ZEUS

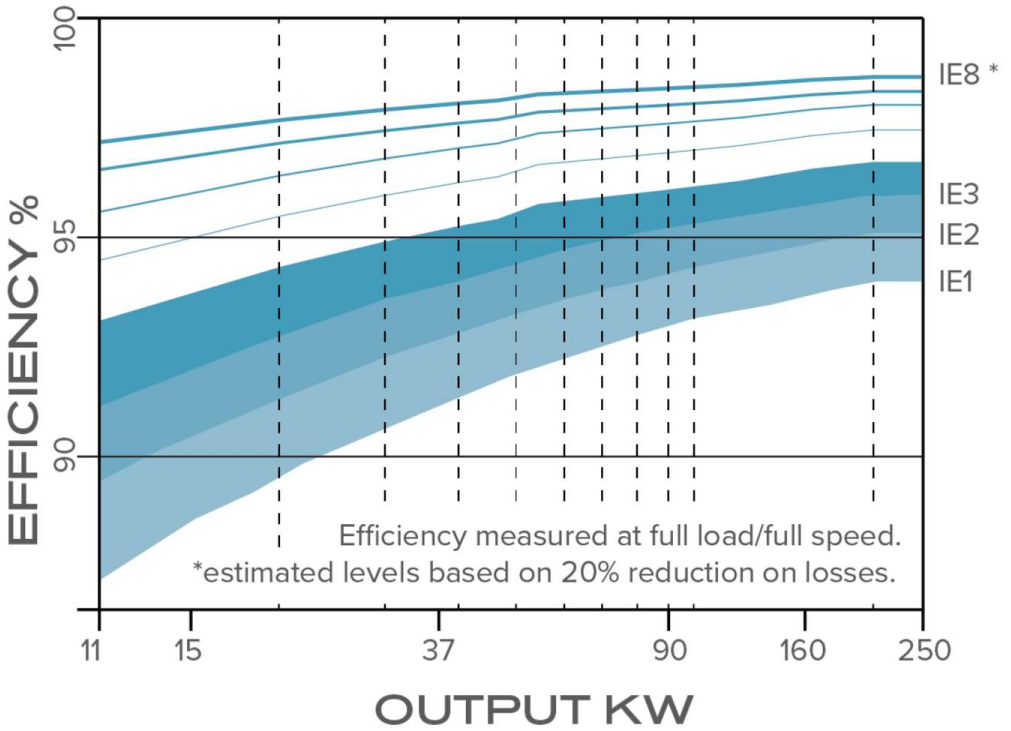
APPENDIX

EFFICIENCY RATINGS

MOTORS ARE REGULATED AND LABELED BY EFFICIENCY.

All commercial motors must be independently tested and rated before being sold.

COUNTRIES CONSUMING 76% OF ELECTRICITY legislate a Minimum Efficiency, according to the IEC (International Electrotechnical Commission). Regulations become more stringent over time. This is how inefficient motors are phased out by governments over time.



IE4/NEMA SUPER PREMIUM MOTORS ARE MOST EFFICIENT MOTORS ON MARKET.

IEC and NEMA set standards, which are coordinated:

IE1 = NEMA Standard
IE2 = NEMA Energy Efficient
IE3 = NEMA Premium Efficiency
IE4 = NEMA Super Premium Efficiecy

* NEMA has not yet released Super Premium rating. Nothing approved above IE4 by IEC. Anything above IE4 has been calculated based on the rating formula of reducing losses by 20% over the previous rating.

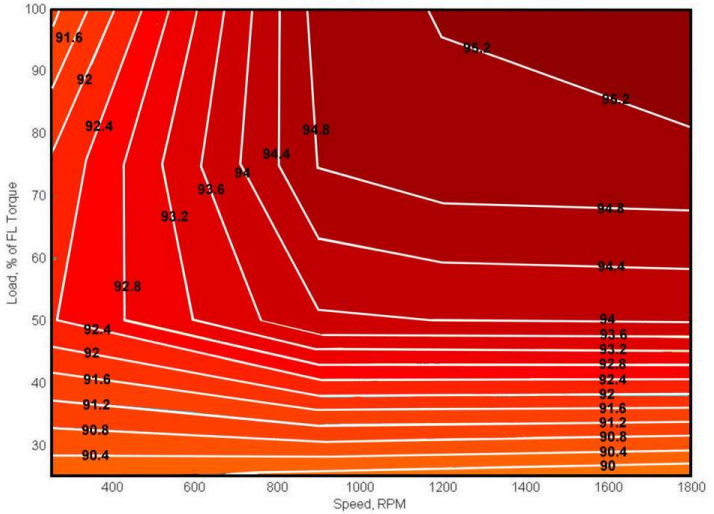
NEMA has three motor efficiency classes: Standard, Energy Efficient and Premium Efficiency. On the other hand, IEC has four classes: IE1, IE2, IE3 and IE4. The first three IEC classes are roughly equivalent to the NEMA classes, while the IE4 class is referred to as Super Premium Efficiency. These efficiency classes are specified in the IEC 60034-30-1 standard, and the latest version was published in 2014.

