Article Summary

INSPIRING RESPIRATORY HEALTH

The attached article is a recent independent study, in which nSpire Health's Anti-Static Pocket Chamber® was recognized to "yield substantially better dose delivery characteristics"[1] when tested alongside competitive aerosol holding chambers.

The objective of this particular testing was to compare particle size characteristics of devices used in Metered Dose Inhaler (MDI) medication delivery. Chambers tested included those manufactured by Monaghan Medical, Respironics, Clement Clarke, Ferraris Respiratory, and nSpire Health. The study notes that "performance characteristics are different for the devices made from nonelectrostactic plastic material than for the devices made from the traditional nonconducting plastic".[1]

nSpire Health's Anti-Static Pocket Chamber is manufactured with anti-static ABS plastic exclusively designed to reduce the electrostatic attraction of the interior surface while significantly increasing the overall effectiveness of drug delivery. nSpire Health's Anti-Static Pocket Chamber maintains the effectiveness of MDI chambers twice its size with the advantage of being a truly pocket-sized device. It features a highly sensitive one-way silicone valve to prevent inadvertent exhalation into the chamber and a whistle alarm to alert patients when the optimum inspiratory rate is exceeded.

"The independent study clearly demonstrates the effectiveness of anti-static MDI chambers," said Rich Rosenthal, Director of Marketing & Business Development. "Clearly, Pocket Chamber and AeroChamber MAX® outperform OptiChamber® and other outdated (non-anti-static) chambers for optimal medication delivery. While AeroChamber MAX® and Pocket Chamber deliver comparable study results, patients we interviewed preferred the Pocket Chamber at one half the size of the AeroChamber MAX®."

References

1. Dhuper S, Foss S "Particle Size Output and Distribution Testing for Albuterol sulfate using 5 Spacer/Holding Chambers with Metered Dose Inhalers". December 07, 2008.

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Particle Size Output
and Distribution Testing for Albuterol sulfate
using 5 Spacer/Holding Chambers with Metered Dose Inhalers.

December, 07 2008

Purpose:

To compare the particle size characteristics of five devices used for Metered Dose Inhaler (MDI) medication delivery under two conditions of delivery using Ventolin HFA (albuterol sulfate), produced by GlaxoSmithKline Corporation (Research Triangle Park, NC). The five devices used were nSpire Health Anti-Static Pocket Chamber (nSpire Health, Longmont, Colorado), Aerochamber Max (Monaghan Medical, Plattsburgh, New York), OptiChamber (Respironics HealthScan, Cedar Grove, New Jersey), Ferraris Respiratory Pocket Chamber (Ferraris Respiratory, Louisville, Colorado) and Able Spacer (Clement Clarke International Limited, Essex, United Kingdom). The first condition examined is the time delay between the actuation of the MDI canister and the inhalation by the patient. The delays used were 1 sec, 2 sec and 5 sec. The second condition examined is when the device is used for the first time versus the device being used after it had been washed.

Method

The five brands of Holding Chambers (HC) that were subjected to evaluation are nSpire Health Anti-Static Pocket Chamber (nSH-ASPC), Aerochamber Max (**Aero**), OptiChamber (**Opti**), Ferraris Respiratory Pocket chamber **(FR-PCnSpire**) and Able Spacer (**EZ**). For each brand, 15 devices were tested under 3 conditions. The conditions to be tested included delay (1sec, 2sec, or 5sec delay) after actuation and before sampling by the ACI, brand and material type (non-electrostatic plastic versus non-conducting plastic), and new devices used from packaging versus the same device used after washing with low ionic detergent (Sunlight, Unilever). For each condition, 5 devices were used. Ordering for the new device group was randomized. Ordering for the washing group was also randomized. Note that the non-

electrostatic plastic material type pertained only to the nSpire Anti-Static Health Pocket Chamber (nSH-ASPC) and Aerochamber (Aero) tested. Table 1 below shows the total number of experiments that were done under each experimental condition. A total count yields 120 experiments.

Table of Experiments						
	New			Washing		
	1 sec	2 sec	5 sec	1 sec	2 sec	5 sec
nSpire Health Anti-Static Pocket Chambers (nSH-ASPC)	N=5	N=5	N=5	N=5	N=5	N=5
AeroChamber Max (Aero)	N=5	N=5	N=5	N=5	N=5	N=5
OptiChamber (Opti)	N=5	N=5	N=5	None	None	None
Ferraris Respiratory Pocket Chamber (FR-PC)	N=5	N=5	N=5	N=5	N=5	N=5
Able Spacer (EZ)	N=5	N=5	N=5	None	None	None

Table 1: Experiment Grid.

