AirVolution^D

Development and Advantages of the AirVolution-D HVLS Fan

The first HVLS fan driven by a transverse flux, brushless DC, direct drive motor.

MacroAir
engineers of air™

INTRODUCTION

Since its inception, the high volume low speed (HVLS) fan has been driven by an AC induction motor. A gearbox is required to achieve the high torque and low speed needed to drive an HVLS fan. Furthermore, a variable frequency drive (VFD) is required to control the fan. These systems can be electrically inefficient, bulky, heavy, hot, loud and have a short lifespan. MacroAir, with its partners, has adapted a transverse flux, brushless, sensor-less direct drive DC motor to run a 24 ft HVLS fan. This motor system, also known as the D-Drive, eliminates most of these problems. This paper will explore the development of this fan and the advantages associated with it.

Traditional Brushless DC Motors and Transverse Flux DC Motors

It has long been understood that a brushless DC, direct drive motor could solve many of the problems listed above, but it has problems of its own. A brushless DC motor is created by putting strong permanent magnets on the rotor part of the motor and electromagnet windings on the stator part of the motor. If more torque is needed more poles can be added to the configuration. Figure 1 shows the stator section of a traditional DC motor that has 18 poles.

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Figure 1, Winding for a traditional DC brushless motor

As can be seen in the image, adding more poles can quickly increase the size of the motor. It also increases the amount of copper needed create the numerous windings. The number of poles required to produce the high torque at low speeds, which are needed for a full size 24 foot HVLS fan, made the use of a traditional brushless DC motor prohibitively large and expensive. Smaller HVLS fans have been developed using these traditional motors but they have not been developed for fans larger than 20 feet in diameter.

