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(54) **ENGINE COOLING SYSTEMS FOR SNOWMOBILES**

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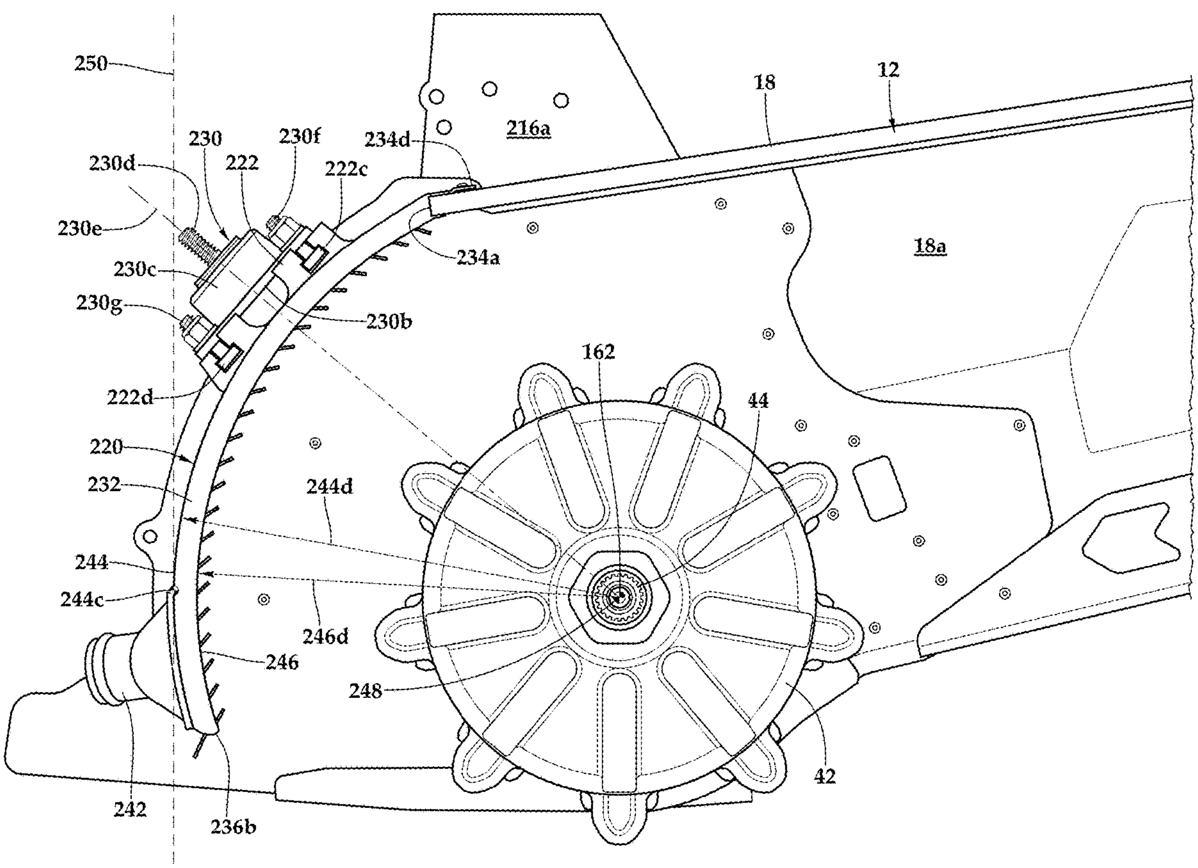
(57) **ABSTRACT**

An engine cooling system for a snowmobile that includes a forward frame assembly, an engine, a tunnel and a track driveshaft having an axis of rotation. The cooling system includes a heat exchanger that is coupled to the forward frame assembly and to the tunnel. The heat exchanger is positioned aft of the engine and is configured to transfer heat from a coolant fluid circulated through the engine and the heat exchanger. The heat exchanger includes a body having an arcuate section with a substantially constant radius of curvature and with a center of curvature proximate the axis of rotation of the track driveshaft.