An 8-stage Anderson Cascade Impactor (ACI) was operated at an inlet flow (at the USP Throat) of 28.3 L/min$\pm$5%. This was regulated by a vacuum pump as per ACI operating manual. The USP throat was mated with an open/shut flow valve. This valve opened based on settings of a timing apparatus (described below). On the opposite side of the valve apparatus, a 22mm ID adapter fitting allowed easy access for a holding chamber to the valve apparatus. Since all holding chambers do not have the same mouthpiece dimensions, a flexible fitting (greater than 22mm ID) was used to mate the holding chamber to the above 22mm ID adapter.

Ventolin HFA was used to deliver five actuations of albuterol sulfate (approximately 90 micrograms each) over a period of 2.5 minutes. Each experiment had a delay associated with it of either 1,2 or 5 seconds. A thin push switch was placed on top of the canister, as it was placed into the MDI boot. The MDI boot was inserted into the back of the holding chamber. The pump for the ACI was turned on and left running for at least 30 secs. The set up was as shown in Fig 1. When the canister was pressed it would actuate and send an electronic signal to the timer. The timer delayed this signal by precisely the

delay time given for the particular experiment and then sent the signal to the solenoid. At this time the solenoid would act to open the valve between the HC and the ACI allowing the collected aerosolized plume to be sampled. After 30 sec, the valve shut and the experimenter actuated the canister. The five actuations were delivered with a 30-second interval between each actuation. The total sampling time was 2.5 minutes. Thirty seconds after the fifth (last) actuation, the flow was discontinued and the HC was removed ending the sampling process. All measurements took place at room temperature of 22-25°C and at relative humidity at 34-66%.

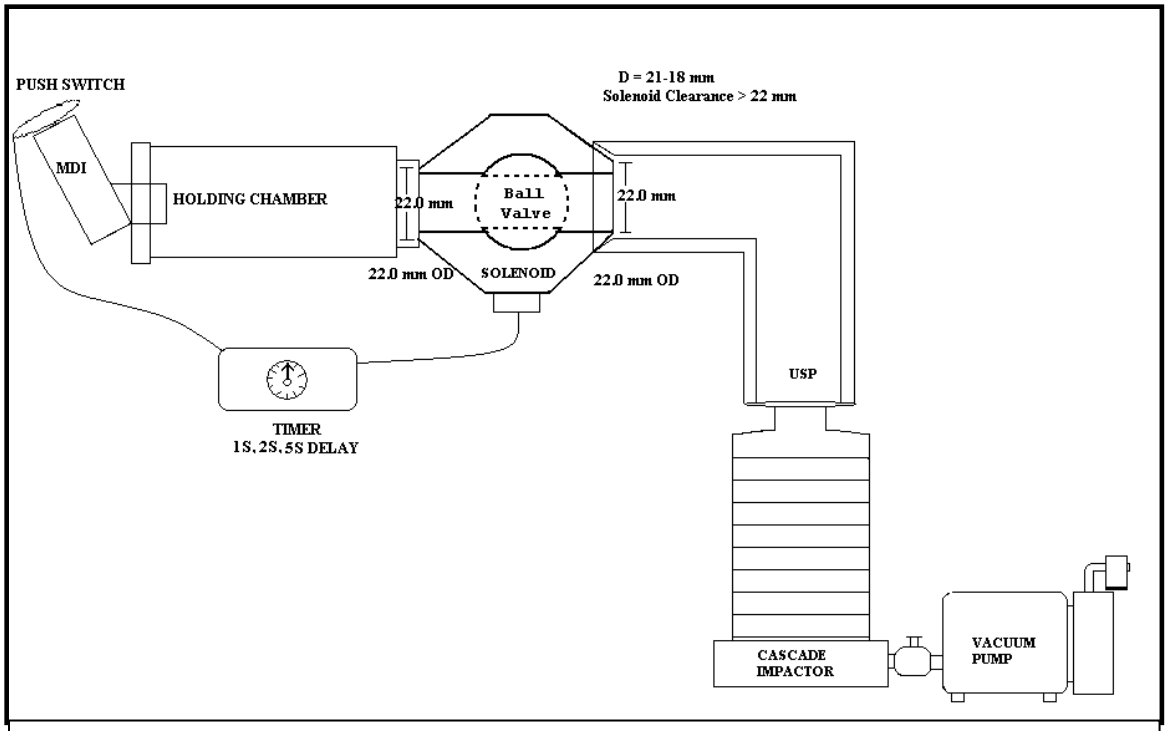

Figure 1: Experimental set up.

The ACI was disassembled according to the operator's manual. The plates were extracted and placed in appropriately sized petri dishes. The plates were individually washed with 10mL of 0.05 mM KCL with 1% acetic acid buffer solution. The dish was mildly agitated to create an albuterol solution. In addition to the plates being washed with the buffer solution, the throat and the end filter will also go through a similar process. The HC was washed with 25ml of buffer in order to dilute the greater amount of

albuterol collected, and were transferred into a volumetric that can hold 25ml for temporary storage. All albuterol solution from all the plates, throat, filter and HC will be transferred into a test tube for temporary storage. As preparation for analysis using HPLC, 1.2ml of solution from each test tube was transferred into HPLC vials.