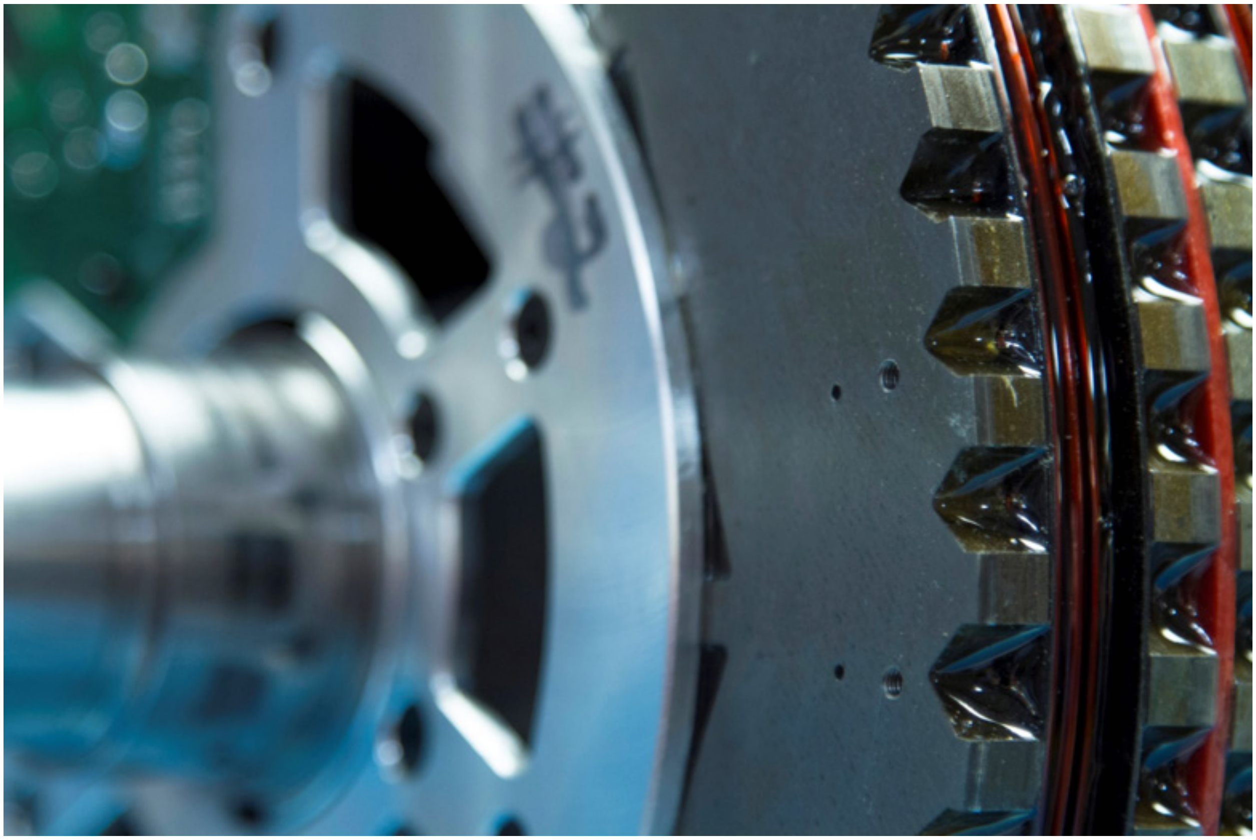

Figure 2, Stator of a 3-phase transverse flux DC brushless motor

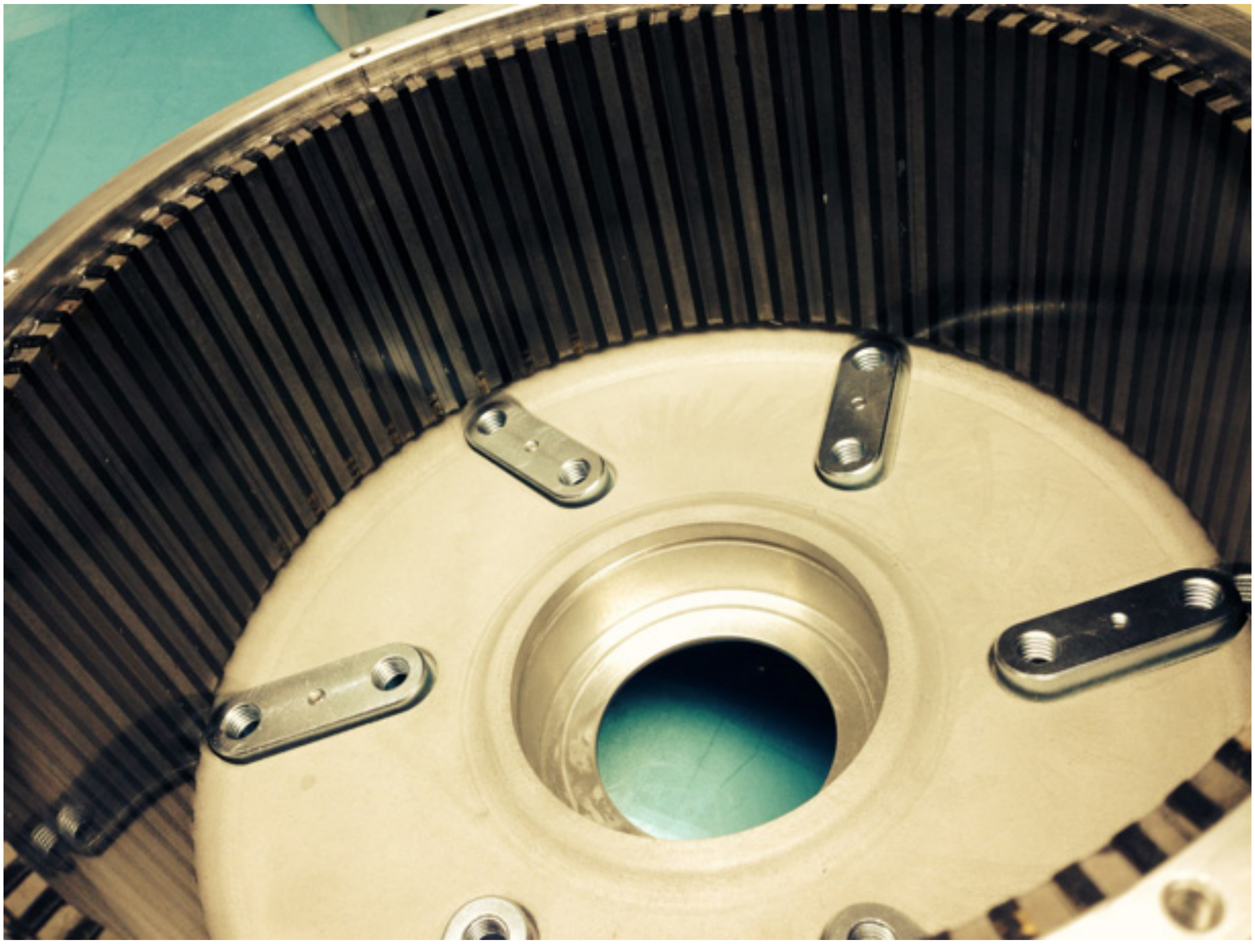

Figure 3, Rotor section of a 3-phase transverse flux DC brushless motor

Creating the multiple polls that are required for a large HVLS fan does not increase the need for copper wiring and only slightly increases the size of the motor. Figure 4 shows a comparison between transverse flux motor and a classic DC brushless motor.

