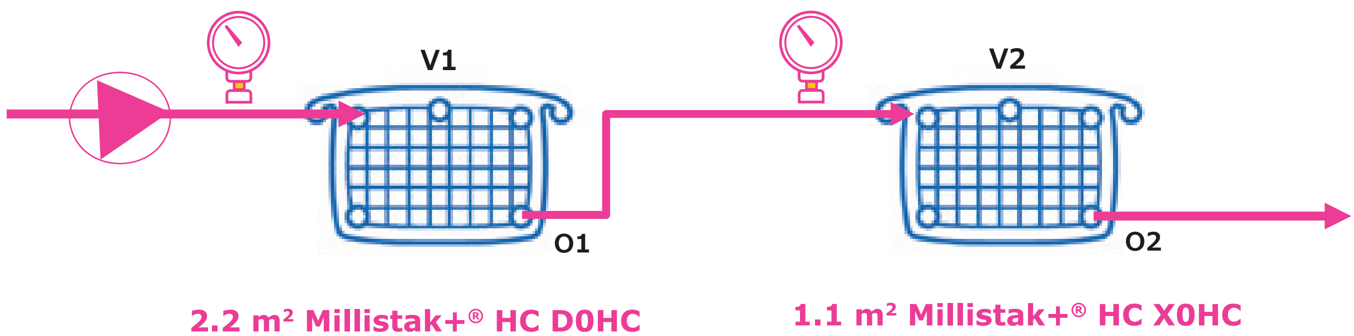



**Figure 5:** Schematic representation of the experimental setup featuring two grades of Millistak+® HC set in series with a ratio D0HC:X0HC 2:1.

## Online conductivity monitoring

Flushing experiments were performed with RO water, and in-line conductivity was monitored at the outlet port. Data demonstrated that there was no direct correlation between the percentage of wetted area and the profile of the conductivity decreasing slope, as shown in **Figure 6**. Consequently, inline conductivity monitoring cannot be used as a robust indicator of a full and wetting of the media when developing an alternative procedure. However; it can be used as routine parameter to prompt the end of the flushing once the applied procedure has been demonstrated to be efficient for fully wetting the filtration area.

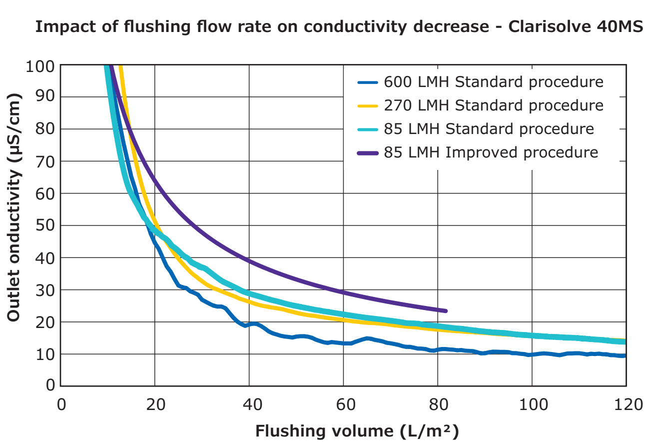



**Figure 6:** Conductivity slope measured at the outlet of Millistak+® D0HC as a function of flushing flow rate and procedure applied.

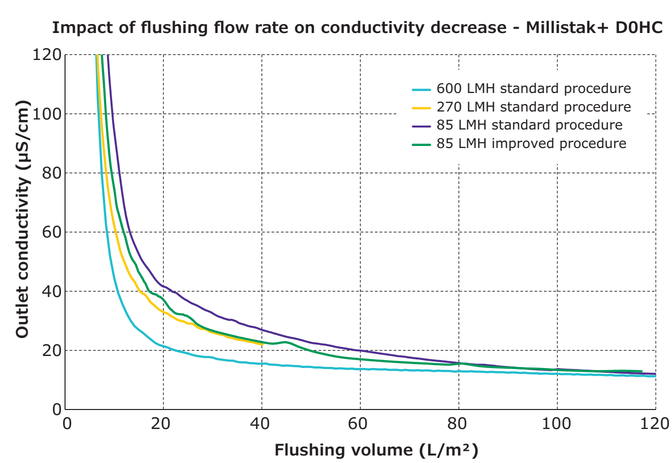



**Figure 7:** Conductivity decrease at Clarisolve® 40MS outlet as a function of flushing flow rate and procedure.

## Conclusions

This study highlighted the lack of relationship between an efficient media wetting and the decrease in conductivity during water flush. Consequently, a low monitored conductivity does not necessarily reflect a full wetting of the media that can only be achieved by applying the appropriate procedure with the recommended flushing volume for each type of Pod.