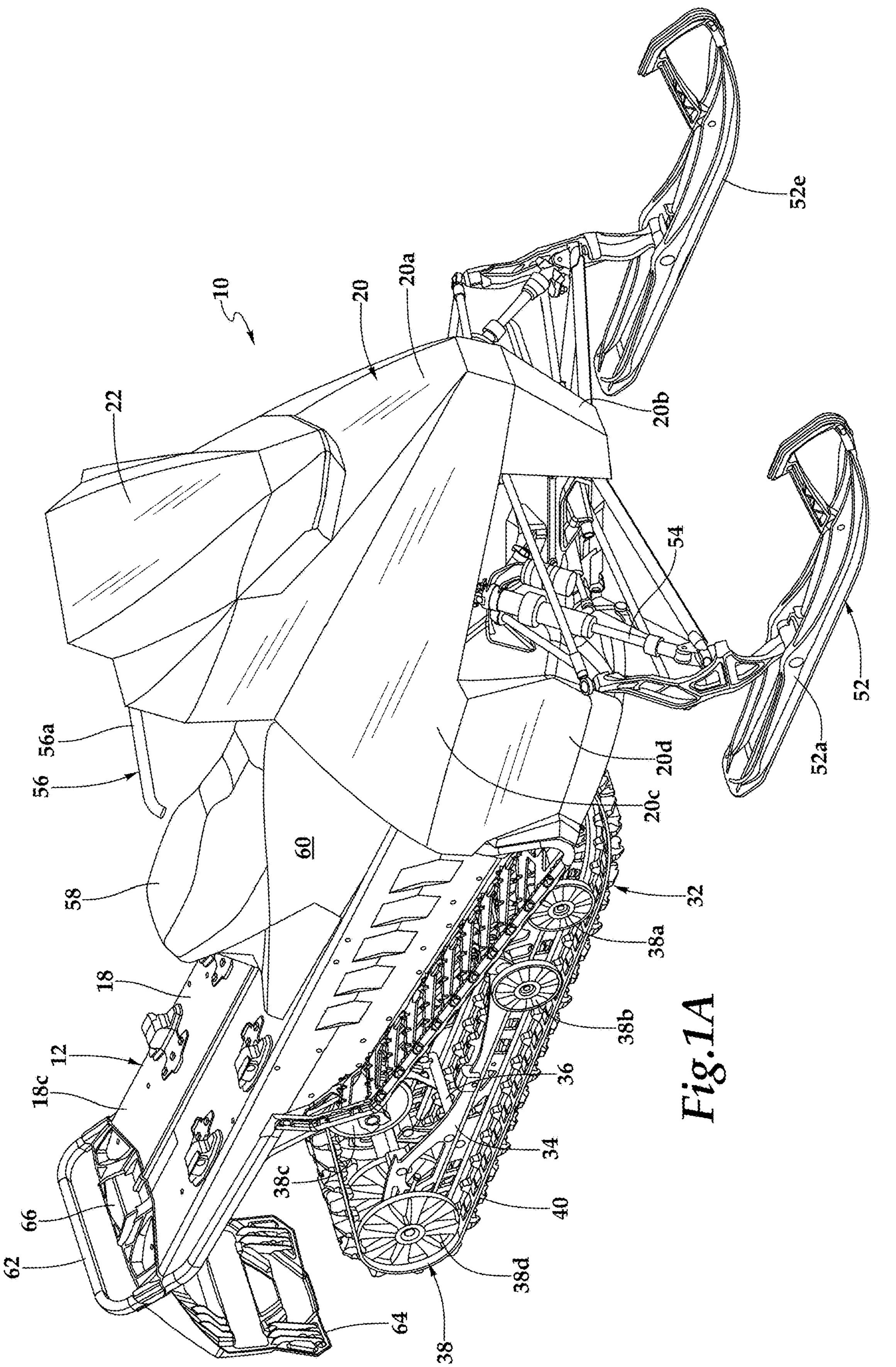

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Fig.1A

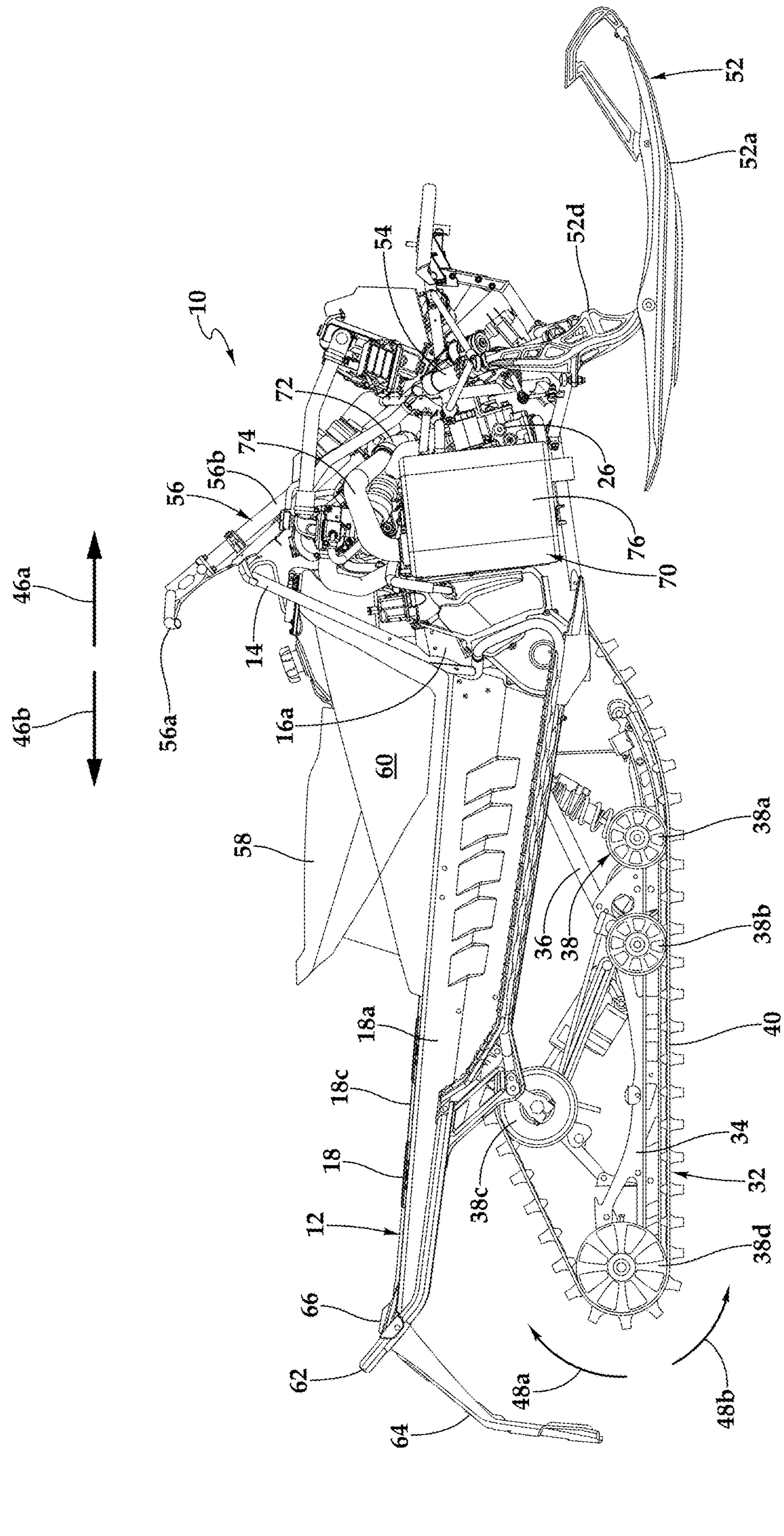
