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(54) **COOLING SYSTEM FOR A MACHINE AND METHOD OF ASSEMBLY OF SAME**

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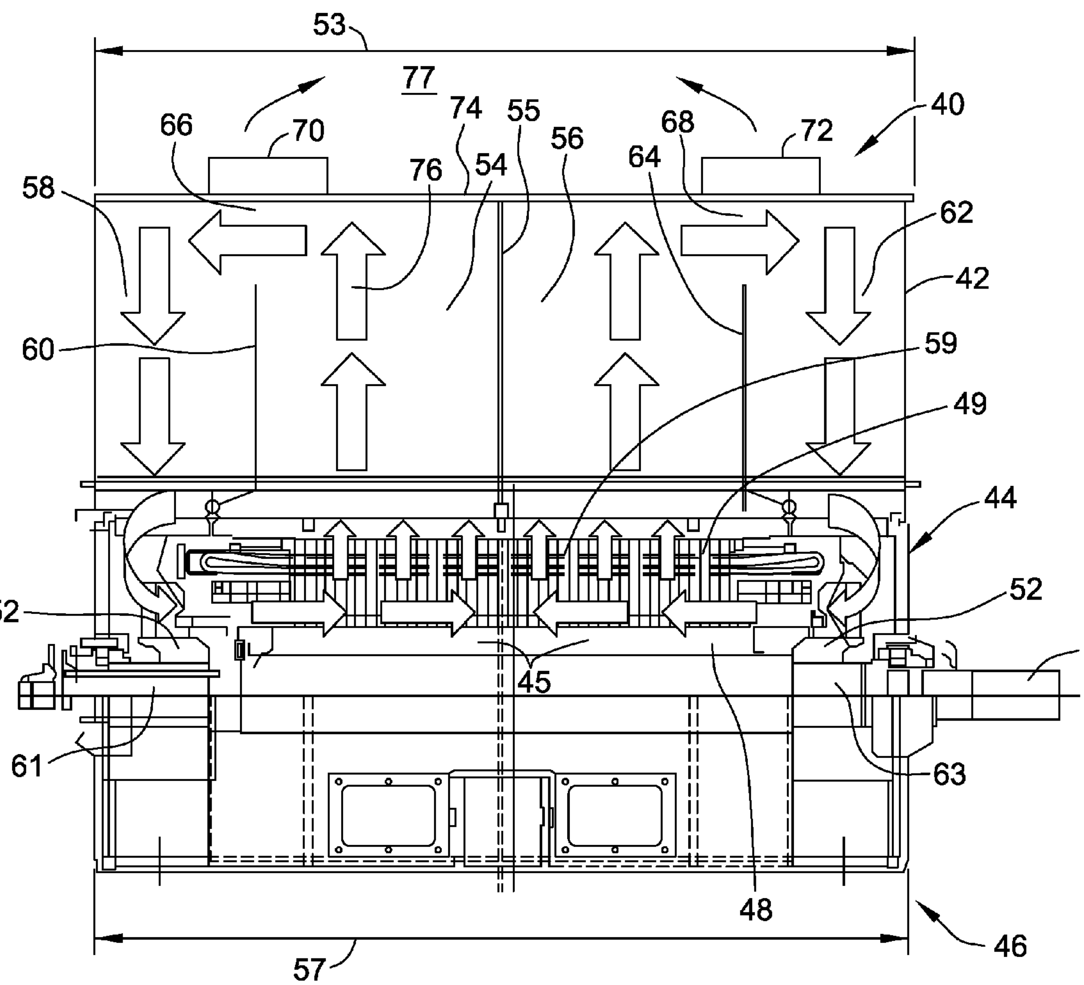
(57) **ABSTRACT**

A cooling system for rotating machines, such as electric motors, is provided. A heat exchanger housing is coupled with the housing of an electric motor. At least one Peltier effect device is coupled to an outer wall of the heat exchanger housing. At least one outflow air passage and at least one return air passage are defined within the heat exchanger housing to extend between the motor housing and the outer wall of the heat exchanger housing. The at least one outflow air passage transports heated air to the outer wall to facilitate heat transfer from the air to the outer wall. The at least one Peltier effect device facilitates heat transfer from the outer wall.



