AoFrio

EBOOK

Increasing Efficiency and Profitability in Commercial Refrigeration through Fan Motors

AoFrio Ltd

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About AoFrio Limited:

AoFrio is a leading provider of IoT solutions, cloud-based fleet management platforms, energy-efficient electronic motors and connected refrigeration control solutions. It serves some of the world's leading food and beverage brands and refrigerator manufacturers and offers proximity-based marketing for Smart Cities to the Australian market. AoFrio's services and products improve sales, decrease costs and reduce energy consumption. Headquartered in Auckland with a global reach, AoFrio is listed on the New Zealand stock exchange under the ticker symbol NZ: AOF

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AoFrio

Introduction

Who we are

AoFrio Limited is a commercial refrigeration specialist and one of the world's leading suppliers of energy efficient electronic motors, refrigeration control solutions, and cloud based IoT fleet management platforms.

We help our refrigeration customers with quieter, more efficient equipment that is less expensive to produce, requires less maintenance and reduces downtime.

Proven global industry leadership

3 million

AoFrio's three million Wellington™ ECR 2 motors have saved an estimated 2.2TWh of energy, while protecting food quality and improving the lifespan of equipment.

1.5 million

With over one and a half million AoFrio™ SCS controllers sold, AoFrio is improving visibility, reliability, and serviceability of refrigeration and frozen fleets.

25

AoFrio's IoT platform is currently deployed across 25 countries and growing.

99.97%

ECR 2 motors specifically designed to last 10 years in tough environments have a proven 99.97% reliability.

Trusted partner of customers around the world

AoFrio's strategy is to make a small number of important customers very happy. We're not the largest motor company in the world. We don't claim to offer everything to everyone. We're experts on refrigeration fans and related applications.

We partner with our customers to deliver uniquely specialized solutions through highly personalized service that directly focuses on saving our partners time, money, and differentiating them in a crowded market.

As industry specialists we understand the importance of a strong global supply chain, and know how critical on time delivery is to your production line. During the COVID-19 global crisis, we are immensely proud of our supplier relationships that allowed us to continue un-interrupted deliveries.

We realize the challenges of building products in a manufacturing environment. That's why all our products are designed to be flexible, easily installed and commissioned, and minimize the required SKUs in inventory.

Quality isn't just something we give lip service to either. Our Global Quality Leader has a direct line to our CEO, ensuring transparency and visibility of our quality programs at the highest levels. Any field failures are investigated by our internal engineering teams, and comprehensive reports are provided to our customers that include corrective actions implemented.

How many other partners provide that level of transparency to you?

Corporate Social Responsibility is as important to us as it is to you too. That's why we are proud to have earned a Silver EcoVadis medal that rank us in at least the top 19% of all companies in the global industrial sector since 2019.

How we help our customers

AoFrio's Wellington ECR motors drive efficiency, reliability, and SKU reduction

ECR 2 electronic motor platform is a breakthrough product for EC motors of its power rating. It uses advanced three-phase control to deliver extremely low levels of noise and vibration while also providing exceptional energy efficiency.

ECR 2 motors have an efficiency of up to 70% and enjoy a power factor of up to 0.95. Most traditional motors are only 18-22% efficient and often have a power factor of less than 0.5. This means ECR 2 motors are over 300% more energy efficient, while also producing less vibration and about 5 dBA less noise.

As a universal voltage motor, the same SKU is used regardless of whether the product is 120V or 230V. Advanced software algorithms mean ECR 2 motors enable SKU reduction and increased operational flexibility because one motor can be programmed to cover a wide range of loads and input voltages in production or the field. Some of our partners have seen SKU reductions greater than 57:1 that drove inventory reductions of at least 23-31%, saving millions of dollars.

The ECR 2 is IP67 rated, which means it's extremely water and dust resistant – a critical requirement in a refrigeration environment. When the benefits of reduced heat load in the cold space are considered, these motors reduce the power consumption of self-contained refrigeration systems by as much as 30%.

Software enhances many aspects of ECR2's performance. While most motors stop during overload conditions, ECR 2 motors automatically reduce speed and continue to operate for as long as possible so that the refrigeration system can continue to maintain food quality.

AoFrio's Wellington™ ECF 2 Fanpack integrates with the ECR 2 motor into a purposedesigned fan and housing assembly that produces both optimum airflow and efficiency. This dramatically reduces an OEMs cost of final assembly, and minimizes the space required for the fan assembly.

AoFrio™ IoT brings the future to your business

A comprehensive ecosystem of hardware, wireless and digital solutions for coolers, freezers and ambient displays, the AoFrio IoT ecosystem offers equipment control, fleet-wide asset management, POS and maintenance insights, as well as proximity-based marketing direct to the consumer's mobile device.

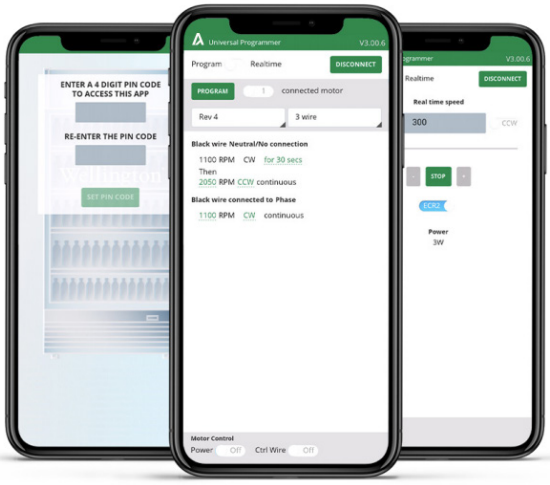
SCS controllers enable intelligent control and fleet-wide asset management

As the world's most widely adopted intelligent controller for bottle coolers, the SCS is the controller of choice for any size or type of cooler or freezer. More than simply providing system control, AoFrio™ SCS automatically minimizes energy consumption while protecting
product quality.

It also delivers powerful cooler and fleet management capabilities, including asset tracking, sales statistics, HACCP data logging, smart maintenance indicators, and diagnostics data without requiring a cellular or Wi-Fi connection.

Private labelled insights delight your customers

In this competitive market, we know that some customers must leverage unique ways to add value and differentiate themselves. AoFrio's IoT is a software tool for your service force and customers that may be completely customized to your products', specific needs and private labelled exclusively for your use. The result is a unique system that delights your customers with on-demand operational and point of sale (POS) insights, AI-based predictive maintenance alerts, easy service team engagement, HACCP data logging, system control, and more. Most importantly, it provides a direct gateway to monitor your own products during the warranty period and afterward.



Let’s make the world better

From protecting the food supply to ensuring medicines remain safe, refrigeration systems are critical for modern life as we know it. AoFrio exists to deliver trusted technology for the real world, that solves our customers unique problems. We believe that by collaborating with our customers and placing our technology in every location, we will ensure a sustainable future with safe foods, beverages, and medicines for our families and future generations.
We invite you to learn more about how AoFrio can partner with you.

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Case studies

www.aofrio.com

Helmer Scientific: Protecting the medicines that save lives

Executive summary

Helmer Scientific targeted improvements in performance, noise, and reliability for their next generation medical-grade refrigeration platform. By using ECR 2 motors, noise was reduced up to 4.5 dBA to levels that had customers questioning if the unit was in operation. They also reduced motor energy consumption up to 75%. ECR 2 motors support rigorous accelerated life testing requirements and reliable operation across healthcare applications.

Challenges

As a leader in the development of customized medical grade refrigerators for hospitals, blood centers, laboratories, pharmacies, clinics, health departments, and research facilities, Helmer Scientific's customers need a reliable refrigerator that is quiet enough to use in clinical and healthcare environments, yet meets the rigorous performance requirements of the medical industry. Equipment failure could mean the expiration of expensive vaccines, loss of medical research, or the loss of temperature uniformity that is critical in many of these applications.

Helmer was seeking to advance medical refrigeration by developing products with improved temperature performance, and reduced noise to avoid disturbing patients or staff.

> We are receiving great feedback on the GX Solutions medical-grade refrigerators that use the ECR 2 motor from our healthcare customers! With GX Solutions, Helmer has introduced innovation in performance, noise, and energy efficiency. These units are so quiet compared to traditional cold storage equipment that it can be difficult to tell the unit is operating!
>
> **- Ben Greenfield -**
> **Director of Marketing and Business Development**

The solution

With over 15 years of experience developing motors for the world's most difficult applications, AoFrio's engineers quickly understood the challenge of reducing noise while also maintaining stringent performance requirements. After discussing various options with Helmer, they quickly determined the ECR 2 motor was the best choice for their specific application.

The ECR 2 is an extremely efficient electronically commutated motor (ECM) with operational efficiency up to 70% and a power factor of up to 0.95. This motor is also fully programmable in the factory or field, operating at 300-1800RPM. It accepts input voltages of 70-264V, enabling them to use the same motor with all models around the world, reducing SKUs and improving operational flexibility.

Results and future plans

After installing the **Wellington ECR 2** motor, Helmer's engineers were amazed by the motor's quiet operation. Some engineers estimated it was up to 4.5 dBA quieter than their previous model. They noticed it was so quiet and smooth when operating in their hands, they could barely tell it was on. Helmer also noted that ECR 2 maintains temperature more uniformly, recovers more quickly after door openings, and is up to 75% more energy efficient than conventional motors. Its reliability has also supported Helmer's commitment to lead the industry in reliability and quality.

Helmer sees the ECR 2's quiet operation, low vibration, and extremely high efficiency as a critical part of their products' quality and performance. They are currently including the ECR 2 in new product updates. Since the ECR 2 accepts a universal input voltage, they are able to use the same SKU in all models around the world – saving cost and greatly simplifying their products.

The better bottler: Eliminating failures and boosting sales

Executive summary

A multi-national beverage bottler was experiencing motor failures that reduced their ability to keep beverages cold. After changing to ECR 2, their failure rate decreased by 10x, they saw an ROI in less than one year, and their customers experienced 10-12% lower energy costs.

Challenges

One of the world's largest beverage bottlers was losing sales and customers. Approximately 5% of their refrigerated bottle coolers were offline for part of the year due to failed motors. This easily overlooked component caused average sales to decrease by up to 14% when the cooler was offering warm drinks to unsatisfied consumers.

How could this bottler keep their product cold and their customers happy?

> Our company is focused on delivering cold products to our customers anywhere at any time. The ECR 2 solved a major challenge we were having with lower quality motors that failed frequently, while paying for itself in less than one year. It is now our motor of choice.
>
> **- Program Manager -**

The solution

Given their history of helping the world's largest beverage brands improve reliability, increase energy savings, and boost revenue, AoFrio's team started analyzing the failed motors. They quickly realized that the two largest causes of motor failure were poor power quality and moisture intrusion.

After discussing various options, AoFrio recommended replacing the existing fleet of motors with advanced **Wellington™ ECR 2** motors. Designed for an average lifespan of 10 years at maximum load, these motors accept input power from 70-264V so they are much more tolerant of poor power quality and voltage spikes. They also come standard with IP67 protection from moisture and have the option of a food grade rated housing for added protection.

Up to 70% efficient and with a power factor of up to 0.95, each motor was also fully programable in the field. This allowed the same motor to replace many different SKUs, making the upgrade program faster and easier.

Results and future plans

A few years after the retrofit program, the bottler has seen motor failures decrease by 10x, such that only 0.025% of motors fail in any given year. Since ECR 2 is 10-12% more energy efficient, their customers are also delighted with the lower energy costs. Given the cost of lost sales and motor replacement, the customer estimates their Return on Investment (ROI) to be less than one year. With this great investment payback and happy customers, this multi-national beverage bottler has now standardized on ECR 2 for their fleet of bottle coolers.