The next version of the IEC standard will introduce the IE5 class, known as Ultra Premium Efficiency. Energy losses are reduced by 20% or more between classes, which means an IE5 motor will have a 20% loss reduction with respect to an IE4 motor. The Ultra Premium Efficiency class has not been specified in standards yet, but some manufacturers have already developed motors that will be compliant.

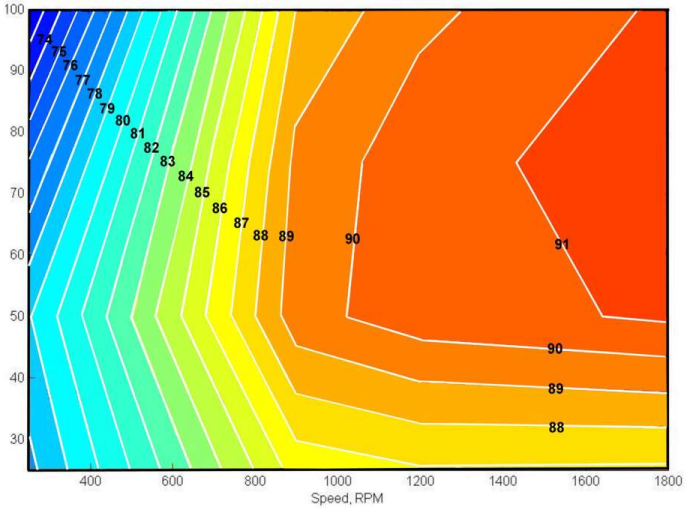
INDEPENDENT TESTING: EFFICIENCY MAPS

To verify the performance of the ZEUS Motor™, Advanced Energy, an independent test lab, conducted a series of tests. Efficiency Maps show motor efficiency through a range of tested speeds and a range of tested loads. These maps generated from 2017 testing data of a ZEUS Motor™ and a competitor NEMA Premium® IM (the most efficient NEMA category of motors currently on the market).

ZEUS MOTOR ™

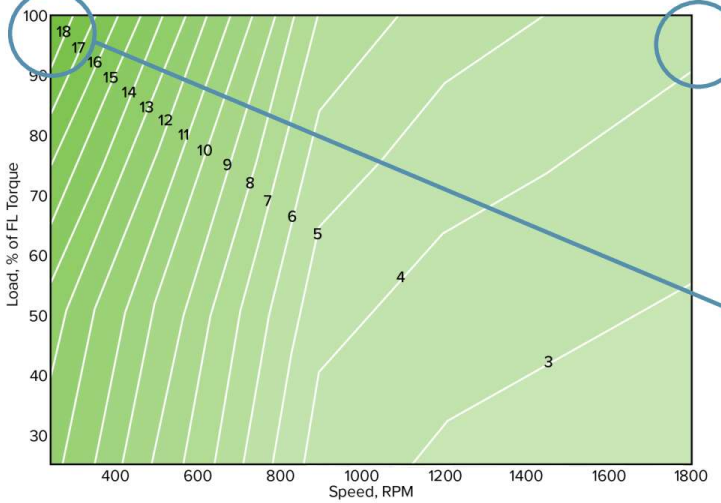


NEMA PREMIUM® IM



Motors spend most of their working lives below full load, high speed, where it is the most efficient and gets its rated number. This means that ZEUS's advantage is usually much greater than the difference in rated efficiencies.

Differences between ZEUS MOTOR ™ & NEMA PREMIUM® IM



2017 TESTING

4.2% more efficient at full load, high speed (testing in 2017)

18% more efficient at full load, low speed (testing in 2017)

NOW TESTING

6% more efficient at full load, high speed (testing now)

19.5% more efficient at full load, low speed (testing now)

Since these efficiency maps were created in 2017, newer ZEUS motors being tested at Advanced Energy perform at higher efficiencies. That data is referenced throughout the investor presentation and in the now testing box.

ZEUS

DETAILED CALCULATIONS: SAVINGS DUE TO EFFICIENCY

SAVINGS CALCULATIONS:
Detailed calculations from p. 5, Motor Advantages: Efficiency slide.