The total mass of albuterol in the solution were determined at wavelength of 276 nm, using high performance liquid chromatography (Waters). For comparison, the Fine Particle Mass (FPM), total emitted mass (TEM), % Respirable Mass, Mass Retained in Device, Total Collected Mass, % Mass Collected in ACI and % Mass Retained in Device were calculated. Comparison could be made between the Devices for the two conditions of new versus washed, time of delay as well as brand and material. Any total mass collected that measured above 150ug albuterol was discounted as an outlier.

Results:

Differences in time delay would have to be compared between devices separately for the New and Washed conditions. This is due to the fact that the set of New experiments included five devices (N=5each) and the set of Washed experiments included three devices (N=5 each). Thus an ANOVA would have to be done separately for each group. A Tukey's honest significant difference test was used as a Post Hoc test between the five devices and three delay conditions for New devices. A Tukey's honest significant difference test was used as a Post Hoc test between the three devices and three delay conditions for Washed devices.

The Condition of New versus Washed:

Differences in performance for the New Devices and Washed Devices would be verified for three devices (N=5 each). An ANOVA would be done using a Tukey's honest significant difference test as a Post Hoc test between the three device brands and three delay conditions for New and Washed devices. The data for New versus Washed devices is shown in **Tables 6-7**.

MMAD and GSD:

MMAD's and GSD's were calculated for the New and Washed Devices, all three time delays and brands separately. These are shown in **Table 8**. Final count used after the subtraction of outliers is also shown in this Table.

The data for the New devices is shown in **Tables 2-3**. The data for the Washed devices is shown in **Tables 4-5**.

Calculation of ***Respirable*** Mass for New Devices Medication: Albuterol Sulfate					
	nSpire Health Anti-Static Pocket Chamber (nSH-ASPC)	Aerochamber Max (Aero)	OptiChamber (Opti)	Ferraris Respiratory Pocket Chamber (FR-PC)	Able Spacer (EZ)
Total Mass Collected In ACI (µg)**	28.0±13.4 24.7±12.1 33.6±13.1	36.0±16.8 36.6±19.5 33.1±10.9	14.1±11.2 10.4±10.1 2.7±4.7	11.5±2.7 7.8±4.9 6.2±5.9	11.8±9.6 9.7±13.5 0±0
Respirable Mass Collected in ACI (µg)***	22.1±9.9 20.6±9.5 27.5±11.5	23.1±13.8 25.0±16.3 26.3±12.2	9.3±9.7 7.9±7.1 2.7±4.7	9.7±1.4 7.1±3.8 3.7±5.5	9.8±7.0 7.8±10.2 0±0
% Respirable Mass in ACI	37.6±3.3 34.0±8.4 32.8±4.7	33.5±14.3n 35.0±12.8n 32.4±13.3n	10.7±10.0 8.9±6.3 2.3±4.0	14.3±5.9 13.6±5.7 2.7±3.9	14.5±7.0 8.1±11.0 0±0
Legend: Delay 1 second 2 second 5 second	* ACI denotes Anderson Cascade Impactor ** Total Mass Collected is Total Emitted Mass (TEM) *** Respirable Mass is defined as Mass in the 0.4-4.7µm range is Fine Particle Mass (FPM)				

Table 2: Respirable Mass for New Device.