Watch our ECR 2 motor demonstration and take the AoFrio challenge

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Use Cases

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Evaporating and condensing units: programmable reliable motors you can count on

Executive summary

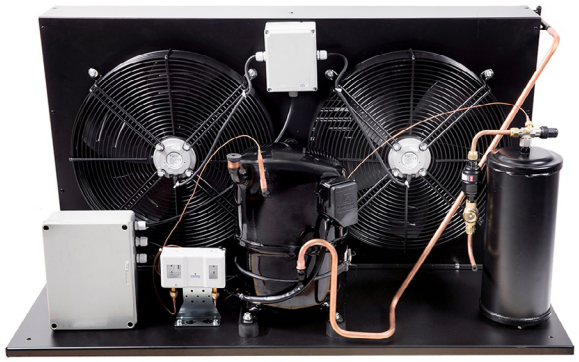
ECR 2 motors are programmable and dual voltage. This flexibility enables their use in virtually any system, substantially reducing your maintained SKUs.
ECR 2's 99.97% reliability and internal system protection capabilities ensure systems remain operational in the most challenging environments.

Challenges

Today's evaporator and condensing unit manufacturers must operate more efficiently to maximize profitability.

Your customers each require different performance specifications from your products, and this often requires you to stock many different motor SKUs for specific RPMs, voltages, and power ratings. Not only is this expensive but it presents multiple points of failure that could bring production to a halt.

How can manufacturers be both efficient and flexible to offer the maximum value for their customers?



Universal ECR 2 minimizes required SKUs and is programmable

The **ECR 2** is an electronically commutated motor (ECM) that accepts input voltage from 70-264V. It can be factory programmed to three discrete speed settings from 300-1800 RPM in either direction, or with timed operations.

This flexibility allows various 5" to 8" fan blades to operate utilizing a single SKU. Further programming, done either in factory production or in the field via a mobile device, enables many different customizable parameters to meet numerous diverse product requirements.

The ECR 2 "universal" motor capabilities greatly reduce the SKUs that manufacturers must stock.

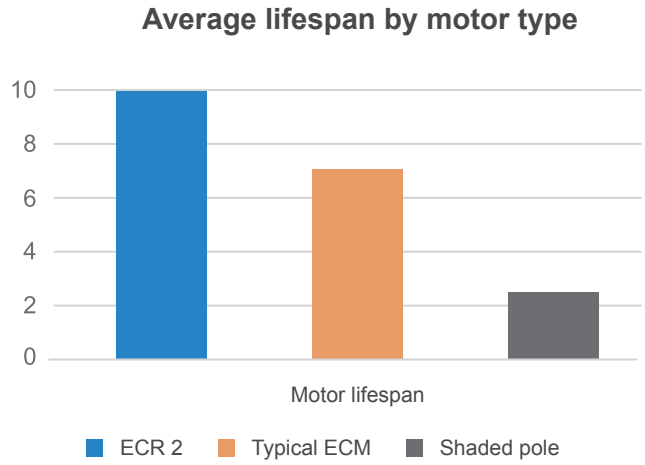
OEMs that switched to ECR 2 have reported SKU reductions of up to 57:1

Universal ECR 2 minimizes required SKUs

The ECR 2 is exceptionally quiet with noise levels of 37dBA which is as quiet as your computer's fan. It is also approved for some ATEX applications and offers a food grade rated housing.

AoFrio knows that your brand's reputation depends on the quality and reliability of the products you use. That's why every ECR 2 built has an average lifespan over 300% longer than typical motors. This saves service calls, customer downtime, and protects your hard-earned reputation.

The ECR 2 also has a unique algorithm that protects the refrigeration system and preserves food quality. While most motors stop during overload conditions, ECR 2 motors continue operation by automatically reducing speed so airflow circulates within the refrigeration system. This reduces the chance of equipment damage, improves temperature control, and protects products in overload conditions.



AoFrio, trusted around the world

With a presence in six continents, AoFrio has developed a reputation for providing real, trusted technology that meets the needs of the most challenging condenser and evaporator applications. We are relentlessly focused around saving OEMs time and money, and are passionate about being the easiest, most flexible company to work with on the planet.

We believe that by sincerely collaborating with our OEM partners and placing our technology in every location, we will ensure a sustainable future with safe foods, beverages, and medicines for our families and future generations. We invite you to learn more about how AoFrio can partner with you and build a better world together.

Specifications	
Input voltage range	70-264V, 50-60Hz (all models)
Output power range	0-13W
Speed range	300-1800 RPM
Max. input power	20.5W
Max. input current	0.10A (@230V), 0.20A (@115V)
Power factor	Up to 0.95 depending on load and voltage
EMC protection	4000V (per EN61000-6-2)
Noise	SWL 37 dBA @ 1300 RPM (per ISO1680)
Insulation class	Class A (105°C)
Thermal protection	Electronic protection. Locked rotor and automatic thermal derating also included
Refrigerant compatibility	HFC, CO2 and hydrocarbon (per IEC 60335-2-89 Annex BB)
ATEX (EX)	IEC 60079-7 Group 2, Category 3G
IP rating	IP67
Operating temp. range	-30°C to +50°C (-22°F to +122°F)
Storage temp. range	-40°C to +80°C (-40°F to +176°F)
Weight	0.54kg (1.2lb)
Approvals	

Lighter weight, outstanding performance: enabling higher volume and lower-cost shipments

Executive summary

ECR 2 motors are packed for shipping up to 33% more densely than their competitors, delivering lower total procurement costs and simplifying logistics in warehouses and production facilities.

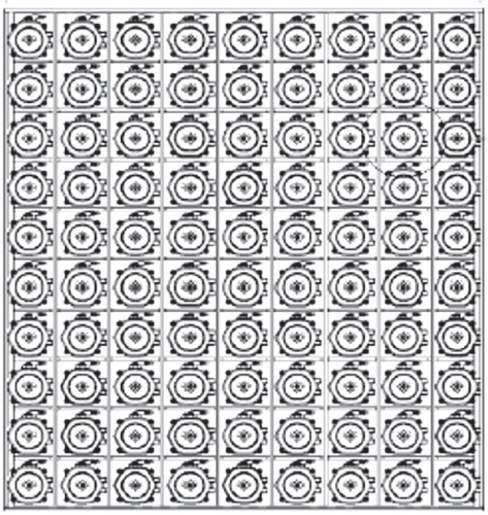
Challenges

Refrigeration OEMs producing a range of products demand a reliable and cost-effective supply chain to boost the productivity of their production environments. Given the unpredictable timing and costs associated with international shipping, it makes sense to work with a partner that understands these challenges and maximizes an OEMs operating efficiency by optimizing product volumes in every shipment.

AoFrio's optimized motor design ensures maximum cost efficiency

As a global leader in motor design with over 30 years of experience, AoFrio's **Wellington ECR 2** motor bodies have been designed using advanced plastic resins that are exceptionally strong and much lighter weight than traditional iron or other metals that other manufacturers use. Without compromising performance, this special construction delivers a host of unique advantages to the ECR 2; including corrosion resistance, a smaller size, and a weight that is up to 40% less than some competitors.

The ECR 2 motor's lower weight and smaller size facilitate higher product density on each pallet.This enables up to 33% more motors to be shipped with each order – often without significantly increasing shipment cost. Since each shipment is palletized, this also means that the motors are also moved more efficiently, often with lower drayage. The net result is that ECR 2's are delivered to our OEM partners reliably, safely, and extremely cost effectively.



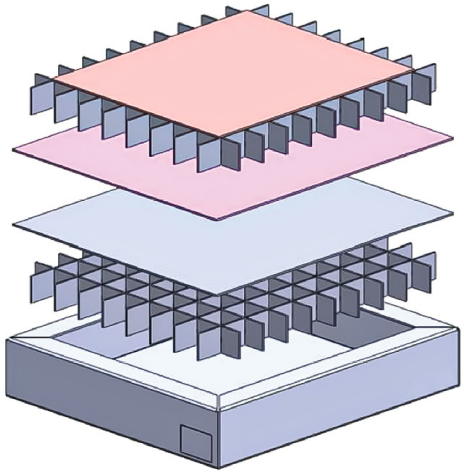
Shipment volume is maximized with 90 motors on each layer and up to 16 layers per carton

The ECR 2 motor is also exceptionally programmable. Each motor arrives preprogrammed to operate at up to three different speeds between 300-1800 RPM, including reversing direction. This enables the same motor to be used for many different SKUs.

Some OEMs have reported SKU reductions of over 57:1 using ECR 2, which drove inventory reductions of 23-31%. Consolidating SKUs also means more of the same ECR 2 motor can be used, resulting in faster inventory turns. Upon request, AoFrio establishes a safety stock of motors, protecting OEMs from potential supply chain disruptions.

The ECR 2 motor is proven to improve working capital, reduce logistical costs, and results in more profitable operations – all without sacrificing performance or supply chain integrity.

Your customers expect the best, and most OEMs can't afford unnecessary logistics costs or supply chain failures. Can you afford not to get the best value for your motors?



Cartons are packaged and protected to ensure motors arrive anywhere in the world without damage

Food grade motor housing: industry leading safety and reliability

Executive summary
ECR 2 motors are available with an IP67 rated food grade housing. This not only protects the motor's normal operation but ensures normal sanitation and cleaning processes that won't cause damage.
Best of all, this protection is often accomplished at a similar cost to a traditional EC motor.

Challenges

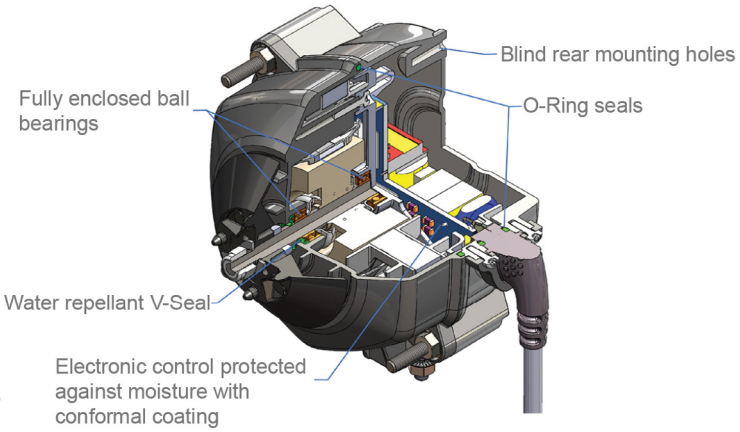
Motors used in foodservice applications, such as coolers, freezers, and food-related equipment, should be protected from their rough operating environments without contaminating any food products. Practically speaking, this means they cannot leach any lubricants or materials that would not be safe for human ingestion, through condensation, for example.

Universal ECR 2 increases versatility in food service applications

AoFrio's **Wellington ECR 2** motors are made with a special corrosion-proof, safe, food-grade plastic, which ensures compliance with NSF requirements.

Unique to the foodservice refrigeration industry, they also come standard with IP67 rated protection. This means each motor has multiple redundant protective features around the shaft, cable connection, and all seams that protect the motors from dust infiltration. The protections are so effective, the motor has even been demonstrated to operate effectively underwater for more than 30 minutes without issue – exceeding IP67 requirements. Best of all, this level of protection is offered at a similar price as a traditional EC motor.

You work hard to build and protect your brand's name and reputation, yet component failures add unnecessary costs and can erode years of work. With customers on six continents and over 30 years of experience behind us, AoFrio is focused on producing the best refrigeration system motors in the world.



Doesn't your brand deserve the best motors for your products?

AoFrio

White Papers

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AoFrio

WHITE PAPER

Cost savings through SKU consolidation

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Reducing product cost with Wellington™ ECR 2 motors

Most manufacturers understand that each product SKU they maintain in their system costs money, since it requires time and labor to stock, track, pay invoices on, provide customer support for, and manage. Wellington ECR 2 motors are completely programmable and enable OEMs to dramatically reduce the number of motor SKUs they need. An AoFrio customer recently reduced the motor SKUs they required for a product line by over 57, replacing it with only one ECR 2 SKU. This reduced their actual inventory by 23-31% and reduced their inventory carrying costs by approximately 30%, saving them hundreds of thousands of dollars, which greatly increased production efficiency, supply chain stability, and profitability.

