THE BAKER COMPANY

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Energy-Efficient Biological Safety Cabinet Reduces Energy Costs While Ensuring Safety

ABSTRACT

As the primary containment devices within laboratories, biological safety cabinets (BSCs) are critical to protect personnel, product and environment from exposure to biohazards and cross-contamination during routine daily procedures. Because of this vital role, the biological safety cabinet is one of the most essential and highly used pieces of equipment within a laboratory.

Biological safety cabinets have been designed to run continuously to maintain aseptic conditions in the workspace. Additionally, BSCs are often operated continuously to help control dust and other airborne particulates.

With current energy prices reaching all-time highs, reducing energy costs is a paramount concern of every laboratory. An analysis published by the U.S. Environmental Protection Agency concluded that laboratories consume five to 10 times more energy per square foot than typical office buildings.[1] The need for energy-efficient equipment has never been more acute.

The Baker Company's new SterilGARD high-efficiency biological safety cabinets offer a significant reduction in energy usage while maintaining a rigorous standard of safety and protection. Recent studies have shown that the reduced airflow mode of operation for the cabinets results in a 50–75% lower operating cost compared to previous designs.

INTRODUCTION

Reducing energy use in biological safety cabinets (BSCs) has been a priority at The Baker Company for some time. Because a BSC uses the flow of filtered air to provide personnel, product and environmental protection, you must reduce this airflow to reduce energy consumption. Turning off a cabinet would result in the ultimate energy reduction and, in some situations, this may be the solution. However, in most situations before you turn a cabinet off it should be decontaminated and then disinfected before it is placed back in service. This process is very time-consuming.

The Baker Company's approach to this problem is to close the sash and operate the BSC at a reduced flow that provides personnel, product and environmental protection while using less energy. This mode of operation is called the ReadySAFE™ mode for the new SterilGARD BSCs. These high-efficiency BSCs automatically switch to the ReadySAFE mode when the sash is closed, and switch back to a normal airflow mode of operation when the sash is opened. Recent studies using microbiological and cleanliness-class/particle-count testing techniques concluded that when operating in the ReadySAFE mode these cabinets meet or exceed NSF/ANSI Standard 49 Class II and ISO class 4 criteria while consuming 50–75% less energy than when operating in the standard mode.

OVERVIEW

Personnel and product protection microbiological tests were performed on cabinet models SG403A HE, SG503A HE and SG603A HE as per the current NSF/ANSI Standard 49 Class II procedures. Additional cleanliness-class/particle-count testing was also performed to verify that the cabinet interior was free of particles over 0.5 µm.

In addition, dynamic sash movement tests were incorporated with each of these standard procedures to simulate real-world usage. These tests alleviated concerns that the movement of the sash and the reduced airflow could cause the cabinet to fail because of changing airflow patterns.

To replicate the motion of opening and closing the sash during non-use and start-up conditions, the sash was moved from open to closed and then closed to open during all of the tests. Since opening and closing the sash involves no penetration of the front air curtain by any object, a cylinder that is used in the standard NSF tests was not used because the sash would not have been able to be closed.

For the SG403A HE and SG603A HE cabinets, tests were performed for 8-, 10- and 12-inch sash heights. For the SG503A HE cabinet, tests were performed for 8- and 12-inch sash heights.

PROCEDURES AND RESULTS

A. Personnel Protection Test

For the personnel protection tests, the impingers and the nebulizer were placed in the prescribed NSF Standard 49 locations. (Figure 1) The nebulizer was filled with 55 mL of *Bacillus subtilis* var. *niger* bacterial spore suspension in water of 5.0 X 10^8 spores per 1 mL for each test, as per the NSF Standard 49.