Calculation of ***Recovered*** Mass for New Devices Medication: Albuterol Sulfate					
	nSpire Health Anti-Static Pocket Chamber (nSH-ASPC)	Aerochamber Max (Aero)	OptiChamber (Opti)	Ferraris Respiratory Pocket Chamber (FR-PC)	Able Spacer (EZ)
Mass Collected In ACI (µg)**	28.0±13.4 24.7±12.1 33.6±13.1	36.0±16.8 36.6±19.5 33.1±10.9	14.1±11.2 10.4±10.1 2.7±4.7	11.5±2.7 7.8±4.9 6.2±5.9	11.8±9.6 9.7±13.5 0±0
Mass Retained in Device (µg)	31.4±16.7 40.6±31.4 53.8±33.7	40.8±27.3 34.4±12.1 46.9±10.1	87.8±45.2 66.0±18.9 76.0±33.3	61.1±20.0 44.2±13.3 90.5±48.3	52.8±22.9 72.1±32.9 74.1±31.5
Total Collected (µg)	59.4±28.2 65.4±41.4 87.4±45.7	76.8±40.9 70.9±28.8 80.0±13.4	101.9±43.7 76.3±28.6 78.7±37.3	72.6±20.0 51.9±14.9 96.7±51.0	64.6±31.3 81.9±36.3 74.1±31.5
% Mass Collected in ACI (µg)	47.0±10.0 40.5±10.2 40.9±7.5	48.8±10.1 50.2±8.5 41.1±10.7	14.8±11.8 11.5±8.9 2.3±4.0	16.8±6.8 14.7±7.7 6.3±6.2	16.7±8.8 10.2±14.6 0±0
% Mass Retained in Device (µg)	53.0±10.0 59.6±10.2 59.1±7.5	51.2±10.1 49.8±8.5 58.9±10.7	85.2±11.8 88.6±8.9 97.7±4.0	83.2±6.8 85.3±7.7 93.7±6.2	83.3±8.8 89.8±14.6 100.00±0.0
Total Collected as % of Labeled Dose (90mcg)	66.0 72.6 97.1	85.3 78.8 88.8	113.2 84.8 87.4	80.6 57.7 107.4	71.8 90.9 82.3
Legend: Delay 1 second 2 second 5 second	* ACI denotes Anderson Cascade Impactor ** Total Mass Collected is Total Emitted Mass (TEM) *** Respirable Mass is defined as Mass in the 0.4-4.7µm range is Fine Particle Mass (FPM)				

Table 3: Recovered Mass for New Device.

Calculation of ***Respirable*** Mass for Washed Devices Medication: Albuterol Sulfate			
	nSpire Health Anti-Static Pocket Chamber (nSH-ASPC)	Ferraris Respiratory Pocket Chamber (FR-PC)	Aerochamber Max (Aero)
Total Mass Collected In ACI (μg)** 	46.1±8.6 38.7±9.6 38.2±15.1	16.8±3.9 8.3±5.7 2.9±3.8	61.2±12.1 62.3±20.4 49.7±12.8
Respirable Mass Collected in ACI (μg)*** 	38.0±6.6 34.5±6.1 32.6±12.5	14.5±4.6 8.0±5.8 2.9±3.8	49.9±13.3 51.4±17.2 42.7±11.3
% Respirable Mass in ACI 	35.3±6.6 34.6±5.2 32.3±9.2	13.0±14.3 27.1±16.7 27.6±15.5	43.2±6.3 42.8±6.7 37.7±4.0
Legend: Delay 1 second 2 second 5 second	* ACI denotes Anderson Cascade Impactor ** Total Mass Collected is Total Emitted Mass (TEM) *** Respirable Mass is defined as Mass in the 0.4-4.7μm range is Fine Particle Mass (FPM)		

Table 4: Respirable Mass for Washed Device.

Calculation of ***Recovered*** Mass for Washed Devices Medication: Albuterol Sulfate			
	nSpire Health Anti-Static Pocket Chamber (nSH-ASPC)	Ferraris Respiratory Pocket Chamber (FR-PC)	Aerochamber Max (Aero)
Mass Collected In ACI (μg)** 	46.1±8.6 38.7±9.6 38.2±15.1	16.8±3.9 8.3±5.7 2.9±3.8	61.2±12.1 62.3±20.4 49.7±12.8
Mass Retained in Device (μg) 	63.3±15.8 61.6±10.2 64.2±19.3	96.9±18.7 114.7±26.5 97.6±9.7	52.9±9.3 55.8±6.4 62.5±9.6
Total Collected (μg) 	109.4±20.6 100.3±13.8 102.4±28.2	113.7±20.1 122.9±23.5 100.5±8.6	114.1±16.8 118.1±25.3 112.2±21.1
% Mass Collected in ACI (μg) 	42.4±6.1 38.4±6.9 37.0±8.2	14.9±3.1 7.2±5.0 3.0±3.9	53.5±5.6 51.8±6.8 43.9±4.1
% Mass Retained in Device (μg) 	57.6±6.1 61.6±6.9 63.0±8.2	85.1±3.1 92.8±5.0 97.0±3.9	46.5±5.6 48.2±6.8 56.1±4.1
Total Collected as % of Labeled Dose 	121.6 111.5 113.7	126.3 136.6 111.7	126.7 131.2 124.6
Legend: Delay 1 second 2 second 5 second	* ACI denotes Anderson Cascade Impactor ** Total Mass Collected is Total Emitted Mass (TEM)		

Table 5: Recovered Mass for New Device.