How Wellington ECR 2 motors reduce SKUs in a production environment

The **Wellington ECR 2** from AoFrio is a high performance, programmable EC motor. Each motor can be set in the factory or field with three discrete speed levels, different directions of rotation, and timed operation upon start. Simply by configuring the black (control) wire connection, the same motor can also be programmed as needed to accommodate small production runs requiring any alternate setting.

Let's look at a simplified, hypothetical example of a manufacturer with products that have the following performance criteria:

Application 1. 50% of products require:

- Condenser runs at 1550 RPM CW
- Evaporator runs at 1550 RPM CCW

Application 2. 40% of products require:

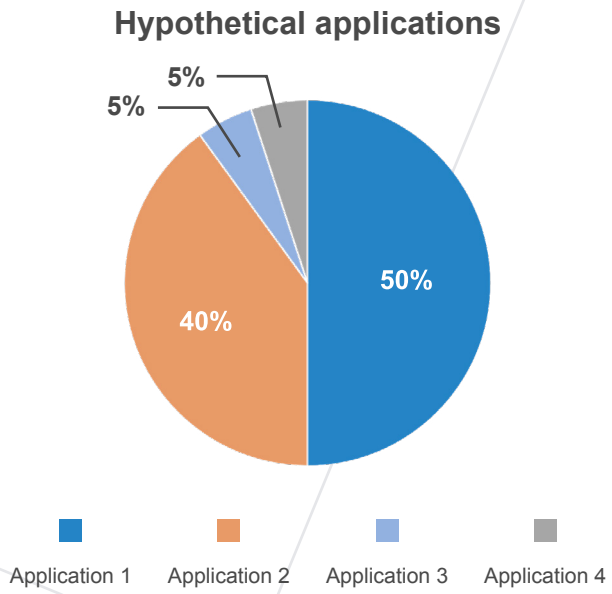
- Condenser runs at 1600 RPM CW
- Evaporator runs at 1550 RPM CCW

Application 3. 5% of products require:

- Condenser runs at 1800 RPM CW
- Evaporator runs at 1800 RPM CCW

Application 4. 5% of products require:

- Condenser runs at 1800 RPM CW
- Evaporator runs at 1450 RPM CCW



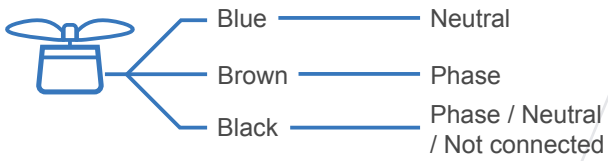
In this example, the manufacturer would normally need to maintain at least six different motor SKUs to meet the needs of these applications. If the applications required different voltages, then it could be 12 or more different SKUs.

However, a single ECR 2 motor accepts universal voltage and can be shipped to their factory, pre-programmed to immediately cover 90% of their needed applications:

- Speed 1. Evaporator runs at 1550 RPM CCW: Blue to Phase, Brown to Neutral, Black (Control) wire not connected
- Speed 2. Condenser runs at 1550 RPM CW: Blue to Phase, Brown to Neutral, Black (Control) wire to Phase
- Speed 3. Condenser runs at 1600 RPM CW: Blue to Phase, Brown to Neutral, Black (Control) wire to Neutral

The same ECR 2 motor can be programmed in the production environment with the following settings to cover the remaining 10% of applications:

- Black wire not connected: Select 1800 RPM CCW continuous
- Black wire connected to Phase: Select 1450 RPM CCW continuous
- Black wire connected to Neutral: Select 1800 RPM CW continuous



Which results in the following wiring:

- Speed 1. Evaporator runs at 1800 RPM CCW: Blue to Phase, Brown to Neutral, Black (Control) wire not connected
- Speed 2. Evaporator runs at 1450 RPM CW: Blue to Phase, Brown to Neutral, Black (Control) wire to Phase
- Speed 3. Condenser runs at 1800 RPM CW: Blue to Phase, Brown to Neutral, Black (Control) wire to Neutral

The ECR 2 is fully programmable via Bluetooth, so a manufacturer can individually configure any quantity of motors for speed, direction, a timeout, and a speed after timeout.

Installation instructions and technology documentation are available upon request.

Reducing product cost with Wellington ECR 2 motors

Anyone with the responsibility for servicing legacy products knows the difficulty of maintaining countless SKUs for products that customers are still using in the market, but which are not currently manufactured. The struggle of deciding which SKUs to make obsolete for financial reasons and which should be kept ready in the warehouse to satisfy potential customer needs is a regular challenge. More difficult still is determining which parts should be stocked in the limited space of a service truck so that a customer's system can be returned to operation on the first service call.

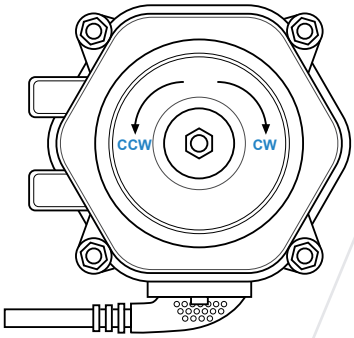
In all these scenarios, a single motor can be stocked in the truck or warehouse and can be quickly programmed as needed by a technician onsite. This eliminates the need to stock dozens of motors, just in case one might be required on the job site. Using only the nameplate of the existing motor, a tool, and a simple app, an ECR 2 can be programmed to match the failed motor's performance. Standard mounting configurations for front and rear baskets, along with foot mounting, makes retrofitting an ECR 2 fast and easy for virtually any refrigeration motor in the field.

Programmig examples

Single speed motor, rated at 1600 RPM CW OSE (opposite shaft end)	Program all three speeds of the ECR 2 to 1600 RPM CCW (our rotation is defined as looking at the shaft)

Programming all three speeds to the same values ensures any future change in wiring configuration will not inadvertently affect motor operation.

Only the blue and brown wires (line and neutral) are required for single speed operation. The black wire should be tied to either blue or brown (or removed) to ensure it doesn't come in contact with any other circuits. We suggest that a label be added to the motor noting the programmed speed for future reference.



Dual speed motor, rated at 1500 RPM CCW and 1800 RPM CCW (shaft end)	Program all three speeds as below: - Speed 1. 1500 RPM CCW: Blue to Phase, Brown to Neutral, Black (Control) wire not connected - Speed 2. 1500 RPM CCW: Blue to Phase, Brown to Neutral, Black (Control) wire to Phase - Speed 3. 1800 RPM CCW: Blue to Phase, Brown to Neutral, Black (Control) wire to Neutral

When wiring, tie the black and brown wires together, so if the black wire becomes disconnected for any reason, the operation will not be affected. We suggest that a label be added to the motor noting the programmed speeds for future reference.

More than just cost savings

When manufacturers consider the total cost of the materials and employee labor required to maintain each SKU in their system, they see that reducing even five or 10 SKUs saves thousands of dollars each year. This is due to reduced stocking, customer support, invoicing, and managing requirements. When additional costs for regulatory approval are considered, the cost savings is even greater.

ECR 2 motors are also some of the most reliable refrigeration motors in the world. With an average lifespan of 10 years, they last over twice as long as traditional motors. Considering service costs to replace failed motors are often more than five times the cost of the motor, ECR 2 continues to save manufacturers money long after the product is sold. Reliable motors also protect your brand's hard-earned reputation.

AoFrio

WHITE PAPER

Power and speed benefits of EC motors

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In this paper, AoFrio's North American Motor Specialist Sue Sieben explores why EC motors are three times more energy efficient than an AC motor.

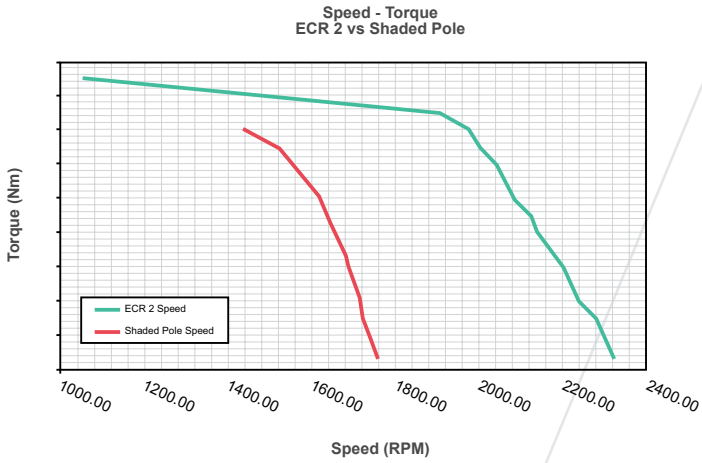
To understand the difference in nameplate rating and efficiency performance between EC and AC (shaded pole and PSC) motors, two factors need to be explained.

1. The EC motor's ability to adjust the power it consumes

The input power of an Electronically Commutated (EC) motor is adjusted for the specific performance required by an application. The microprocessor in the EC motor's electronics is analogous to the driver of a car.

As you drive the car, to travel at less than the maximum speed, you lift your foot off the gas. This reduces the power of the engine and fuel consumption. With more weight in the car, you will need more throttle for the same speed, and you will use more gas. When you reach a hill, you can put your foot down further to maintain the same speed up the hill, or you can maintain the throttle position and let the car go slower.

The EC motor's electronics do the same thing as a car. If it's programmed to maintain a constant set speed, it will automatically adjust the input power to do just that. If you use a smaller fan blade with the motor, or if the backpressure reduces, the electronics will throttle back the motor to only the minimum power necessary to maintain the set speed. This contrasts with an AC motor which operates at full power all the time. When the load is light, this means it uses more power than necessary.



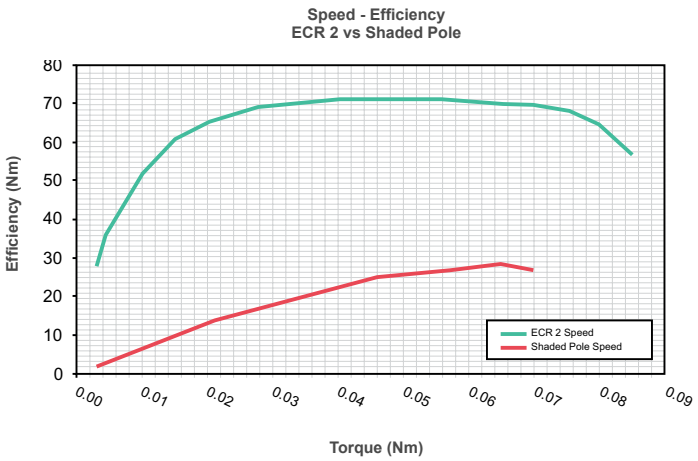
The Wellington ECR 2 has a much larger speed range and delivers more torque than an AC motor, enabling it to be used in more applications.

One benefit flowing from EC motors is that there is no penalty for using a more powerful motor than strictly needed. If you load a 13W motor with only 9W of load, it will throttle itself back and act like a 9W motor. And just like a car, there are times when it's useful to have some extra power up your sleeve.

This is unlike AC motors, where a more powerful motor uses more power all the time, so normal practice is to use the lowest power motor that will do the job. This often leads to shaded pole motors seeing higher winding temperatures and reduced motor lifespans in "real world" conditions.

2. The relationship between speed and power

AC motors have a speed-power relationship which doesn't change much between motors. A 60Hz 4-pole motor will run unloaded at somewhere near 1800 RPM, and it will reach its peak torque at around 1500-1550 RPM. This is true for AC motors of any power level.



The Wellington ECR 2 has significantly higher efficiency at all torque levels, so it delivers more power more efficiently.

In contrast, an EC motor reaches its maximum torque at zero RPM, and its maximum speed varies depending on the rated power. A more powerful EC motor will run faster at no load and develop more torque at stall than a less powerful EC motor. For example, an EC motor rated at 9W @ 1500 RPM will reach about 1750 RPM unloaded, whereas the same EC motor in a version rated at 13W @ 1800 RPM will run at 2200 RPM unloaded.

