# Effectiveness of Priming Features Operated by Motor-driven IntelliGen® LV Two-stage Dispense System

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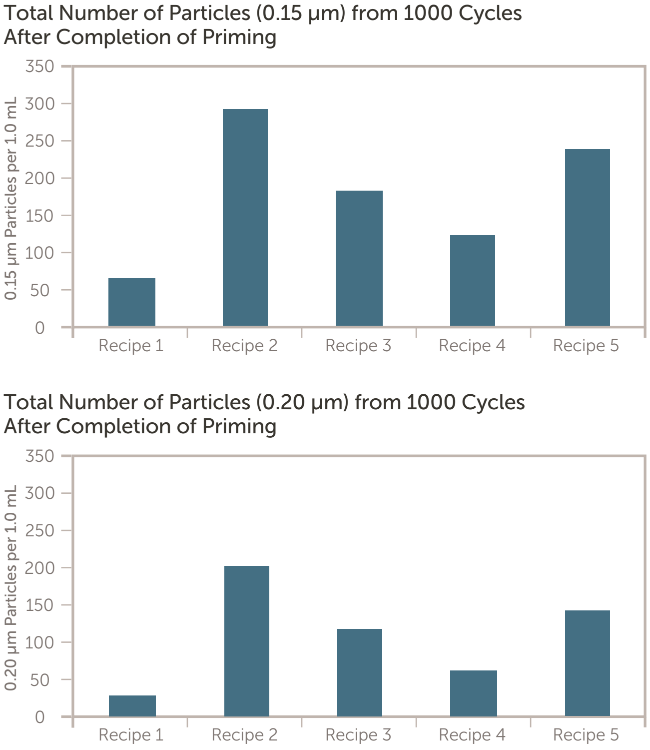
## INTRODUCTION

As semiconductor devices have been miniaturized, high requirements of impurity control have become essential. To respond to this demand, a very tight pore size point-of-use filter has been developed. Although tight pore size filters are effective in terms of impurity removal, filter preparation becomes difficult.

The IntelliGen® LV is a motor-driven two-stage dispense system developed to have the capability to fill tight pore size membranes. This application note demonstrates how the motor-driven two-stage structure of the IntelliGen LV enhances the liquid filling ability in a very small pore membrane filter during priming. Priming is the feature of the dispense system in which air is eliminated and the point-of-use filter is fully filled with liquid. However, the tighter the pore size is, the more difficult it is to fully fill the membrane pores.

The innovative IntelliGen LV design, featuring a motor-driven two-stage dispense system, provides four attributes essential to effective priming: high filtration pressure, backflush to vent; low filtration rate, and a combination of low fill and outlet rates. Figure 1 demonstrates the summation of bubbles measured in 0.15 µm (top chart) and 0.20 µm (bottom chart) sizes during 1000 dispenses after completion of priming. Priming Recipe 1 combines the four attributes into a single process while Recipes 2–4 are run without one of the attributes in successive order. The results show that when used together, effective priming of tight membranes can be achieved.


Total Number of Particles (0.15 µm) from 1000 Cycles After Completion of Priming

Total Number of Particles (0.20 µm) from 1000 Cycles After Completion of Priming

*Figure 1. Particle summary from 1,000 continuous dispense cycles after priming.*

Since the Intelligen LV dispense system can provide these four attributes in one dispense unit even a tight pore size filter can be effectively wetted, resulting in better filtration performance. These four attributes are the benefit of the motor-driven two-stage technology integrated with dual pressure sensors. The integration of dual pressure sensors with the two-stage structure enables an accurate detection of pressure to be measured which allows high pressure to be maintained in the second stage during filtration. In addition, the second stage in the two-stage structure enables the process fluid to flow backward from the filter downstream to the vent, helping wet the filter without pulling air into the dispense chamber. Moreover, because of the motor-driven structure, a low flow rate during filtration, fill and dispense can be controlled, which consequently leads to the reduced generation of microbubbles. These advantages enable the IntelliGen LV dispense system to serve well in the advance technology node where high-level impurity control is required.

## CHARACTERISTICS OF INTELLIGEN LV DISPENSE SYSTEM

A pneumatically-driven single-stage dispense unit cannot provide the characteristics and benefits that a motor-driven two-stage design provides. The characteristics and benefits of the four major attributes used in this test are summarized in Table 1.

Figure 2 depicts the two-stage design in correlation to the valves and chambers. Figure 3 identifies the four mentioned attributes in relation to the two-stage design.