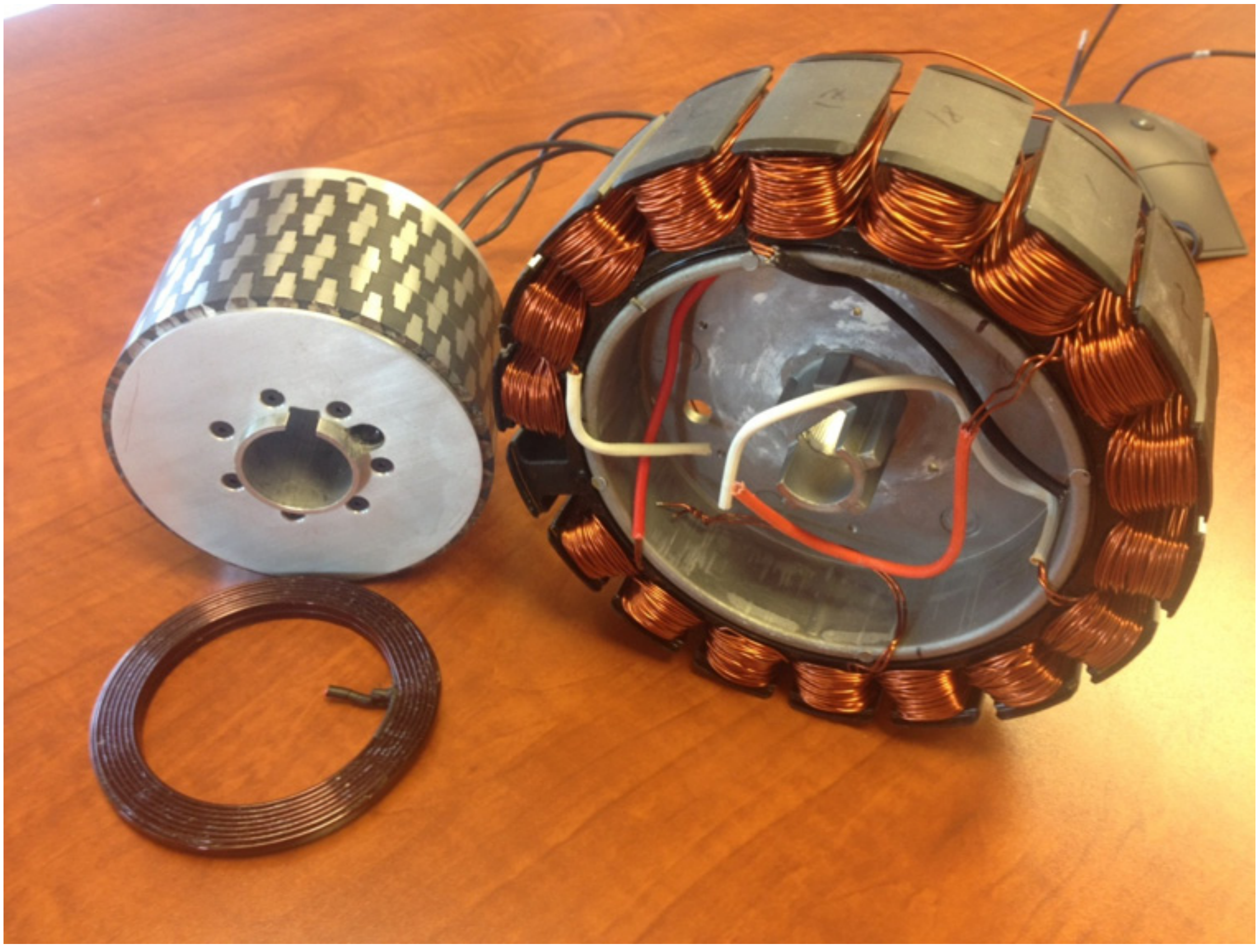

Figure 4, Comparison between motor types. Copper winding for a single phase of the transverse flux motor is in the foreground. A complete 3-phase transverse flux motor is on the left. The stator section of a traditional brushless DC motor is on the right.

While both motors provide the same peak torque, the transverse flux motor provides three times the continuous torque at only half the size. Additionally, since there is less copper wiring the electrical losses due to resistance are greatly reduced, making the transverse flux motor more efficient. Using transverse flux brushless DC motors over traditional brushless DC motors results in considerable savings of size, weight, raw materials and electrical usage.

Driving a Brushless DC Motor

The theory behind brushless DC motors (both traditional and transverse flux) has been around for a long time. However, modern electronics and computational power have been needed to produce a viable method for running these motors. Both types have traditionally used position sensors such as hall sensors or an encoder. This sent the position of the motor to the drive so that it can precisely control the motor. These sensors are often a fail point. They don't have as long life as the rest of the motor components and if one goes out, the motor would need to be repaired or replaced.

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MacroAir's developmental partners have been able to eliminate the need for hall sensors. Through a proprietary algorithm they have been able to extract position informant from the motor itself, bypassing the need for sensors. Therefore, the motors used for the larger AirVolution-D fans are not only brushless and transverse flux, they are sensor-less as well. This provides a longer life and the ability to run in harsher environments. That is why MacroAir can offer a warranty of 50,000 hours, which translates to more than 5 years of continuous run time and over 24 years at 40 hours per week.

In order for the fan to be controlled correctly without brushes and without sensors, a custom drive was developed. Figure 5 shows the circuit board for the drive.