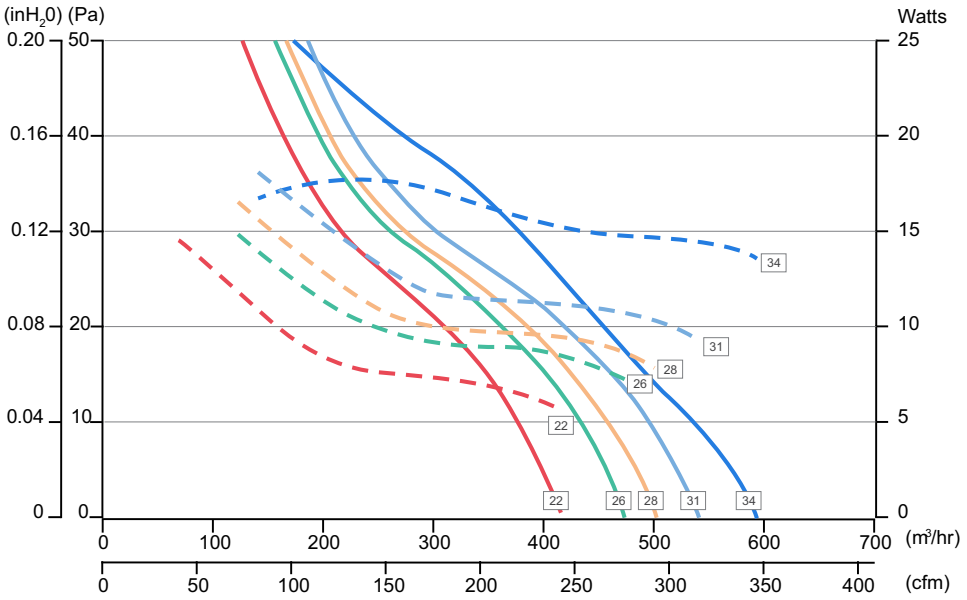
This is like pedaling a bicycle. You push the pedals hardest when you are just starting, and if you stay in a low gear, there will come a point where you simply can't move your legs any faster. A stronger person on the same bike could push harder at takeoff, but they could also pedal faster in the low gears.

This means that when you need higher motor speed, you need an EC motor with higher rated power. However, because of the automatic throttling capability in the electronics, a "more powerful" EC motor doesn't use more power.

For example, an EC motor rated at 13W output power will run at 1800 RPM and have an input power of 20W. But if this same motor is coupled to an 8" 28° fan, it's input power will only be 11.4W, because the 8" fan does not require all the motor's available power. If the same EC motor is then attached to a very small fan such as a 5.5" 25°, and programmed to run at maximum speed, it will run as fast as 2300 RPM – generating much more airflow than the same fan attached to a shaded pole motor - but the input power will be as low as 6.2W.

The effect of the motor self-adjusting can be seen in the below chart and corresponding tables, which shows the same motor driving a range of different pitched 8" fans. It is clear that the power requirement reduces with finer pitched fans.

200mm (8 inches) at 1550RPM



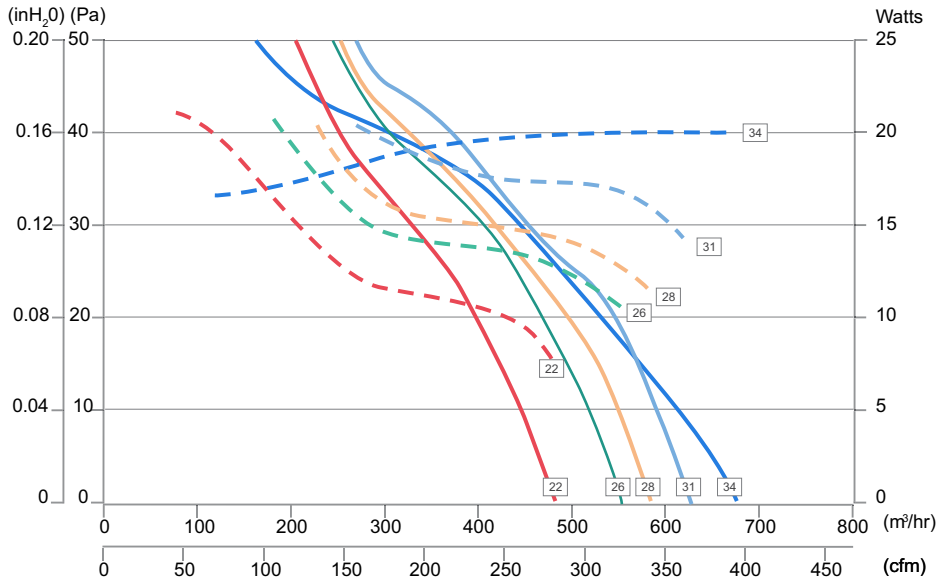
0 Pa (0 inH_20)													
Pitch	**10°**	**12°**	**14°**	**16°**	**18°**	**20°**	**22°**	**24°**	**26°**	**28°**	**30°**	**31°**	**34°**
Airflow [m3/hr]							414		475	502		544	595
Airflow [cfm]							244		279	296		320	350
Input Power [W]							5.5		7.1	7.8		9.3	13.5

25 Pa (0.1 inH_20)													
Pitch	**10°**	**12°**	**14°**	**16°**	**18°**	**20°**	**22°**	**24°**	**26°**	**28°**	**30°**	**31°**	**34°**
Airflow [m3/hr]							274		321	338		369	412
Airflow [cfm]							161		189	199		216	243
Input Power [W]							7.5		9.1	11.4		11.4	15.3

50 Pa (0.2 inH_20)													
Pitch	**10°**	**12°**	**14°**	**16°**	**18°**	**20°**	**22°**	**24°**	**26°**	**28°**	**30°**	**31°**	**34°**
Airflow [m3/hr]							122		153	163		180	165
Airflow [cfm]							72		90	96		106	97
Input Power [W]							11.2		13.3	14.4		16.2	17

The **Wellington ECR 2** will also self-protect by reducing output speed and power if it is overloaded, such as with high back pressure or larger pitched fans. This can be seen with an 8” 34° fan operating at 1800 RPM. The airflow is reduced, compared to an 8” 31° fan. At a higher backpressure, both the airflow and input current are reduced.

200mm (8 inches) at 1800rpm



0 Pa (0 inH$_2$0)													
Pitch	**10°**	**12°**	**14°**	**16°**	**18°**	**20°**	**22°**	**24°**	**26°**	**28°**	**30°**	**31°**	**34°**
Airflow [m3/hr]							481		554	585		627	676
Airflow [cfm]							283		326	345		369	398
Input Power [W]							7.9		10.4	11.3		14.1	20.0

25 Pa (0.1 inH$_2$0)													
Pitch	**10°**	**12°**	**14°**	**16°**	**18°**	**20°**	**22°**	**24°**	**26°**	**28°**	**30°**	**31°**	**34°**
Airflow [m3/hr]							360		439	453		506	487
Airflow [cfm]							211		264	267		298	287
Input Power [W]							10.9		13.4	14.3		17.3	20.0

50 Pa (0.2 inH$_2$0)													
Pitch	**10°**	**12°**	**14°**	**16°**	**18°**	**20°**	**22°**	**24°**	**26°**	**28°**	**30°**	**31°**	**34°**
Airflow [m3/hr]							200		235	255		265	173
Airflow [cfm]							118		138	150		165	102
Input Power [W]							15.1		17.0	18.4		20.2	17.0

The two factors described previously explain why most EC motors are usually around three times more energy efficient than an AC motor. EC motors operate as high as 70% efficiency with a power factor of up to 0.95, while AC motors are typically around 15 -25% efficient with a power factor of around 0.2-0.4. Given the material differences in how each motor type is built, EC motors typically last at least two to three times longer than AC motors as well. This has powerful implications for equipment reliability, service cost, and lifetime ownership cost.

AoFrio

WHITE PAPER

IP protection: solving the problem of motor protection from moisture, water and dust in commercial refrigerators

WT9392_i4 06/20

Overview

Moisture, water and dust are common causes of motor failure in commercial refrigeration applications like refrigerated display cases, beverage merchandisers and vending machines. IP ratings are often used by motor manufacturers to indicate how tolerant their products are to these conditions.

This white paper discusses the meaning and effectiveness of different motor IP ratings in commercial refrigeration applications, and compares moisture, water and dust protection for AoFrio's Wellington™ ECR motors to the ratings of other common types of refrigeration motors.

1. IP ratings

Ingress Protection (IP) ratings are a standardized method established by the International Electrotechnical Commission (IEC) to describe the ability of enclosures of electrical devices to withstand exposure to dust particles and water. IP ratings are defined by IEC standard 60529.

These ratings consist of the letters "IP" followed by two numbers. The first number denotes the degree of protection against foreign objects and dust's access to sensitive parts of the motor, ranging from 0 (not protected) to 6 (dust tight). The second number indicates the degree of protection against water, which ranges from 0 (not protected) to 8 (suitable for continuous immersion).

Tables describing the meaning of individual IP ratings are found at the end of this white paper.

2. The problem

Electric motors used in refrigeration applications require protection against moisture, water and dust due to the environment found in refrigerated display cases, beverage merchandisers and vending machine condensers and evaporators. Motors are typically exposed to the following elements:

- **Water from condensation forming on cooled parts**
  Condensation is common in the cold space of all types of commercial refrigerators.

- **Melting of built-up ice**
  Ice on evaporators is melted during defrost cycles and water from this often drips onto motors. In low temperature applications, it is also not uncommon to find built-up ice melting over the motors because of the heat radiated by the motors themselves. This problem is less significant in the case of ECM motors because they generate less heat than shaded pole and PSC induction products.

- **Water jet spraying**
  In applications containing food, like refrigerated display cases, the lower portion of display cases are periodically cleaned with water sprayed by a hose in order to meet sanitation and cleanliness standards. Motors are also sprayed during this process.

- **Spillage**
  Liquid products stored in the refrigerator can be spilled, and where evaporators are mounted below the product, this spillage often finds its way onto evaporator fan motors.

- **Dust**
  In self-contained refrigerators, condenser fans are often mounted low in the refrigerator and suck air in from the outside. This leaves them highly exposed to a build-up of dust from the external environment. In open-front coolers, dust is often introduced through the air curtain and recirculated by the fan blades.

Dust ingress is hazardous to motors because it contaminates bearing grease leading to rapid failure, blocks air circulation leading to motor overheating, and increases the risk of electrical short circuits.

Water ingress is hazardous because it causes electrical short circuits, corrosion and can contaminate bearing grease.

3. Refrigeration motors IP ratings

Shaded pole motors are commonly used in commercial refrigeration applications and are typically rated IP42 or IP44. These motors often suffer from water ingress, especially if not mounted horizontally. Also, because of their low efficiency, these motors generate a lot of heat that makes water evaporate more quickly when water droplets do enter the motor. Water and dust ingress will shorten a shaded pole motors' life, but water ingress is less likely to cause rapid failures in shaded pole motors than in ECMs. Shaded pole motors also tend to have a shorter life than ECMs due to their greater self-heating and poor starting torque, which reduces the effective bearing life. Lower IP rating is therefore more likely to be tolerable in shaded pole motors, particularly if long life is not a concern.

ECM motors for commercial refrigeration applications are offered with varying IP ratings ranging from IP42 to IP67. Electronically commutated (ECM) motors require higher degrees of protection to avoid getting the electronic control wet, as electronics do not mix well with water. An IP42 rating leaves the ECM motor open to the ingress of dust and indicates very limited protection against moisture and none against water jet spraying.