1) 75 kW (100 hp) motor that runs 90% of time for 60,000 hours (over 7 years) in a medium cost environment will use 75kW x 60,000 hrs x $0.15/kWh = $675,000 of electricity. In going from a IE3 to an IE7, the efficiency saving is 3.9% to give a saving of $26,325. Our 100 hp motor has a list price of $12,900 (equal to less than half of the savings).

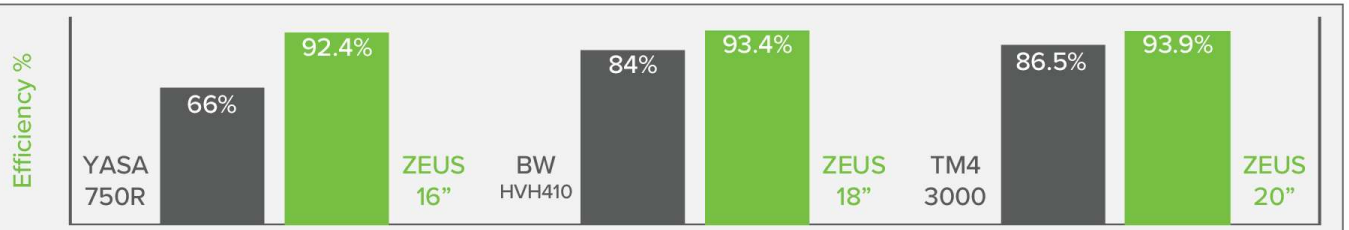
2) An electric school bus had a 155.4 kWh battery pack and a 230 hp IE3 electric motor. It used 1.57 kWh/mile and its range was 69 miles. We substituted an IE7 ZEUS motor, reduced the battery pack to 133.2 kWh, and achieved 0.97 kWh/mile and a range of 80 miles on the smaller battery pack.

MOTOR ADVANTAGES: PERFORMANCE FOR TRACTION (VEHICLE) MOTORS

We compare here three different size ZEUS motors with analogous motors by competitors YASA, Borg Warner, and TM4

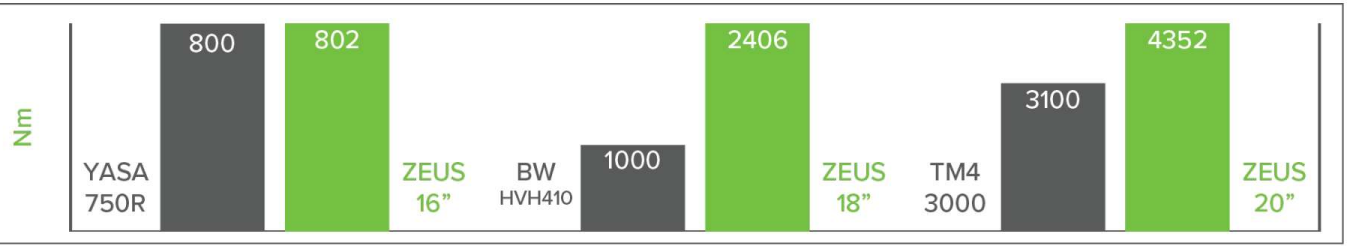
EFFICIENCY AT LOW SPEED.

Higher low speed efficiency increases range for stop/start BEVs (battery electric vehicles). Especially advant-ageous for delivery trucks, and buses



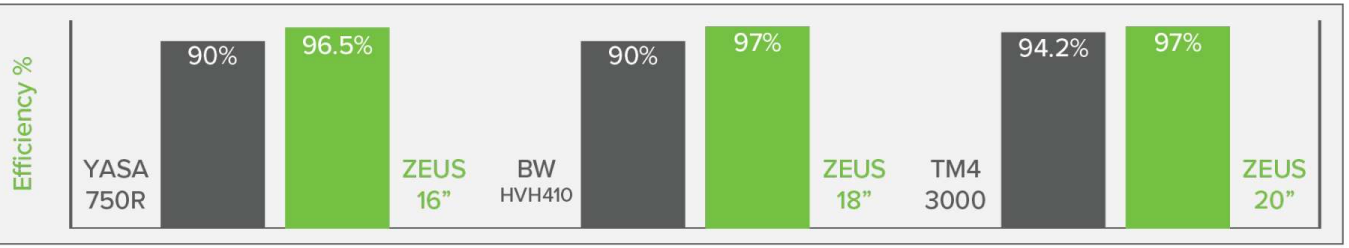
PEAK TORQUE AT LOW SPEED.

Higher peak torque at low speeds allows direct connect, eliminating gearbox. This reduces cost and complexity.