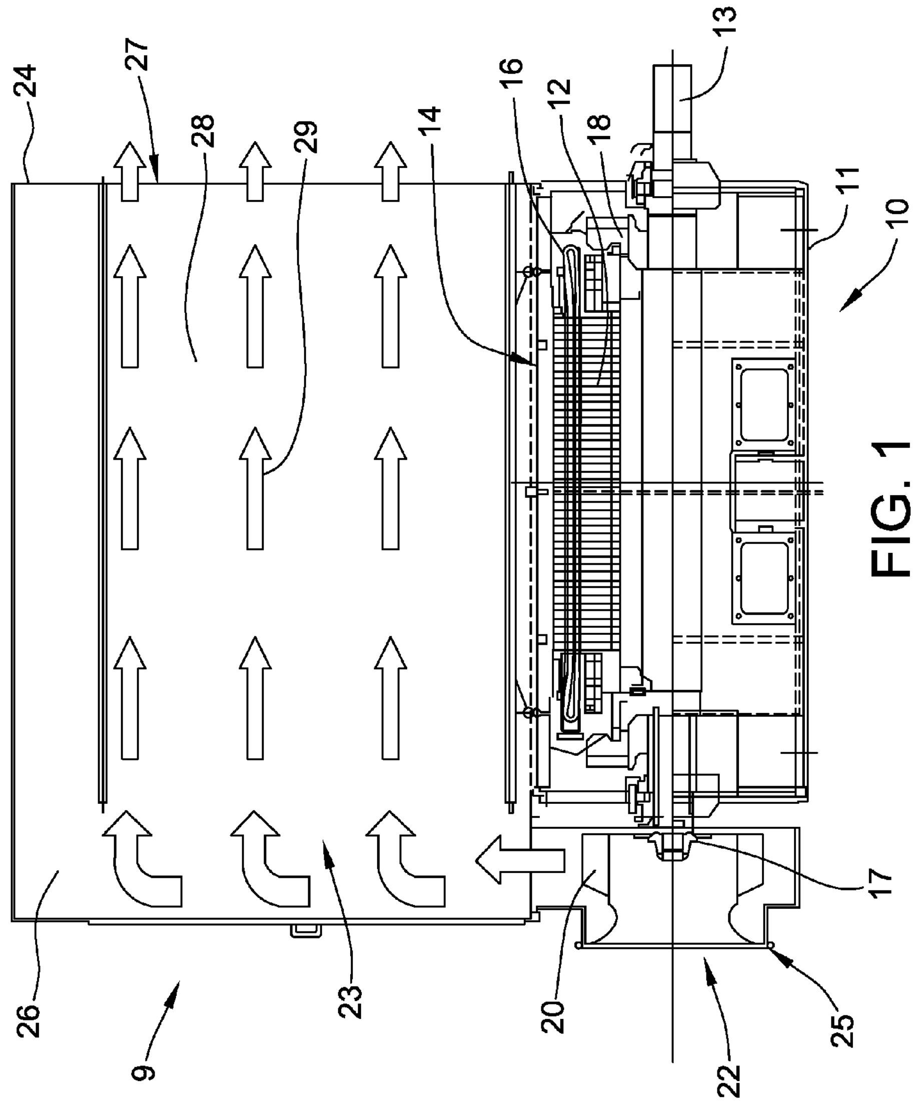


FIG. 1
PRIOR ART

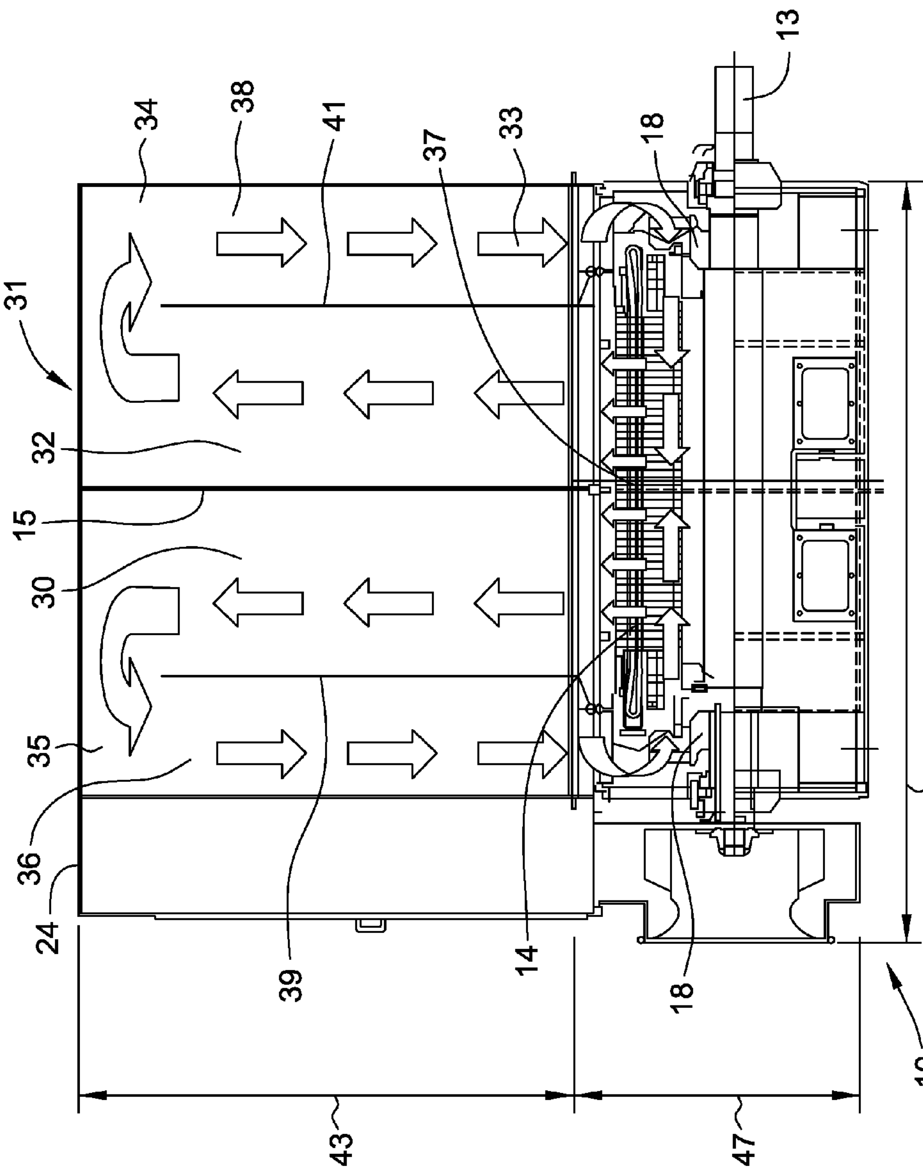


FIG. 2
PRIOR ART

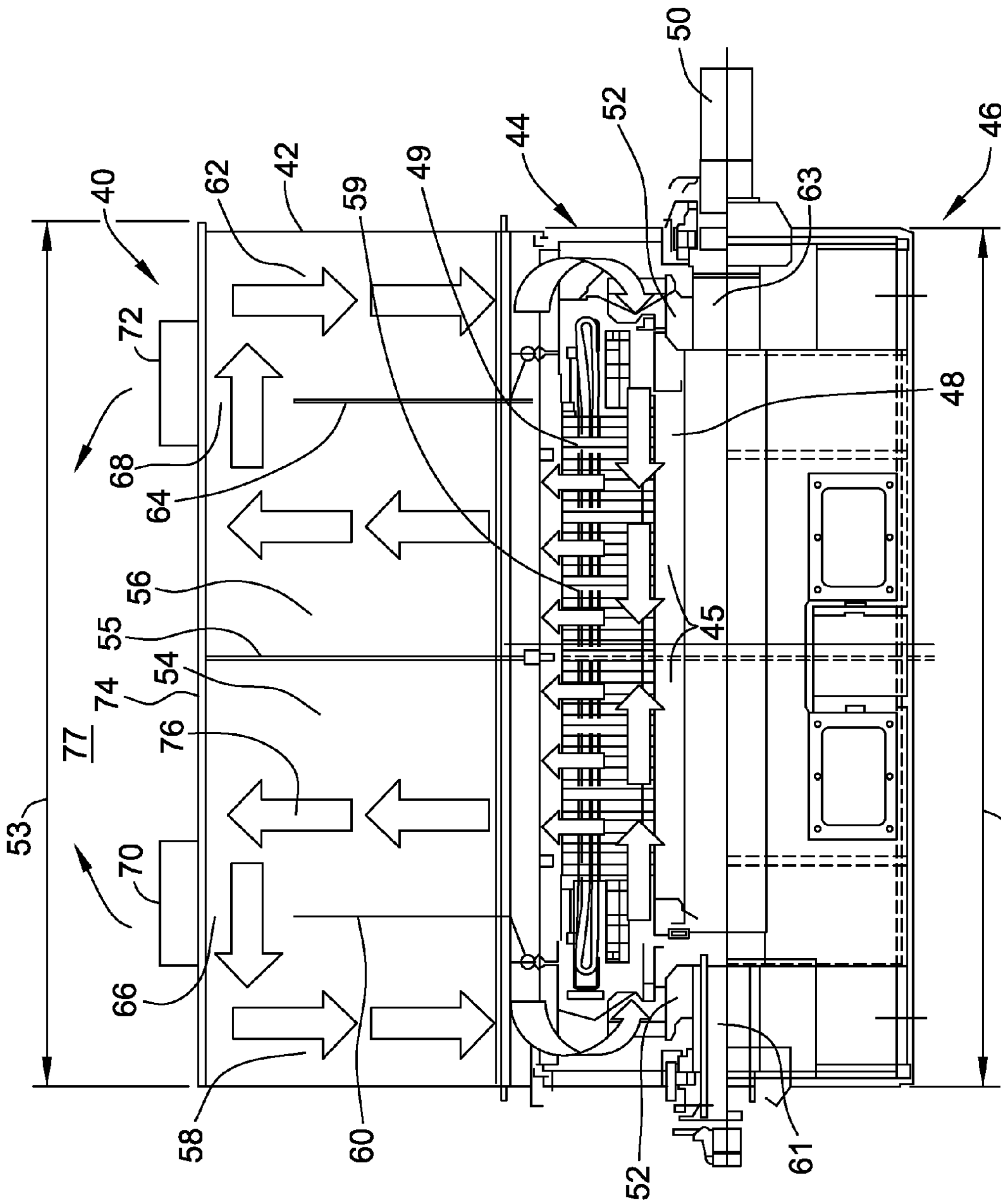

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FIG. 3

COOLING SYSTEM FOR A MACHINE AND METHOD OF ASSEMBLY OF SAME

BACKGROUND OF THE INVENTION

[0001] The present disclosure relates generally to cooling systems for use with machines and more particularly, to methods of assembly for same.

[0002] Machines, such as electric motors, generate heat during operation as a result of both electrical and mechanical losses. Typically, an electric motor must be cooled to ensure efficient and continued operation of the motor. Excessively high motor temperatures may result in motor bearing failure and/or damage to the stator and/or to the rotor, in addition to a general loss of efficiency of the motor.

[0003] Motors are designed based on many considerations. For example, rotor temperature is a limiting factor in motor design as the rotor can generate a disproportionally high amount heat. At least some known electric motors include an enclosure including a frame and endshields. Electric motor enclosures are typically either "open" (cage-like) or totally enclosed. In an open enclosure, ambient air circulates within the enclosure, and heat is removed via convection between the air and higher temperature motor components operating within the enclosure. The heated air is subsequently exhausted from the enclosure. However, the locations in which open enclosure-type motors can be used are generally limited.

[0004] In contrast, totally enclosed electric motors are often used in applications in which the entry of airborne contaminants, such as dirt, oil, or mist, into the enclosure must be prevented. Forced convection cooling within a totally-enclosed motor enclosure is typically provided by a fan coupled to the rotor shaft, external to the enclosure. However, an external, shaft-mounted fan provides only limited heat dissipation with respect to the opposite end of the motor. Consequently, components within the enclosure, such as drive end bearings, can still overheat due to inefficient cooling. Shaft-mounted fans also provide only limited heat dissipation with respect to the rotor. In addition, coupling a fan to the rotor shaft increases the overall footprint of the motor assembly and creates drag on the motor that consumes a portion of the power of the motor.