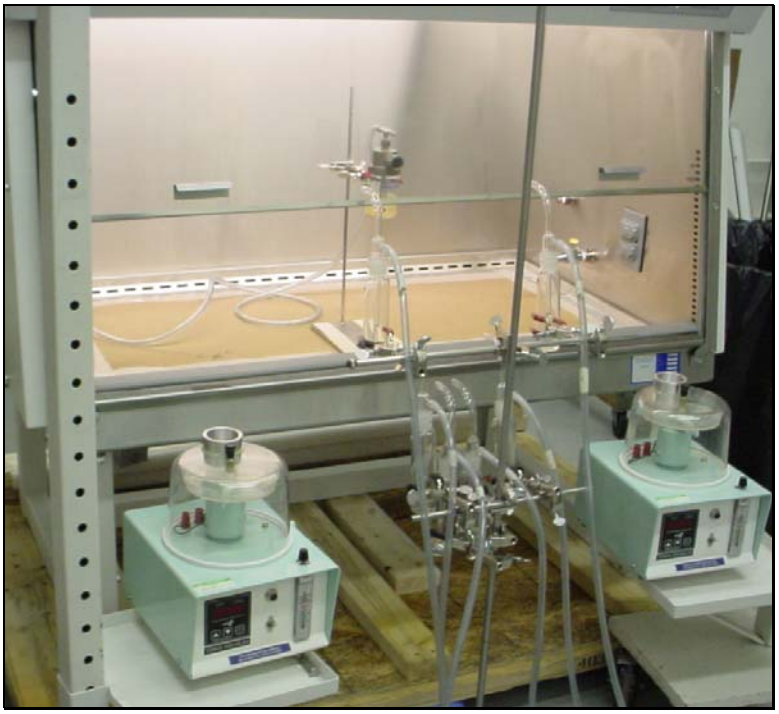

Figure 1. Personnel protection test for model SG403A HE with sash open at 12-inch height.

Two tests were conducted for each sash height. During the first test for personnel protection, the sash was initially in the open position. (Figure 1) One minute after the impingers and nebulizer started, the sash was closed, engaging the low-flow mode. The remainder of the test procedure was performed with the sash closed and the cabinet in ReadySAFE mode.(Figure 2)

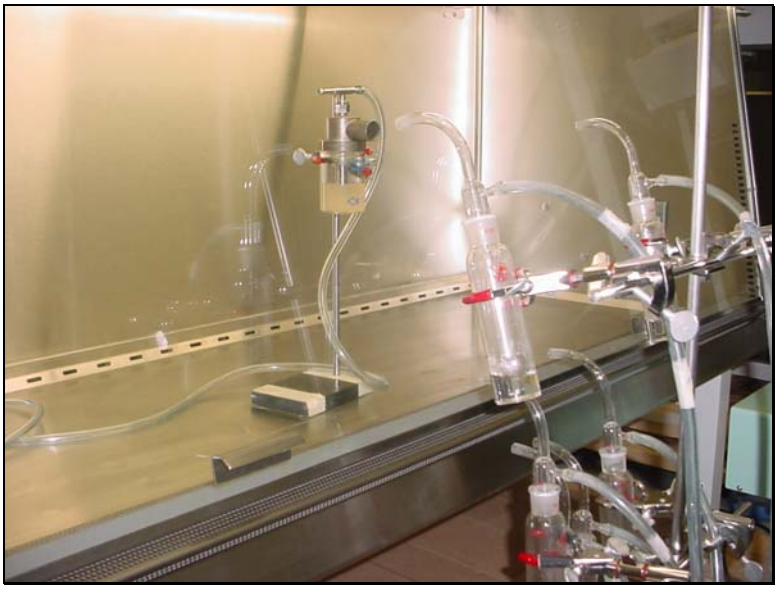

Figure 2. Personnel protection test for model SG403A HE with sash closed.

During the second test for personnel protection, the sash was closed initially and the cabinet was in ReadySAFE mode. One minute after the impingers and nebulizer started, the sash was opened, immediately switching to normal airflow. The remainder of the test procedure was performed with the sash opened and the cabinet in normal operating mode. The nebulizers were run for 15 minutes rather than the required NSF standard of five minutes for both tests. The Baker Company considers this to provide an additional challenge to the cabinet.