Calculation of ***Respirable*** Mass for New vs. Washed Devices. Medication: Albuterol Sulfate			
	nSpire Health Anti-Static Pocket Chamber (nSH-ASPC)	Aerochamber Max (Aero)	Ferraris Respiratory Pocket Chamber (FR-PC)
Total Mass Collected In ACI (μg)** New Washed	29.2±12.4 41.0±11.2	35.3±15.1 57.4±15.1	8.3±4.9 10.3±7.2
Respirable Mass Collected in ACI (μg)*** New Washed	23.7±10.1 35.1±8.5	24.8±13.3 47.8±13.3	6.5±4.5 9.3±6.6
% Respirable Mass in ACI New Washed	34.7±5.7 34.0±6.8	33.7±12.3 41.1±5.9	9.4±7.4 8.3±5.7
Legend: New vs. Washed New Washed	* ACI denotes Anderson Cascade Impactor ** Total Mass Collected is Total Emitted Mass (TEM) *** Respirable Mass is defined as Mass in the 0.4-4.7μm range is Fine Particle Mass (FPM)		

Table 6: Respirable Mass for New vs. Washed Devices.

Calculation of ***Recovered*** Mass for New vs. Washed Devices. Medication: Albuterol Sulfate			
	nSpire Health Anti-Static Pocket Chamber (nSH-ASPC)	Aerochamber Max (Aero)	Ferraris Respiratory Pocket Chamber (FR-PC)
Mass Collected in ACI (μg)** New Washed	29.2±12.4 41.0±11.2	35.3±15.1 57.4±15.1	8.3±4.9 10.3±7.2
Mass Retained in Device (μg) New Washed	42.9±28.1 63.0±14.4	40.2±17.0 57.2±9.1	67.8±36.5 103.9±21.1
Total Collected (μg) New Washed	72.0±38.6 104.0±20.5	75.5±27.5 114.5±19.4	76.0±37.3 114.2±20.2
% Mass Collected in ACI (μg) New Washed	42.6±8.9 39.3±7.0	47.0±9.8 49.6±6.7	12.0±7.8 9.2±6.2
% Mass Retained in Device (μg) New Washed	57.4±8.9 60.7±7.0	53.0±9.8 50.4±6.7	88.0±7.8 90.8±6.2
Total Collected as % of Labeled Dose New Washed	83.9 127.3	80.0 115.6	84.5 126.9
Legend: Delay New Washed	* ACI denotes Anderson Cascade Impactor ** Total Mass Collected is Total Emitted Mass (TEM)		

Table 7: Recovered Mass for New vs. Washed Devices.

MMAD, GSD and Included Device Counts for Final Calculations							
Delay	**Condition**	**Data**	**Aero**	**nSH-ASPC**	**EZ**	**FR-PC**	**Opti**
1 sec	**New**	**MMAD**	**2.88**	**2.17**	**2.09**	**1.91**	**3.56**
		GSD	**2.02**	**2.31**	**2.07**	**2.46**	**1.68**
		Count	**4**	**4**	**4**	**3**	**3**
	Washed	**MMAD**	**2.61**	**2.50**		**2.43**	
		GSD	**2.18**	**2.02**	**NA**	**2.50**	**NA**
		Count	**5**	**5**		**5**	
2 sec	**New**	**MMAD**	**2.59**	**2.29**	**1.15**	**2.18**	**1.43**
		GSD	**2.31**	**1.96**	**1.61**	**1.68**	**2.29**
		Count	**5**	**4**	**3**	**3**	**4**
	Washed	**MMAD**	**2.02**	**2.44**		**2.07**	
		GSD	**2.11**	**1.87**	**NA**	**1.47**	**NA**
		Count	**4**	**5**		**5**	
5 sec	**New**	**MMAD**	**2.48**	**2.48**	**No Dose**	**1.29**	**Low Dose**
		GSD	**2.16**	**2.36**	**Measured**	**0.74**	**Measured**
		Count	**4**	**5**	**4**	**4**	**3**
	Washed	**MMAD**	**2.59**	**2.54**		**1.80**	
		GSD	**2.01**	**1.87**	**NA**	**0.78**	**NA**
		Count	**5**	**5**		**3**	

Table 8: MMAD, GSD and Included Device Counts for Final Calculations.

Discussion:

New Devices: (All significance testing is based on p<.05).

From the data we found that for new devices tested in accepted ranges there was no difference between the Aero and nSH-ASPC in the percentage of albuterol captured in the device, the percentage captured in the impactor and the percentage captured as respirable dose as shown in Table 8.

We found that for new devices tested in accepted ranges there was a difference between both the Aero and nSH-ASPC and the other three devices in the percentage of albuterol captured in the device, the percentage captured in the impactor and the percentage captured as respirable dose as shown in Table 9. There was no significant difference between the FR-PC, Opti and Ez.

Significance Levels using Tukey Test between New Devices.

