Energy Efficiency in Biological Safety Cabinets

With our planet's finite resources and the successive energy, environmental and financial crises, we have been repeatedly reminded of the need to be more careful of how we expend our resources. As a commonly used piece of laboratory equipment, the biological safety cabinet (BSC) is vital in ensuring the safety of the user as well as the sample. However, these cabinets can consume vast amounts of energy. This article looks at how to ensure that the important safety benefits and quality of work offered by Class II BSCs, can be maintained while still consuming resources more efficiently.

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A COSTLY EXHAUST

Many life science research protocols require the use of BSCs to provide protection for the operator, product and environment. They achieve this through the use of an inward flow of air at the front aperture, in combination with the filtration of air circulated into, and exhausted from, the cabinet.

However, filters are only able to capture solid particles, not gases, so if BSCs are used with volatile toxic chemicals or radionuclides, it is recommended that the exhaust be conveyed out of the laboratory through the buildings' air ducts, which can be costly. In addition, every cubic meter of air conveyed out of the building must be replaced to ensure balance is maintained.

As such, energy is expended moving the air, while the replacement air may need to be treated for temperature and/or cleanliness, increasing the cost of using externally ducted cabinets.

When researching low flow fume hoods in 2003, Mills and Sartor [1] of Livermore National Laboratories in the United States estimated that the average annual cost of exhausted air was US$2.65 per cubic meter per hour (CMH).

It is clear therefore that in order to increase energy-efficiency, external exhaust requirements need to be reduced. There are three ways of doing this:

Review the substances and applications used. The effectiveness of HEPA filtration is not always fully appreciated. Some users may request an externally exhausted BSC to handle biological hazards, when this application can be adequately addressed by the HEPA filters within the BSC.

Consider the requirement and frequency for externally exhausted BSCs. Rather than installing ten externally exhausted BSCs in a laboratory, for example, it might be possible to use seven BSCs without external exhaust and two or three shared BSCs with external exhaust. If researchers are only working with anesthetic gas once or twice a month, it is much more efficient to provide a standard BSC for normal use and arrange access to an externally exhausted BSC for these more specialised procedures.

Reduce the non-operational external exhaust requirements. A typical 1.2 meter wide BSC connected to an external exhaust requires a draw of ~400 CMH.* Over the course of seven days, a constantly operating external exhaust would expel 67200 cubic meters of air. If the external exhaust can be closed when not operational, without disturbing the balance within the laboratory or operation of other devices, the same cabinet can operate for 40 hours and only expel 16,000 cubic meters of air - a reduction of over 75%.

The complexity of the facility ventilation system has a key part to play in how the balance can be met. A simple building with only a few externally exhausted BSCs will require minimal adjustments to facilitate these energy savings. However, a building with many laboratories will have high energy and heat loads, as well as a wide variety of external exhaust devices and critical room pressurisation specifications to manage environmental and product containment.

The number of externally exhausted devices, including BSCs and other types of containment equipment, can have an enormous combined exhaust. Advanced ventilation systems will use flow controls to minimise this exhaust, while meeting the requirements for every device in use and maintaining the required room pressure.

These systems are highly complex with multifaceted interrelationships between temperature, pressure, supply flow, and exhaust flow. Therefore, while the more complex systems are the most likely to see the benefit of reduced exhaust flow, they are also the most complex to implement.

HEAT AND POWER

Power consumption

BSCs use electricity to power the fans and blowers that move the air through the filters to provide cleanliness and containment. There have been huge advances in the efficiency of fans and blowers, where the implementation of brushless DC motors (as used in the Thermo Scientific 1300 Series A2 BSC – *Figure 1*) has resulted in operational energy reductions of 50 - 75%.*

Table 1 shows the power consumption for four different 1.2 meter wide BSCs, along with life-time power consumption and cost. This has been calculated using an assumed lifespan of 15 years and usage of forty hours per week.