Model/Sash Height	Test Number	Sash Movement	Total CFU* Slit Samplers	Total CFU Filter	Results (Pass <= 10 CFUs AGI* Filtered) (Pass <= 5 CFUs Slit Samplers)
SG403A HE 8 inch	Test 1	Open – Close	1 CFU	0 CFU	Pass
	Test 2	Open – Close	0 CFU	1 CFU	Pass
	Test 3	Open – Close	1 CFU	0 CFU	Pass
	Test 4	Close – Open	0 CFU	0 CFU	Pass
	Test 5	Close – Open	0 CFU	0 CFU	Pass
	Test 6	Close – Open	0 CFU	0 CFU	Pass
SG403A HE 10 inch	Test 1	Open – Close	0 CFU	0 CFU	Pass
	Test 2	Open – Close	2 CFU	1 CFU	Pass
	Test 3	Open – Close	0 CFU	0 CFU	Pass
	Test 4	Close – Open	0 CFU	0 CFU	Pass
	Test 5	Close – Open	0 CFU	0 CFU	Pass
	Test 6	Close – Open	0 CFU	0 CFU	Pass
SG403A HE 12 inch	Test 1	Open – Close	1 CFU	0 CFU	Pass
	Test 2	Open – Close	0 CFU	0 CFU	Pass
	Test 3	Open – Close	0 CFU	0 CFU	Pass
	Test 4	Close – Open	1 CFU	0 CFU	Pass
	Test 5	Close – Open	0 CFU	0 CFU	Pass
	Test 6	Close – Open	0 CFU	0 CFU	Pass
SG503A HE 8 inch	Test 1	Open – Close	1 CFU	0 CFU	Pass
	Test 2	Open – Close	3 CFU	7 CFU	Pass
	Test 3	Open – Close	0 CFU	0 CFU	Pass
	Test 4	Close – Open	0 CFU	0 CFU	Pass
	Test 5	Close – Open	0 CFU	0 CFU	Pass
	Test 6	Close – Open	0 CFU	0 CFU	Pass
SG503A HE 12 inch	Test 1	Open – Close	0 CFU	0 CFU	Pass
	Test 2	Open – Close	3 CFU	0 CFU	Pass
	Test 3	Open – Close	1 CFU	1 CFU	Pass
	Test 4	Close – Open	3 CFU	1 CFU	Pass
	Test 5	Close – Open	1 CFU	0 CFU	Pass
	Test 6	Close – Open	3 CFU	3 CFU	Pass
SG603A HE 8 inch	Test 1	Open – Close	3 CFU	0 CFU	Pass
	Test 2	Open – Close	2 CFU	0 CFU	Pass
	Test 3	Open – Close	2 CFU	1 CFU	Pass
	Test 4	Close – Open	2 CFU	0 CFU	Pass
	Test 5	Close – Open	1 CFU	0 CFU	Pass
	Test 6	Close – Open	0 CFU	0 CFU	Pass
SG603A HE 10 inch	Test 1	Open – Close	4 CFU	0 CFU	Pass
	Test 2	Open – Close	3 CFU	0 CFU	Pass
	Test 3	Open – Close	0 CFU	0 CFU	Pass
	Test 4	Close – Open	3 CFU	0 CFU	Pass
	Test 5	Close – Open	3 CFU	0 CFU	Pass
	Test 6	Close – Open	0 CFU	0 CFU	Pass
SG603A HE 12 inch	Test 1	Open – Close	1 CFU	0 CFU	Pass
	Test 2	Open – Close	0 CFU	0 CFU	Pass
	Test 3	Open – Close	0 CFU	0 CFU	Pass
	Test 4	Close – Open	0 CFU	0 CFU	Pass
	Test 5	Close – Open	2 CFU	0 CFU	Pass
	Test 6	Close – Open	2 CFU	0 CFU	Pass

*CFU: colony-forming unit, AGI: all-glass impinger

Table 1. Personnel protection test results. Microbiological challenge was 15 x 10^8 spores.

B. Product Protection Test

The product protection microbiological tests were performed with the nebulizer positioned at the standard NSF location of 4 inches from the bottom edge of the sash with the output of the nebulizer horizontal with the bottom edge. (Figure 3) Tests were conducted with the nebulizer on for 15 minutes (the NSF standard is 5 minutes), and then off for 10 minutes. The nebulizer was filled with 55 mL of *Bacillus subtilis* var. *niger* bacterial spore suspension in water with a concentration of 5.0 X 10^6 spores per 1 mL, as per the NSF Standard 49.