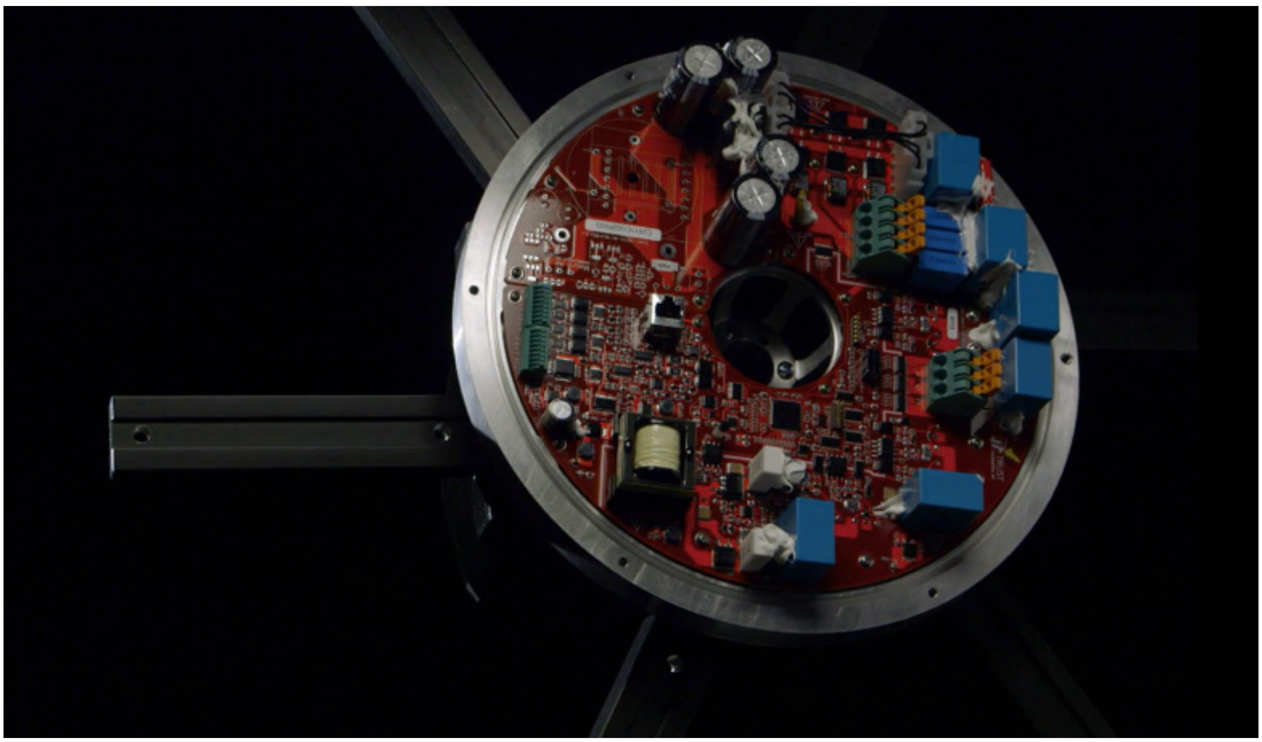

Figure 5, Image of the drive for the AirVolution-D, it controls the transverse flux brushless sensor-less DC motor.

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While it takes a lot of work to develop a custom drive, there are many advantages as well. The first advantage can be readily seen from the figure is that it can be produced in the same footprint of the motor and incorporated in the motor housing. HVLS fans that are run with VFDs require an additional place to mount the drive for a bulky housing next to the motor.

As we were developing the custom drive we took advantage of the added computational power to include some helpful features. One of the most advantageous of these features is the ability to accept a wide range of voltages. The 780 and 550 models are offered with either low or high voltage module. The voltages that they accept are found in Table 1.

Module	*Phase*	*Nominal Voltage Range (VAC)*	*Allowable Variation from Nominal*	*AC Frequency (Hz)*
High	*1 or 3*	*380-600*	*+/-10%,*	*50/60*
Low	*1 or 3*	*110 (550 only), 208-277*	*+/-10%,*	*50/60*

Table 1, High and low input voltage range for the AirVolution-D 780 and 550 models

This wide range allows for easy installation of the fans throughout the world, especially in America, Canada, Europe and Asia. It can also be tied into special lighting circuits that run at 277 VAC. It also allows MacroAir and our distributors to keep a small inventory of motor systems that can be used across a wide range of voltages. Therefore, customers will soon be able to receive the AirVolution-D much more quickly because the stocking of fans has become a cost effective and viable option.

Two safety features were added as well. A level sensor so that if the fan moves past a certain angle the fan will slow down and stop. This situation can occur if it is hit with an object or experiences serious cross winds. Secondly, the drive monitors the speed of the motor and checks it against an acceptable torque range. If it is outside that range, the fan will slow down and stop so the problem can be fixed. This can happen if a blade becomes damaged or is broken off. It can also happen if the wrong size blades are placed on the fan. These added intelligent features to the custom drive allow the already safe fan to be even safer, while allowing for easy installation of the fan across various input voltages.

