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University of Michigan Field Study of Class II Biological Safety Cabinet Energy Consumption Costs

Theoretical research indicates that, with all variables controlled, Class II biosafety cabinets (BSCs) with brushless direct current (BLDC) motors can save up to 80% in energy costs over conventional cabinets with alternating current (AC) motors. To validate this theory, the University of Michigan (Ann Arbor) conducted a field study on three brands of biosafety cabinets. The study showed that the BLDC cabinets can save significant amounts of energy over conventionally powered units and that this benefit is realized over a wide range of filter loading conditions. Therefore, the energy savings available from BLDC Class II biosafety cabinets warrant earnest consideration before purchasing AC motor Class II biosafety cabinets.

Table 1 Energy consumption in watts of BSCs with nominal width of four feet in different modes

	Operational	Blower on and Lights Out	Unit Off	Unit Off with UV On	Blower reduced and Lights Out	Blower reduced and UV On	Blower off and Lights On
Thermo Scientific Model 1440, BLDC Motor 10" high window opening	**208**	**142.5**	**5.5**	**25.9**	**66.5**	**87.0**	**67.0**
Biosafety Cabinet "A". AC Motor, 10" high window opening	841	780	2.2	No UV	N/A	N/A	61.0
Biosafety Cabinet "B". AC Motor, 8" high window opening	790	725	3.7	59.1	N/A	N/A	N/A
Biosafety Cabinet "C". AC Motor, 10" high window opening	660	602	0.0	No UV	N/A	N/A	61.8

Table 2 Energy consumption in watts of BSCs with nominal width of six feet in different modes

	Operational	Blower on and Lights Out	Unit Off	Unit Off with UV On	Blower reduced and Lights Out	Blower reduced and UV On	Blower off and Lights On
Thermo Scientific Model 1387, BLDC Motor, 10" high window opening	**399**	**346**	**3.0**	**N/A**	**119.0**	**160.0**	**62.0**
Thermo Scientific Model 1460, BLDC Motor, 10" high window opening	**247**	**185**	**6.5**	**41.0**	**67.8**	**102.0**	**72.3**
Biosafety Cabinet "D". AC Motor, 8" high window opening	1,100	1,034	2.1	94.2	N/A	N/A	N/A
Biosafety Cabinet "E". AC Motor, 10" high window opening	958	883	0.0	No UV	N/A	N/A	76.3

Energy consumption rate comparisons among Class II biosafety cabinets

Class II BSCs are used in most research laboratories to provide personal and product protection from work hazards due to biological aerosols, splashes, and spills, as well as to maintain sterile conditions in tissue culture applications. Class II BSCs are ventilated enclosures that use controlled airflow and HEPA filtration. In the past, energy-efficient biosafety cabinets were hard to find because Class II BSCs are not ENERGY STAR labeled.

In 2007, the University of Michigan Procurement Services Department was presented with a new Thermo Scientific Class II biosafety cabinet (**Thermo Fisher Scientific**, Waltham, MA) using BLDC motors that offered significant energy savings, lower maintenance costs, more safety and ergonomic features, and competitive pricing. The University of Michigan Procurement Services decided to compare the BLDC motor energy usage rates of the cabinet against the AC motor biosafety cabinets.

Field-testing methodology

To validate the theoretical inferences, a joint team consisting of members from the University of Michigan and **Thermo Fisher Scientific** conducted a field study in research laboratories and compared energy rates among BLDC and the top three manufacturers of AC Class II biosafety cabinets. The analysis compared energy consumption and procurement costs. The BLDC motor Class II biosafety cabinets included in the field tests were the Thermo Scientific models 1440, 1460, and 1387. The field test results of the AC motor Class II biosafety cabinets were randomly assigned as cabinets "A," "B," "C," "D," and "E."

The field testing was conducted in multiple laboratories at three locations at the University of Michigan, Ann Arbor. The team members consisted of representatives from the University of Michigan: the BioSafety Officer, one Design Engineer, and one Mechanical Engineer from Utilities/Plant Engineering, Procurement Services; **Thermo Fisher** had two representatives.

Examining the cost of operation

The goal of the field test was to accurately determine energy consumption and the associated cost of operation of Class II

Table 3 Annual energy consumption in kilowatt-hours of BSCs with nominal width of four feet in different use types

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1440, BLDC Motor, 10" high window opening	**1,820**	**864**	**453**
Biosafety Cabinet "A". AC Motor, 10" high window opening	7,350	6,940	1,700
Biosafety Cabinet "B". AC Motor, 8" high window opening	6,900	6,460	1,600
Biosafety Cabinet "C". AC Motor, 10" high window opening	5,770	5,380	1,320

Note. The values of all Tables are rounded to three significant digits.