Figure 3. Product protection test for model SG403A HE with sash open at 12-inch height.

Two tests were conducted for each sash height. During the first test for product Protection, the sash was initially in the open position and then closed, engaging the ReadySAFE mode. In the second test, the sash was initially in the closed position with the cabinet in ReadySAFE mode and then opened, engaging normal airflow.

Model/Sash Height	Test Number	Sash Movement	Total CFUs*	Results (Pass <= 5 CFUs)
SG403A HE 8 inch	Test 1	Open - Close	2 CFU	Pass
	Test 2	Open - Close	0 CFU	Pass
	Test 3	Open - Close	0 CFU	Pass
	Test 4	Close - Open	2 CFU	Pass
	Test 5	Close - Open	1 CFU	Pass
	Test 6	Close - Open	0 CFU	Pass
SG403A HE 10 inch	Test 1	Open - Close	0 CFU	Pass
	Test 2	Open - Close	0 CFU	Pass
	Test 3	Open - Close	0 CFU	Pass
	Test 4	Close - Open	0 CFU	Pass
	Test 5	Close - Open	0 CFU	Pass
	Test 6	Close - Open	0 CFU	Pass
SG403A HE 12 inch	Test 1	Open - Close	0 CFU	Pass
	Test 2	Open - Close	2 CFU	Pass
	Test 3	Open - Close	2 CFU	Pass
	Test 4	Close - Open	1 CFU	Pass
	Test 5	Close - Open	0 CFU	Pass
	Test 6	Close - Open	0 CFU	Pass
SG503A HE 8 inch	Test 1	Open - Close	1 CFU	Pass
	Test 2	Open - Close	0 CFU	Pass
	Test 3	Open - Close	0 CFU	Pass
	Test 4	Close - Open	0 CFU	Pass
	Test 5	Close - Open	1 CFU	Pass
	Test 6	Close - Open	2 CFU	Pass
SG503A HE 12 inch	Test 1	Open - Close	1 CFU	Pass
	Test 2	Open - Close	0 CFU	Pass
	Test 3	Open - Close	0 CFU	Pass
	Test 4	Close - Open	0 CFU	Pass
	Test 5	Close - Open	0 CFU	Pass
	Test 6	Close - Open	0 CFU	Pass
SG603A HE 8 inch	Test 1	Open - Close	1 CFU	Pass
	Test 2	Open - Close	0 CFU	Pass
	Test 3	Open - Close	1 CFU	Pass
	Test 4	Close - Open	2 CFU	Pass
	Test 5	Close - Open	0 CFU	Pass
	Test 6	Close - Open	0 CFU	Pass
SG603A HE 10 inch	Test 1	Open - Close	0 CFU	Pass
	Test 2	Open - Close	1 CFU	Pass
	Test 3	Open - Close	3 CFU	Pass
	Test 4	Close - Open	3 CFU	Pass
	Test 5	Close - Open	3 CFU	Pass
	Test 6	Close - Open	3 CFU	Pass
SG603A HE 12 inch	Test 1	Open - Close	0 CFU	Pass
	Test 2	Open - Close	1 CFU	Pass
	Test 3	Open - Close	0 CFU	Pass
	Test 4	Close - Open	0 CFU	Pass
	Test 5	Close - Open	0 CFU	Pass
	Test 6	Close - Open	0 CFU	Pass

*CFU: colony-forming unit

Table 2. Product protection test results. Microbiological challenge was 15 x 10^8 spores.

C. Cleanliness-Class/Particle-Count Test

To demonstrate the ability of the high-efficiency cabinets to provide product protection from outside particulate when the sash is in motion, additional testing was conducted using cleanliness-class/particle-count methods. Particle counts were measured with a Met One® laser particle counter. (Figure 4)

Figure 4. Met One laser particle counter used during testing.

The background particle count was measured and recorded before each test. If the count was below 100,000 particles per cubic foot at 0.5-µm particle size, PAO was introduced to the room until the level exceeded 100,000 particles.