Because ECM motors typically have ball bearings, they can be mounted at any angle so water resistance from all directions is required. Further, short-term water ingress is hazardous to electronic controls so protection from hose down washings is necessary. AoFrio therefore recommends that *all refrigeration fan ECMs be rated at IP55 as a bare minimum.*

However, it is important to understand that, apart from the IPx8 rating test, IP certification tests are all of short duration. Over their lifetime, refrigeration motors are subject to many effects that reduce their water and dust tolerance: these include wear on seals and other moving parts, vibration, and thermal cycling. There are also water ingress mechanisms, such as capillary action, and “pumping” past seals due to expansion and contraction of trapped air inside the motor. In particular, pumping causes water ingress at a rate too slow to be detected in the IP certification test. To give peace of mind, especially for long life applications or where the design exposes motors to continual dripping, *AoFrio recommends the use of ECMs with the highest IP rating available.*

4. AoFrio’s Wellington ECR solution

Wellington ECR motors are specifically designed for commercial refrigeration applications. This makes them highly resistant to all environments typically found in refrigerated display cases, beverage merchandisers and vending machines, including low temperature applications and those with defrost cycles.

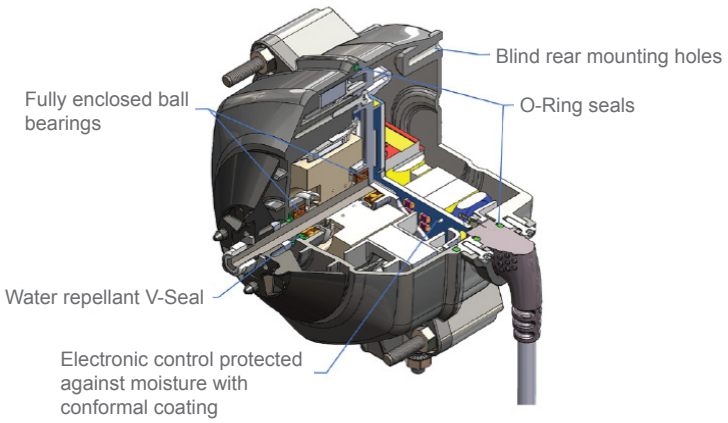
Our ECR 01 and ECR 82/92 motors have been independently tested to IP55 standard according to IEC60529. They are suitable for everyday refrigeration applications where purchase cost is the major driver.

Our **Wellington ECR 2** motor has been designed to be the most reliable and flexible ECM in the market. This includes having best in class ingress protection to minimize the chance of water or dust ingress shortening its life. The ECR 2 motor has been independently tested to IP67 standard, proving that it is even capable of running underwater in the test’s conditions. This provides a comfortable buffer against the circumstances likely to be encountered in a refrigeration application over time. Note however that as AoFrio provides customerspecific connectors on ECR motors, to get the full benefit of the IP67 rating either the connectors must also be IP67 or IP68 rated, or the cable end must be located in a position protected from moisture.

As well as the IP rating test, AoFrio tests all ECR motor designs using a 2,500 hour water spray test per MIL-810G part 506.5. During this test, the motor duty cycle is one hour on, five minutes off while under continuous water spray to allow thermal cycling of the air volume inside the motors to maximize the chance of leakage.

Wellington ECR 2 motors achieve a degree of protection that allows them to solve all the moisture, water and dust problems typical of commercial refrigeration applications with the design features illustrated in Figure 1 below.

Figure 1. ECR 2 motors moisture, water and dust resistance features



In the IP rating system, each digit and value corresponds to a specific level of protection that the motor provides. The first digit relates to protections for humans and motor components (Table 1) and protections against solid foreign objects (Table 2). The second digit shows protections against water (Table 3).

Table 1 - Protections provided to humans as well as components in the motor

First characteristic digit	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against access to hazardous parts with the back of a hand	The access probe, sphere of 50 mm , shall have adequate clearance from hazardous parts
2	Protected against access to hazardous parts with a finger	The jointed test finger of 12 mm , 80 mm length, shall have adequate clearance form hazardous parts
3	Protected against access to hazardous parts with a tool	The access probe of 2,5 mm shall not penetrate
4	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm shall not penetrate
5	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm shall not penetrate
6	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm shall not penetrate

Table 1 - Protections provided to humans as well as components in the motor (continued)

NOTE: In the case of the first digit being 3, 4, 5 or 6, protection against access to hazardous parts is satisfied if adequate clearance is kept. The adequate clearance should be specified by the relevant product committee in accordance with 12.3.

Due to the simultaneous requirement specified in Table 2, the definition “shall not penetrate” is given in Table 1.

From: International Electrotechnical Commission Central Office Switzerland. International Standard IEC 60529 Edition 2.1. 2001-02

Table 2 - Protections provided against solid foreign object penetration

First characteristic digit	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against solid foreign objects of 50 mm and greater	The object probe, sphere of 50 mm , shall not fully penetrate[1])
2	Protected against solid foreign objects of 12,5 mm and greater	The object probe, sphere of 12,5 mm , shall not fully penetrate1)
3	Protected against solid foreign objects of 2,5 mm and greater	The object probe, sphere of 2,5 mm , shall not penetrate at all[1])
4	Protected against solid foreign objects of 1,0 mm and greater	The object probe, sphere of 1,0 mm , shall not penetrate at all[1])
5	Dust-protected	Ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety
6	Dust-tight	No ingress of dust
1) The full diameter of the object probe shall not pass through an opening of the enclosure.		

From: International Electrotechnical Commission Central Office Switzerland. International Standard IEC 60529 Edition 2.1. 2001-02

Table 3 - Protections against water penetration

First characteristic digit	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against condensation and vertically falling water drops	Vertically falling drops shall have no harmful effects
2	Protected against vertically falling water drops when enclosure tilted up to 15°	Vertically falling drops shall have no harmful effects when the enclosure is tilted at any angle up to 15'' on either side of the vertical
3	Protected against spraying water drops	Water sprayed at an angle up to 60°on either side of the vertical shall have no harmful effects

Table 3 - Protections against water penetration (continued)

First characteristic digit	Degree of protection	
	Brief description	Definition
4	Protected against splashing water drops	Water splashed against the enclosure from any direction shall have no harmful
5	Protected against water jets	Water projected in jets against the enclosure from any direction shall have no harmful effects
6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects
7	Protected against immersion in up to 1 meter of water for up to 30 minutes	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
8	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7

From: International Electrotechnical Commission Central Office Switzerland. International Standard IEC 60529 Edition 2.1. 2001-02

AoFrio

WHITE PAPER

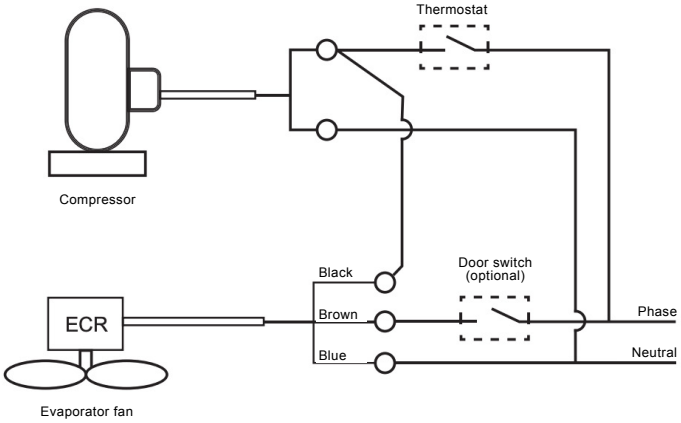
Saving energy and lowering product cost with multi speed fan motors in beverage merchandisers

WT9428_i2 07/20

Wellington™ ECR 2 motors reduce power consumption and thermal losses in beverage coolers and vending machines by switching the fan to low speed when the compressor is not operating. This is done by wiring the motor's control wire (black wire) directly into the compressor circuit. This eliminates the need and expense of a system controller with fan control outputs.

Most beverage merchandisers use an evaporator fan driven by a shaded pole or EC motor capable of operating at one speed. Usually this fan runs continuously. Continuous operation wastes energy because:

- When the compressor is off, no heat is being extracted from the cooler, so no airflow is required. Operating the motor during this time wastes energy. Additionally, all this power is being dissipated as heat inside the cooler, so even more power must be used by the compressor to extract this heat.
- Unnecessary airflow during the time when the compressor is off increases heat transfer through the cooler walls. This results in faster warming, shorter compressor-off periods, and more wasted energy.



In coolers with system controllers, the evaporator fan runs continuously when the compressor is on. When the compressor is off, the fan is cycled on and off to reduce stratification of warm and cold air. This reduces wasted power, but several problems remain:

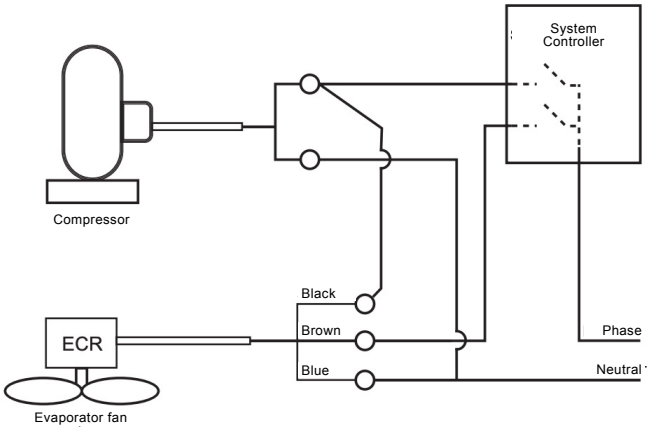
- Some power is still wasted due to the fan running at full power during the "on" part of the cycle.
- Some stratification still occurs during the off period, increasing the temperature variation of product, and often decreasing the products' quality.
- A system controller capable of independently controlling the evaporator fan is required.
- At fan turn-on, a pulse of warm air from the evaporator is circulated around the cooler, potentially causing false readings from the temperature sensor and reducing control effectiveness.

If a three speed ECR 2 is used, the evaporator fan may be switched to lower speed when the compressor is off.

- The advantages of this approach are:
- Air is circulated continuously, so stratification and false temperature readings are eliminated.
- The fan's energy consumption is proportional to fan speed cubed. So, during compressor-off periods a fan running continuously at part speed uses less power than one running intermittently at full speed, and significantly less power than one running continuously at full speed. For example, a fan operating at half speed uses about 1/8th the energy as a fan operating at full speed. That's an energy savings of over 87%!

- No system control connection is required. If a system controller is used, a low-cost unit without a fan control output is suitable.

For best results, the ECR 2 motor should be connected so that the motor runs at full speed when the compressor is on, at reduced speed when the compressor is off, and stops when the door switch is open.



AoFrio

WHITE PAPER

Saving energy and lowering product cost with multi speed fan motors in closed-front supermarket and food service display cases, and medical refrigeration systems

WT9426_i3 07/20

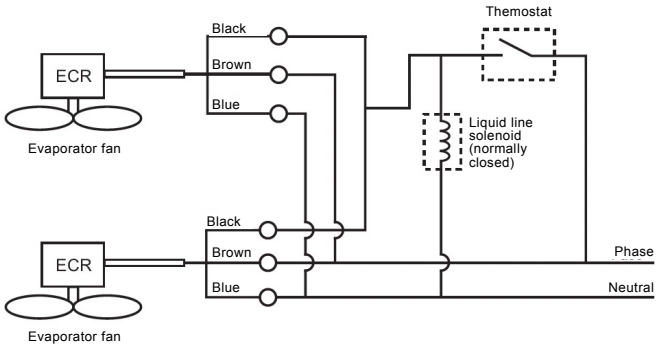
Three speed motors, like the AoFrio's **Wellington™ ECR 2**, reduce power consumption and thermal losses in display cases. In closed-door cases, this is achieved by switching the fan to a lower speed when the evaporator is not in a cooling cycle.

In many closed-door display cases, the evaporator and condenser fans run continuously irrespective of the system's cooling cycle. This continuous operation is wasteful because:

- When the system is not cooling, no heat is being extracted from the case, so no airflow is required. Operating the motor during this time wastes energy. Additionally, all this power is being dissipated as heat inside the case, so even more power must be used by the compressor to extract it.
- Un-needed airflow during the non-cooling period increases heat transfer through the case walls. This results in faster warming, shorter compressor-off periods, and wasted energy.
- Unnecessary airflow during the non-cooling period increases drying out of exposed perishable products.