Table 4 Annual energy consumption in kilowatt-hours of BSCs with nominal width of six feet in different use types

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1387, BLDC Motor, 10" high window opening	**3,490**	**1,600**	**818**
Thermo Scientific Model 1460, BLDC Motor, 10" high window opening	**2,160**	**951**	**538**
Biosafety Cabinet "D". AC Motor, 8" high window opening	9,610	9,170	2,210
Biosafety Cabinet "E". AC Motor, 10" high window opening	8,370	7,860	1,920

- Use type #1: The BSC is on 24 hours per day, 7 days per week, 52 weeks per year.
- Use type #2: The BSC is used 8 hours per day, 5 days per week, 50 weeks per year, and is left on to maintain the sample chamber cleanliness and containment all other times. For BSCs with reduced flow capability, this would be with the fan at reduced flow, the sample chamber lights off and the UV lights off. For BSCs without reduced flow capability, this would be with the fan at normal flow, the sample chamber lights off and the UV lights off.
- Use type #3: The BSC is used 8 hours per day, 5 days per week, 50 weeks per year, and is turned off all other times.

Using the energy consumption measurements and types of use provided above, the annual energy consumption was calculated in kilowatt-hours of each BSC for the three types of use shown in *Tables 3* and *4*.

Examining the cost of cooling

A further cost to operating a biosafety cabinet is the additional heat generated from the cabi-

BSCs using BLDC and AC motors. The field test was not done to endorse the Thermo Scientific brand or to engage in future testing of subsequent BSCs. The BSCs included were not externally exhausted; thus only electricity and cooling factors are examined.

For the purpose of this study, the cost of operation is energy consumption, or the electricity required to physically operate the BSC. BSCs use a blower/motor system to establish the airflow needed to protect the sample chamber and to move air through the filters before being exhausted from the cabinet or delivered to the sample chamber.

For each cabinet surveyed, the team measured the energy in watts while the units were operating under three normal usage conditions and four nontypical conditions. The nontypical measurements were found not significant and only the three normal conditions are presented in this article. No operating laboratory equipment (such as pipet aids, etc.) was plugged into the cabinet receptacles.

After determining the consumption of the biosafety cabinets in various modes, the team examined three types of use. These measurements are provided in *Tables 1* and *2*.

Table 5 Annual operational costs of BSCs in BSRB with nominal width of four feet with energy costs of $0.085/kWh and cooling costs of $17.63/MMBTU

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1440, BLDC Motor, 10" high window opening	**$264**	**$125**	**$66**
Biosafety Cabinet "A". AC Motor, 10" high window opening	$1,070	$1,010	$247
Biosafety Cabinet "B". AC Motor, 8" high window opening	$1,000	$937	$232
Biosafety Cabinet "C". AC Motor, 10" high window opening	$838	$782	$192

Note. The values of all tables are rounded to the nearest U.S. dollar.

Table 6 Annual operational costs of BSCs in BSRB with nominal width of six feet with energy costs of $0.085/kWh and cooling costs of $17.63/MMBTU

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1387, BLDC Motor, 10" high window opening	**$506**	**$232**	**$119**
Thermo Scientific Model 1460, BLDC Motor, 10" high window opening	**$314**	**$138**	**$78**
Biosafety Cabinet "D". AC Motor, 8" high window opening	$1,400	$1,330	$321
Biosafety Cabinet "E". AC Motor, 10" high window opening	$1,220	$1,140	$279

net's fans and lights measured in British Thermal Units, or BTUs. One BTU is the amount of heat required to increase the temperature of a pint of water by one degree Fahrenheit, and can be calculated by multiplying the energy consumption in kilowatt hours by 3412.141.

Estimating total operating cost at the University of Michigan

The actual annual cost of operating these BSCs can be determined from the field measurements already listed. The electricity and cooling costs at the University of Michigan can be estimated with more precision. According to the University's Utilities & Plant Engineering, the cost per kWh varies with the unit paying for it. The cost per kWh is based on November 1, 2007 rates. For the Biomedical Science & Research Building (BSRB) and Life Science Institute (LSI) building, it is $0.085/kWh. The Cancer Center & Geriatric Center (CCGC) is split between the hospital and general fund, and can be $0.085/kWh or around $0.071/per kWh. For cooling costs, the university used $17.63/million BTUs (MMBTU) for the BSRB and $7.58 per MMBTU for the LSI and CCGC buildings.