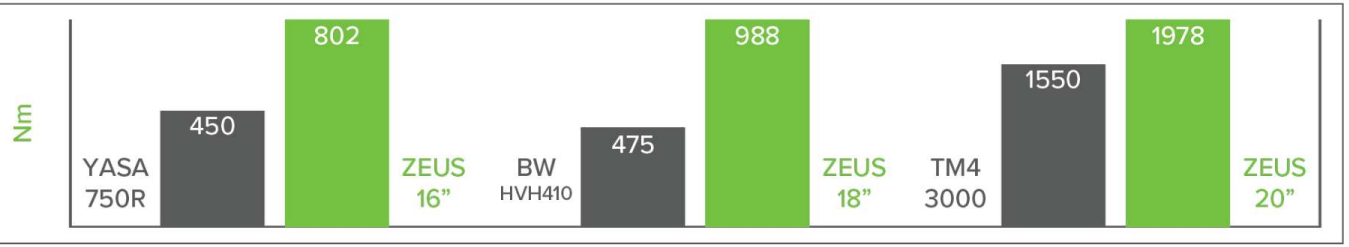
EFFICIENCY AT CRUISE SPEED.

Most fuel is used when operating at cruise speeds. High efficiency improves fuel economy and the vehicle’s range.



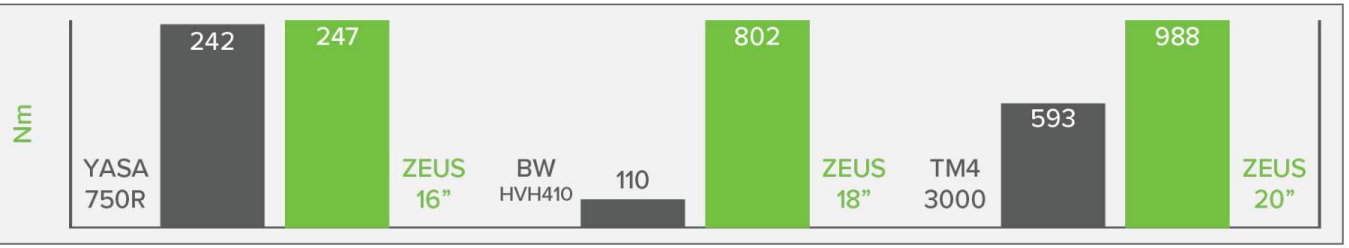
PEAK TORQUE AT CRUISE SPEED.

Passing another vehicle at cruise speeds is the most dangerous part of driving a vehicle. High peak torque facilitates safe passing.



CONTINUOUS TORQUE AT TOP SPEED.

Driving slowly up a slope can cause other vehicles to attempt to pass. High continuous torque facilitates heavy vehicle climbing slopes; also towing.



IN ALL CASES, ZEUS™ OUT-PERFORMS THE COMPETITOR.

ZEUS

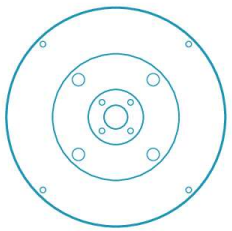
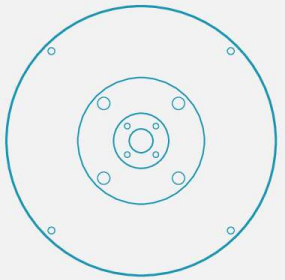
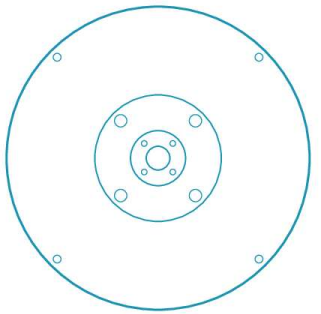
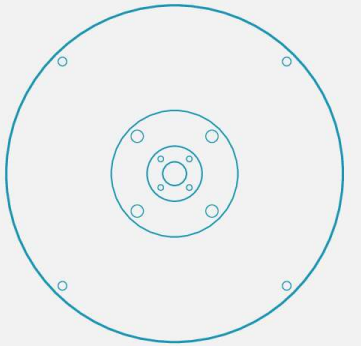
ZEUS MOTOR™ MODELS

ZEUS MOTOR FRAME MODULARITY

Driver and inverter changes allow same frame to serve as multiple products. CAN PRODUCE 27 DIFFERENT MOTOR MODELS WITH 4 FRAME SIZES, plus additional explosion-proof models with little to no modification necessary.

Versatility due to over-sized permanent magnets that rarely, if ever, demagnetize, so motor can go through incredible AMP range (13”⌀ 250 AMP-1400 AMP), enabling it to serve as both industrial and traction motors.