Historically, the procedure for wetting and flushing Pod depth filters required important flow rates capacities for proper preparation before use. Modern systems, especially systems using a disposable flow path, are not always able to generate such high flow rates. The present study allowed for tailoring and adapting the procedure to properly wet and flush all Pod formats, whatever the flow rate and pump capability available on the systems. This provides users with more flexibility and consistency between traditional systems and modern ones.

This alternative procedure[2] was successfully applied on a “standard” configuration, with two different grades of Pods installed and flushed in series at a surface ratio (grade 1: grade 2) equal to 2:1, enabling a restoration of the full filtration capacity at low flow rate.

**Initial water fill in at 50-150 LMH**

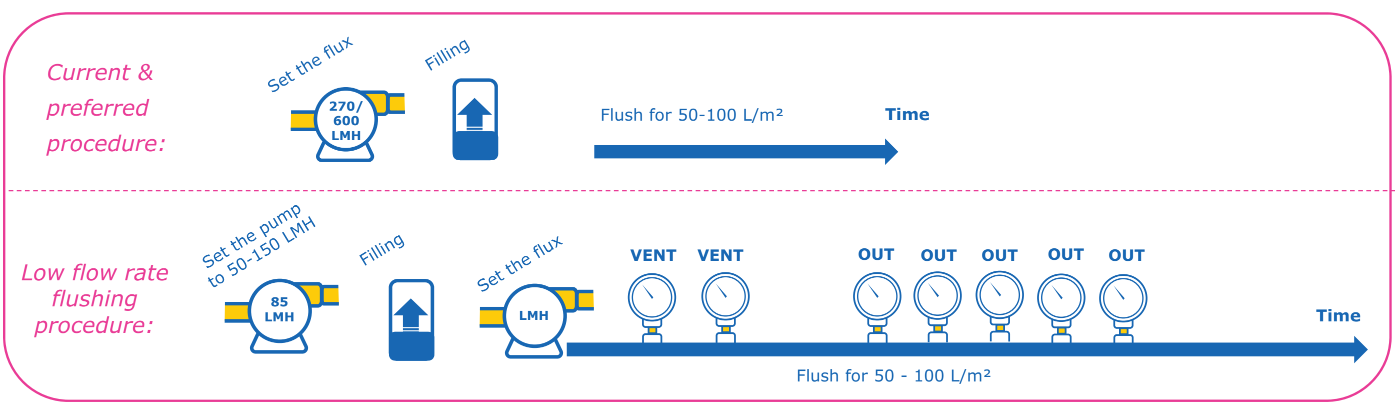
**Flow rate 270 – 600 LMH**
(All Pods except Clarisolve®)

**Flush 100 L/m² with RO water**
(except Millistak+® HC Pro 50 L/m²)

**Flow rate < 270 LMH**
(all Pods)

Improved wetting procedure with pressurization / quick pressure release

**Flush 100 L/m² with RO water**
(except Millistak+® HC Pro 50 L/m²)




**References**

1. According to Millistak+® Performance Guide PF1119EN00
2. It is of customer’s responsibility to verify whether the equipment / pump can accommodate with the proposed procedure.

**Disclaimer**

The procedure described above is dynamical and involves pressure generation in the assembly or system.

As this can lead to hazardous situations, a special attention must be paid by operators while running this procedure.

System and components integrity must be checked accurately and alarms and emergency stops procedure set accordingly.

It is of operator’s responsibility to verify whether system, pumps and equipment accommodate with the proposed flushing procedure with respect to safety requirements.

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