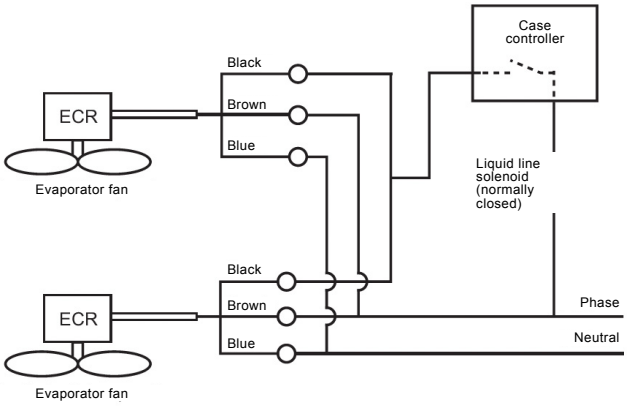
In other cases, the evaporator and condenser fans are switched off when the system is not cooling. This saves power but still leads to air stratification inside the case, allowing the temperature of products inside to vary unacceptably.

By using the ECR 2's three speed capability to reducefan speed without turning it off, energy is saved whilemaintaining good temperature control. The ECR 2 is setup to run at reduced speed when not cooling,providing just enough airflow to prevent stratification.



ECR 2 three speed motor in a display case without a case controller. Fan speed is controlled by wiring the black control wire either into the liquid line solenoid (if a line power solenoid is present) or into the fan motor output of the case controller.

To do this, the ECR 2 motor should be wired so that the blue and brown wires are permanently connected to phase and neutral, and the black wire is connected to phase when the system is cooling and disconnected or connected to neutral when the system is not cooling.



ECR 2 three speed motor in a display case with a case controller. The controller should be programmed for "fan off" when not in cooling cycle, so the motor can operate at a minimum speed.

AoFrio

WHITE PAPER

Multi-speed condenser fan motors

WT9465_i1 11/20

Multi-speed speed condenser fan motors, like the AoFrio's Wellington™ ECR 2, can reduce power consumption and perceived noise and improve safety in self-contained display cases, bottle coolers and medical refrigerators. In most self-contained coolers, the condenser fans are wired to the compressor and run at a fixed speed whenever the compressor is operating. This is undesirable in many circumstances.

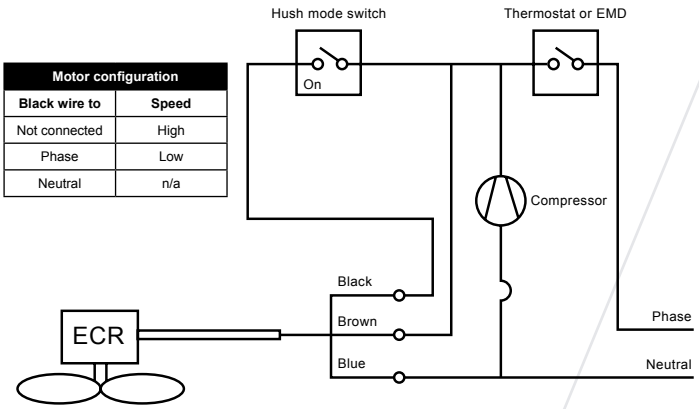
Coolers are typically specified to meet performance requirements at worst-case operating conditions, meaning condenser airflow is more than necessary in many circumstances. As the condenser fan is one of the main noise sources in the cooler, this results in an unnecessarily intrusive cooler.

If a multi-speed ECR 2 motor is used for the condenser fan, users can be given some control over this, by fitting a switch to the cooler which lets users select a lower speed for the condenser fan (hush mode). This reduces the noise level of the cooler, although possibly at some cost in increased energy consumption. A hush mode option is particularly beneficial in coolers which have been specified for tropical conditions but are often used in airconditioned offices, or other quiet temperature-controlled environments.

With the increasing use of hydrocarbon refrigerants, it is desirable to continuously ventilate the compressor deck to dissipate flammable gasses in case of a refrigerant leak. One option is to run the fan continuously at full speed; however, this is intrusive and wasteful. A better option is to use a multi-speed ECR 2 motor for the condenser fan and run the fan continuously at low speed. ECR 2 motors will run at speeds as low as 300 RPM, such that the speed is just enough to dissipate the gas, but noise and power consumption are trivial.

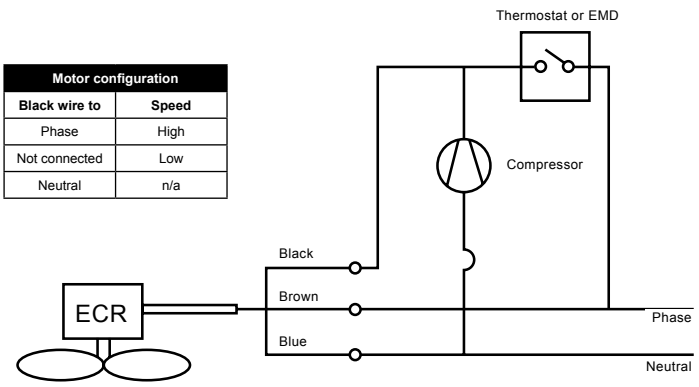
To take advantage of ECR 2 motors multi-speed capability, the motors should be wired so that the blue and brown wires are connected to phase and neutral. The black (control) wire can then be wired into the cooler harness such that it is connected to phase, neutral, or not connected, depending on the operating state of the cooler. Often this can be done by directly connecting it to existing relays or switches. Because each state (black to phase, black to neutral, and black not connected) can be independently configured to a different motor speed setting, this allows airflow inside the case to be optimized for each operating state. Some example wiring diagrams are shown below.

Motor configuration	
Black wire to	**Speed**
Not connected	High
Phase	Low
Neutral	n/a



In this example the ECR 2 motor is wired so that when the compressor is off, no power is supplied so the motor stops. A user-operable switch changes the connection of the black wire, giving two options for operating speed when the compressor is running. A three-speed version of this would also be possible.

Motor configuration	
Black wire to	**Speed**
Phase	High
Not connected	Low
Neutral	n/a



In this example the black control wire is connected to the thermostat output, allowing the motor to run continuously at low speed to ventilate the compressor deck.

The multi-speed capability of ECR 2 fan motors can also give performance benefits when used for the evaporator fan. See our white paper on multi-speed motors in remote cases for more details on page 49. The ideas explained in that document are also applicable to self-contained coolers.

Multi-speed ECR 2 motors can also be configured for different timed behaviors at each speed, further increasing the possibilities for improved cooler performance. See our white paper on timed behaviors on page 47, for ideas on how to take advantage of this advanced capability.

When used with AoFrio™ SCS refrigeration controllers or compatible hardware, ECR 2 motors can also operate with fully variable speed adjustable in real-time, unlocking another level of cooler features and performance.

AoFrio

WHITE PAPER

Timed behaviors

WT9468_i1 11/20

AoFrio's Wellington ECR® 2 fan motors have many advanced features which enable OEMs to improve cooler performance, one of these features is timed behavior. The timed behavior function allows the motor to run in one mode for a period, then change to a different mode, without any change in the control inputs. Creative use of this feature offers many opportunities to enhance and differentiate cooler behavior.

ECR 2 fan motors achieve simple on-off control by removing power from the brown (phase) wire. Alternatively, they are configurable for three "speed" settings, these are selected by connecting the black (control) wire to phase, to neutral, or not connecting it.

For any given connection position of the black wire (i.e. to phase, neutral, or nothing), the motor behavior can be configured so:

- the motor runs at a particular speed and direction till the black wire connection status changes;
- or the motor runs at a particular speed and direction for a fixed period (1-3600 seconds), then runs at a different speed and direction till the black wire connection status changes.

The speeds specified can be 0 RPM or anywhere between 300 RPM and maximum speed, and can be different for each of the three black wire states. Timed behaviors can be either pre-configured at AoFrio's factory or configured on your cooler production line.

Example applications of the timed behavior function include:

- Condenser cleaning. Run the condenser fan in reverse for a period, either when the compressor is switched off or when it is switched on, to blow dust out of the coil, then either stop or go to a very low speed (for compressor deck safety ventilation). The reverse speed can be higher than the normal speed (for maximum cleaning) or lower (if needed to meet noise specifications: fans are usually louder when running backwards than forwards).
- Defogging. Run the evaporator fan at a higher speed for a period after the door has been opened, to help remove condensation from the glass.
- Condenser and evaporator delay start. When the compressor starts, there is a period where the system is charging during which very little heat transfer occurs. During this time, running the condenser and evaporator fans is just wasted power. Starting the fans sometime after the compressor, or starting them slowly then speeding up later, also spreads out the increase in noise level, making it less intrusive.
- Evaporator delay stop. When the compressor starts, residual refrigerant remains in the evaporator, giving "free" additional cooling capacity which can be extracted by running the fan for a period after the compressor stops. Running the fan for some time after the compressor, or slowing it down for a period before stopping it, also spreads out the increase in noise level, making it less intrusive.
- Boost mode. If the compressor has been running for a long period of time, it may need additional airflow from the condenser or evaporator to help it pull down or maintain temperature. The fans can be configured to increase speed after (e.g.) 1 hour of continuous running.
- Smart hush mode. If a hush mode has been enabled for the condenser fan (see our white paper on using multi-speed motors in condensers on pages 44-46), the system can protect itself against users too aggressively using hush mode, by increasing the speed back to "non-hush" normal after (e.g.) 30 minutes of continuous compressor operation.

AoFrio

WHITE PAPER

Multi-speed motors in remote cases

WT9469_i1 11/20

Multi-speed evaporator fan motors, like the AoFrio's Wellington ECR 2, can reduce power consumption, thermal losses, and noise in display cases.

In many closed-door display cases, the evaporator fans run continuously irrespective of the system's operating state. This continuous operation is undesirable for the following reasons.

- When the system is not cooling, no heat is being extracted from the case, so no airflow is required. Operating the motor during this time wastes energy. Additionally, all this power is being dissipated as heat inside the case, so even more power must be consumed by the compressor to extract it.

- Excessive or unnecessary airflow increases heat transfer through the case walls. This results in faster warming, shorter compressor-off periods, and wasted energy.

- Excessive or unnecessary airflow increases drying out of exposed perishable products.

- Excessive or unnecessary airflow causes unnecessary noise, a particular problem in environments with large banks of cases.

In closed-front cases, these issues can be solved by switching the fan to a lower speed when the evaporator is not in a cooling cycle. In open-front cases, they can be solved by switching the fan to a lower speed – or a combination of lower speeds – when the night blind is down, and an air curtain does not need to be maintained.