[0005] Known motor cooling systems typically use air-to-air or air-to-liquid heat exchangers. However, air-to-air heat exchangers may produce objectionable noise, and air-to-liquid heat exchangers are often complex and require more enhanced maintenance requirements, as compared to air-to-air heat exchangers. Moreover, both air-to-air and air-to-liquid heat exchangers require large housings whose dimensions are often larger than those of the motors to which they are coupled. Accordingly, it would be desirable to provide a cooling system for machines, such as electric motors, that provides enhanced and more efficient cooling of a machine, and that has a physically smaller size as compared to known cooling systems.

BRIEF DESCRIPTION OF THE INVENTION

[0006] In one aspect, a cooling system for a machine including a machine housing is provided. The cooling system includes a heat exchanger housing coupled to the machine housing. The heat exchanger housing includes an outer wall, the heat exchanger housing defining at least one outflow air passage therein and coupled in flow communication with an interior region defined in the machine housing. The heat exchanger housing further defines at least one return air passage coupled in flow communication with the interior region of the machine housing to enable air to be channeled from the interior region towards the outer wall for transferring heat from the air to said outer wall. The cooling system further includes at least one Peltier effect device coupled to the outer wall of the heat exchanger housing, the at least one Peltier effect device configured to facilitate heat transfer from the outer wall.

[0007] In another aspect, a method for assembling a cooling system for a machine including a machine housing is provided. The method includes coupling a heat exchanger housing to the machine housing, wherein the heat exchanger housing includes an outer wall. The method also includes coupling at least one outflow air passage defined within the heat exchanger housing in flow communication with an interior region defined in the machine housing. The method also includes coupling at least one return air passage defined within the heat exchanger housing in flow communication with the interior region of the machine housing and in flow communication with the at least one outflow air passage, to enable air to be channeled from the interior region towards the outer wall to facilitate heat transfer heat from the air to the outer wall. The method also includes coupling at least one Peltier effect device to the outer wall of the heat exchanger housing, wherein the at least one Peltier effect device facilitates heat transfer from the outer wall.

[0008] In a further aspect, a machine is provided. The machine includes a housing, and a heat exchanger housing coupled to the machine housing. The heat exchanger housing includes an outer wall, the heat exchanger housing defining at least one outflow air passage coupled in flow communication with an interior region defined in the machine housing. The heat exchanger housing further defines at least one return air passage coupled in flow communication with the machine housing interior region and in flow communication with the at least one outflow air passage to enable air to be channeled from the interior region towards the outer wall to facilitate heat transfer from the outer wall. The machine also includes at least one Peltier effect device coupled to the outer wall, the at least one Peltier effect device configured to facilitate heat transfer from the outer wall.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a side sectional view of an exemplary known motor cooling system.

[0010] FIG. **2** is a side sectional view of the motor cooling system illustrated in FIG. **1**.

[0011] FIG. **3** is a side sectional view of an exemplary motor cooling system.

DETAILED DESCRIPTION OF THE INVENTION

[0012] FIG. **1** is a side sectional view of an exemplary known motor **10**, illustrating a motor cooling system **9**. In the exemplary embodiment, motor cooling system **9** includes an air-to-air cooling circuit **21**, and in particular, an ambient air flow portion **23** of air-to-air cooling circuit **21** is illustrated. Motor **10** includes a motor housing **11** that substantially completely encloses motor **10**, to substantially prevent intrusion of dirt, oil or other contaminants into motor **10**, as well as to substantially prevent the escape of motor lubricant from motor **10**. Motor **10** includes a rotor **12** that is supported on a rotor shaft **13** that is rotatably coupled within motor housing **11**. Rotor **12** is surrounded by a stator **14** including a plurality of end windings **16**. A plurality of fan blades **18** are securely coupled to rotor shaft **13**. An impeller **20** is securely coupled to an end **17** of rotor shaft **13**, external to motor housing **11**.

[0013] A heat exchanger housing **24** is mounted atop motor housing **11**. Ambient air flow portion **23** of air-to-air cooling circuit **21** includes a vertical plenum **26** and one or more transverse air flow passages **28** formed in heat exchanger housing **24**. Heat exchanger housing **24** substantially encloses impeller **20**. An aperture **25** in heat exchanger housing **24** enables ambient air **22** to be drawn into heat exchanger housing **24**, along a path illustrated by arrows **29**. Specifically, during operation of motor **10**, rotation of rotor shaft **13** causes rotation of impeller **20**, thus drawing ambient air **22** through aperture **25**, and through vertical plenum **26**. Ambient air **22** travels along transverse air flow passage **28**, and is eventually discharged from heat exchanger housing **24** through one or more end openings **27** defined in heat exchanger housing **24**.