MOTOR FRAMES

13”⌀, 130 lbs	16”⌀, 275 lbs	18”⌀, 414 lbs	20”⌀, 618 lbs
			

INDUSTRIAL MOTORS

15 HP 20 HP 25 HP 30 HP 40 cont. HP	50 HP 60 HP 75 HP 100 cont. HP	125 HP 150 cont. HP	175 HP 200 HP 250 cont. HP

Industrial motors sold at two speeds: 1500/1800 & 3000/3600 rpm. Industrial motors are rated by their "continuous power" output which they can maintain indefinitely.
*explosion-proof models available with little to no modification necessary

TRACTION MOTORS

100 HP 125 HP 150 HP 200 peak HP	250 HP 300 HP 400 HP 500 peak HP	600 HP 700 peak HP	800 HP 900 HP 1000 peak HP

Traction motors are rated by their “peak power” which they can maintain for 30 seconds before overheating.

ZEUS MOTOR™ PATENTS

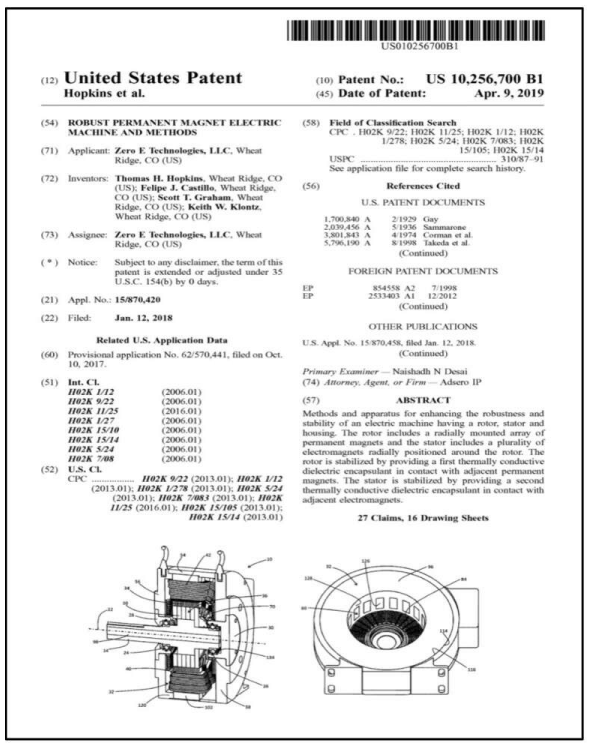
From: Jim Brown Date: Fri, Jan 11, 2019, 2:25 PM
Subject: Zero-e Patent Status Report
To: Thomas Hopkins

Dear Tom:
It was very enjoyable speaking with you on Wednesday. This note is being sent to summarize the extraordinary progress we have made with the Zero-e patent portfolio in 2017. I am very pleased to report that significant claims in each of the three US patent applications filed on January 12, 2018 have been allowed by the USPTO and will issue as three separate patents in January or February of 2019...

I am thrilled with the scope of the claims the USPTO has allowed during the first year of prosecution. This is a testament to the creativity and ingenuity your team has brought to bear when designing the Zero-e permanent magnet motor. As I mention over the phone, there is significant and wide ranging subject matter still to be pursued in this patent family and I anticipate good fortune prosecuting several divisional and continuation application, in 2019.

Sincerely, Jim Brown, Adsero IP

ROBUSTNESS



US010256700B1

(12) **United States Patent**
Hopkins et al.

(10) **Patent No.: US 10,256,700 B1**
(45) **Date of Patent: Apr. 9, 2019**

(54) **ROBUST PERMANENT MAGNET ELECTRIC MACHINE AND METHODS**

(71) Applicant: **Zero E Technologies, LLC**, Wheat Ridge, CO (US)

(72) Inventors: **Thomas H. Hopkins**, Wheat Ridge, CO (US); **Felipe J. Castillo**, Wheat Ridge, CO (US); **Scott T. Graham**, Wheat Ridge, CO (US); **Keith W. Klontz**, Wheat Ridge, CO (US)

(73) Assignee: **Zero E Technologies, LLC**, Wheat Ridge, CO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/870,420**

(22) Filed: **Jan. 12, 2018**

Related U.S. Application Data

(60) Provisional application No. 62/570,441, filed on Oct. 10, 2017.

(51) **Int. Cl.**
H02K 1/12 (2006.01)
H02K 9/22 (2006.01)
H02K 11/25 (2016.01)
H02K 1/27 (2006.01)
H02K 15/10 (2006.01)
H02K 15/14 (2006.01)
H02K 5/24 (2006.01)
H02K 7/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H02K 9/22*** (2013.01); ***H02K 1/12*** (2013.01); ***H02K 1/278*** (2013.01); ***H02K 5/24*** (2013.01); ***H02K 7/083*** (2013.01); ***H02K 11/25*** (2016.01); ***H02K 15/105*** (2013.01); ***H02K 15/14*** (2013.01)

(58) **Field of Classification Search**
CPC . H02K 9/22; H02K 11/25; H02K 1/12; H02K 1/278; H02K 5/24; H02K 7/083; H02K 15/105; H02K 15/14
USPC 310/87–91
See application file for complete search history.

