The Advantages of Using an Electronically Commutated Motor (ECM) in Biosafety Cabinets

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Introduction

The modern Class II Biosafety Cabinet (BSC) was developed in the early 1960's as a result of the increased availability of High Efficiency Particulate Air (HEPA) filter technology. At the time, the motor of choice to drive the cabinet's blower was the Permanent Split Capacitor (PSC) type. The PSC motor, which is an alternating current (AC) motor, offered manufacturers an inexpensive power source whose speed could be electronically controlled to allow for airflow adjustment as the HEPA filter(s) loaded.

The PSC motor is known as an induction type. In the motor, stationary windings (known as a stator) surround the rotating part (rotor) composed of iron or steel. As current passes through the stator, it induces a magnetic field in the rotor, causing it to rotate towards the shifting field in the stator. Because a magnetic field must be induced in the rotor, the PSC motor is asynchronous, with the rotor constantly lagging behind the fields being created in the stator. As a result of this asynchronous operation, and the induction of a constantly changing magnetic field in the rotor, the PSC motor is inefficient, and generates high amounts of waste heat. Attempting to control the blower speed by reducing its voltage only increases the inefficiency of the PSC motor.

Direct current (DC) motors are more efficient than their AC counterparts. In a typical DC motor, the stator in an AC motor is replaced with permanent magnets. The rotor then has a series of windings around it. When current is applied to the motor, a magnetic field is created in some of the windings of the rotor, causing it to rotate toward the magnetic field created by the permanent magnets. Brushes in contact with a commutator allow the current, and thus the magnetic field in the rotor, to progressively shift from winding to winding, forcing the rotor to keep rotating.

The greatest drawbacks of brushed DC motors are the brushes and commutator, which wear each other down, eventually causing motor failure. With the development of greater microprocessor power in the 1970s and 80s, the stage was set for an even more efficient type of DC motor — the Electronically Commutated Motor (ECM), Figure 1.

Figure 1

Electronically Commutated Motor (ECM)

In the ECM, the magnets and windings switch positions – the permanent magnet is on the rotor, and the series of windings are placed around the rotor. The microprocessor precisely controls the magnetic fields in the stator, so it is always synchronous with the rotor. As a result, the ECM runs 50% more efficiently and much cooler than a comparable PSC motor, Table 1. Because of the simple, robust construction of the ECM, it offers far greater reliability and operational service life than the PSC motor.

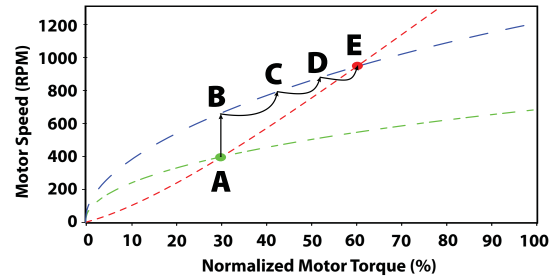
Specification	ECM-Powered BSC	PSC-Powered BSC
Power during operation	290 Watts	582 Watts
Heat Load	990 BTU/hr	1986 BTU/hr
Average Motor Life	>50,000 hours	10-15,000 hours

Table 1. A comparison of 4-foot BSCs

Controlling the motor's operation with a microprocessor offers significant advantages. The ECM can measure and regulate its speed and power output (torque) without the use of external sensors or controllers — something a PSC motor could never do. The motor can also communicate its status to the equipment it is powering, offering instant feedback of the unit's performance. The ECM's microprocessor and memory allow the BSC manufacturer to develop and encode any number of programs controlling motor speed, power and even direction of rotation. The ultimate expression of the power of the ECM was the development of software and firmware by ECM manufacturer Regal-Beloit™, which allows the motor/blower to deliver a constant volume of air as the HEPA filters load, and their pressure drop increases.

Labconco Corporation's Purifier® Logic™ Biosafety Cabinet utilizes an ECM motor with a patent-pending process of delivering constant airflow.

Constant Airflow - How does the motor know what to do?



Purifier Logic Biosafety Cabinet Contant Air Volume Curve

New HEPA Filter Curve (Torque & RPM needed as flow rate varies)

Loaded HEPA Filter Curve

How the ECM motor maintains constant airflow: The Constant Airflow Profile (red) line indicates the motor torque and speed required to maintain a constant volume as needed by the cabinet. This line is programmed into the motor as a series of constants generated during the characterization process. The green line represents the starting filter pressure in the BSC. As the HEPA filters load, the new pressure will be represented as the blue line.