[0014] FIG. **2** is a side sectional view of motor **10** and illustrates an internal cooling air circuit **31**. In the exemplary embodiment, internal cooling air circuit **31** includes a pair of outflow air passages **30** and **32** that are separated from each other by a wall **15** and by a pair of return air passages **36** and **38**. Outflow air passage **30** is separated from return air passage **36** by a wall **39**, and outflow air passage **32** is separated from return air passage **38** by a wall **41**. Outflow air passage **30** is coupled in flow communication with return air passage **36** via a transverse air passage **35**. Outflow air passage **32** is coupled in flow communication with return air passage **38** via a transverse air passage **34**. Transverse air flow passage **28** (illustrated in FIG. **1**) is isolated from outflow air passages **30** and **32**, and from return air passages **36** and **38**, via a vertical wall (not shown) in heat exchanger housing **24**. Outflow air passages **30** and **32**, and return air passages **36** and **38** are coupled in flow communication with motor **10** via apertures (not shown) defined in motor housing **11**.

[0015] During operation of motor **10**, fan blades **18** draw air **33** towards a central region **37** of motor **10**, and propel air **33** through stator **14**. Air **33** removes heat from rotor **12** and stator **14**. Air **33** is channeled through the apertures defined in motor housing **11** into air passages **30** and **32**. As air **33** rises through outflow air passages **30** and **32**, and subsequently returns through return air passages **36** and **38**, heat is transferred from air **33** through the vertical wall (not shown) and into ambient air **22** passing through transverse air flow passage **28** (illustrated in FIG. **1**). Although only one transverse air flow passage **28**, one pair of outflow air passages **30** and **32**, and one pair of corresponding return air passages **36** and **38** are illustrated in FIGS. **1** and **2**, in typical known motors, multiple transverse air flow passages and multiple pairs of outflow air passages and return air passages are included.

[0016] Cooling of a motor, such as motor **10**, requires the creation of a temperature gradient between motor **10**, specifically high temperature regions of motor **10**, and its surroundings. Motor **10** relies on the use of heat exchanger housing **24** and impeller **20** to provide cooling for motor **10**. In known motor-heat exchanger housing configurations, a height **43** of heat exchanger housing **24** is often as much as twice as high as a height **47** of a motor **10**. The addition of impeller **20** to rotor shaft **13** further increases an overall length **51** of motor **10**. Accordingly, a significant volume of space may be required by the system for cooling motor **10**.

[0017] FIG. **3** is a side sectional view of an exemplary motor cooling system **40** that may be used with motor **10**, for example. In the exemplary embodiment, motor cooling system **40** includes a heat exchanger housing **42** coupled to a motor housing **44** of an electric motor **46**. In the exemplary embodiment, heat exchanger housing **42** has a length **53** that is approximately equal to a length **57** of motor housing **44**. A rotor **48** is rotatably mounted in motor housing **44** to a rotor shaft **50**. A plurality of fan blades **52** are securely coupled to opposed ends **61** and **63** of rotor shaft **50**, to propel air **45** through motor housing **44** and heat exchanger housing **42** along the paths illustrated by arrows **76**. A stator **49** substantially surrounds rotor **48**. Heat exchanger housing **42** includes a pair of outflow air passages **54** and **56** that are separated from each other by a wall **55**. Heat exchanger housing **42** also includes a return air passage **58** that is located adjacent to, and separated from, outflow air passage **54** by a wall **60**. Heat exchanger housing **42** also includes a return air passage **62** that is located adjacent to, and separated from, outflow air passage **56** by a wall **64**. Outflow air passage **54** communicates with return air passage **58** via an opening **66**, and outflow air passage **56** communicates with return air passage **62** via an opening **68**. Each passage **54** and **56**, and each passage **58** and **62**, is coupled in flow communication with an interior **59** of motor housing **44** through apertures (not shown) defined in motor housing **44**. Although in the exemplary motor cooling system **40**, only one pair of outflow air passages **54** and **56**, and only one pair of return air passages **58** and **62** are illustrated, in alternative embodiments, additional outflow air passages and/or return air passages are provided.