Cleanliness-class/particle-count testing began with the sash in the open position and the cabinet in the normal operating mode. (Figure 5)

Figure 5. Cleanliness-class/Particle-count test.

Twelve particle-count sample readings were taken on the work surface for each cabinet using a 3 x 4 grid. (Figure 6) Corner readings were measured 1 inch from the back and side walls, with the isokinetic nozzle opening facing upward in the direction of the air stream 4½ inches from the work surface. Four readings of three rows were taken, evenly spaced from left to right and from front to back.

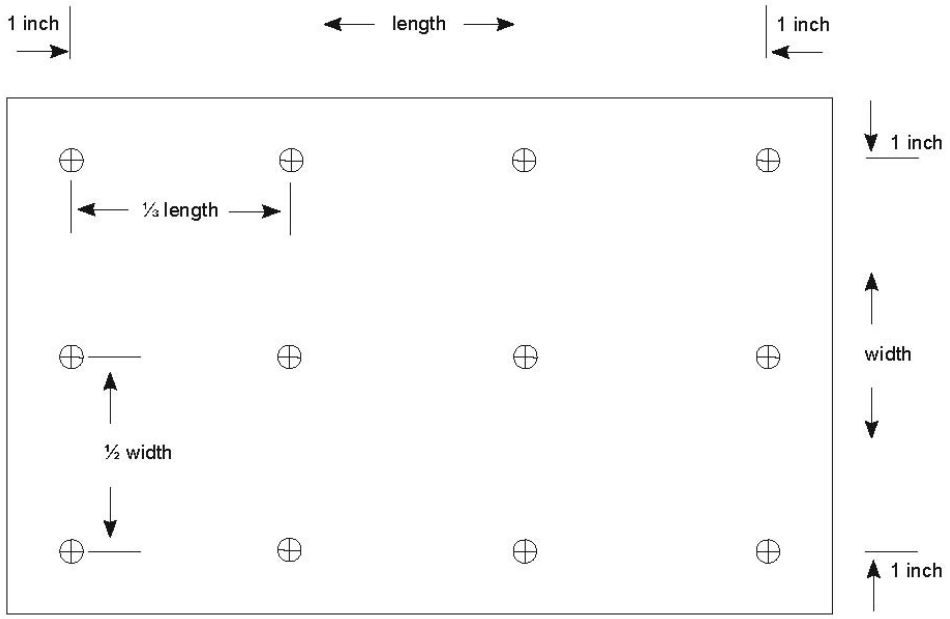

Figure 6. Sample locations for cleanliness-class/particle-count test.

Each sample was taken for a total time of one minute, sampling a volume of air equal to 1 cubic foot per location. Particle sizes of 0.3 µm and 0.5 µm were recorded for each cubic foot sample.

The tests began with the sash in the open position. (Figures 7 and 8)

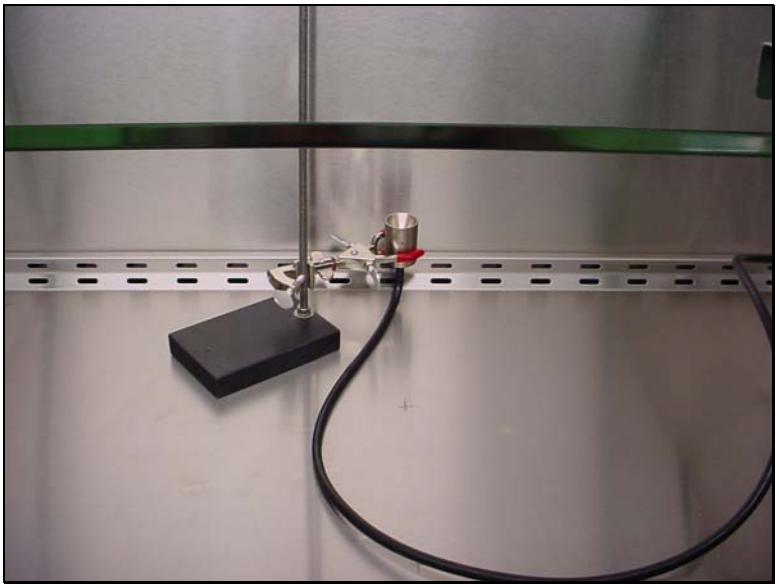

Figure 7. Isokinetic nozzle for particle-count testing.

