Simplicity in Airflow Generation for Class II Biological Safety Cabinets Improves Safety and Reliability

From the first generation of Class II Biological Safety Cabinets, the simplicity of using a single motor/blower have improved safety and reliability to generate and control cabinet airflow for both downflow and inflow versus more complex two motor/blower systems that generate and control downflow and inflow independently.

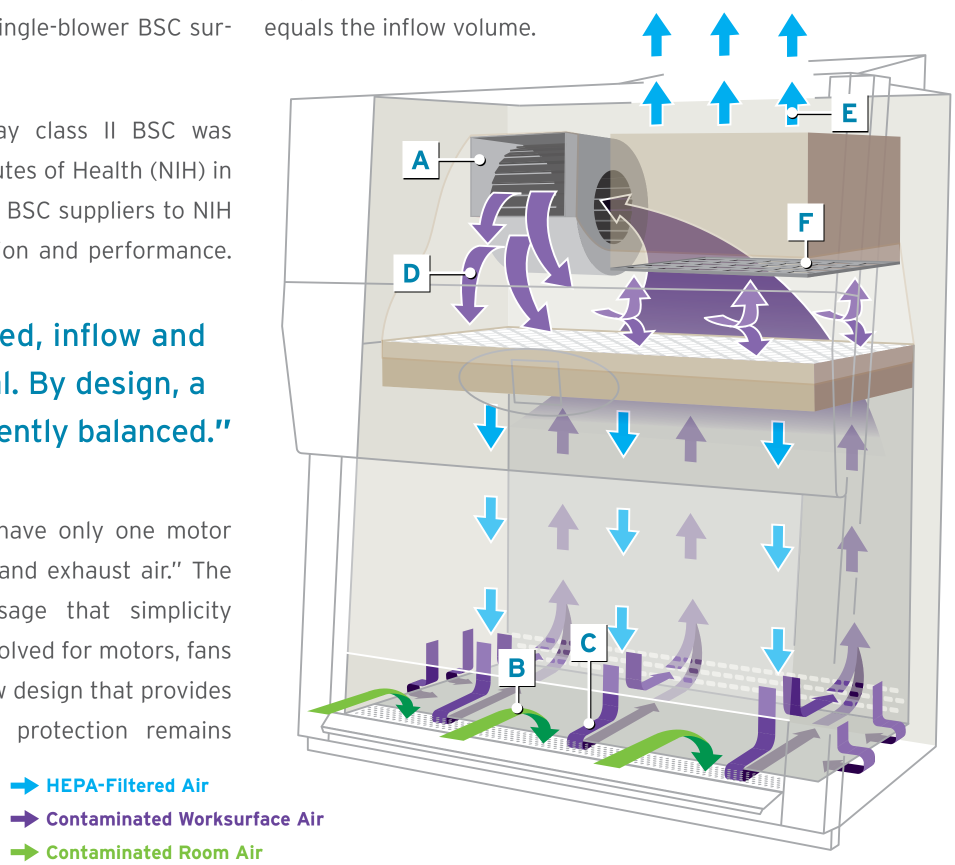
A wide range of processes in research and various industries require a class II Biological Safety Cabinet (BSC). Scientists and lab technicians use this technology as the primary engineering control to protect themselves (personnel) and their work materials (products) when working with hazardous biological or chemical particulate materials in various forms of life science and pharmaceutical research, as well as hazardous drug preparation. Given the crucial safeguards provided by a BSC, these engineering controls must perform both continuously and reliably. In addition, a BSC must supply the necessary level of safety at an affordable lifetime cost of ownership. Meeting those criteria as effectively as possible depends on a BSC's design and components. As this discussion shows, the engineering and economic principles of a single-blower BSC surpass those of a dual-blower approach.

The first generation of the modern-day class II BSC was originally specified by the National Institutes of Health (NIH) in the early 1970's document NIH-03-112 for BSC suppliers to NIH as minimum requirements for construction and performance.

> "With a change in blower speed, inflow and downflow speed remain equal. By design, a single-blower system is inherently balanced."