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(Continued)

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U.S. Appl. No. 15/870,458, filed Jan. 12, 2018.
(Continued)

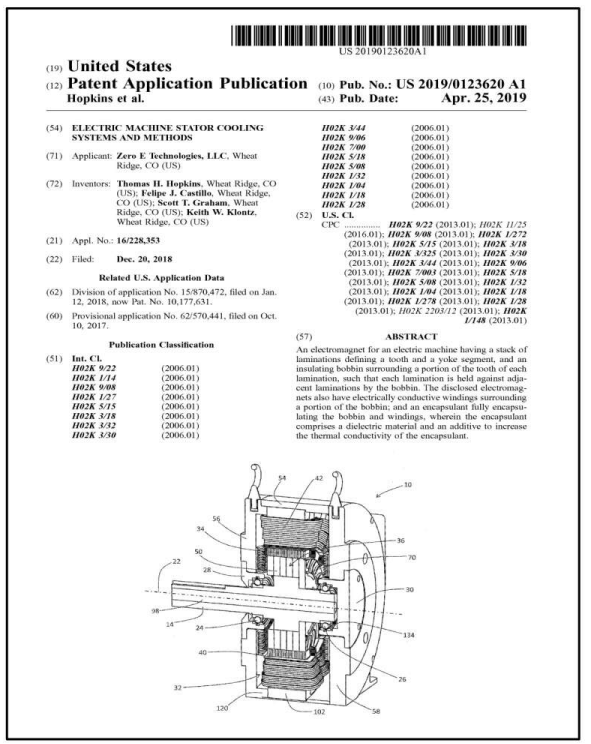
Primary Examiner — Naishadh N Desai
(74) *Attorney, Agent, or Firm* — Adsero IP

(57) **ABSTRACT**

Methods and apparatus for enhancing the robustness and stability of an electric machine having a rotor, stator and housing. The rotor includes a radially mounted array of permanent magnets and the stator includes a plurality of electromagnets radially positioned around the rotor. The rotor is stabilized by providing a first thermally conductive dielectric encapsulant in contact with adjacent permanent magnets. The stator is stabilized by providing a second thermally conductive dielectric encapsulant in contact with adjacent electromagnets.

27 Claims, 16 Drawing Sheets

STATOR COOLING



US 20190123620A1

(19) **United States**
(12) **Patent Application Publication**
Hopkins et al.

(10) **Pub. No.: US 2019/0123620 A1**
(43) **Pub. Date: Apr. 25, 2019**

(54) **ELECTRIC MACHINE STATOR COOLING SYSTEMS AND METHODS**

(71) Applicant: **Zero E Technologies, LLC**, Wheat Ridge, CO (US)

(72) Inventors: **Thomas H. Hopkins**, Wheat Ridge, CO (US); **Felipe J. Castillo**, Wheat Ridge, CO (US); **Scott T. Graham**, Wheat Ridge, CO (US); **Keith W. Klontz**, Wheat Ridge, CO (US)

(21) Appl. No.: **16/228,353**

(22) Filed: **Dec. 20, 2018**

Related U.S. Application Data

(62) Division of application No. 15/870,472, filed on Jan. 12, 2018, now Pat. No. 10,177,631.

(60) Provisional application No. 62/570,441, filed on Oct. 10, 2017.

Publication Classification

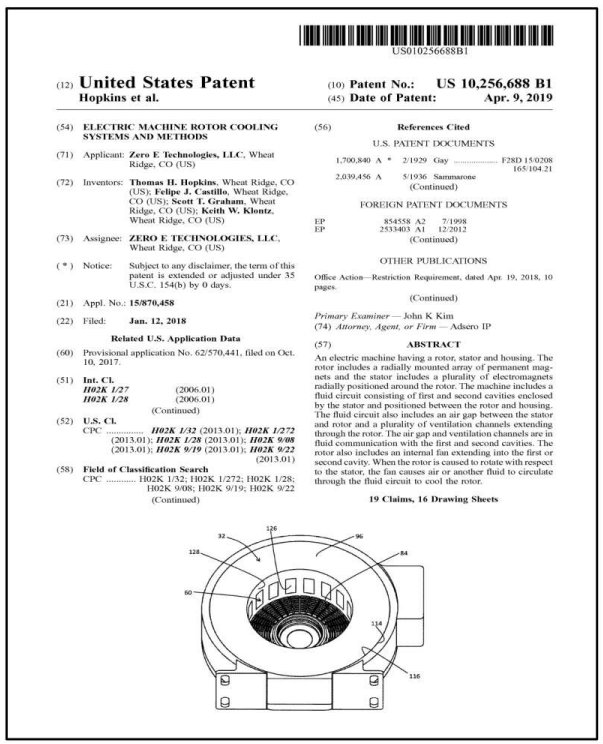
(51) **Int. Cl.**
H02K 9/22 (2006.01)
H02K 1/14 (2006.01)
H02K 9/08 (2006.01)
H02K 1/27 (2006.01)
H02K 5/15 (2006.01)
H02K 3/18 (2006.01)
H02K 3/32 (2006.01)
H02K 3/30 (2006.01)
H02K 3/44 (2006.01)
H02K 9/06 (2006.01)
H02K 7/00 (2006.01)
H02K 5/18 (2006.01)
H02K 5/08 (2006.01)
H02K 1/32 (2006.01)
H02K 1/04 (2006.01)
H02K 1/18 (2006.01)
H02K 1/28 (2006.01)