[0018] In contrast to heat exchanger housing **24** (shown in FIGS. **1** and **2**), that includes both vertically-extending passages **30**, **32**, **34**, and **36**, as well as transverse passage **28**, heat exchanger housing **42** includes only substantially vertically-extending passages **54**, **56**, **58**, and **62**, thus incorporating a simpler heat exchanger housing configuration. Accordingly, heat exchanger housing **42** is simpler to construct and maintain than known air-to-air or liquid-to-air heat exchanger housing constructions.

[0019] A pair of Peltier effect devices **70** and **72** is securely coupled to an outer wall **74** of heat exchanger housing **42**. Peltier effect devices **70** and **72** are of any suitable configuration as needed to enable motor cooling system **40** to function as described herein. In the exemplary motor cooling system **40**, Peltier effect devices **70** and **72** are powered by an electrical power supply (not shown), are coupled to suitable control devices (not shown), and are secured to heat exchanger housing **42** in such a manner, that when powered, Peltier effect devices **70** and **72** conduct heat away from heat exchanger housing **42**. Specifically, Peltier effect devices **70** and **72** channel heat conducted through outer wall **74** to an ambient atmosphere **77** through the creation of a steep temperature gradient, within each of Peltier effect devices **70** and **72**, which is greater than a temperature gradient achievable through heat transfer accomplished by simple conduction and/or impeller or fan-induced convection.

[0020] When motor **46** is in operation, rotation of rotor shaft **50** causes fan blades **52** to propel air within motor **46** and heat exchanger housing **42** (as illustrated by arrows **76**) along rotor **48** and through stator **49**, in a manner similar to that as described herein with respect to motor **10** (shown in FIGS. **1** and **2**). As heated air is propelled by fan blades **52** from motor housing **44**, and through outflow air passages **54** and **56** towards outer wall **74**, heat is transferred to outer wall **74**. As

Peltier devices **70** and **72** function as heat sinks, heat in outer wall **74** is subsequently transferred away from outer wall **74** by Peltier effect devices **70** and **72**, into the ambient atmosphere. Cooled air is channeled away from outer wall **74** and returned to motor housing **44** via openings **66** and **68**, and return air passages **58** and **62**. In an exemplary embodiment, Peltier effect devices **70** and **72** are powered only during operation of motor **46**. In an alternative embodiment, Peltier effect devices **70** and **72** remain powered for a predefined period of time after operation of motor **46** has ended, to facilitate continued cooling of motor **46**. In the exemplary embodiment, the use of Peltier effect devices **70** and **72** means that the circulation of air **45** within heat exchanger housing **42** that is provided by fan blades **52** is sufficient to enable effective removal of heat from air **45**, without the need for an additional impeller, such as impeller **20** (shown in FIG. **1**).

[0021] Exemplary embodiments of a cooling system for a machine and method for assembling same are described above in detail. The cooling system for a machine and method for assembling same are not limited to the specific embodiments described herein, but rather, components of the cooling system and/or steps of the method can be utilized independently and separately from other components and/or steps described herein. For example, the cooling systems and methods described herein can also be used in combination with other machines and methods, and are not limited to practice with only the motor as described herein. Rather, the exemplary embodiments can be implemented and utilized in connection with many other motor and/or turbine and/or power and/or generator applications.

[0022] Although specific features of various embodiments of the invention may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the invention, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

[0023] In contrast to known electric motor cooling systems, the cooling systems described herein facilitate increased heat dissipation from the motor, through the use of Peltier effect devices coupled to the motor housing, in combination with outflow and return air passages defined within the heat exchanger housing. In addition, the cooling systems described herein permit electric motors to be constructed with significantly reduced footprints and reduced overall package volumes and weights. The cooling systems described herein also create a steeper temperature gradient between a motor housing and the ambient surroundings, resulting in more efficient and effective cooling of an electric motor, and accordingly, improved motor efficiency. The cooling systems described herein also eliminate the need for rotor shaft-mounted impellers or fans. The cooling systems described herein also reduce maintenance requirements by enabling the use of a simplified heat exchanger housing. The cooling systems described herein also provide a reduction in overall motor noise as compared to fan-equipped air-to-air heat exchanger-provided motors. The cooling systems described herein also provide for increased bearing life due to improved cooling of the motor bearings.