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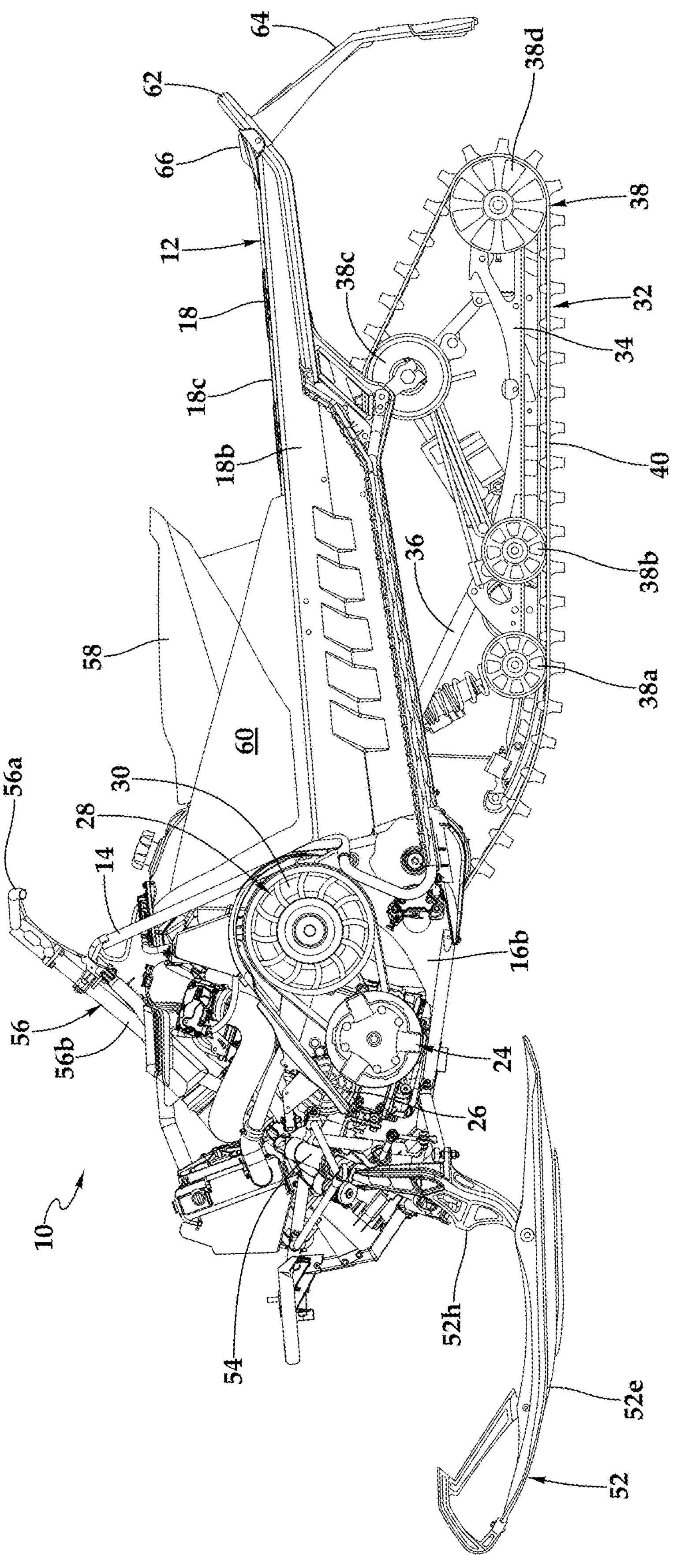
Fig.1B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56b
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52h