Figure 1. The Thermo Scientific 1300 Series A2, Class II Type A2 biological safety cabinet delivers exceptional design and technology advancements such as superior protection with patented airflow design, exceptional ergonomics for a safe and comfortable environment, and outstanding energy efficiency for operational cost savings

Heat output

The amount of heat produced by a BSC is directly proportional to the electrical energy it consumes. As a result, externally exhausted BSCs generally release any heat produced with the BSC exhaust. Units that are not externally exhausted will release approximately 3,412 BTU or 3,600 kilojoules for every kilowatt of power consumed. If this air is released into the laboratory, it may need to be cooled, increasing the total power consumption by up to 30%.

NON-OPERATIONAL OPTIMISATION

Some users and protocols require the BSC to maintain cleanliness and containment levels, even when not in active operation. In such cases, any fluorescent lights can be switched off, leaving just the blowers running, resulting in an annual energy reduction of up to 8%. Some operational energy consumption reduction techniques can also be applied to reduce non-operational energy consumption. For example, brushless DC motors are capable of varying speeds to provide a reduced flow, or "night" mode, with the front window closed therefore enabling the BSC to still maintain a contaminant-free work area.

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Table 1. A comparison of power consumption and cost of four different BSC. Consumption values are from each vendor's own data.

	Thermo Scientific 1300 Series A2	Traditional Alternative A	Traditional Alternative B	Traditional Alternative C
Power Consumption	200 Watts	810 Watts	1000 Watts	1150 Watts
Lifetime Power Consumption 40hrs/week for 15 years	6 240 kilowatt-hours	25 272 kilowatt-hours	31 200 kilowatt-hours	35 880 kilowatt-hours
Lifetime cost using 0.0632 USD/kWhr¬	$394	$1 597	$1 972	$ 2 268

¬ Key World Energy Statistics 2009 by International Energy Agency provides the retail price for electricity to industrial customers in US Dollars for three countries in and near Asia; South Korea, Japan and New Zealand. The average price of electricity weighted by domestic consumption yields the price 0.0632 USD.

Table 2. Annual cost comparison between a demanding and an energy efficient BSC

	Demanding BSC	Energy Efficient BSC	Savings
Non-operational exhaust	$807.62	$0.00	$807.62
Operational exhaust	$252.38	$0.00	$252.38
Non-operational power consumption (including additional 20% cost of cooling for non-externally exhausted BSC)	$412.25	$16.20	$396.05
Operational power consumption (including additional 20% cost of cooling for non-externally exhausted BSC)	$131.46	$31.55	$99.91
Annual cost of exhaust and power consumption	**$1,603.71**	**$47.75**	**$1,555.96**

Figures above assume both BSCs have 400 CMH exhaust, 45 watt power consumption for UV light. The demanding BSC consumes 1000 watts operational and 935 watts with fans on and lights off. Energy efficient BSC consumes 200 watts operational, 32 watts with reduced fans and lights off and 2.5 hour UV decontamination cycle. Generic assumptions are cost of $2.65 per CMH per year for external exhaust, $0.0632 per kilowatt-hour, 2080 operational hours per year, 6656 non-operating hours per year, 8736 total hours per year, and 250 UV decontamination cycles per year.

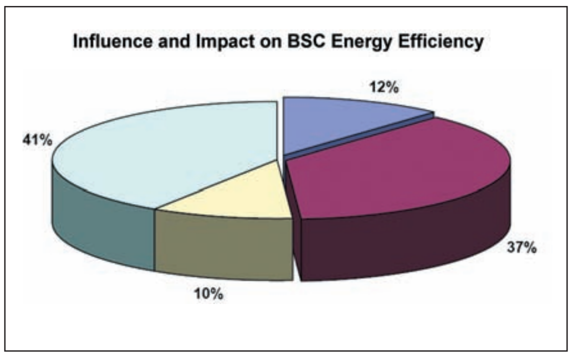

Figure 2. Influences and impact of BSC energy efficiency on cost savings

Germicidal (UV) light can also be used effectively to reduce non-operational energy consumption. The sample chamber of the BSC is commonly wiped down at the beginning and end of each work day, as well as in-between each experiment use. In addition to this, many researchers use the germicidal light to fully decontaminate the sample chamber overnight. This assures the decontamination of any minute droplets of biological material from the interior surfaces of the chamber,