The specification read: "The unit shall have only one motor driven fan system for both recirculated and exhaust air." The NIH specification reinforced the message that simplicity improves reliability. As technology has evolved for motors, fans and controls, the basic class II BSC airflow design that provides personnel, product and environmental protection remains essentially the same.

The class II BSC function provides airflow that starts with the cabinet's motor/blower system. [A] The motor/blower pulls airflow through the cabinet's work access opening and into half of the work zone front grill providing personnel protection. [B] The motor/blower also pulls downflow air into the work zone's rear and remaining half of the front grill providing controlled flow within the work zone [C]. The motor/blower then pushes the air through the supply HEPA filter providing the downflow and product protection [D]. In addition, some of the air pushed from the motor/blower must exit the cabinet through the exhaust HEPA filter at the same volume as the inflow [E]. The exhaust volume is pushed by the motor/blower through a baffle plate [F] that controls the amount of exhaust air so that it equals the inflow volume.



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In a dual-blower system, the airflow pattern is identical, but the exhaust airflow is controlled by a second motor/blower.

Reliability and Balance

Reliability makes up the key feature of any BSC. Only a reliable BSC is a safe one. As Edsger Dijkstra—the late Dutch computer scientist and winner of the 1972 Turing Award—said, "Simplicity is prerequisite for reliability."

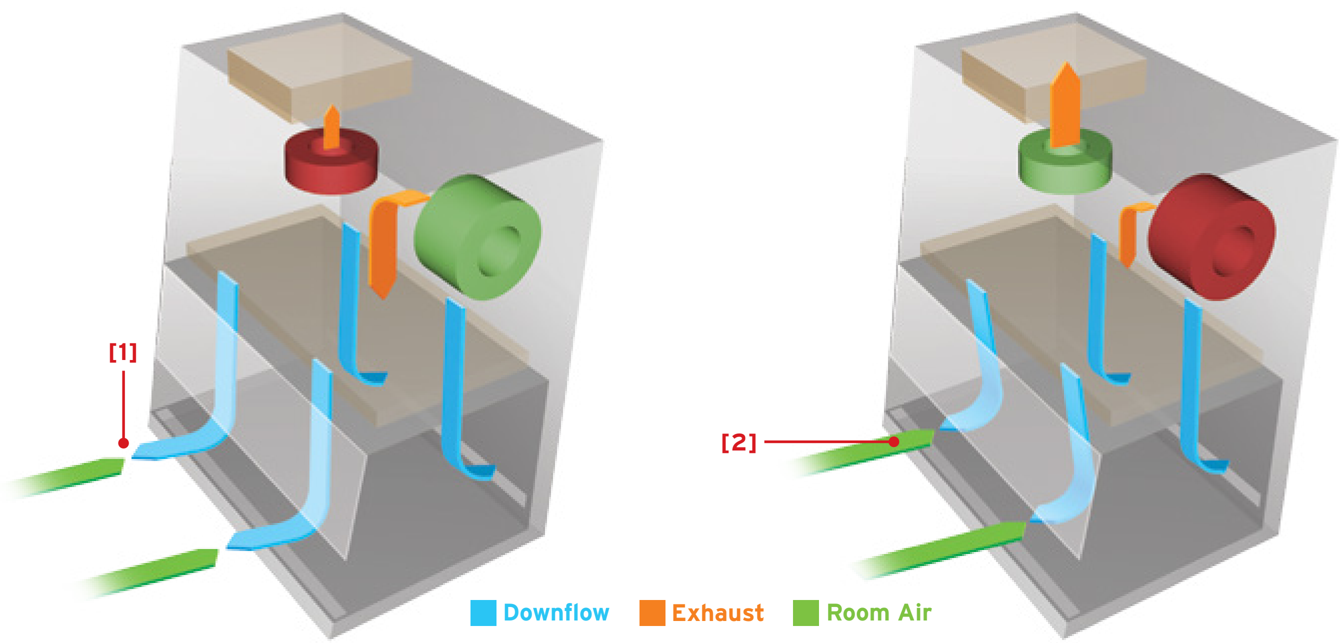
From that very fundamental thinking alone, a single-blower BSC is more reliable than a dual-blower system. Everything else being equal, a dual-blower system will experience twice the failure rate of a single-blower system. Conversely, a single-blower BSC is twice as reliable as a dual-blower one.