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52e
52

Fig.1C

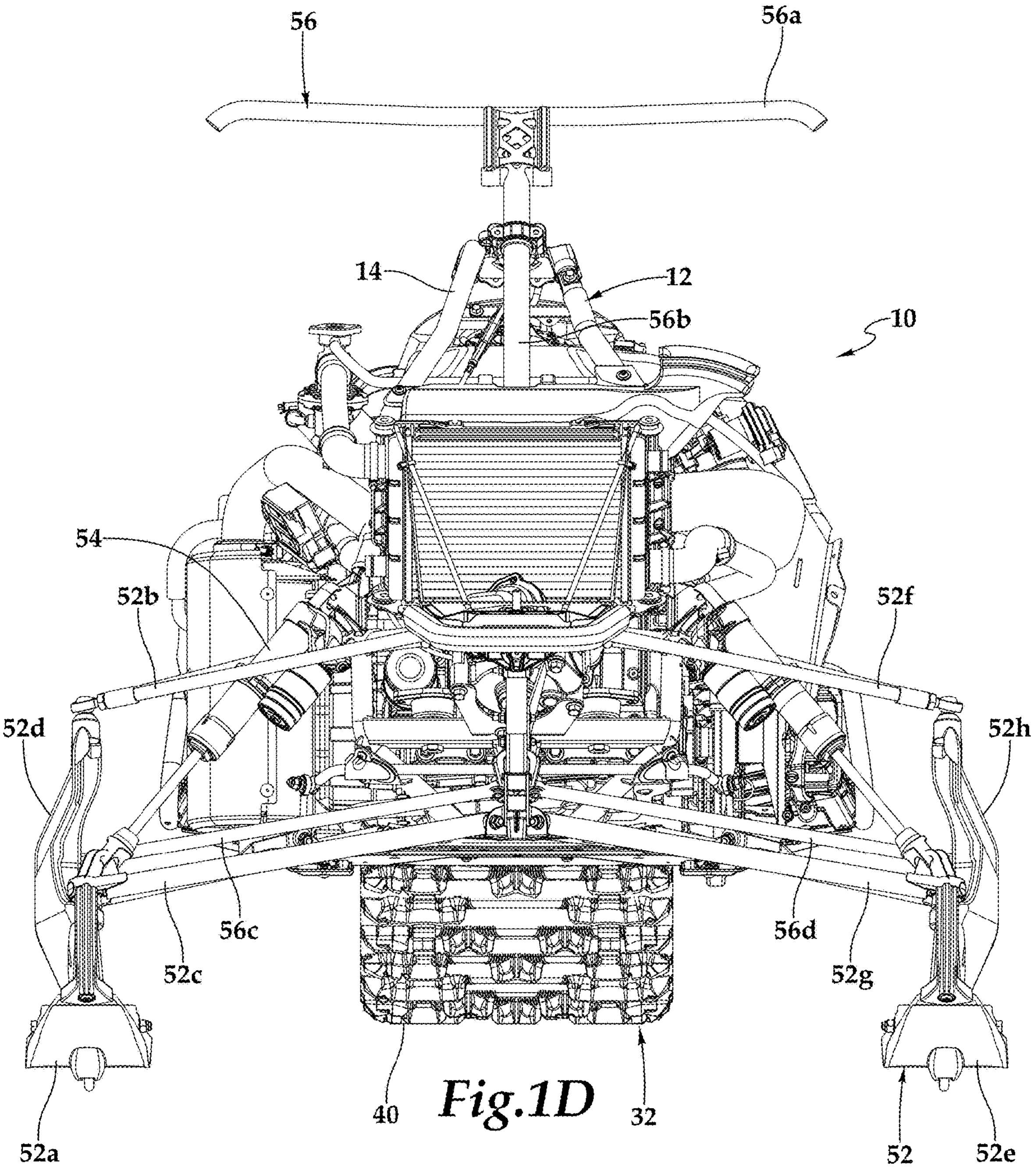
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