The various exposure times required to sterilise different biological agents are readily available, enabling users to avoid unnecessarily lengthy sterilisation periods. Many BSCs have timed UV lights, allowing users to select the length of each UV decontamination cycle. Using the customary assumptions for UV intensity within a BSC and UV lamp life, a 2.5 hour cycle provides the necessary exposure for even the most resistant organisms. Such measures can also extend the life of a UV bulb from one to eleven years.

DISCUSSION

There are a various number of different methods which can be employed to reduce external exhaust and consequently the power consumption of BSCs. Identifying the best opportunities to improve BSC energy efficiency is the main challenge when providing a cost-effective laboratory solution, which still provides the required level of protection for the sample, personnel and environment. As seen in *Table 2*, the energy savings between a demanding BSC and an energy efficient unit can be vast. The worst case is an externally exhausted 1.2m BSC, which uses traditional fans and germicidal lights, which are left on when not in use. The best case is a new, non-externally exhausted, 1.2m BSC with energy efficient fans and timed UV decontamination cycles.

These figures clearly show that: BSCs that can remove the need for operating the external exhaust when not in use, provide a potential annual saving of $807.62. Furthermore, if the externally exhausted BSC could be replaced with a non-externally exhausted BSC (by reviewing the nature of the materials being used or by sharing an exhausted BSC), there could be additional savings of $252.38 for a total of $1,060 per year. If a reduced flow mode is used to maintain cleanliness and containment when the BSC is not in operation, users could save an additional $396.05 per year, and if energy efficient blowers are used, a further saving of $99.91 per year can be made. As a result, potential savings could reach $1,555.96 - over 95%. For BSCs that are not externally exhausted, the possible savings from energy efficient fans can reach $495.96 or over 90%. These savings are illustrated in *Figure 2*.

CONCLUSION

Through advances in technology and careful design, BSCs can now provide superior cleanliness and containment while also offering energy efficiency that was not possible in the past.

The development of more advanced filter technologies, in combination with DC motors and timed decontamination cycles enables researchers to maintain a clean work space, free from potentially contaminating substances, while significantly reducing any associated running costs.

In addition, through informed and appropriate use of external exhaust, and the selection of energy efficient BSCs, it is also easier to make choices which reduce the overall running cost without compromising on hazard control.

REFERENCES

[1]. Mills E, Sartor D. Energy use and savings potential for laboratory fume hoods. Energy 2005; 30: 1859 – 1864.

** All data presented here are derived from publically available information from Thermo Scientific or other BSC vendors. Where data are used in a comparison, care was taken to select 'like-for-like' models.*

CLASS II BSC TYPES

Class II BSCs are available in a number of different 'types' depending on their inflow, downflow and exhaust processes.

The two most commonly encountered types are: A2, which recirculates filtered air and can be vented into the laboratory or externally via a thimble connection, and B2, which externally vents 100% of the air drawn in (no recirculation). The illustration below highlights the key features of these BSCs.

Types	Downflow Air	Inflow Air	Exhaust Air
Class II, Type A2 vented to room 	The downflow air is supplied by a filtered mix of laboratory and sample chamber air.	The inflow air is drawn from the laboratory into the front grille and prevented from entering the work area.	The filtered exhaust air is vented into the laboratory.
Class II, Type A2 with thimble exhaust 	The downflow air is supplied by a filtered mix of laboratory and sample chamber air.	The inflow air is drawn from the laboratory into the front grille and prevented from entering the work area.	The filtered exhaust air is completely exhausted through the thimble connection and exhausted out of the building.
Class II, Type B2 with direct duct "total exhaust" 	The downflow air is supplied entirely by filtered air from the laboratory.	The inflow air is drawn from the laboratory into the front grille, and prevented from entering the work area.	The filtered exhaust air is completely exhausted through the direct duct connection and exhausted out of the building.