(52) **U.S. Cl.**
CPC ***H02K 9/22*** (2013.01); *H02K 11/25* (2016.01); ***H02K 9/08*** (2013.01); ***H02K 1/272*** (2013.01); ***H02K 5/15*** (2013.01); ***H02K 3/18*** (2013.01); ***H02K 3/325*** (2013.01); ***H02K 3/30*** (2013.01); ***H02K 3/44*** (2013.01); ***H02K 9/06*** (2013.01); ***H02K 7/003*** (2013.01); ***H02K 5/18*** (2013.01); ***H02K 5/08*** (2013.01); ***H02K 1/32*** (2013.01); ***H02K 1/04*** (2013.01); ***H02K 1/18*** (2013.01); ***H02K 1/278*** (2013.01); ***H02K 1/28*** (2013.01); *H02K 2203/12* (2013.01); ***H02K 1/148*** (2013.01)

(57) **ABSTRACT**

An electromagnet for an electric machine having a stack of laminations defining a tooth and a yoke segment, and an insulating bobbin surrounding a portion of the tooth of each lamination, such that each lamination is held against adjacent laminations by the bobbin. The disclosed electromagnets also have electrically conductive windings surrounding a portion of the bobbin; and an encapsulant fully encapsulating the bobbin and windings, wherein the encapsulant comprises a dielectric material and an additive to increase the thermal conductivity of the encapsulant.

ROTOR COOLING



US010256688B1

(12) **United States Patent**
Hopkins et al.

(10) **Patent No.: US 10,256,688 B1**
(45) **Date of Patent: Apr. 9, 2019**

(54) **ELECTRIC MACHINE ROTOR COOLING SYSTEMS AND METHODS**

(71) Applicant: **Zero E Technologies, LLC**, Wheat Ridge, CO (US)

(72) Inventors: **Thomas H. Hopkins**, Wheat Ridge, CO (US); **Felipe J. Castillo**, Wheat Ridge, CO (US); **Scott T. Graham**, Wheat Ridge, CO (US); **Keith W. Klontz**, Wheat Ridge, CO (US)

(73) Assignee: **ZERO E TECHNOLOGIES, LLC**, Wheat Ridge, CO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/870,458**

(22) Filed: **Jan. 12, 2018**

Related U.S. Application Data

(60) Provisional application No. 62/570,441, filed on Oct. 10, 2017.

(51) **Int. Cl.**
H02K 1/27 (2006.01)
H02K 1/28 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H02K 1/32*** (2013.01); ***H02K 1/272*** (2013.01); ***H02K 1/28*** (2013.01); ***H02K 9/08*** (2013.01); ***H02K 9/19*** (2013.01); ***H02K 9/22*** (2013.01)

(58) **Field of Classification Search**
CPC H02K 1/32; H02K 1/272; H02K 1/28; H02K 9/08; H02K 9/19; H02K 9/22
(Continued)

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FOREIGN PATENT DOCUMENTS

EP 854558 A2 7/1998
EP 2533403 A1 12/2012
(Continued)

OTHER PUBLICATIONS

Office Action—Restriction Requirement, dated Apr. 19, 2018, 10 pages.
(Continued)

Primary Examiner — John K Kim
(74) *Attorney, Agent, or Firm* — Adsero IP

(57) **ABSTRACT**

An electric machine having a rotor, stator and housing. The rotor includes a radially mounted array of permanent magnets and the stator includes a plurality of electromagnets radially positioned around the rotor. The machine includes a fluid circuit consisting of first and second cavities enclosed by the stator and positioned between the rotor and housing. The fluid circuit also includes an air gap between the stator and rotor and a plurality of ventilation channels extending through the rotor. The air gap and ventilation channels are in fluid communication with the first and second cavities. The rotor also includes an internal fan extending into the first or second cavity. When the rotor is caused to rotate with respect to the stator, the fan causes air or another fluid to circulate through the fluid circuit to cool the rotor.