		Device Percentage of Dose	Impactor Percentage Of Dose	Repirable Dose Percentage of Dose
Aero	nSH-ASPC	0.724	0.724	0.999
	Ez	0.000	0.000	0.000
	FR-PC	0.000	0.000	0.000
	Opti	0.000	0.000	0.000
nSH-ASPC	Aero	0.724	0.724	0.999
	Ez	0.000	0.000	0.000
	FR-PC	0.000	0.000	0.000
	Opti	0.000	0.000	0.000
Ez	Aero	0.000	0.000	0.000
	nSH-ASPC	0.000	0.000	0.000
	FR-PC	0.927	0.927	0.984
	Opti	0.999	0.999	1.000
FR-PC	Aero	0.000	0.000	0.000
	nSH-ASPC	0.000	0.000	0.000
	Ez	0.927	0.927	0.984
	Opti	0.979	0.979	0.986
Opti	Aero	0.000	0.000	0.000
	nSH-ASPC	0.000	0.000	0.000
	Ez	0.999	0.999	1.000
	FR-PC	0.979	0.979	0.986

Table 9: Significance levels between new devices for Device Percentage, Impactor Percentage and Respirable Dose Percentage.

From the data we found that for New Devices tested in accepted ranges there was a no difference between the nSH-ASPC, Aero, FR-PC and Ez in the amount of albuterol captured in the device but there was a difference between the Opti and the aforementioned devices except for the Aero. This is shown in Table 10. From the data we found that for New devices tested in accepted ranges there was a no difference between the Aero and nSH-ASPC in the amount captured in the impactor and the amount captured as respirable dose and that there was a difference between both the Aero and nSH-ASPC and the other three devices in the amount captured in the impactor and the amount captured as respirable dose. There was no significant difference between the FR-PC, Opti and Ez for the amount captured in the impactor and the amount captured as respirable dose.

There was no difference between any of the devices for total albuterol collected.

Significance Levels using Tukey Test between New Devices.					
		Respirable Dose Captured	Impactor Dose Captured	Dose Captured in Device	Total Dose Captured
Aero	nSH-ASPC	0.999	0.671	0.999	0.999
	Ez	0.000	0.000	0.197	1.000
	FR-PC	0.001	0.000	0.161	1.000
	Opti	0.001	0.000	0.038	0.970
nSH-ASPC	Aero	0.999	0.671	0.999	0.999
	Ez	0.001	0.000	0.294	1.000
	FR-PC	0.001	0.001	0.244	0.999
	Opti	0.002	0.002	0.064	0.909
Ez	Aero	0.000	0.000	0.197	1.000
	nSH-ASPC	0.001	0.000	0.294	1.000
	FR-PC	1.000	0.999	1.000	1.000
	Opti	0.999	0.992	0.934	0.934
FR-PC	Aero	0.001	0.000	0.161	1.000
	nSH-ASPC	0.001	0.001	0.244	0.999
	Ez	1.000	0.999	1.000	1.000
	Opti	1.000	1.000	0.972	0.981
Opti	Aero	0.001	0.000	0.038	0.970
	nSH-ASPC	0.002	0.002	0.064	0.909
	Ez	0.999	0.992	0.934	0.934
	FR-PC	1.000	1.000	0.972	0.981

Table 10: Significance levels between new devices for Device Dose Captured, Impactor Dose Captured and Respirable Dose Captured.

Washed Devices: (All significance testing is based on p<.05)

From the data we found that for Washed Devices tested in accepted ranges there was no difference between the Aero, nSH-ASPC andFR-PC in the percentage of albuterol captured in the device, the percentage captured in the impactor and the percentage captured as respirable dose as shown in Table 11.

Significance Levels using Tukey Test between Washed Devices.				
%		Device Percentage of Dose	Impactor Percentage of Dose	Respirable Dose Percentage of Dose
Aero	nSH-ASPC	0.000	0.000	0.008
	FR-PC	0.000	0.000	0.000
nSH-ASPC	Aero	0.000	0.000	0.008
	FR-PC	0.000	0.000	0.000
FR-PC	Aero	0.000	0.000	0.000
	nSH-ASPC	0.000	0.000	0.000

Table 11: Significance levels between washed devices for Device Percentage, Impactor Percentage and Respirable Dose Percentage.

From the data we found that for Washed Devices tested in accepted ranges there was a difference between the Anti, Aero and nSpire in the amount of albuterol captured as respirable dose as shown in Table 12. From the data we found that for Washed Devices tested in accepted ranges there was also a difference between the Aero, nSH-ASPC and FR-PC in the amount captured in the impactor. But for the amount captured in the device there was no difference between the Aero and the nSH-ASPC but there was a difference between the FR-PC and the other two devices as shown in Table 12. From Table 12 there was no difference between any of the three devices for total albuterol collected.