With a single-blower BSC, minor adjustments will balance the airflow. Small adjustment to blower speed and/or the damper is all that's necessary to achieve the best result. In most cases, an annual adjustment of the choke (baffle) plate provides precise airflow balance. Once the choke (baffle) is set, it doesn't move. Plus, with a change in the blower speed, the inflow and downflow remain equal, because a single-blower system is always balanced.

With a dual motor/blower system, however, more complicated issues must be considered. Here both motor/blowers must be controlled accurately, because even minor changes in either motor/blower can alter the inflow and/or the downflow. Even a slight change in the speed of one motor/blower must be immediately compensated by the other motor/blower. In short, the two motor/blowers tend to fight (counteract) each other. Furthermore, the safety level of a dual motor/blower BSC depends entirely on how precisely the two motor/blowers can be controlled. It is a delicate balancing act to keep two

> **"Motor/blowers in a multiple motor/blower system have a tendency to counteract each other disrupting the delicate airflow balance."**

Dual-Motor/Blowers Out of Balance



With a dual motor/blower system both motor/blowers must be controlled accurately, because even minor changes in either motor/blower can alter the inflow and/or the downflow. A failure, or reduction in speed of the exhaust motor/blower can result in a high downflow condition, forcing potentially contaminated air into the room [1]. A reduction in speed of the supply motor/blower can cause low downflow and allow room air to enter, and contaminate the work space [2].

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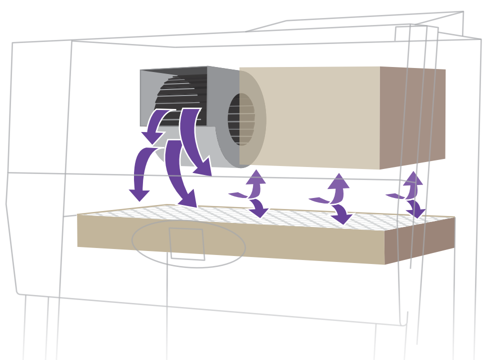
blowers properly performing when they are in a constant state of pulling air from the same plenum and discharging in opposite directions.

Filter Loading

Keeping the proper level and balance of airflow also depends on the filters. The static pressure or resistance on the filter changes over time as it gathers particulates, which results in so-called filter loading. With a single motor/blower system, as particulates load during the year between certifications, the ratio of downflow to inflow remains virtually the same. In addition, some motor/blower systems accommodate filter loading over time by adjusting the speed of the motor/blower as needed based on feedback systems designed to provide constant volume control.



As particulate loads HEPA filters between certifications, a single motor/blower system maintains a consistent ratio of downflow to inflow, preventing uneven filter loading.

In some dual motor/blower systems, the two manually controlled motor/blowers are set once a year during the certification process. Manually controlled motor/blowers typically do not compensate for filter loading and can result in an unbalanced ratio of inflow to downflow, potentially compromising containment performance. Other dual motor/blower systems use multiple feedback systems or sensors to automatically adjust the two motor/blowers, which can be required due to changes in either blower or because of filter loading. The increased numbers of parts required to keep a dual motor/blower system operating make the system more complex and less reliable.

Certification and Safety

To ensure the safe operation of any BSC, it should be certified upon installation, after any repair or being moved and, otherwise, annually. The field certification process should follow the NSF/ANSI 49 (Annex F).

The certification process of a BSC is performed by five tests: downflow velocity test, inflow velocity test, HEPA filter leak test, smoke pattern test and site installation test. The downflow and inflow velocity tests are performed at the same time, because adjusting either the motor/blower or baffle system affects both results. However, since the baffle system is fixed and not dynamic, adjustment can be made rapidly without system changes. It is always desirable for the certifier to set the nominal airflow velocities in the center of the NSF acceptable range that produces the highest level of containment performance.