Table 1. Summary of characteristics and benefits of the four major attributes

| ATTRIBUTE | CHARACTERISTICS AND BENEFITS |
|---|---|
| **1. High filtration pressure** | The two-stage design provides the capability for **high filtration pressure** |
| | Dual pressure sensors with real-time data allows the second stage to control and maintain pressure at a constant and high level |
| | **High filtration pressure** reduces microbubbles by preventing cavitation and dissolving microbubbles into liquid |
| | **High filtration pressure** helps prime the filter by enabling the liquid to flow through small pores of the filter medium |
| | **High filtration pressure** is most effective in the early stages of the priming sequence |
| **2. Backflush to vent cycle** | **"Backflush to vent"** is a priming feature unique to the two-stage design |
| | This step reverses the flow through the filter, pushing fluid from the dispense chamber out to vent |
| | **Backflush to vent** reduces microbubbles by pushing liquid from the filter downstream to vent to replace air inside the membranes' pores and refill the dispense chamber through filter so no air can enter or be accumulated in the dispense chamber |
| | **Backflush to vent** helps prime the filter by eliminating air from filter downstream directly to vent which leads to a faster start-up time |
| | **Backflush to vent** is most effective after initial vent cycling early in the priming sequence |
| **3. Low filtration rate** | The motor-driven design provides the capability to control the filtration at low rates |
| | **Low filtration rate** reduces microbubbles by reducing the pressure drop during the flow of liquid through filter |
| | **Low filtration rate** helps prime filter by reducing the generation of microbubbles at filter downstream |
| | **Low filtration rate** is most effective in the latter stages of the priming sequence |
| **4. Combination of low fill rate and low outlet rate** | The motor-driven design provides the capability to control the fill and outlet rates at a low rate |
| | **Low fill rate** reduces microbubbles by preventing cavitation in the fill chamber |
| | **Low fill rate** helps prime the filter by reducing the generation of bubbles in the fill chamber |
| | **Low outlet rate** reduces microbubbles by reducing the degree of turbulence in the outlet |
| | **Low outlet rate** helps prime the filter by reducing the generation of microbubbles in the outlet |
| | **Low fill rate** and **low outlet rate** are most effective in the latter stages of the priming sequence |

Valves and Chambers in a Two-stage Design

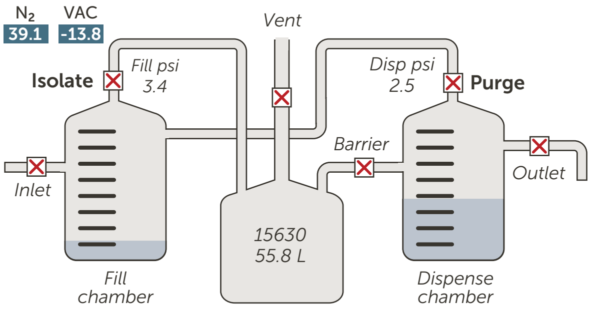


*Figure 2. IntelliGen LV dispense system valve and chamber types.*

Attributes in Relation to the Two-stage Design

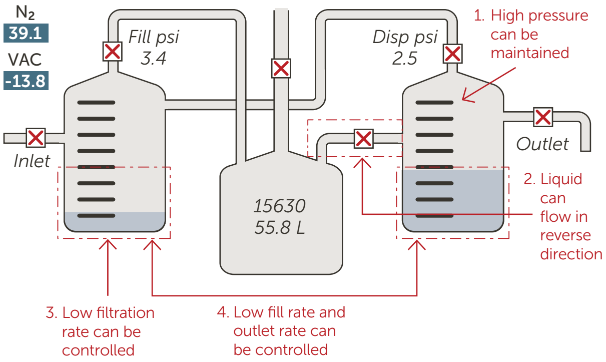


*Figure 3. IntelliGen LV dispense system design relating to provided attributes.*

## TEST BACKGROUND

### Equipment Setup

An IntelliGen® LV pump with firmware "Released M1001" and installed with an Impact® 8G UC DUO 3.0 nm filter was used. PGMEA was used as the dispensed fluid. After priming, the dispensed liquid is stored in the 30 mL cylindrical collection vessel before being drawn into the particle counter by the syringe sampler. After passing through the particle counter, the liquid is returned to the bottle. Particle counter models Rion® KS41-A and Rion® KS42-A measuring 0.15 µm and 0.20 µm microbubbles were used. A sample flow of 1.0 mL at 2.0 mL/s was measured every 30 seconds and recorded over 1,000 cycles after completion of priming.