Significance Levels using Tukey Test between Washed Devices.					
Dose		Respirable Dose Captured	Impactor Dose Captured	Dose Captured in Device	Total Dose Captured
Aero	nSH-ASPC	0.005	0.001	0.576	0.378
	FR-PC	0.000	0.000	0.000	0.999
nSH-ASPC	Aero	0.005	0.001	0.576	0.378
	FR-PC	0.000	0.000	0.000	0.415
FR-PC	Aero	0.000	0.000	0.000	0.999
	nSH-ASPC	0.000	0.000	0.000	0.415

Table 12: Significance levels between washed devices for Device Dose Captured, Impactor Dose Captured and Respirable Dose Captured.

Delay Comparisons:

From the data we found that for new devices tested in accepted ranges there was no difference between devices tested with delay of one second and delay of two seconds for the percentage of albuterol captured in the device, the percentage captured in the impactor, the percentage captured as respirable dose, the amount captured in the impactor, the amount of albuterol captured in the device as respirable dose and the amount of albuterol captured in the device as shown in Table 13. From the data we found that for new devices tested in accepted ranges there was no difference between devices tested with delay of five seconds and delay of one or two seconds for the amount captured in the impactor, the amount of albuterol captured in the device as respirable dose and the amount of albuterol captured in the device as shown in Table 13. But, from the same table, we see that for new devices tested in accepted ranges there was a difference between devices tested with delay of five seconds and delay of one or two seconds for the percentage of albuterol captured in the device, the percentage captured in the impactor and the percentage captured as respirable dose. Under no delay condition was there a difference between any of the devices for total albuterol collected.

Significance Levels for delay interval using Tukey Test between New Devices.								
Time Delays (secs)		Device Percentage of Dose	Impactor Percentage of Dose	Respirable Dose Percentage of Dose	Respirable Dose Captured	Impactor Dose Captured	Dose Captured in Device	Total Dose Captured
1	2	0.733	0.733	0.849	0.989	0.937	0.953	0.933
	5	0.003	0.003	0.024	0.788	0.480	0.266	0.651
2	1	0.733	0.733	0.849	0.989	0.937	0.953	0.933
	5	0.019	0.019	0.079	0.862	0.688	0.150	0.423
5	1	0.003	0.003	0.024	0.788	0.480	0.266	0.651
	2	0.019	0.019	0.079	0.862	0.688	0.150	0.423

Table 13: Significance levels for delay intervals between new devices for Device Percentage, Impactor Percentage, Respirable Dose Percentage, Device Dose Captured, Impactor Dose Captured and Respirable Dose Captured.

From the data we found that for washed devices tested in accepted ranges there was no difference between devices tested with delay of one second and delay of two seconds for the percentage captured as respirable dose, the amount captured in the impactor, the amount of albuterol captured in the device as respirable dose and the amount of albuterol captured in the device as shown in Table 14. But, from the same table, we see that for washed devices tested in accepted ranges there was a difference between devices tested with delay of one seconds and delay of two seconds for the percentage of albuterol captured in the device and the percentage captured in the impactor. From the data we found that for washed devices tested in accepted ranges there was no difference between devices tested with delay of five seconds and delay of one or two seconds for the percentage of albuterol captured in the device, the percentage captured in the impactor, the percentage captured as respirable dose, the amount captured in the impactor and the amount of albuterol captured in the device as respirable dose as shown in Table 14. But, from the same table, we see that for washed devices tested in accepted ranges there was a difference between devices tested with delay of five seconds and delay of one or two seconds for the amount of albuterol captured in the device. Under no delay condition was there a difference between any of the devices for total albuterol collected.

Significance Levels for delay interval using Tukey Test between Washed Devices.								
Time Delays (secs)		Device Percentage of Dose	Impactor Percentage of Dose	Respirable Dose Percentage of Dose	Respirable Dose Captured	Impactor Dose Captured	Dose Captured in Device	Total Dose Captured
1	2	0.027	0.027	0.282	0.493	0.260	0.576	0.378
	5	0.063	0.063	0.416	0.473	0.264	0.000	0.999
2	1	0.027	0.027	0.282	0.493	0.260	0.576	0.378
	5	0.948	0.948	0.970	0.998	1.000	0.000	0.415
5	1	0.063	0.063	0.416	0.473	0.264	0.000	0.999
	2	0.948	0.948	0.970	0.998	1.000	0.000	0.415

Table 14: Significance levels for delay intervals between new devices for Device Percentage, Impactor Percentage, Respirable Dose Percentage, Device Dose Captured, Impactor Dose Captured and Respirable Dose Captured.

From the data we found that for both new and washed devices, together, tested in accepted ranges there was no difference between devices tested with delay of one second and delay of two seconds for the percentage of albuterol captured in the device, the percentage captured in the impactor, the percentage captured as respirable dose, the amount captured in the impactor, the amount of albuterol captured in the device as respirable dose and the amount of albuterol captured in the device as shown in Table 15. From the data we found that for new devices tested in accepted ranges there was no difference between devices tested with delay of five seconds and delay of one or two seconds for the amount captured in the impactor, the amount of albuterol captured in the device as respirable dose, the percentage captured as respirable dose and the amount of albuterol captured in the device as shown in Table 15. But, from the same table, we see that for new devices tested in accepted ranges there was a difference between devices tested with delay of five seconds and delay of one or two seconds for the percentage of albuterol captured in the device and the percentage captured in the impactor. Under no delay condition was there a difference between any of the devices, new or washed compared together, for total albuterol collected.