The certification process can be somewhat more complicated in a dual motor/blower system that is not fixed, but dynamic with feedback and sensor systems. As you adjust one motor/blower, the system pressure will change causing an increase or decrease load on the second motor/blower. This can make the certification of a dual motor/blower BSC more difficult when balancing the airflow: The certifier might measure the inflow, adjust one motor/blower, measure the downflow, adjust the second motor/blower, and this might be repeated a few times, especially if one motor/blower keeps speeding up and slowing down due to system pressures.

Without current certification, a BSC cannot be considered safe, but other factors also affect safety. For example, although some sources suggest that dual motor/blower systems are safer than single motor/blower systems, engineering experience does not support such a conclusion. The thinking behind this argument, simply that two are better than one, does not stand up to analysis.

If a single motor/blower fails, it would be handled exactly with the same procedure as a power interruption. The cabinet user would immediately stop work, cover any open containers and exit the cabinet.

If either motor fails in a dual motor/blower system, safety issues may arise. When the supply blower fails, the exhaust motor/blower will continue to run, which would provide some degree

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of inflow. However, the inflow movement would be dynamically different because it would be pulled more from the rear grill of the work zone. The inflow movement would be more lateral and actually may cause more material to escape during the cabinet user's stop work procedure, because of the large eddy currents that would be generated by the cabinet user's body—acting highly similar to a fume hood, but not designed for this purpose. When the exhaust motor/blower fails, a required safety interlock system must turn off the supply blower; otherwise personnel safety will also be compromised.

Furthermore, the additional requirement of the safety interlock creates another potential weak spot in a dual motor/blower system. The interlock must depend on a sensor system and function at a known safe airflow level to ensure that the supply motor/blower turns off whenever the exhaust fails. The timing of the interlock is very critical. In most cases, there is a slight delay from the moment the exhaust blower fails and when the interlock will disable the supply blower. During this brief time, there is potential for loss of containment resulting in potential contamination to the end user. Overall, simplicity increases ease of certification, safety and reliability.

"Simplicity in a single motor/blower design provides a more stable and reliable system than a dual motor/blower BSC system design."

Total Cost of Ownership

To evaluate the total cost of ownership, motor/blower system capacity must be considered. As a basic engineering principle, it takes more motor capacity or horsepower overall for a dual motor/blower system to produce the same system capacity of a single motor/blower system. The additional motor capacity is needed to overcome the loss from the dual motor/blower system fighting itself. If a manufacturer provides the required additional horsepower, the BSC creates more noise and vibration, as well as consuming more energy. The typical end result of today's cabinets that use dual motor/blower systems is that they don't provide an equal amount of system capacity. With lower system capacity, HEPA filter replacement occurs twice as often.

As a case in point, some dual motor/blower BSCs require filter replacements—a several thousand dollar repair—every 4 to 5 years, because the motor/blowers lack the equivalent necessary horsepower to properly compensate for filter loading. For example, today the NSF/ANSI 49 standard tests for the motor/blower system to handle at least a 50 percent increase of the starting filter load without readjusting the motor speed control. However, in the past, the NSF/ANSI 49 standard required a benchmark of total system capacity to handle at least 180% with adjusting the motor speed control. This benchmark was removed as a requirement from the standard since the use of more energy efficient DC and AC motor systems. The result is that some dual motor/blower systems struggle to compensate for just 150 percent of the starting filter load. On the other hand, NuAire BSC's with a properly designed, energy-efficient DC ECM single motor/blower can handle up to and exceeding in some cases 250 percent of the starting filter load. Consequently, the single motor/blower system works safely for 10 or more years between filter replacements.

Last, even if the two different motor/blower designed BSCs used all of the same components, the dual motor/blower system would cost more over time because doubling the parts will cost more for replacement when they fail in terms of both labor and material. When this occurs, the BSC must be decontaminated, and—in most cases—both blowers will be replaced, rather than risking a repeat of the procedure a year or two later for the other blower.

The Comparative Conclusion

A single motor/blower BSC system design provides a more stable and reliable system than a dual motor/blower BSC system design. Probability indicates a higher level of safety when considering all aspects of BSC ownership, including service and usage. Basic economic comparisons reveal the superior total cost of ownership of a single motor/blower BSC system.

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