Fig.1D

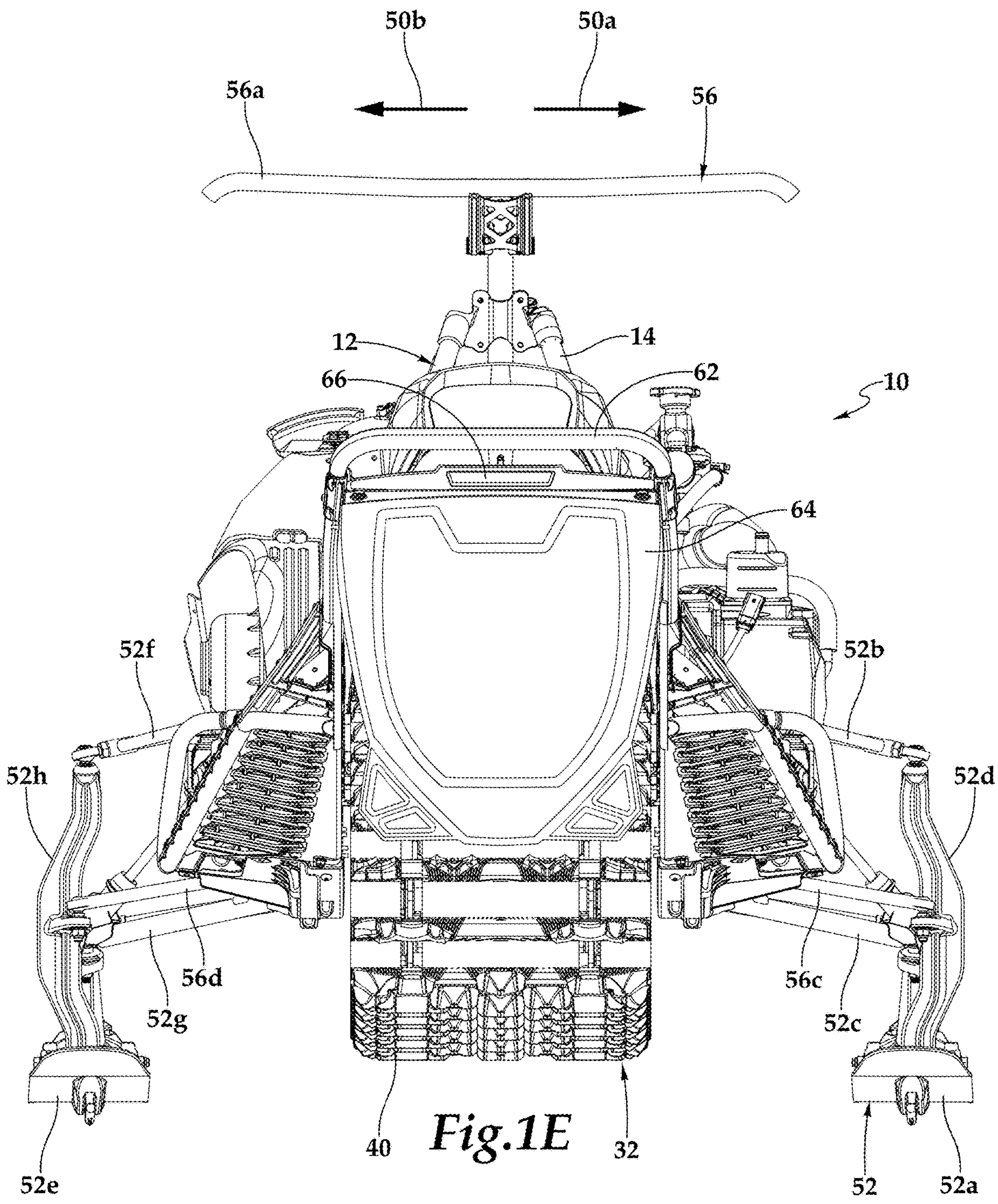
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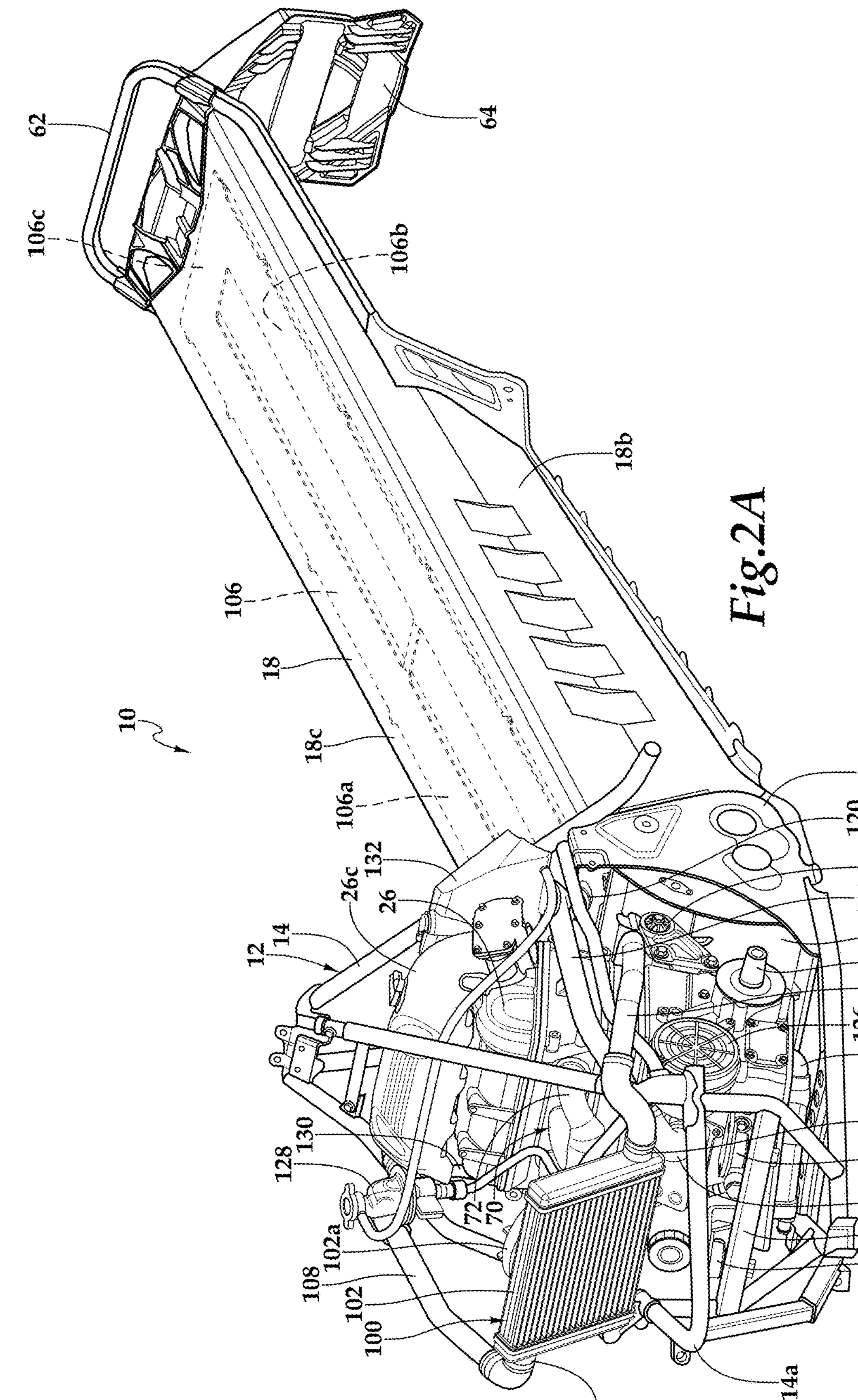