Significance Levels for delay interval using Tukey Test between New and Washed Devices.								
Time Delays (secs)		Device Percentage of Dose	Impactor Percentage of Dose.	Respirable Dose Percentage of Dose	Respirable Dose Captured	Impactor Dose Captured	Dose Captured in Device	Total Dose Captured
1	2	0.174	0.174	0.587	0.584	0.351	0.974	0.903
	5	0.003	0.003	0.078	0.554	0.265	0.382	0.939
2	1	0.174	0.174	0.587	0.584	0.351	0.974	0.903
	5	0.245	0.245	0.447	0.999	0.982	0.509	0.724
5	1	0.003	0.003	0.078	0.554	0.265	0.382	0.939
	2	0.245	0.245	0.447	0.999	0.982	0.509	0.724

Table 15: Significance levels for delay intervals between new and washed devices for Device Percentage, Impactor Percentage, Respirable Dose Percentage, Device Dose Captured, Impactor Dose Captured and Respirable Dose Captured.

Conclusion:

The conclusion drawn from these experiments is clear. There is an overall difference in the performance between devices where the Aerochmber Max and the nSpire Health Anti-Static Pocket Chamber yield substantially better dose delivery characteristics than the OptiChamber, Ferraris Respiratory Pocket Chamber and Able Spacer. This performance difference was observed for all three delays for the actuation of medication. There was an overall difference in the performance in dose delivery characteristics between the factors of delay. Although there was no difference in the performance in dose delivery characteristics between delay levels of one and two seconds, there was a difference between these levels and that of 5 seconds. This was seen in all of the devices.

The amount of respirable dose that was collected at 1 seconds in the impactor before washing was statistically similar for the nSH-ASPC (22.1±9.9ug) and the Aero (23.1±13.8ug). Both of these figures were statistically greater than the FR-PC (9.7±1.4ug), EZ (9.8±7.0ug) and Opti (9.3±9.7ug) which were statistically similar to each other. The amount of respirable dose that was collected at 1 seconds in the impactor after washing was statistically similar for the nSH-ASPC (38.0±6.6ug) and the Aero (49.9±13.3ug). Both of these figures were greater than the FR-PC (14.5±4.6ug).

The amount of respirable dose that was collected at 5 seconds in the impactor before washing was statistically similar for the nSH-ASPC (27.5±11.5ug) and the Aero (26.3±12.2ug). Both of these figures were statistically greater than the FR-PC (3.7±5.5ug), EZ (0±0ug) and Opti (2.7±4.7ug) which were statistically similar to each other. The amount of respirable dose that was collected at 5 seconds in the impactor after washing was statistically similar for the nSH-ASPC (32.6±12.5ug) and the Aero (42.7±11.3ug). Both of these figures were greater than the FR-PC (2.9±3.8ug).

It is clear from these results that the performance characteristics is different for the devices made from nonelectrostatic plastic material (Aero and nSH-ASPC) than for the devices made from the traditional nonconducting plastic used. For both time delays the Aero and nSH-ASPC would yield albuterol dosages in the respirable range of between 22-49ug. The devices made from nonconducting plastic all ranged from 9-10ug albuterol for respirable dose with a one second delay. The respirable dose would drop to below

4ug albuterol for all three devices made from nonconducting plastic using a 5 second delay when used for the first time. This trend was also observed for the FR-PC after being washed. We would conclude from this data the nonelectrostatic plastic material does have an effect on the dose delivery characteristics regardless of being used new or washed and regardless of time delay in actuation. For the devices of nonelectrostatic plastic material we conclude that there is no significant difference between the Aero and nSH-ASPC the percentage of albuterol captured in the device, the percentage captured in the impactor, the percentage captured as respirable dose, the amount captured in the impactor, the amount of albuterol captured in the device as respirable dose, the amount of albuterol captured in the device and the total dose captured for New Devices. For the devices of nonelectrostatic plastic material we conclude that there is a significant difference between the Aero and nSH-ASPC the percentage of albuterol captured in the device, the percentage captured in the impactor, the percentage captured as respirable dose, the amount captured in the impactor and the amount of albuterol captured in the device as respirable dose for Washed Devices. For the devices of nonelectrostatic plastic material we conclude that there is no significant difference between the Aero and nSH-ASPC the amount of albuterol captured in the device and the total dose captured for Washed Devices.