### Priming Recipe

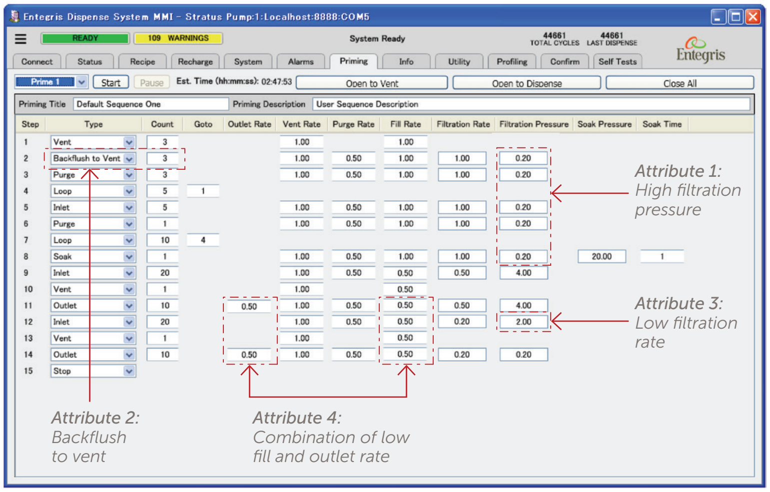
The baseline priming recipe used for this test was the recommended recipe for zero wet particles with PGMEA. Previous testing determined that high filtration pressure, backflush to vent, low filtration rate and a combination of low fill and outlet rates are the key attributes to low microbubble levels. Using the baseline recipe as a reference, five recipes were tested.

- Recipe 1 includes all four attributes
- Recipe 2 was tested without a high filtration pressure
- Recipe 3 was tested without a backflush to vent segment
- Recipe 4 was tested without a low filtration rate
- Recipe 5 was tested without a low fill rate and low outlet rate (see table 2)

Figure 4 shows the priming recipe sequence with all the key attributes included (Recipe 1)

Table 2. Summary of key attributes included in each recipe

| Attribute | Recipe 1 | Recipe 2 | Recipe 3 | Recipe 4 | Recipe 5 |
|---|---|---|---|---|---|
| 1. High filtration pressure | Yes | No | Yes | Yes | Yes |
| 2. Backflush to vent | Yes | Yes | No | Yes | Yes |
| 3. Low filtration rate | Yes | Yes | Yes | No | Yes |
| 4. Combination of low fill rate and low outlet rate | Yes | Yes | Yes | Yes | No |



Est. Time (hh:mm:ss): 02:47:53

Priming Title: Default Sequence One

Priming Description: User Sequence Description

| Step | Type | Count | Goto | Outlet Rate | Vent Rate | Purge Rate | Fill Rate | Filtration Rate | Filtration Pressure | Soak Pressure | Soak Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Vent | 3 | | | 1.00 | | 1.00 | | | | |
| 2 | Backflush to Vent | 3 | | | 1.00 | 0.50 | 1.00 | 1.00 | 0.20 | | |
| 3 | Purge | 3 | | | 1.00 | 0.50 | 1.00 | 1.00 | 0.20 | | |
| 4 | Loop | 5 | 1 | | | | | | | | |
| 5 | Inlet | 5 | | | 1.00 | 0.50 | 1.00 | 1.00 | 0.20 | | |
| 6 | Purge | 1 | | | 1.00 | 0.50 | 1.00 | 1.00 | 0.20 | | |
| 7 | Loop | 10 | 4 | | | | | | | | |
| 8 | Soak | 1 | | | 1.00 | 0.50 | 1.00 | 1.00 | 0.20 | 20.00 | 1 |
| 9 | Inlet | 20 | | | 1.00 | 0.50 | 0.50 | 0.50 | 4.00 | | |
| 10 | Vent | 1 | | | 1.00 | | 0.50 | | | | |
| 11 | Outlet | 10 | | 0.50 | 1.00 | 0.50 | 0.50 | 0.50 | 4.00 | | |
| 12 | Inlet | 20 | | | 1.00 | 0.50 | 0.50 | 0.20 | 2.00 | | |
| 13 | Vent | 1 | | | 1.00 | | 0.50 | | | | |
| 14 | Outlet | 10 | | 0.50 | 1.00 | 0.50 | 0.50 | 0.20 | 0.20 | | |
| 15 | Stop | | | | | | | | | | |