[0024] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is formed by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A cooling system for a machine including a machine housing, said cooling system comprising:

a heat exchanger housing coupled to the machine housing, said heat exchanger housing comprising an outer wall, said heat exchanger housing defining at least one outflow air passage therein and coupled in flow communication with an interior region defined in the machine housing, said heat exchanger housing further defining at least one return air passage coupled in flow communication with the interior region of the machine housing to enable air to be channeled from the interior region towards said outer wall for transferring heat from the air to said outer wall; and

at least one Peltier effect device coupled to said outer wall of said heat exchanger housing, said at least one Peltier effect device configured to facilitate heat transfer from said outer wall.

2. A cooling system in accordance with claim **1**, wherein said at least one outflow air passage comprises at least two outflow air passages separated from each other by a dividing wall.

3. A cooling system in accordance with claim **1**, wherein said at least one outflow air passage extends substantially parallel to said return air passage.

4. A cooling system in accordance with claim **1**, wherein said at least one outflow air passage extends from the machine housing to said outer wall.

5. A cooling system in accordance with claim **1**, wherein said at least one return air passage extends from the machine housing to said outer wall.

6. A cooling system in accordance with claim **1**, wherein the machine includes a rotor shaft, at least one of said at least one outflow air passage and said at least one return air passage is oriented substantially perpendicular to the rotor shaft.

7. A cooling system in accordance with claim **1**, wherein the machine housing has a first length, and said heat exchanger housing has a second length that is approximately equal to the machine housing first length.

8. A cooling system in accordance with claim **1**, wherein said at least one outflow air passage is adjacent to said at least one return air passage.

9. A method for assembling a cooling system for a machine including a machine housing, said method comprising:

coupling a heat exchanger housing to the machine housing, wherein the heat exchanger housing includes an outer wall;

coupling at least one outflow air passage defined within the heat exchanger housing in flow communication with an interior region defined in the machine housing;

coupling at least one return air passage defined within the heat exchanger housing in flow communication with the interior region of the machine housing and in flow communication with the at least one outflow air passage, to enable air to be channeled from the interior region towards the outer wall to facilitate heat transfer heat from the air to the outer wall; and coupling at least one Peltier effect device to the outer wall of the heat exchanger housing, wherein the at least one Peltier effect device facilitates heat transfer from the outer wall.

10. A method in accordance with claim **9**, wherein coupling at least one outflow air passage comprises:

coupling at least two outflow air passages within the heat exchanger housing; and

isolating the at least two outflow air passages from each other by a dividing wall.

11. A method in accordance with claim **9**, further comprising coupling said at least one outflow air passage parallel to said return air passage.

12. A method in accordance with claim **9**, further comprising coupling said at least one outflow air passage to extend from the machine housing to said outer wall.

13. A method in accordance with claim **9**, further comprising coupling said at least one return air passage to extend from the machine housing to said outer wall.

14. A method in accordance with claim **9**, wherein the machine includes a rotor shaft, said method further comprising orienting at least one of said at least one outflow air passage and said at least one return air passage substantially perpendicular to the rotor shaft.

15. A method in accordance with claim **9**, wherein the machine housing has a first length, said method further comprising configuring said heat exchanger housing with a second length that is approximately equal to the machine housing first length.

16. A method in accordance with claim **9**, further comprising coupling said at least one outflow air passage adjacent to said at least one return air passage.

17. A machine comprising:

a housing;

a heat exchanger housing coupled to the machine housing, said heat exchanger housing comprising an outer wall, said heat exchanger housing defining at least one outflow air passage coupled in flow communication with an interior region defined in the machine housing, said heat exchanger housing further defining at least one return air passage coupled in flow communication with said machine housing interior region and in flow communication with said at least one outflow air passage to enable air to be channeled from said interior region towards said outer wall to facilitate heat transfer from said outer wall; and

at least one Peltier effect device coupled to said outer wall, said at least one Peltier effect device configured to facilitate heat transfer from said outer wall.

18. A machine in accordance with claim **17**, wherein said at least one outflow air passage comprises two outflow air passages separated from each other by a dividing wall.

19. A machine in accordance with claim **17**, wherein said at least one outflow air passage extends substantially parallel to said return air passage.

20. A machine in accordance with claim **17**, wherein said at least one outflow air passage extends from the machine housing to said outer wall.

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