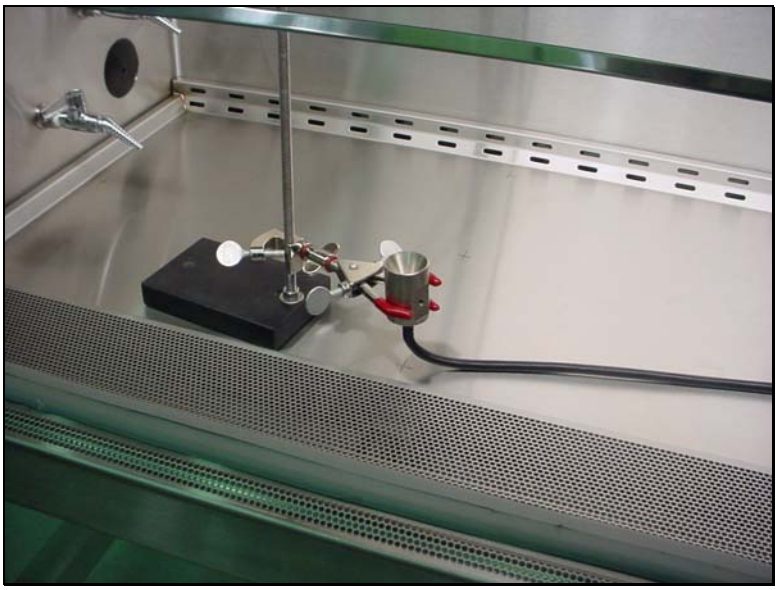

Figure 8. Isokinetic nozzle for particle-count testing near front air perforation with sash open and normal airflow.

Within 2 seconds, the sash was pushed closed, switching to the ReadySAFE mode. (Figure 9)

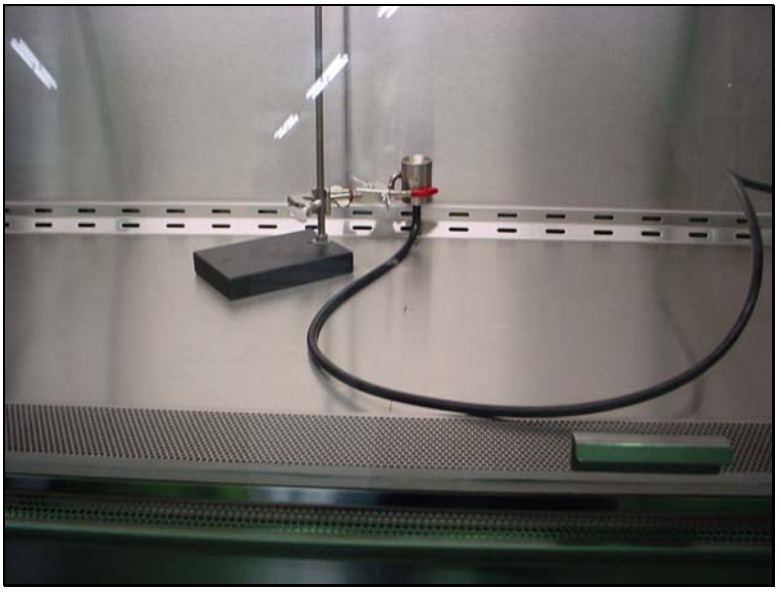

Figure 9. Isokinetic nozzle for particle-count testing with sash closed and ReadySAFE mode.

Once the sash was closed, particles continued to be counted for approximately 28 seconds. At half the sample time, the sash was raised to the full open height, switching to normal airflow. Particles continued to be counted for the remaining time of approximately 28 seconds. (Table 3)

Time (sec)	Sash	Airflow	Sample
0	Opened	Normal	Start (t = 0 sec)
2	Closing	Normal	
28	Closed	ReadySAFE	
2	Opening	Normal	
28	Opened	Normal	End (t = 60 sec)

Table 3. Sash movement during cleanliness-class/particle-count testing.