*Attribute 1:* High filtration pressure

*Attribute 3:* Low filtration rate

*Attribute 2:* Backflush to vent

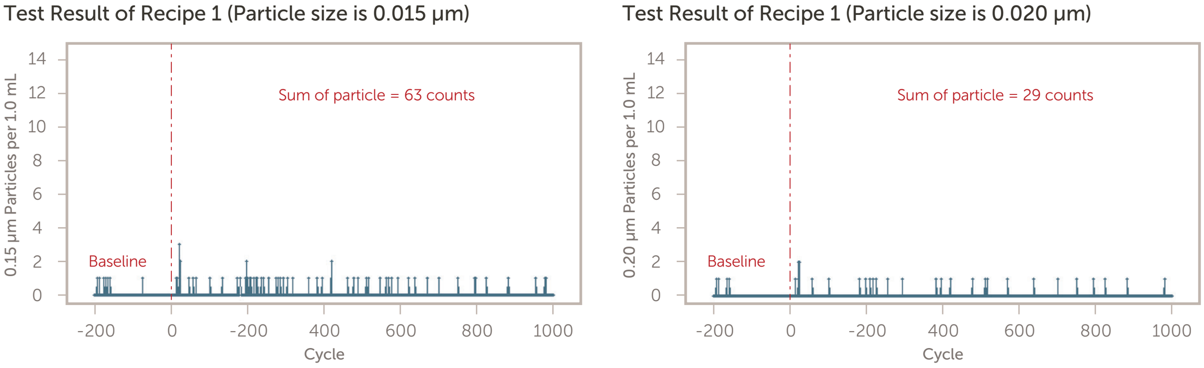
*Attribute 4:* Combination of low fill and outlet rate

*Figure 4. Priming Recipe 1 matrix showing where the four key attributes are attained.*

## TEST RESULT

### 1. Charts plotting particles versus dispense cycle

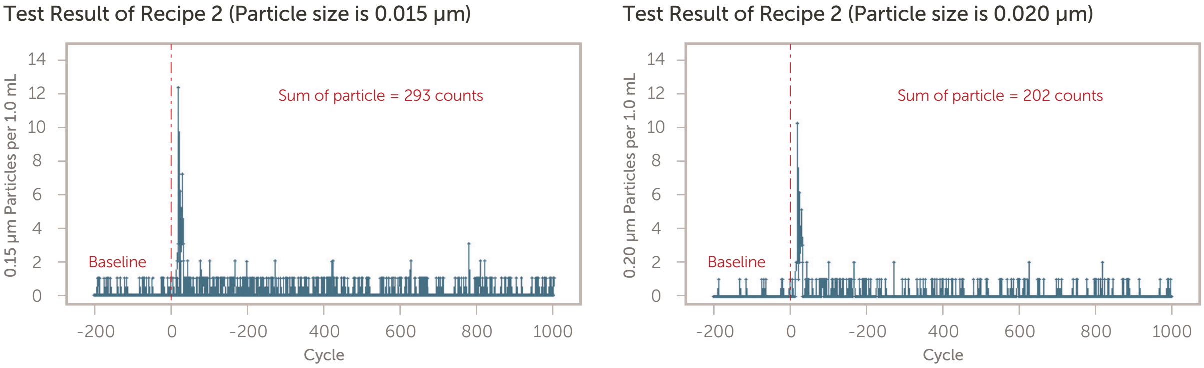
Recipe 1 test result: Figure 5 shows the particle level of 1,000 dispense cycles after priming completes.


Test Result of Recipe 1 (Particle size is 0.015 µm)

Test Result of Recipe 1 (Particle size is 0.020 µm)

