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GilAir Plus QuadMode℠ – Split Sampling in the High Flow Mode

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Background

Personal monitoring pumps have incorporated *constant flow control* since the late 1970s. Constant flow control in a personal monitoring pump works much like the cruise control feature on an automobile. If the back pressure increases during the course of a sample (e.g., a sample filter loading up during a dust sample), the pump will sense the flow rate decreasing and automatically increase the flow rate to compensate, much like cruise control increases the slowing speed of a car on an upgrade. The concept of constant flow control is to maintain the flow rate in flow sensitive sampling as with cyclones in particle size selection, where size cut point is relative to airflow speed through the device.

In the early 1980s, *constant pressure control* was developed for low flow applications like hydrocarbon solvent sampling with activated charcoal tubes (e.g., 20 to 200mcc/min). This control mode maintains air flow through the sample media by holding a constant negative pressure inside the connection tubing between the pump and the sample head. This allows the user to split a sample, and collect two or more samples simultaneously. It works, because the force driving the sample flow does not change during the course of the sample. If the flow rate decreases in one sampling channel, it will not affect the other(s), because the driving force is constant. The down side to this control format is that the flow is not compensated if the back pressure increases. This flow control is suitable for sorbent tube sampling, because the back pressure in such sampling is normally steady from the beginning of the sample to the end. A charcoal tube (for example) does not change in back pressure as it becomes loaded with sample, because the physical properties of the collection media do not change. That is, the charcoal particles do not grow in size, and the space between them does not diminish, so the flow restriction is unchanged. Most sorbent tube media will follow this pattern, with the possible exception of silica gel in high humidity air.

A common request among Gilian product users is to be able to split samples in the high flow mode; that is above 1 LPM, where most pumps only provide constant flow control. Splitting a sample in the constant flow control mode becomes tricky on several fronts. First, setting the flow rates of the multiple samples is difficult, because a flow rate change on one side of the split will affect the other side(s). Slow the flow rate on one side, and the other side will speed up, because the pump is speeding up (i.e., increasing the total flow rate) to compensate for the total slowed flow. Second, a similar problem occurs during the course of the sample, if one side loads up faster than the other. Theoretically, these problems are overcome with constant pressure control. However the high flow sampling methods by their nature are more likely to encounter changes in back pressure.

The low flow sampling applications (i.e., below 1 LPM) do not tax the pump to the same extent as the high flow applications (i.e., up to 4 or 5 LPM) in a constant pressure control format. In the constant pressure sampling mode, the pump is working to maintain 18 to 20 inches of negative pressure. So the pump must work to maintain that level of negative pressure, while 1 LPM is being pulled from the area. If you are pulling air out of this area at the rate of 5 LPM, it must work considerably harder, which relates to current draw, and hence run time. The higher the collective flow rate of the split samples, the shorter the run time. This becomes a concern in splitting samples in the high flow mode. How much air flow can the system provide and still meet an 8 to 10 hour run time?

Scope

The purpose of the testing is two-fold; to determine if popular NIOSH test methods could be run simultaneously at a steady back pressure and provide a reasonable (i.e., full work shift) run time, and to determine the effects of increasing back pressure on the sample flow rate. Three common sampling methods were chosen as outlined below.

- NIOSH 7300: This is a general air sampling method entitled “Elements by ICP” that is used to determine the presence of 32 different elements, including most heavy metals like lead, chromium, nickel and cadmium, as well as more exotic ones like beryllium and lithium. It uses a 37 mm diameter, 0.8 micron pore size mixed cellulose filter at 1 to 4 LPM, similar to other test methods for heavy metals, and therefore it represents a wide range of common air sampling.
- NIOSH 7400: This is the common test method for asbestos, using a 25 mm diameter, 0.8 micron mixed cellulose filter at 1 to 4 LPM (0.5 to 2.5 LPM for the OSHA equivalent method) for personal samples. Asbestos sampling is very common in many industries, and the filter media produces a relatively high back pressure, due to the smaller cassette size. If split sampling can accommodate this test method, then many other test methods of lower back pressures should be workable as well.
- NIOSH 1500: This is a general hydrocarbons air sampling method that is designed for common hydrocarbon solvents like cyclohexane and heptane. Further, it is the same sampling method that is applied to benzene, xylene, styrene, and many other hydrocarbons; so again, it represents a very common sampling system. It uses a standard size 150 mg activated charcoal tube at 10 to 200 cc/min.

The following combinations were tested at various flow rates to determine if an adequate sample run time is possible under conditions of stable back pressures.