Cooling the Drive

An issue that did arise as MacroAir was developing our custom drive, was that in some scenarios the drive would overheat. We came up with an innovative new way to overcome this problem. First, an aluminum heat sink was designed that attaches directly to the board. We then used the movement of the fan blades to our advantage. By replacing the solid end caps with hollow ones and minimizing the gap between the heat sink and the spinning blade we created air flow that is generated by the centripetal motion of the air within the hollow blade. As can be seen in Figure 6, air is sucked from the bottom center of the fan housing, across the heat sink and then out through the spinning blades.

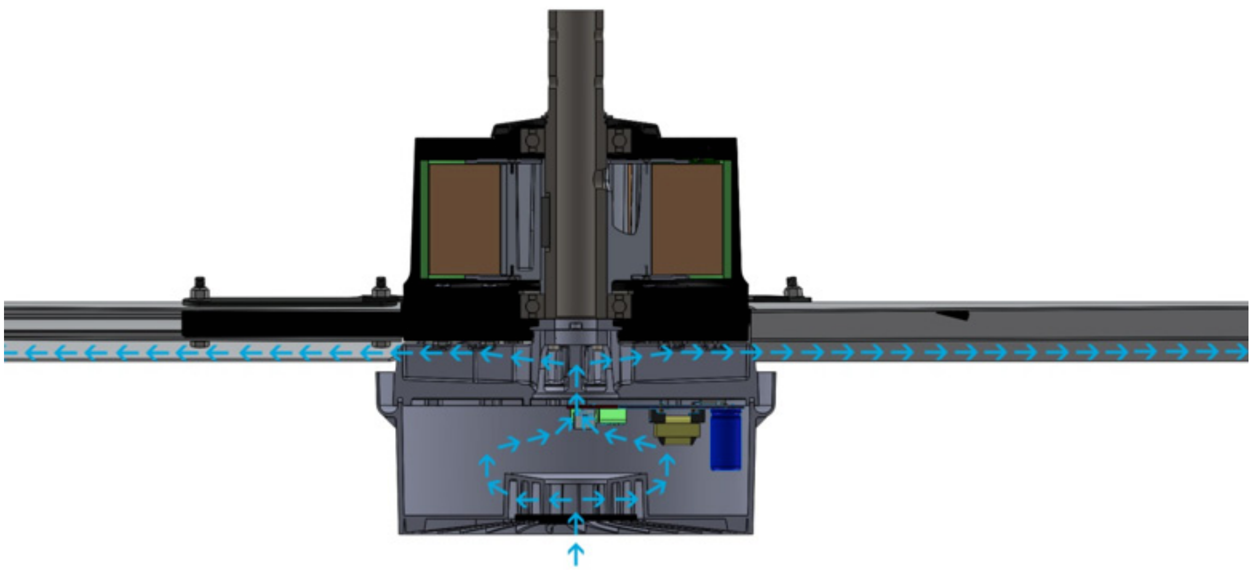

Figure 6, Drawing of the air flow across the heat sink and through the blade.

No additional active air movement is required. This system works so well that we are able to offer the fan rated up to 140°F (60°C). This is 18°F (10°C) higher than any other HVLS fan and allows it to go into the hottest climates, even high up in hot rafters.

Fan Performance

The AirVolution-D 780 model uses our largest transverse flux motor. It has a capacity to turn with 170 Nm (125.4 ftlb) of continuous torque. It is difficult to make a direct comparison to power ratings of AC induction motors because they are quite a bit different in configuration and movement principles. The 170 Nm motor has approximately 5% greater capacity than a standard 2 HP AC induction motor.

Tests were run to see how well the 24 foot AirVolution-D performs alongside our own 24 foot AirSpan fan and a 24 foot fan of one of our leading competitors. Figure 7 shows the comparison of the air flow in cubic feet per minute (CFM) from each fan calculated from the AMCA 230-99 version of the equation.