19 Claims, 16 Drawing Sheets

ZEUS

POTENTIAL CLIENTS & EXECUTION

Our initial push is in both industrial and traction motors. We are in discussions with several parties, with which we have executed NDAs. Some potential clients want to license our motor, and some want us to supply them with motors.

PUMP MANUFACTURERS

We are in discussions with two companies that manufacture pumps. One is focused on down-hole pumps, and the other is focused on water distribution systems. Our motor's ***high efficiency*** is a big attraction.

MILITARY SUPPLIERS

We are in discussions with one company that supplies the US Navy with utility motors for its warships. Our motor's ***small volume*** is a big attraction.

HEAVY VEHICLES

We are in discussions with one company that makes BEV school buses. Our motor's ***high efficiency*** is an advantage that increases the bus's range and/or reduces its battery pack and weight.

ELECTRIC CHASSIS MANUFACTURERS

We are in discussions with two manufacturers of electric chassis for vans and delivery trucks. Our motor's extreme ***efficiency*** and ***smoothness*** at slower speeds are attractions.

INTERNET SALES

We are in discussions with Amazon for them to sell & distribute our 13" dia. motors. Because these smaller motors ***weigh less than 150 lbs***, they qualify for Prime service (believed to be the only motor in that power range – 15, 20, 25hp – that does).

DETAILED FINANCIAL SCNENARIO: 1.25% MARKET SHARE

ZEUS

What If Scenario: What Would ZMI's Financials look like if and when it achieves motor sales of 100,000 units per year and its licensees sell another 400,000 paying a 2.5% licensing fee?

ZEUS Motor Inc.	Inhouse	Licensees	Combined	
UNIT SALES			*Actual Units*	
Units				
ZEUS Motor Sales	100,000		100,000	
Licensee Motor Sales		400,000	400,000	
PROFIT & LOSS			*$'s in 000s*	
Sales				
ZEUS Motor for Sale	$572,493		$572,493	*Excludes Licensee Sales*
Total Sales	$572,493		$572,493	
Cost Products Sold				
Motor for Sale	$335,415		$335,415	
Total CPS	$335,415		$335,415	*Excludes Licensee CPS*
Gross Profit	$237,078		$237,078	
Gross Profit %	41.4%		41.4%	
Selling Expense	$97,234		$97,234	
General & Admin	$58,075		$58,075	*Includes 1.5% R&D fee*
Earnings from Operations	$81,689		$81,689	
Other Income & Expense	$8,346	$63,090	$71,436	*Includes 2.5% License fee*
Taxes @ 25%	$22,509	$15,772	$38,281	
Net Earnings After Taxes	$67,527	$47,317	$114,844	

NOTE FROM THE CEO:

A director of Zero E advised me, "Never show investors a projection that suggests more than 20x times their money back. That is not believable."

This has been a problem for us. First, electric motors are an enormous market—$150 billion. Second, our motor has significant advantages—it is much more efficient, uses a fraction of the materials, and hence it is potentially less expensive. Third, there are some market segments where we could expect a home run.

Despite all these advantages, I dutifully showed projections showing investors getting only 20x their investment back. Investors would ask me, "Why are you making such modest projections... don't you believe your own story?"

Then I came across a discussion of the many "unicorns" that American VCs have invested in. The article asked what these VCs had been looking for when they invested. Answer: they were seeking companies that could scale up quickly, that could blitzscale. To Hell with 20x times their investment. Investors want much more.

Here's the revelation: ZEUS's strategy of licensing technology to manufacturers around the world will permit rapid scaling. This scenario shows that ZEUS will sell 100,000 motors, while our licensees will sell 400,000 motors. We believe we could realistically sell double this.

RARE EARTHS

RISKS WITH RARE EARTHS

Because people remember when their price suddenly increased in 2010-2011, rare earths are perceived as being a limited and risky material to work with. However, the limited availability and price increase resulted from a bubble. It is now recognized that rare earths aren't rare at all—they are common. The price of rare-earth permanent magnets has collapsed due to oversupply.

The risk of rare earths is mitigated by extensive supply.

WILL PERMANENT MAGNET MOTORS AND GENERATORS TAKE OFF?

High-efficiency machines are projected to be the fastest growing segment requiring motors and generators. Permanent magnet motors are significantly more efficient than conventional induction motors.

Assumption: Export Price = 110% x Shagnhai Metals Market price