Table 1: NIOSH Test Methods

Side A	Side B
7300	1500
7300	7300
7400	7300
7400	1500

In addition, method 7300 was tested with increasing back pressures to study the effect of flow loss due to increases back pressure.

Procedure

A prototype sample splitter was prepared by Sensidyne's engineering group with four available channels, all with brass needle valves. (See Figure 1). The testing described here incorporated only two channels. One side, designated as side A, had the flow monitored with a Sensidyne/Gilian Challenger air flow calibrator, serial number 15. The other side was monitored by the precision rotameters in a Gilian Diagnostics Panel, P/N 800783-3. This item includes a 0 to 40 inches H2O Magnehlic pressure gauge, three precision rotameters (0.5 to 5 LPM, 20 to 200 cc/min. and 1 to 50 cc/min., respectively) to accommodate both high and low flow rates, and a needle valve to administer simulated back pressures. GilAir Plus pump P/N 610-0901-03R, S/N 20110530006 was used in the constant pressure, high flow mode with the back pressure at the factory default setting of 18 inches H2O. This back pressure setting is user selectable. However, 18 inches H2O was chosen, because it is the factory default back pressure, and running at the least back pressure possible will provide the longest run time.

Testing was conducted between 8/11/11 and 8/30/11. Tests were run between 8:00 AM and 6:00 PM, and the run times were halted whenever the pump ran the full day, in order to charge the pump's battery for the next day's testing. A total of 14 tests were conducted, and they are summarized in the accompanying tables. The back pressures, run times and predicted run times listed in ***Tables 2*** and ***3*** were taken from the pump's display.

Figure 1: High-flow Dual-Variable Manifold

Results

Discussion follows on the various sample combinations. (See ***Tables 2*** and ***3***).

1) **Methods 7300 & 1500**: This combination was run at 2LPM for 7300 & 150 cc/min for 1500, at 2.5 LPM and 100 cc/min, at 3.0 and 100 cc/min, and at 3.5 and 150 cc/min, respectively. The combination appears to be workable at all of these flow rate formats. The initial test run on 8/11/11 faulted short of 8 hours, and this is likely due to inadequate battery cycling prior to use. The pump was unused for two months prior to testing with only one battery cycle prior to this test. The test run on 8/15 was started late, and shut off at 457 minutes, but the predicted run time was displayed at 4.7 hours at shut off. The test on 8/12 had run for over 10 hours (600 minutes) at shut off. This combination is a likely one to be run together, and it appears to work quite well. (***See Table 2***).
2) **Methods 7300 & 7300**: A total of four tests were run with two 7300 methods. The flow rates were 2 & 2 LPM, 1.5 & 1.5 LPM, 3 & 1.5 LPM and 2.5 & 2.5 LPM. These were conducted to look at maximum flow rate conditions. Note that the total flow rates are 4, 3, 4.5 and 5 LPM. The pump ran nicely at the first two tests, running for 571 and 581 minutes before being shut off for the day. The second two at 4.5 and 5 LPM total flow rate both faulted, but both also ran over 8 hours at 547 and 497

minutes, respectively. To assure an 8-hour run, this combination should probably be limited to 4 LPM or less of total flow rate.

3) **Methods 7300 & 7400**: This combination was run at 1.5 and 1.5 LPM and at 2.0 and 2.0 LPM. Both formats ran about nine hours prior to being shut down, so this combination appears to be workable at these flow rates.
4) **Methods 7400 & 1500**: One test was run with this combination, and the result was in line with the 7300/1500 combination. The flow rates were at 2 LPM and 150 cc/min. The sample was shut down after 562 minutes with 5.3 hours of predicted run time displaying. This combination appears to be workable.
5) **Method 7300 at increasing back pressures**: Method 7300 was run at 2.5 LPM with regular back pressure additions during the day. The first test saw back pressures raised in approximately 0.5 inch increments (5 times, totaling 2.5 inches) during the day. The flow rate dropped to 1.90 LPM or about 24%, which equates to about 9.6% per inch of added back pressure. The second test added back pressure in 1 inch increments (7 for a total of 7 inches) at about 1 hour intervals. The flow dropped from 2.56 to 1.51 LPM, or about 41%, which is about 6% per inch of added back pressure. This exercise illustrates that the split sampling will be limited to applications where the back pressure must be fairly steady. Dust sampling should not be conducted in this mode, since wide back pressure changes are possible through dust loading on the sample filter. Constant flow control was developed for dust sampling, particularly for cyclone sampling, where flow rate is critical to proper operation. (*See Table 3*).