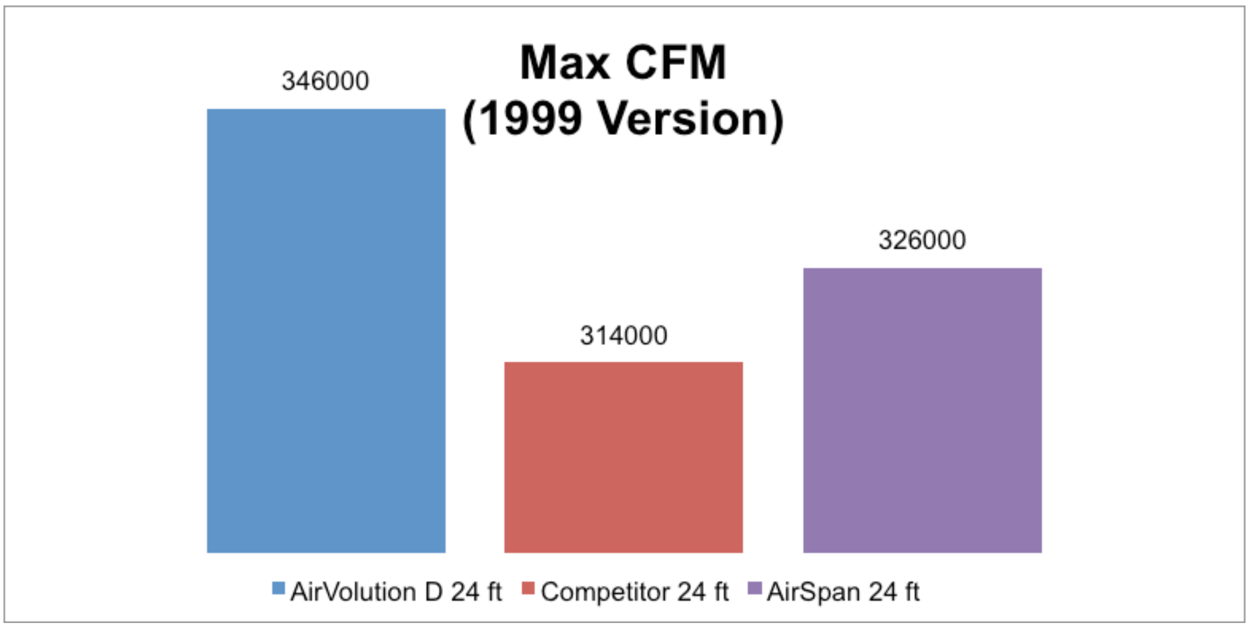

Figure 7, Comparison of CFM between AirVolution-D, AirSpan and Competitor's 24 foot fans.

The figure shows the improved performance the new AirVolution-D has, and not just over the competition but over our own fan as well. The AirVolution-D has 6% more airflow than the AirSpan and 10% more than the competitor's. We also compared the electro-mechanical efficiency of these three fans. This measures how well the drive and motor system transfer the electrical energy to mechanical energy. We found this by calculating the mechanical power produced by the motor shaft which is the rotational speed multiplied by the torque. After converting this value to Watts it is divided by the amount of power in Watts that is delivered by the motor.

Figure 8 below shows the efficiency results when the fans are run at various percentages of full speed.

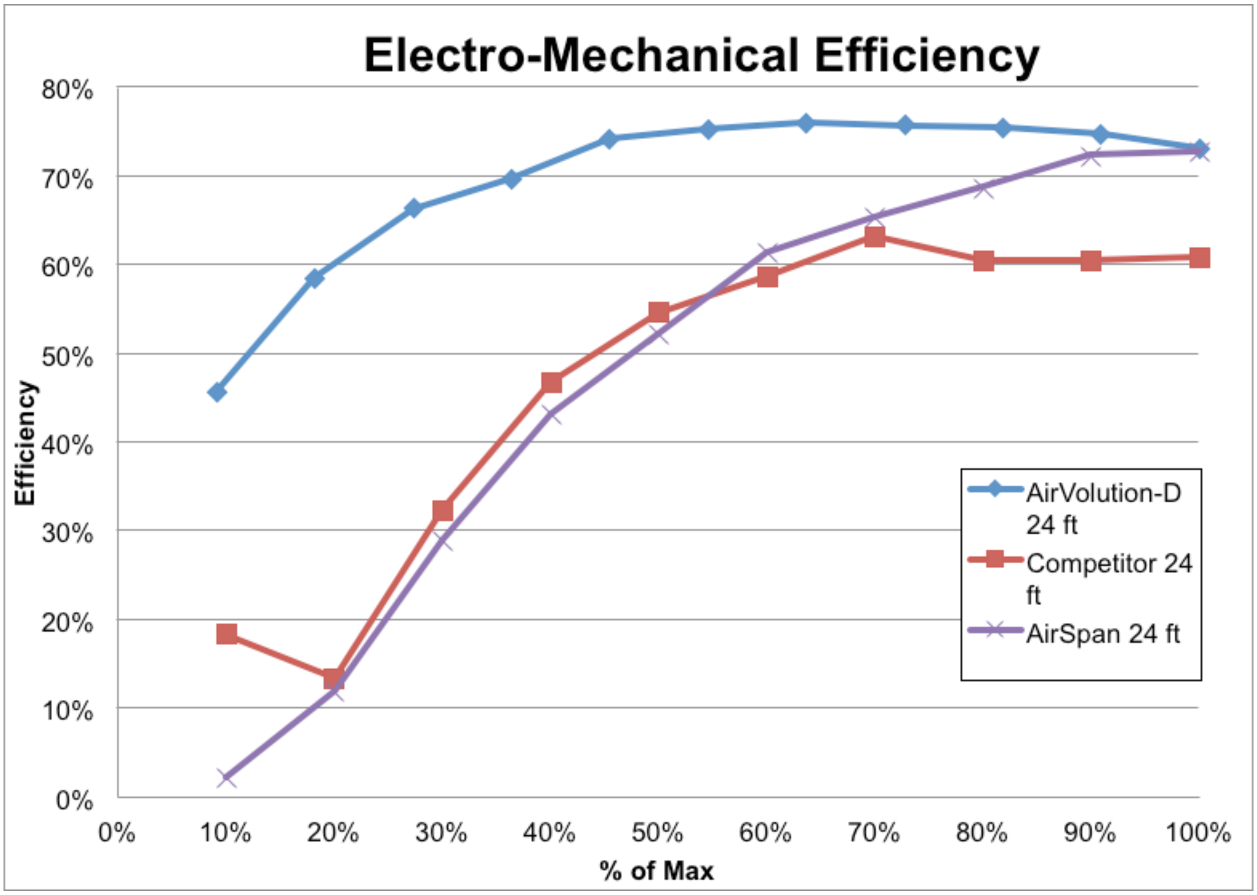

Figure 8, Efficiency comparison of three 24 ft fans.