The BSC operates stably at point "A," until the filters load. As loading occurs, the blower speeds up to point "B," as a result of increased pressure and reduced airflow. This increase in speed (referred to by some as "self-compensation") happens with any type of motor, and is similar to a car's tires losing traction on ice and spinning.

Unlike the PSC motor, that would remain at point "B," the ECM checks its speed and torque. Because point B is not on the Constant Airflow Profile line, the ECM increases its speed and torque to points "C," "D," and finally "E" until its speed and torque fall back onto the red line.

Teaching a Motor to Deliver Constant Volume

The process of "teaching" a BSC motor/blower to deliver constant airflow volume is a patent-pending process developed by Labconco. The process consists of **Characterization, Verification** and **Programming**.

Air Volume vs. Filter Pressure for the Purifier® Logic™ Biosafety Cabinet ECM Constant Airflow Program and a Conventional PSC-Powered BSC

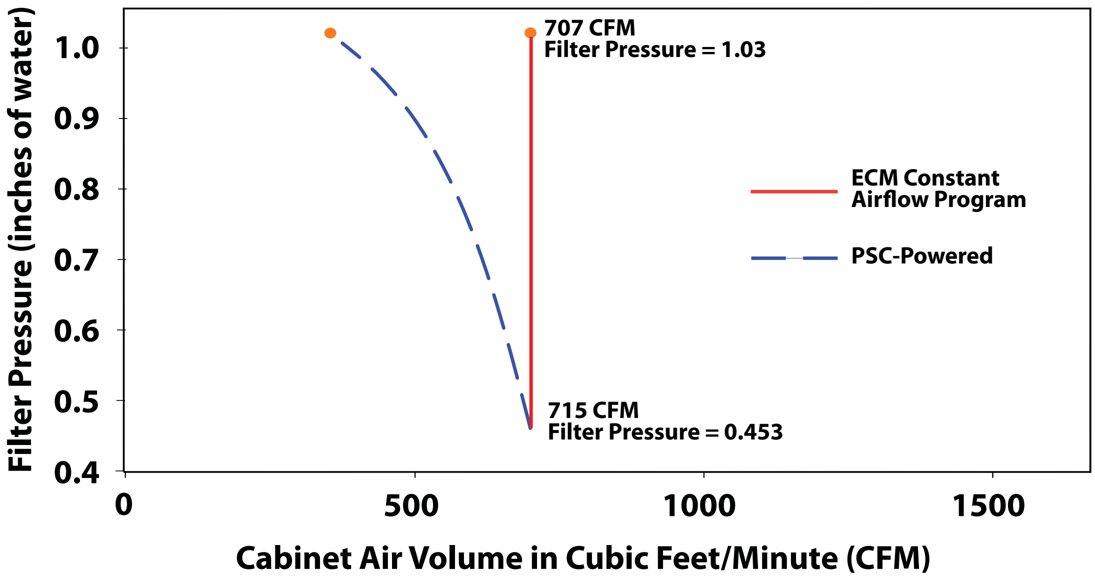


Figure 2

Characterization

The BSC Characterization process is proprietary, exclusively developed by Labconco and is unique for each size cabinet. In order to program the motor to deliver a constant air volume, its performance (speed and torque requirements) is recorded at a variety of airflows and with different HEPA filters in a sample BSC. The speed, torque and airflow data are processed by Regal-Beloit™ software, generating unique motor blower constants.

Verification

The accuracy of the motor blower constants are then verified by programming a motor in a production model BSC. The BSC's inflow and downflows are adjusted to nominal values, and then the HEPA filters are replaced with control filters specifically manufactured to have a higher pressure drop, in order to simulate filter loading. Without readjusting the blower speed control, the inflow and downflows are measured again, and the subsequent drop in airflow volume is calculated. With the improved accuracy of Labconco's proprietary Characterization process, the BSC will typically only lose 1-2% of the volume of air it displaces when the pressure drop across the HEPA filters is doubled, as shown in Figure 2.

Programming

Once the accuracy of the motor blower curves for each size BSC is established, the proper model software is programmed into every motor that will be used in that particular BSC. Because the program's constants vary with each size of BSC, each motor is checked during assembly and motor blower performance is verified at final testing to ensure the proper software is loaded.

Conclusions

The ECM motor offers numerous advantages over earlier PSC technology. Its inherent efficiency offers an energy savings of 50% or more, while its rugged design provides an operational lifespan approximately 3 times longer than the PSC. The cooler operation of the ECM minimizes the rise in air temperature in the working environment of the BSC, promoting user comfort. Microprocessor sensing and control of motor speed and torque allow for the programming of the motor to deliver constant air volume to the BSC even as HEPA filter loading changes.

References

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