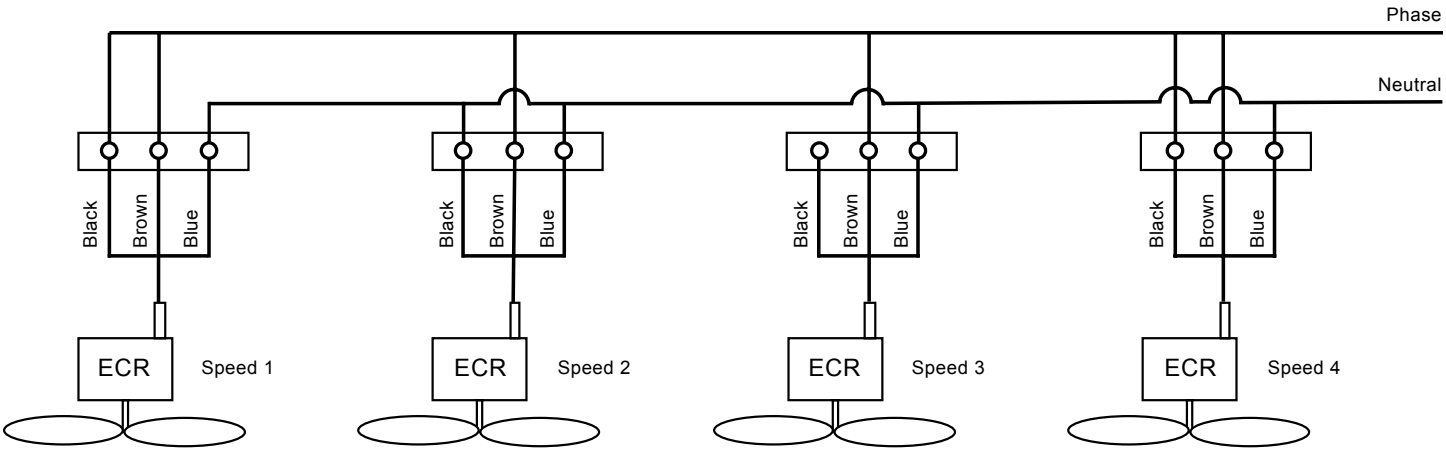
Some existing closed-front cases switch the evaporator fans off or run them intermittently when the system is not cooling. Although this is more efficient than leaving them running, the superior solution is to run at a lower speed. This improves performance by:

- Reducing average power use: a fan running continuously at low speed uses less power than one running intermittently at full speed;

- Reducing perceived noise: a fan running at low speed is very much quieter than one running at high speed, and the intrusive change of noise due to stopping and starting is eliminated;

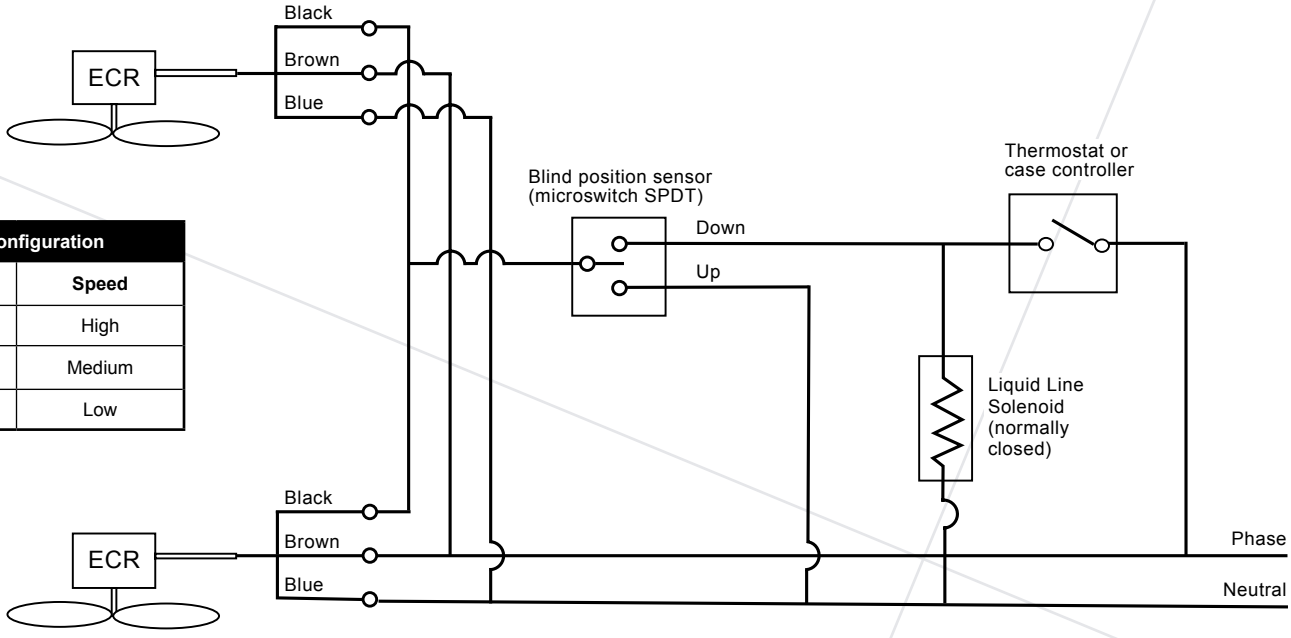
- Improving temperature control, due to reduction in stratification and continuous airflow over the temperature probe.

To take advantage of ECR 2 motors multi-speed capability, the motors should be wired so that the blue and brown wires are permanently connected to phase and neutral. The black (control) wire can then be wired into the case harness such that it is connected to phase, neutral, or not connected, depending on the operating state of the cooler. Often this can be done by directly connecting it to existing relays or switches. Because each state (black to phase, black to neutral, and black not connected) can be independently configured to a different motor speed setting, this allows airflow inside the case to be optimized for each operating state. Some example wiring diagrams are shown below.



Example fixed wiring for multiple speeds from a single ECR 2 SKU and use in different applications by changing the wiring configuration.

The diagram shown above shows ways multi-speed motors can be used to optimize remote cases by adjusting the fan wiring harness to allow different motors to run at different speeds in the same case. This can be useful in split-level cases, cases with a mix of open and closed frontages, cases with localized flow restrictions, or in open-front cases where an optimum air curtain requires different flow at the case ends from the centre. In these situations, a small adjustment to the speed of individual fans can have a large impact on case performance. By programming the ECR 2 motor for all the required speeds, and configuring the harness plug according to the required speed in each location, a common fan motor can be installed in all positions, simplifying assembly and service enough to make this a feasible option.

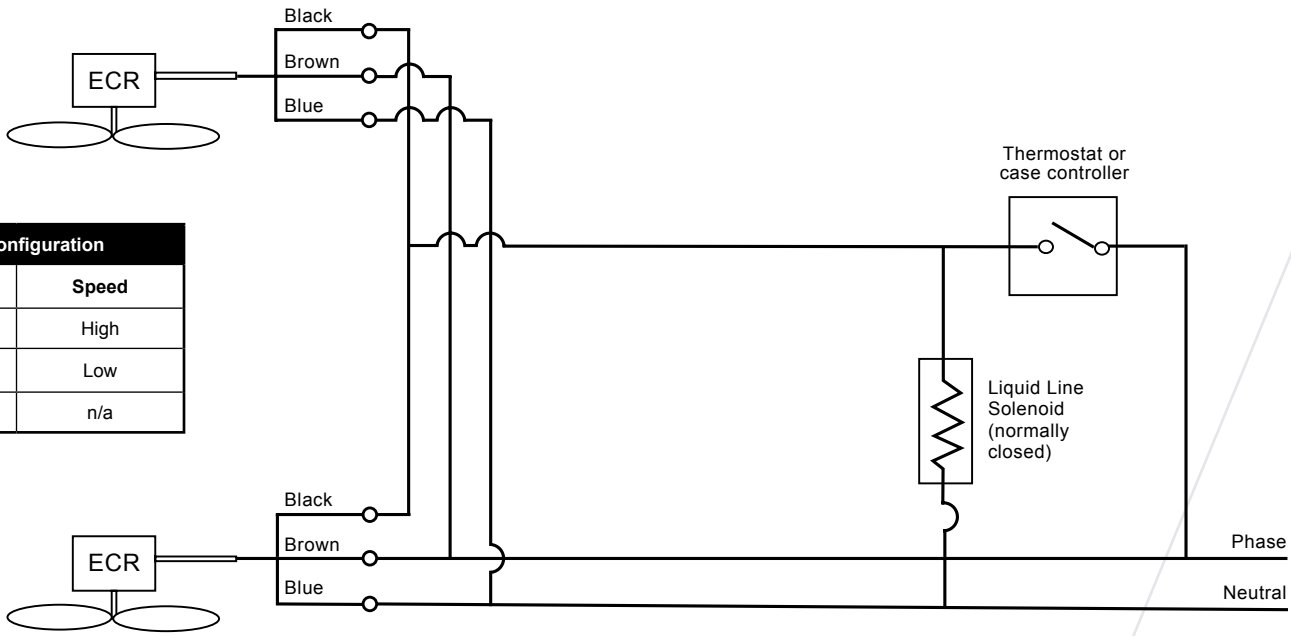


Motor configuration	
Black wire to	**Speed**
Neutral	High
Phase	Medium
Nothing	Low

Example wiring configuration to switch ECR 2 motors between different speeds: high, medium and low.

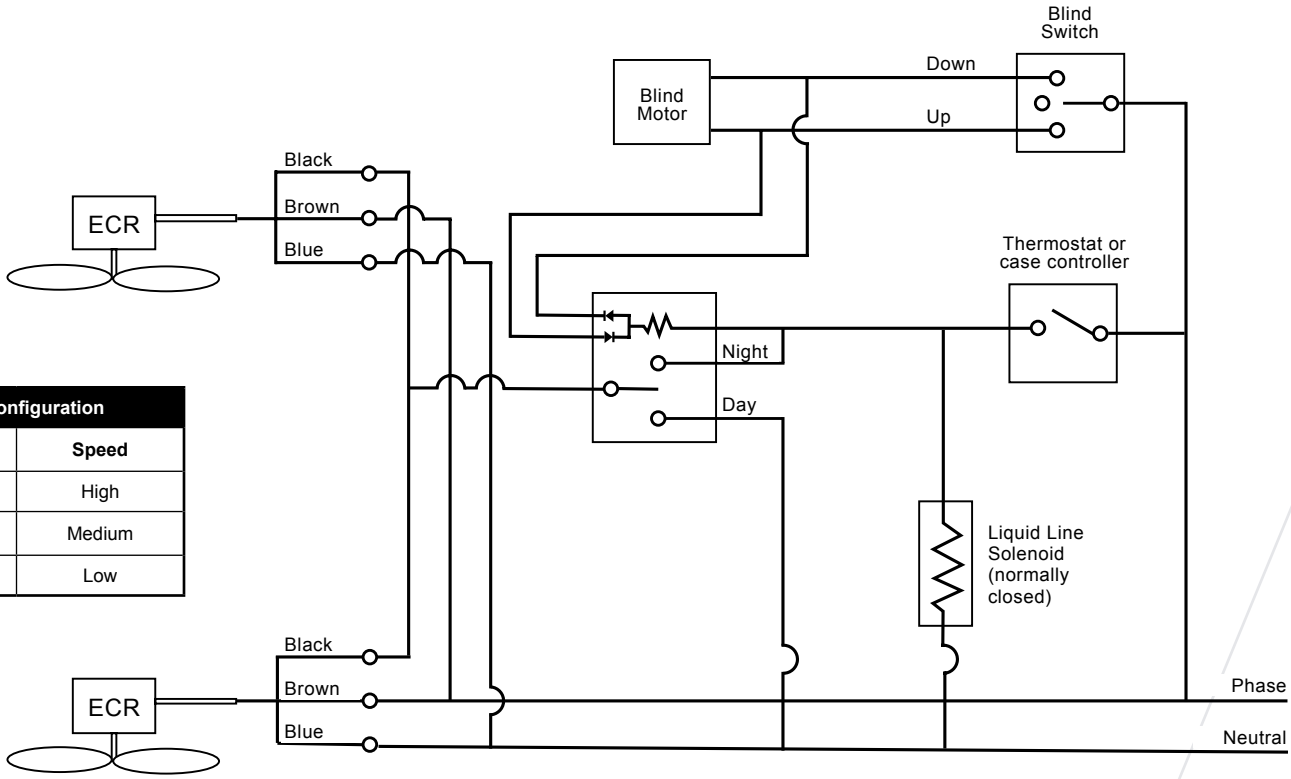
Multi-speed ECR 2 motors can also be configured for different timed behaviors at each speed, further increasing the possibilities for improved cooler performance. See our white paper on timed behaviors for ideas on how to take advantage of this advanced capability.

When used with AoFrio SCS refrigeration controllers or compatible hardware, ECR 2 motors can also operate with fully variable speed adjustable in real time, unlocking another level of cooler features and performance.