As can be seen from the chart, the AirSpan and competitor's fans perform quite well and can compete with the AirVolution-D at and near max speed. This is because the gearboxes and VFDs are sized and tuned to perform nicely at these speeds. But as the speed turns down we can see the added value and efficiency of the direct drive motor. In fact, the AirVolution-D sees its best efficiency between 60% and 70%. Since fans are more often run at two thirds of full power; this means that the AirVolution-D is most often run at max efficiency when the other fans are not.

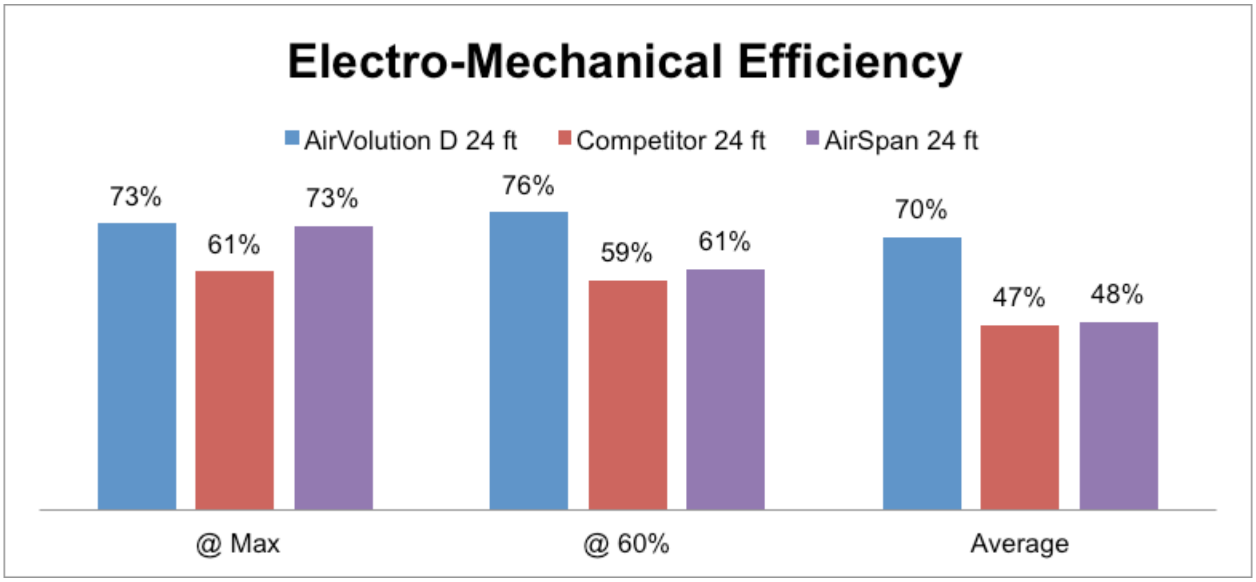

Figure 9, Electro-Mechanical Efficiency at max rate, 60% and an average

Figure 9 is another way of looking at the data. It compares the efficiency at max rate, 60% and then an average of all the tested speeds. This clearly shows the advantage the new D-Drive gives, especially at slower speeds.

Not only does the AirVolution-D perform better than the other 24 foot fans on the market but it comes in a smaller package. Figures 10 and 11 show the weights and heights of each of the fans.