For each cabinet tested at each sash height, no particles of 0.5 µm were measured. The particle counts measured for each cabinet as per the ISO 14644-1 standard are listed in Tables 4, 5 and 6 for each model.

Background 0.5 micron	Sash Height	Particle Counts (0.3 micron, 0.5 micron)				Allowed Counts for ISO Class 5
160,000	8	(0, 0)	(0, 0)	(0, 0)	(1, 0)	(292, 100)
		(0, 0)	(0, 0)	(0, 0)	(0, 0)	
		(0, 0)	(0, 0)	(0, 0)	(0, 0)	
234,000	10	(1, 0)	(0, 0)	(0, 0)	(1, 0)	(292, 100)
		(0, 0)	(0, 0)	(0, 0)	(0, 0)	
		(0, 0)	(0, 0)	(0, 0)	(0, 0)	
160,000	12	(0, 0)	(0, 0)	(0, 0)	(1, 0)	(292, 100)
		(1, 0)	(2, 0)	(1, 0)	(0, 0)	
		(0, 0)	(0, 0)	(0, 0)	(0, 0)	

Table 4. Cleanliness-class/Particle-count test results for model SG403A HE.

Background 0.5 micron	Sash Height	Particle Counts (0.3 micron, 0.5 micron)				Allowed Counts for ISO Class 5
282,000	8	(0, 0)	(1, 0)	(2, 0)	(0, 0)	(292, 100)
		(3, 0)	(0, 0)	(3, 0)	(0, 0)	
		(0, 0)	(2, 0)	(0, 0)	(4, 0)	
106,000	12	(1, 0)	(0, 0)	(0, 0)	(0, 0)	(292, 100)
		(0, 0)	(0, 0)	(0, 0)	(0, 0)	
		(0, 0)	(4, 0)	(2, 0)	(1, 0)	

Table 5. Cleanliness-class/Particle-count test results for model SG503A HE.

Background 0.5 micron	Sash Height	Particle Counts (0.3 micron, 0.5 micron)				Allowed Counts for ISO Class 5
373,000	8	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(292, 100)
		(0, 0)	(1, 0)	(0, 0)	(0, 0)	
		(1, 0)	(3, 0)	(1, 0)	(0, 0)	
111,000	10	(1, 0)	(1, 0)	(0, 0)	(0, 0)	(292, 100)
		(2, 0)	(0, 0)	(1, 0)	(4, 0)	
		(2, 0)	(1, 0)	(0, 0)	(1, 0)	
117,000	12	(0, 0)	(2, 0)	(1, 0)	(2, 0)	(292, 100)
		(2, 0)	(1, 0)	(3, 0)	(1, 0)	
		(0, 0)	(2, 0)	(0, 0)	(3, 0)	

Table 6. Cleanliness-class/Particle-count test results for model SG603A HE.

D. Energy Reduction Results

Using the ReadySAFE mode of operation will result in better than a 55% reduction in energy usage. Table 7 illustrates the percent reduction in energy used for each of the SterilGARD cabinets at the various sash height openings.

Model	Sash Height	Normal Flow Amps	ReadySAFE Amps	Percent Reduction
SG403A HE	8	3.6	1.6	55%
	10	4.0	1.7	58%
	12	5.6	1.8	67%
SG503A HE	8	4.0	1.7	58%
	12	6.7	1.9	64%
SG603A HE	8	5.5	2.0	63%
	10	6.7	2.0	70%
	12	7.2	2.1	71%

Table 7. Energy reduction results during microbiological testing.

While the actual savings will depend upon how each laboratory uses this new feature, the following tables demonstrate the savings per year for each of the SterilGARD models using normal flow for eight hours and the ReadySAFE mode for sixteen hours. These calculations include costs of 4.5 cents, 10 cents and 15 cents per kilowatt.