Fig.1E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70
72
100
102
102a
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106c
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130
132

Fig.2A

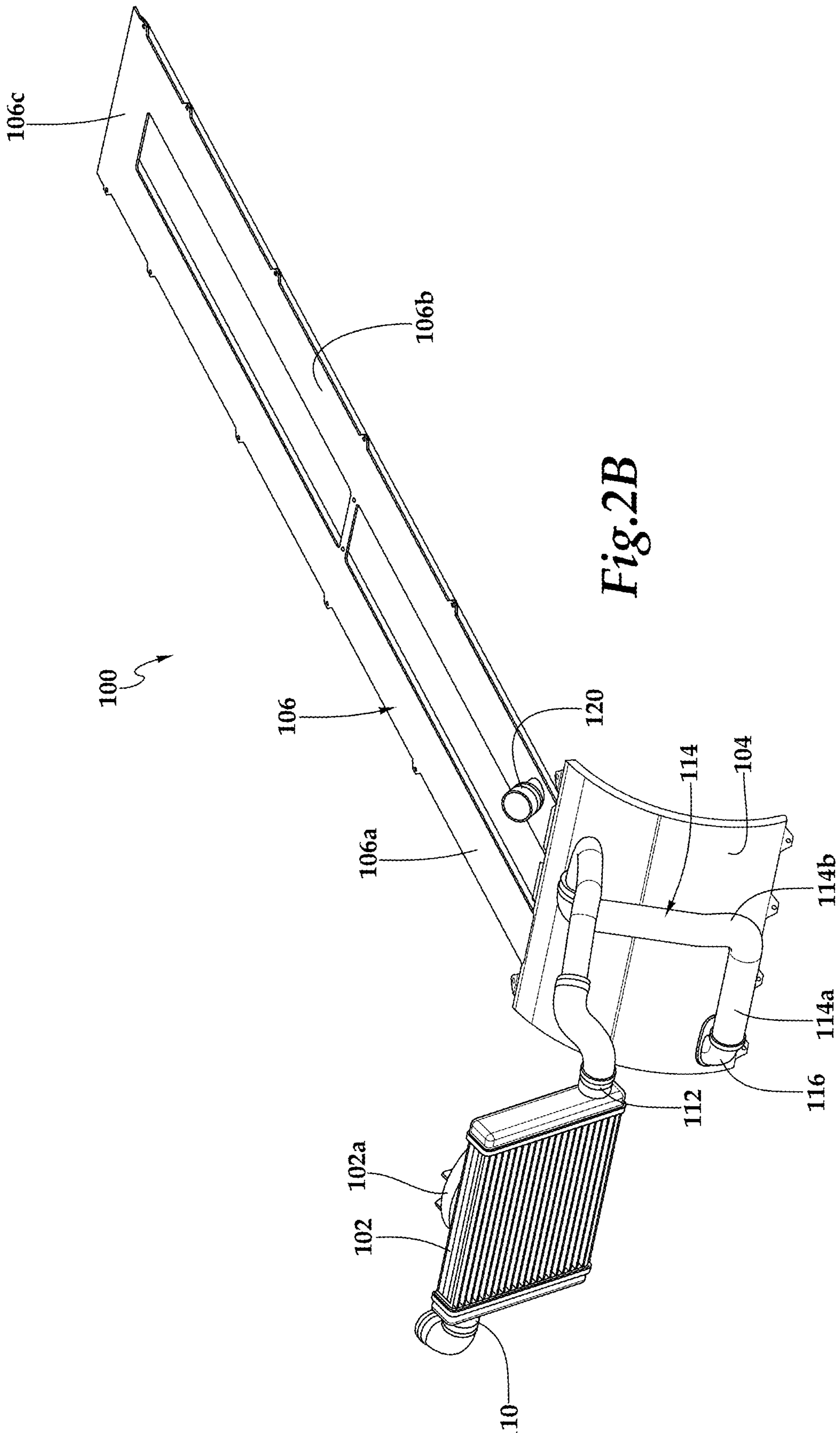
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Fig.2B

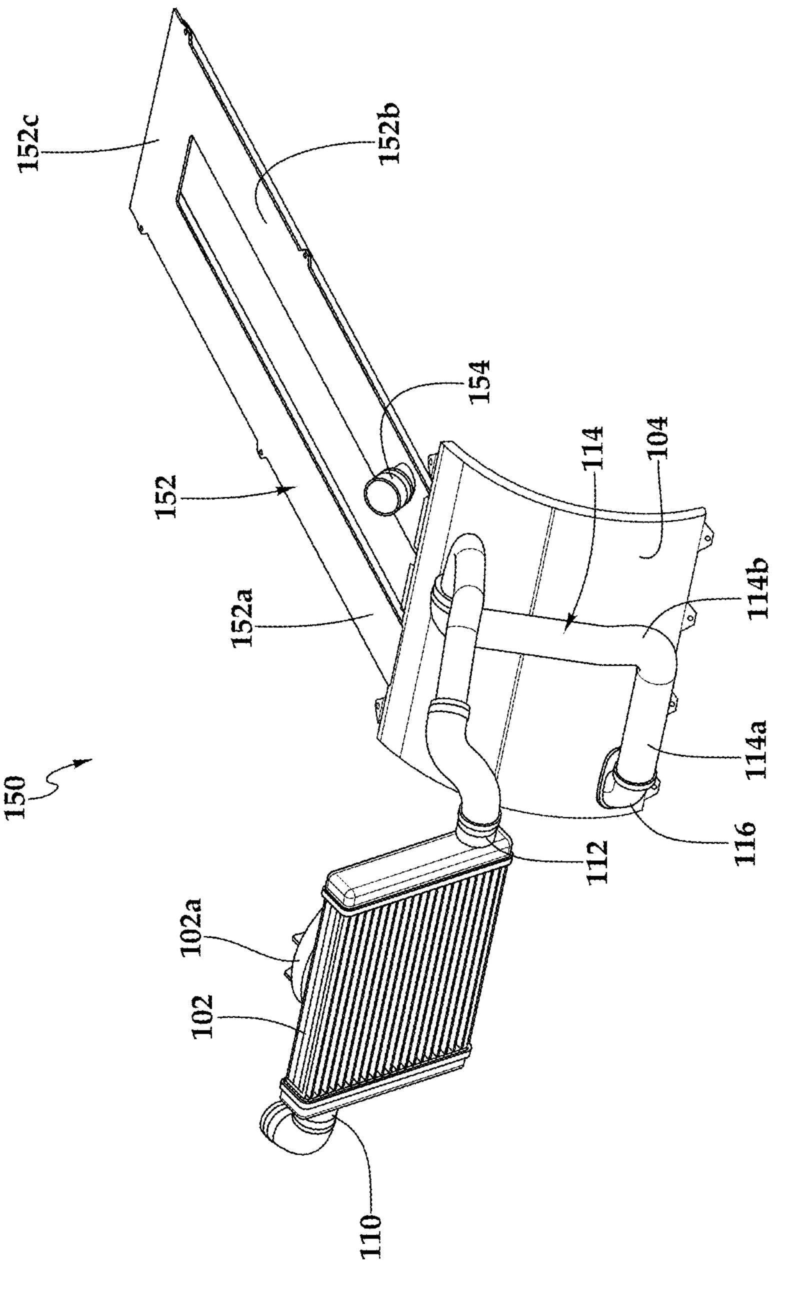