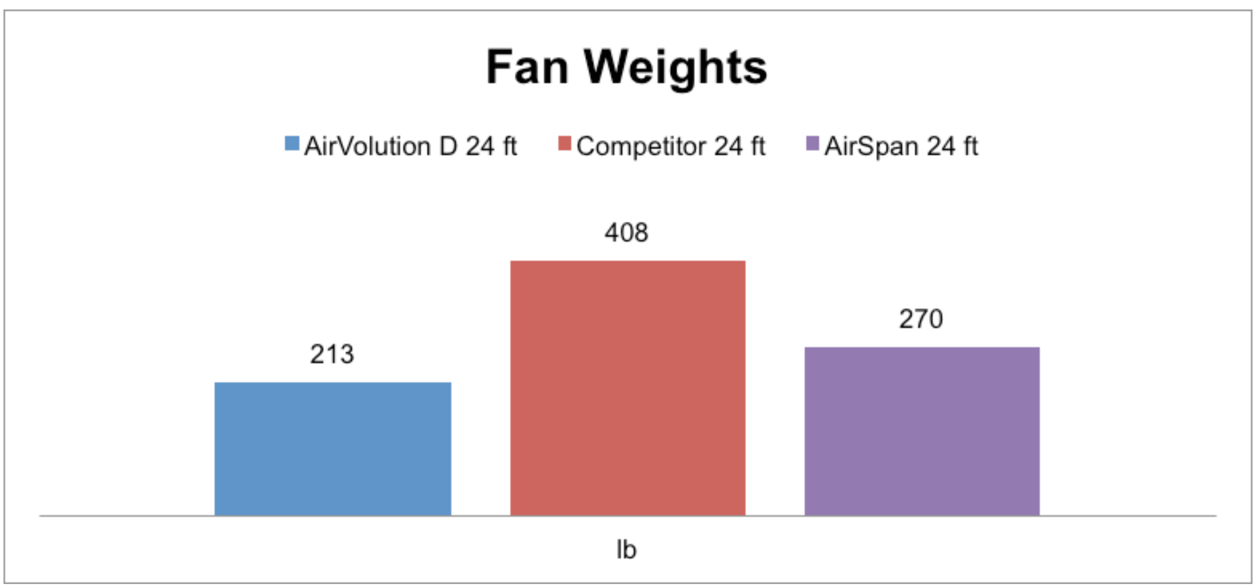

Figure 10, Comparison of fan weights.

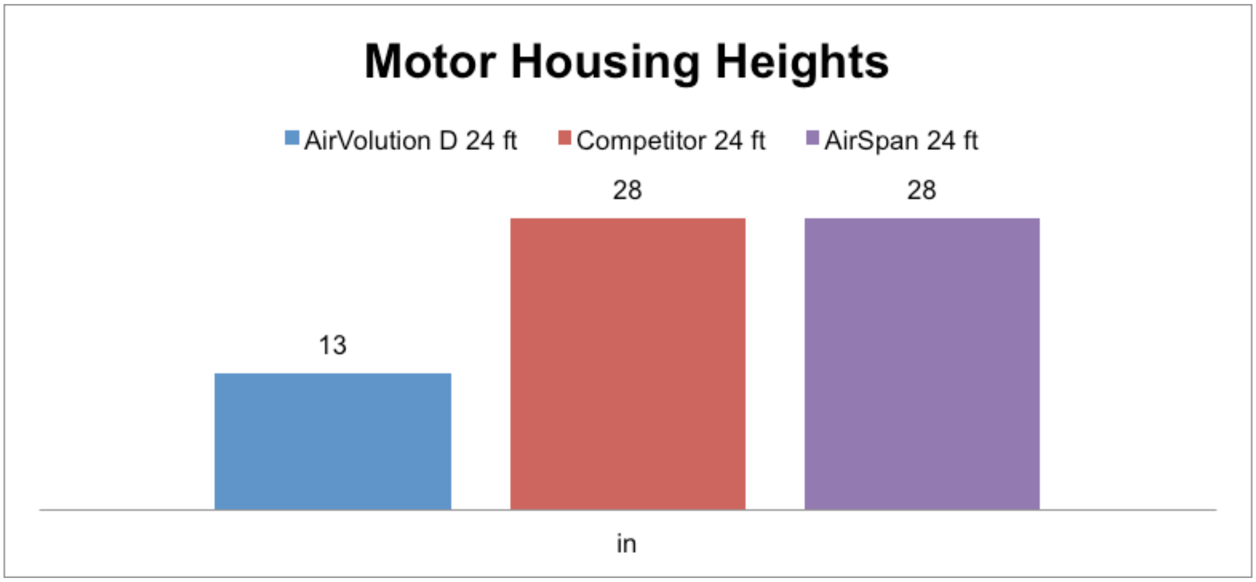

Figure 11, Comparison of fan heights

The AirVolution-D is much smaller and lighter than AC induction fan systems. AirVolution-D weighs 47% less than the competitor and 21% less than the AirSpan and is 53% shorter than both of them.

Conclusion

The adaptation of the transverse flux brushless DC direct drive motor for HVLS fans represents a breakthrough in large ceiling fan technology. In doing so, a jump was made not only from AC induction motors with a gearbox and VFD to a brushless DC direct drive motor, but to a sensor-less brushless transverse flux direct drive DC motor. This has allowed for a fan with a greater lifespan, wider range of input voltage, additional safety features and the ability to run at higher temperatures. When the AirVolution-D is compared with other 24 foot fans on the market it shows improvements and advantages in numerous measurable areas, (summarized in Table 2).

Table 2, Comparison summary of 24 ft fan performance

		AirVolution-D 24 ft	Competitor 24 ft	AirSpan 24 ft
Air Flow (CFM 1999)	Value	346000	314000	326000
	% Improvement	NA	10%	6%
Electro-Mechanical Efficiency @ 60%	Value	76%	59%	61%
	% Improvement	NA	30%	24%
Weight (lb)	Value	213	408	270
	% Lighter	NA	48%	21%
Height (in)	Value	13	28	28
	% Shorter	NA	54%	54%

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