*Figure 5. Recipe 1 test results.*

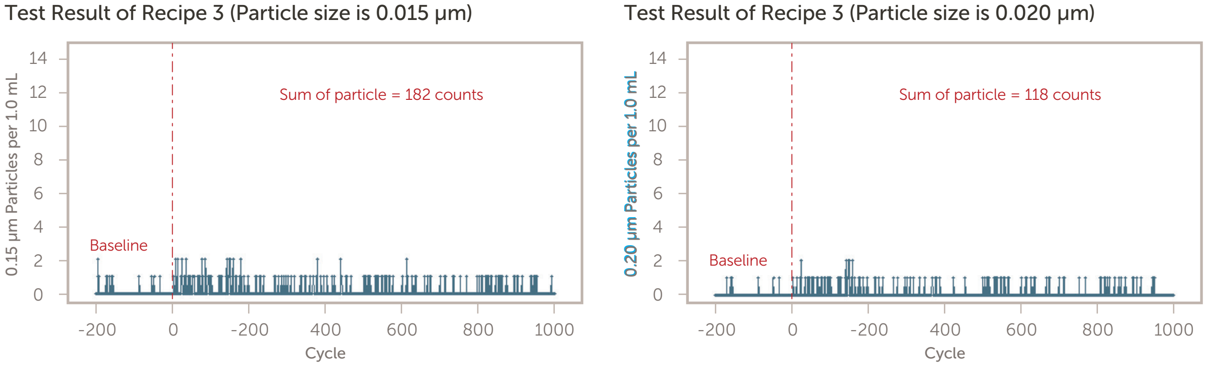
Recipe 2 test result: Figure 6 shows the particle level of 1,000 dispense cycles when Attribute 1, **high filtration pressure**, is missing from the priming recipe.


Test Result of Recipe 2 (Particle size is 0.015 µm)

Test Result of Recipe 2 (Particle size is 0.020 µm)

*Figure 6. Recipe 2 test results.*

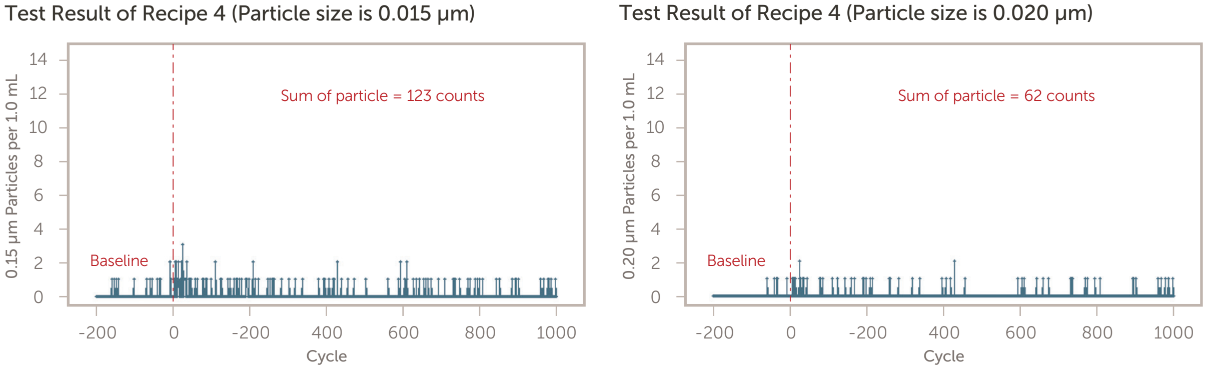
Recipe 3 test result: Figure 7 shows the particle level of 1,000 dispense cycles when Attribute 2, **backflush to vent cycle**, is missing from the priming recipe.


Test Result of Recipe 3 (Particle size is 0.015 µm)

Test Result of Recipe 3 (Particle size is 0.020 µm)

*Figure 7. Recipe 3 test results.*

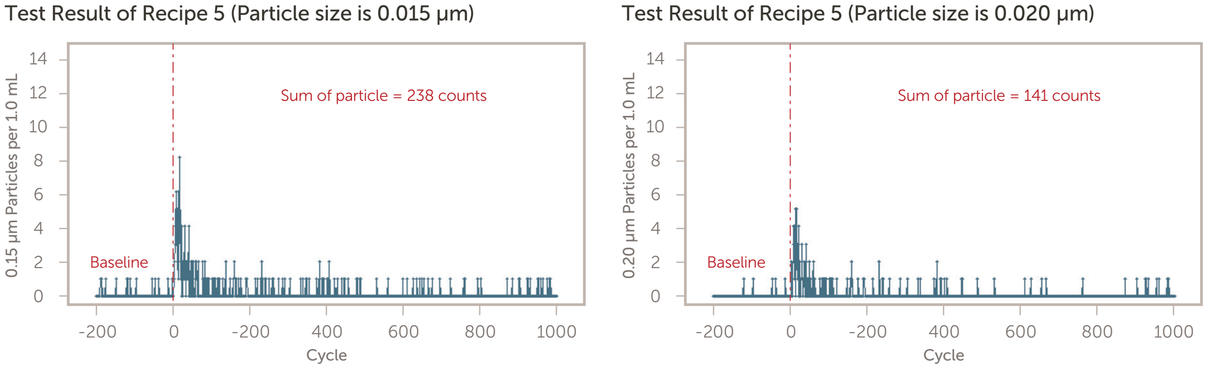
Recipe 4 test result: Figure 8 shows the particle level of 1,000 dispense cycles when Attribute 3, **low filtration rate,** is missing from the priming recipe.