Based on the information provided, following are the three possible combinations of energy and cooling costs for the buildings in which the field testing took place:

1. In the BSRB, there are energy costs of $0.085/kWh and cooling costs of $17.63/MMBTU.
2. In the LSI and parts of the CCGC buildings, there are energy costs of $0.085/kWh and cooling costs of $7.58/MMBTU.
3. In the other parts of CCGC, there are energy costs of $0.071/kWh and cooling costs of $7.58/MMBTU.

The charge for electricity is used to determine the operational cost of each BSC for each usage pattern. This is then added to the cooling costs. This method is used to calculate the total cost for each of the eight biosafety cabinets, in each of the three usage patterns. The costs based on the three combinations of electrical and cooling costs are provided in the following three separate sets of tables (*Tables 5–10*).

Tables 5 and 6 present the combined energy and cooling costs for the BSRB with energy costs of

Table 7 Annual operational costs of BSCs in LSI and parts of CCGC with nominal width of four feet with energy costs of $0.085/kWh and cooling costs of $7.58/MMBTU

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1440, BLDC Motor, 10" high window opening	**$202**	**$96**	**$50**
Biosafety Cabinet "A". AC Motor, 10" high window opening	$815	$770	$188
Biosafety Cabinet "B". AC Motor, 8" high window opening	$765	$716	$177
Biosafety Cabinet "C". AC Motor 10" high window opening	$640	$597	$146

Table 8 Annual operational costs of BSCs in LSI and parts of CCGC with nominal width of six feet with energy costs of $0.085/kWh and cooling costs of $7.58/MMBTU

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1387, BLDC Motor, 10" high window opening	**$387**	**$177**	**$91**
Thermo Scientific Model 1460, BLDC Motor , 10" high window opening	**$239**	**$105**	**$60**
Biosafety Cabinet "D". AC Motor, 8" high window opening	$1,070	$1,020	$245
Biosafety Cabinet "E". AC Motor, 10" high window opening	$928	$871	$213

Table 9 Annual operational costs of BSCs in CCGC with nominal width of four feet with energy costs of $0.071/kWh and cooling costs of $7.58/MMBTU

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1440, BLDC Motor, 10" high window opening	**$176**	**$84**	**$44**
Biosafety Cabinet "A". AC Motor, 10" high window opening	$712	$672	$165
Biosafety Cabinet "B". AC Motor, 8" high window opening	$668	$625	$155
Biosafety Cabinet "C". AC Motor, 10" high window opening	$559	$521	$128

Table 10 Annual operational costs of BSCs in CCGC with nominal width of six feet with energy costs of $0.071/kWh and cooling costs of $7.58/MMBTU

	First Type Use- 24 hrs day, 7 days wk, 52 weeks per year	Second Type Use- 8 hrs day, 5 days wk, 50 wks yr & reduced flow or blower only on all other times	Third Type Use- 8 hrs day, 5 days wk, 50 wks per yr & off all other times
Thermo Scientific Model 1387, BLDC Motor, 10" high window opening	**$338**	**$155**	**$79**
Thermo Scientific Model 1460, BLDC Motor, 10" high window opening	**$209**	**$92**	**$52**
Biosafety Cabinet "D". AC Motor, 8" high window opening	$931	$888	$214
Biosafety Cabinet "E". AC Motor, 10" high window opening	$811	$761	$186

$0.085/kWh and cooling costs of $17.63/MMBTU. Tables 7 and 8 show the combined energy and cooling costs for the LSI building and parts of the CCGC building with energy costs of $0.085/kWh and cooling costs of $7.58/MMBTU. Tables 9 and 10 present the combined energy and cooling costs for the other parts of the CCGC with energy costs of $0.071/kWh and cooling costs of $7.58/MMBTU.

These results are remarkable in their own right, with BLDC motorized units using approximately a quarter of the wattage of a comparable AC motorized unit. However, one must take into account that the BLDC motor units were relatively new and the AC motor units were not comparatively new. There is good evidence from the BLDC motor manufacturers and laboratory trials from other laminar flow device manufacturers that the energy efficiency gain of BLDC over AC trails off from 75% down closer to 30% as the filters load, and the motors must overcome higher static pressures in order to maintain the required airflow within the units. But in BSCs, such loading on the University of Michigan campus can take up to 8 years. This means the use of BLDC motorized BSCs gives many years of energy advantage above 50%, with the worst-case savings in the 30% range.

Performance results in these ranges beg the obvious question of break-even or return-on-investment as offsetting considerations for the cost of new units. There is good evidence to support the reconsideration of the University's planned antiquation and replacement strategy for BSCs over the next 5–10 years, with BLDC motorized BSCs playing an important role in reducing the overall energy profile of major research facilities.

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