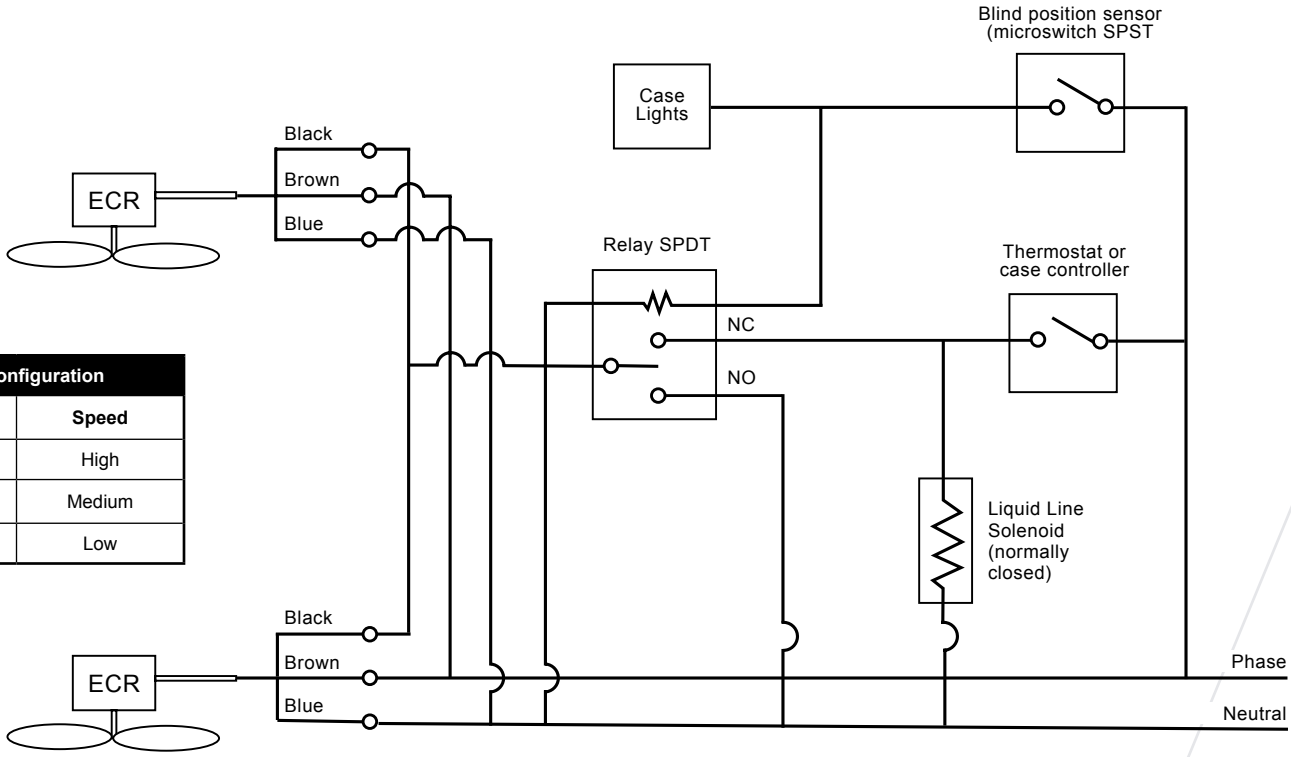
Motor configuration	
Black wire to	**Speed**
Phase	High
Not connected	Low
Neutral	n/a

ECR 2 two-speed motor in a closed front display case. Fan speed is controlled by wiring the black control wire into the liquid line solenoid or into the fan motor output of the case controller (the case controller should be set to “fan off when no refrigerant flow” in this case).



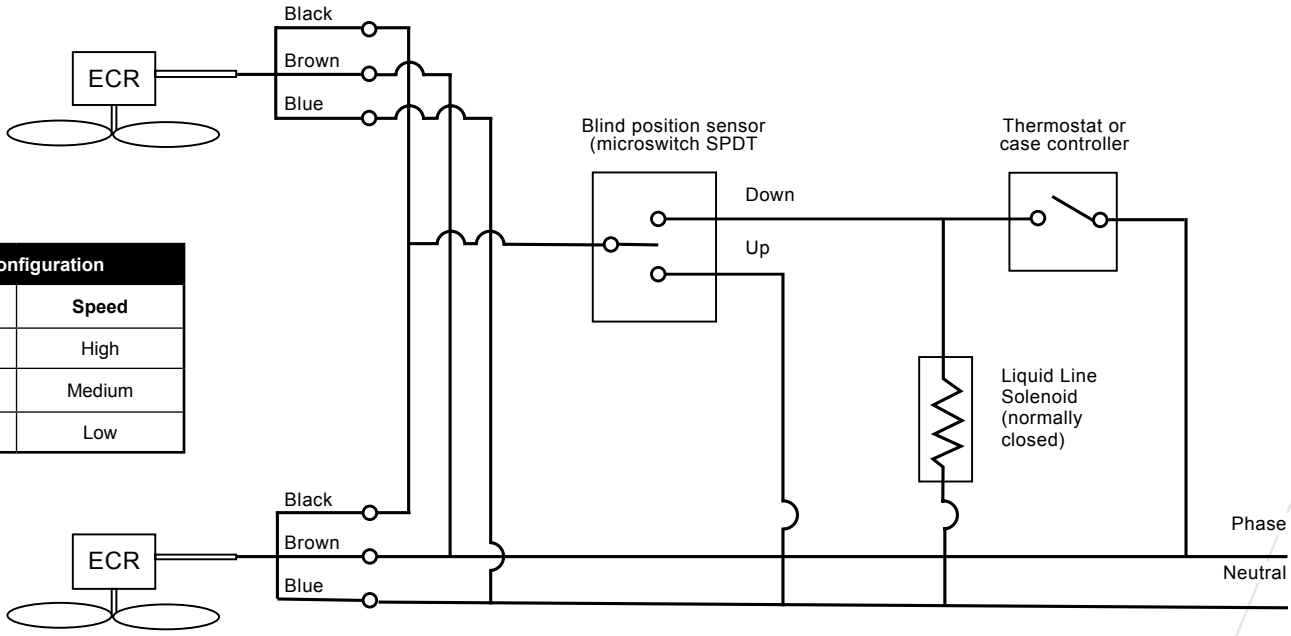
Motor configuration	
Black wire to	**Speed**
Neutral	High
Phase	Medium
Nothing	Low

ECR 2 three-speed motor in an open front display case with automatic blinds. By using a latching relay, the fan runs at full speed when the blind is up and an air curtain is needed, at medium speed when the blind is down but refrigerant is flowing, and at low speed when the blind is down and no refrigerant is flowing.



Motor configuration	
Black wire to	**Speed**
Neutral	High
Phase	Medium
Nothing	Low

ECR 2 three-speed motor in an open front display case with manual blinds. By using a relay to invert the signal from the lighting switch, the fan runs at full speed when lights are on (i.e. the blind is up and an air curtain is needed), at medium speed when the blind is down but refrigerant is flowing, and at low speed when the blind is down and no refrigerant is flowing.



Motor configuration	
Black wire to	**Speed**
Neutral	High
Phase	Medium
Nothing	Low

An alternate open-front configuration. Where lighting is controlled independent of blind position, a microswitch can be used to detect blind position, and no relay is required. Current flowing through the black wire is always very low, so a high current switch is not needed.

Sign up to get a trial ECR 2 motor

aofrio.com/trialmotor

E: info@aofrio.com www.aofrio.com

AoFrio

ECF 2 datasheet

ECF 2™

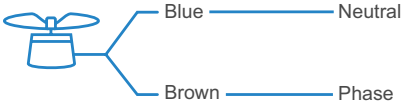
ATEX option

- Quiet - as low as 36.5 dBA
- Efficient - up to 70%
- Highly reliable - up to 10x more reliable
- Universal voltage (70-246V) - use one SKU anywhere
- 57:1 SKU reduction - reduces inventory and boosts profits

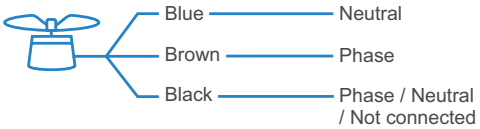
Specifications	
Input voltage range	70-264V, 50-60Hz (all models)
Output power range	0-13W
Speed range	300-1800 RPM
Max. input power	20.5W
Max. input current	0.10A (@230V), 0.20A (@115V)
Max power factor	0.95
EMC protection	4000V (per EN61000-6-2)
Insulation class	Class A (105°C)
Electronic protection	Locked rotor and automatic thermal de-ratingalso included
Refrigerant compatibility	HFC, CO_2 and hydrocarbon (per IEC 60335-2-89 Annex BB)
IP rating	IP67
Operating temp. range	-30°C to +50°C (-22°F to +122°F)
Storage temp. range	-40°C to +80°C (-40°F to +176°F)
Weight	0.86kg (1.9lb)
Approvals	CE DVE Ex RoHS cULus

Wiring diagram

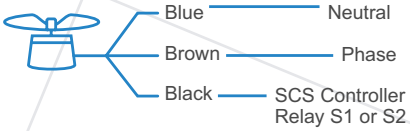
For single speed operation



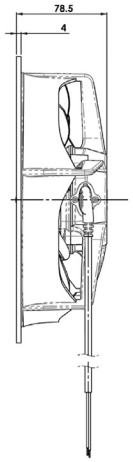
For three speed or reversible operation

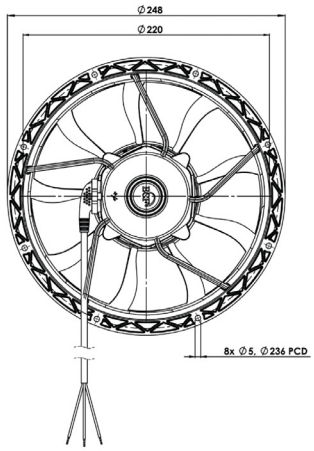


For variable speed operation



Dimensions





Airflow data

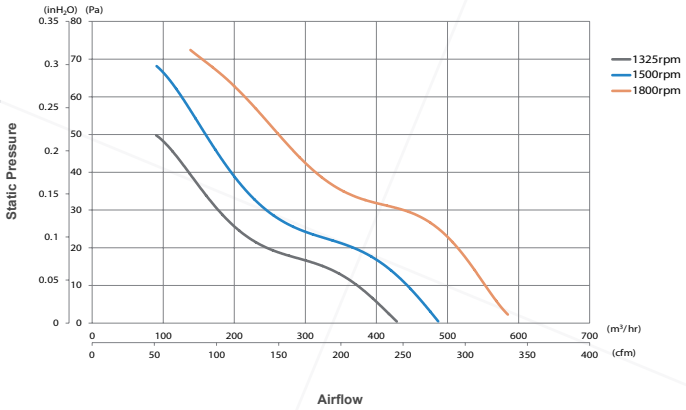
Fan Speed N [RPM]	Input Power Pe [W]	Sound Pressure* LpA [dB(A)]	Inlet Sound Power Level ** LwA [dB(A)]	Static Pressure P [Pa]	Airflow Q [m³/hr]
1325	6.8	42.4	49.4	5	432.0
1325	7.5	41.7	48.7	15	377.1
1325	7.5	44.3	51.3	20	291.8
1325	8.7	46.2	53.2	35	172.7
1325	9.9	47.3	54.3	50	107.7
1500	9.8	44.9	51.9	5	505.2
1500	10.5	44.5	51.5	15	464.9
1500	10.8	44.7	51.7	20	431.9
1500	11.1	50.1	57.1	35	232.2
1500	12.8	50.0	57.0	50	179.1
1800	14.6	49.1	56.1	5	606.5
1800	16.2	48.7	55.7	15	581.7
1800	17.3	48.8	55.8	20	566.7
1800	17.8	48.9	55.9	35	452.7
1800	18.2	54.7	61.7	50	283.5

* Average inlet sound pressure, measured according to ISO 10302-1, measured at 1m radius
** Inlet sound power equivalent according to ISO 13347-1

OEM options

- Preprogrammed or factory/field programmable speeds
- Realtime continuously variable speed control over third mains wire (no extra cables required)
- Custom cable and plug options
- Metric, imperial, or custom hardware
- 3 speed, reversible, or timed-reverse options

Airflow graph



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