Test Result of Recipe 4 (Particle size is 0.015 µm)

Test Result of Recipe 4 (Particle size is 0.020 µm)

*Figure 8. Recipe 4 test results.*

Recipe 5 test result: Figure 9 shows the particle level of 1,000 dispense cycles when Attribute 4, **combination of low fill rate and low outlet rate** is missing from the priming recipe.


Test Result of Recipe 5 (Particle size is 0.015 µm)

Test Result of Recipe 5 (Particle size is 0.020 µm)

*Figure 9. Recipe 5 test results.*

2. Summary of the percentage increase in microbubbles when using recipe 1 as baseline.

Table 3. Increase of microbubble percentage when one attribute is missing from Recipe 1

| Missing attribute | Recipe | Sum of 0.15 µm bubble | Increase | Sum of 0.20 µm bubble | Increase |
|---|---|---|---|---|---|
| None | 1 | 63 | — | 29 | — |
| High filtration pressure | 2 | 293 | 365% | 202 | 597% |
| Backflush to vent | 3 | 182 | 189% | 118 | 307% |
| Low filtration rate | 4 | 123 | 95% | 62 | 114% |
| Low fill and outlet rates | 5 | 238 | 278% | 141 | 386% |

## CONCLUSION

From the data cited above, the following determinations can be made on each of the four attributes.

### 1. High Filtration Pressure

1.1 Based on Henry's law, dissolubility of gas into liquid increases with pressure. Therefore, if microbubbles are generated in the dispense chamber, the ability to increase the pressure up to 20 psi would help dissolve the microbubbles into liquid, leading to the reduction of air in the system.

1.2 The ability to maintain high pressure at filter downstream would help prevent cavitation and lead to less microbubble generation. When a liquid flows, especially through a porous medium, the liquid pressure will drop. In the case of volatile liquids, if the pressure drops to the point it is lower than the liquid vapor pressure, outgassing will occur. This mechanism is known as cavitation and can be prevented by maintaining high pressure in the second stage of the dispense unit.

1.3 In a non-homogeneous porous structure, a fluid prefers to flow through a larger pore because there is less resistance. This behavior of fluid will lead to a generation of non-wetting area inside the filter. The Intelligen® LV was built to automatically increase the upstream pressure to a higher level than the setpoint of the downstream pressure. When high filtration pressure is used, the upstream pressure will be higher and therefore force fluid to flow through smaller pores of the non-homogeneous porous structure. This ability reduces the nonwetting area of the tight pore size filter.

1.4 High filtration pressure is the most important effect among the four attributes. Without high filtration pressure, there is a microbubble increase of 365% at 0.15 µm and a 597% increase at 0.20 µm.

## 2. Backflush to Vent Cycle

2.1 The backflush to vent cycle is the priming cycle where liquid is forced to flow from the dispense chamber to vent while refilling the dispense chamber through the filter. This ability enables the dispense unit to remove air from the dispense chamber while wetting the filter without air being pulled into the dispense chamber. Consequently, the accumulation of air in the dispense chamber is reduced.

2.2 Backflush to vent is the third most important effect among the four attributes. Without backflush to vent, there is a microbubble increase of 189% at 0.15 µm and a 307% increase at 0.20 µm.

## 3. Low Filtration Rate

3.1 The motor-driven structure enables liquid to flow through the filter at a very low rate. This decreases the generation of a large differential pressure between the filter upstream and downstream, reducing the generation of microbubbles due to less pressure drop.

3.2 Low filtration rate is the least important effect among four attributes. Without a low filtration rate, there is a microbubble increase of 95% at 0.15 µm and a 114% increase at 0.20 µm.

## 4. Low Fill Rate and Outlet Rate

4.1 The motor-driven design allows fluid to refill the fill chamber at a low flow rate. This prevents the generation of negative pressure in the fill chamber, leading to the reduction of cavitation and the prevention of microbubbles in the fill chamber.

4.2 Low outlet rate in a priming sequence reduces the degree of turbulence, leading to reduced microbubble generation.

4.3 Low fill and outlet rates are the second important effects among the four attributes. Without low fill and outlet rates, there is a microbubble increase of 278% at 0.15 µm and 386% at 0.20 µm.

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