Table 2: Split Flow Testing

Date		NIOSH Method	Initial Flow Rates	Ending Flow Rates	Start Time AM	End Time PM	Set BP in.H2O	RT (min)	End PRT (min)	Notes
8/11	A	7300	2.12 LPM	2.15 LPM	7:58	~3:30	18	463	N/A	Faulted.
	B	1500	155 cc/min	152 cc/min						
8/12	A	7300	2.09 LPM	2.12 LPM	8:00	6:05	18	602	8.2	Shut it off.
	B	1500	185cc/min	185cc/min						
8/15	A	7300	2.51 LPM	2.54 LPM	9:03	4:45	18	457	4.7	Shut it off.
	B	1500	100 cc/min	95 cc/min						
8/16	A	7300	2.04 LPM	2.05 LPM	8.02	6:00	18	571	3.8	Shut it off.
	B	7300	2.00 LPM	2.02 LPM						
8/17	A	7300	1.506 LPM	1.526 LPM	7:48	5:47	18	589	4.3	Shut it off.
	B	7300	1.50 LPM	1.50 LPM						
8/18	A	7300	3.07 LPM	2.97 LPM	7:48	5:18	18	547	N/A	Faulted.
	B	7300	1.50 LPM	1.45 LPM						
8/19	A	7300	3.12 LPM	3.14 LPM	7:57	5:52	18	584	3.3	Shut it off.
	B	1500	115 cc/min	115 cc/min						
8/22	A	7300	3.54 LPM	3.55 LPM	7:48	4:43	18	514	3.8	Shut it off.
	B	1500	150 cc/min	153 cc/min						
8/23	A	7300	2.54 LPM	2.44 LPM	7:47	4:27	18	497	N/A	Faulted.
	B	7300	2.52 LPM	2.45 LPM						
8/24	A	7300	1.52 LPM	1.537 LPM	7:58	5:38	18	569	3.5	Shut it off.
	B	7400	1.50 LPM	1.50 LPM						
8/25	A	7300	2.01 LPM	2.03 LPM	8:08	5:23	18	535	2.6	Shut it off.
	B	7400	2.00 LPM	2.00 LPM						
8/26	A	7400	2.01 LPM	2.02 LPM	8:04	5:25	18	562	5.3	Shut it off.
	B	1500	150 cc/min	152 cc/min						

Table 3: Varying Back Pressure Testing

Date	NIOSH Method	Flow (LPM) Start	Flow (LPM) End	Start Time AM	End Time PM	Set BP in.H2O	RT (min)	PRT (end)	Notes
8/29	**7300**	**2.50**	**1.903**	**7:55**	**5:00**	**18**	**547**	**5.5**	**Shut it off. Raised sample bp by 2.5 in. (~0.5 inches/hour)**
8/30	**7300**	**2.56**	**1.505**	**7:38**	**5:23**	**18**	**583**	**3.2**	**Shut it off. Raised sample bp by 7 in. (~1 inch/hour)**

Conclusions

The constant pressure, high flow sampling mode is suitable for split sampling in the four combinations tested and in the flow ranges tested. Sample run times using the standard rechargeable NiMH battery, were adequate in most combinations, although split sample combinations above 4 LPM of total flow rate may fall short of full work-shift sampling. The constant pressure high flow mode is not suitable for applications where the back pressure is likely to change, such as dust sampling. Testing showed that as little as one inch of added back pressure can cause a 2 LPM flow rate to fall out of the +/- 5% guideline for flow control. This sampling mode cannot be recommended for dust sampling, especially for cyclone sampling, which requires flow control within +/- 5% for size distribution accuracy. In conclusion, the constant pressure, high flow mode can be used for split sampling if the combinations are carefully chosen.

It should be noted that all testing conducted in this study was done using the pump's standard NiMH rechargeable battery. Two additional power options were not investigated here, and either option could offer additional run time in nonhazardous areas. A special battery pack for single use batteries (e.g., alkaline or lithium batteries) is available, and the use of over-the-counter lithium batteries could provide improved run times over the NiMH single charge, based on the advertised battery capacities. Further, a DC conversion is offered that will allow continuous sampling through the unit's charge/dock station for area sampling applications (i.e., not on a person). It is imperative to know that only the NiMH rechargeable battery carries the intrinsic safety approval ratings. The two power options described here are limited to use in nonhazardous atmospheres.