Model	Sash Height	Kilowatt Use per Day		Normal Flow Only Cost		Normal Flow (8 hr) and ReadySAFE (16 hr) Cost		Savings per Year
		Normal Flow Only	Normal Flow (8 hr) and ReadySAFE (16 hr)	Per Day	Per Year	Per Day	Per Year	
SG403A HE	8	10.94	6.72	$0.49	$178.85	$0.30	$109.50	$69.35
	10	13.82	7.87	$0.62	$226.30	$0.35	$127.75	$98.55
	12	18.43	9.60	$0.83	$302.95	$0.43	$156.95	$146.00
SG503A HE	8	10.66	6.82	$0.48	$175.20	$0.31	$113.15	$62.05
	12	14.40	8.45	$0.65	$237.25	$0.38	$138.70	$98.55
SG603A HE	8	15.84	9.12	$0.71	$259.15	$0.41	$149.65	$109.50
	10	19.87	10.46	$0.89	$324.85	$0.47	$171.55	$153.30
	12	20.74	10.66	$0.93	$339.45	$0.48	$175.20	$164.25

Table 8a. Savings per year using ReadySAFE mode for sixteen hours per day at a kilowatt cost of 4.5 cents.

Model	Sash Height	Kilowatt Use per Day		Normal Flow Only Cost		Normal Flow (8 hr) and ReadySAFE (16 hr) Cost		Savings per Year
		Normal Flow Only	Normal Flow (8 hr) and ReadySAFE (16 hr)	Per Day	Per Year	Per Day	Per Year	
SG403A HE	8	10.94	6.72	$1.09	$397.85	$0.67	$244.55	$153.30
	10	13.82	7.87	$1.38	$503.70	$0.79	$288.35	$215.35
	12	18.43	9.60	$1.84	$671.60	$0.96	$350.40	$321.20
SG503A HE	8	10.66	6.82	$1.07	$390.55	$0.68	$248.20	$142.35
	12	14.40	8.45	$1.44	$525.60	$0.85	$310.25	$215.35
SG603A HE	8	15.84	9.12	$1.58	$576.70	$0.91	$332.15	$244.55
	10	19.87	10.46	$1.99	$726.35	$1.05	$383.25	$343.10
	12	20.74	10.66	$2.07	$755.55	$1.07	$390.55	$365.00

Table 8b. Savings per year using ReadySAFE mode for sixteen hours per day at a kilowatt cost of 10 cents.

Model	Sash Height	Kilowatt Use per Day		Normal Flow Only Cost		Normal Flow (8 hr) and ReadySAFE (16 hr) Cost		Savings per Year
		Normal Flow Only	Normal Flow (8 hr) and ReadySAFE (16 hr)	Per Day	Per Year	Per Day	Per Year	
SG403A HE	8	10.94	6.72	$1.64	$598.60	$1.01	$368.65	$229.95
	10	13.82	7.87	$2.07	$755.55	$1.18	$430.70	$324.85
	12	18.43	9.60	$2.76	$1007.40	$1.44	$525.60	$481.80
SG503A HE	8	10.66	6.82	$1.60	$584.00	$1.02	$372.30	$211.70
	12	14.40	8.45	$2.16	$788.40	$1.27	$463.55	$324.85
SG603A HE	8	15.84	9.12	$2.38	$868.70	$1.37	$500.05	$368.65
	10	19.87	10.46	$2.98	$1087.70	$1.57	$573.05	$514.65
	12	20.74	10.66	$3.11	$1135.15	$1.60	$584.00	$551.15

Table 8c. Savings per year using ReadySAFE mode for sixteen hours per day at a kilowatt cost of 15 cents

CONCLUSION

This series of tests demonstrate that The Baker Company's new SterilGARD biological safety cabinets met or exceeded the NSF/ANSI Standard 49 Class II and ISO class 4 criteria during dynamic sash movements while operating in the ReadySAFE mode. This mode of operation maintains personnel and product protection while reducing energy consumption 50–75% (Table 7), and can result in significant monetary savings (Table 8). This testing gives the researcher confidence that this energy-saving feature will maintain containment and still protect the work environment from particulate when operating in the ReadySAFE mode.

REFERENCES

1. U.S. Environmental Protection Agency, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Federal Energy Management Program. *Laboratories for the 21st Century: Energy Analysis*. April 2003.