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Fig.3

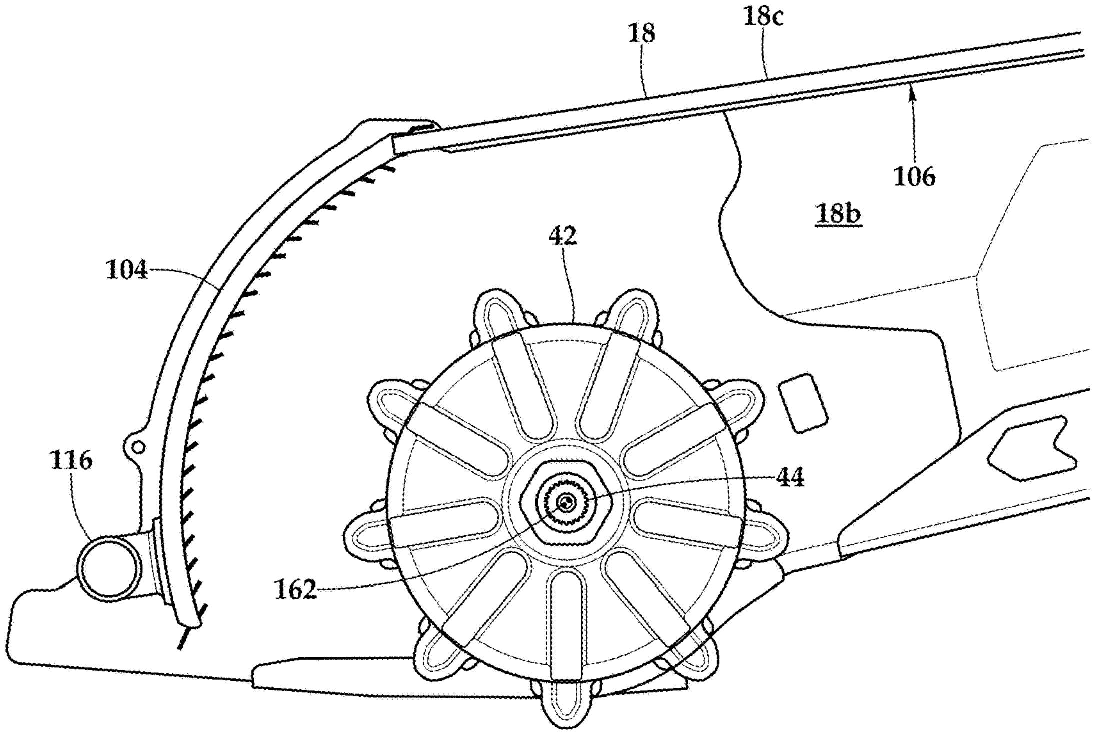
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Fig.4A

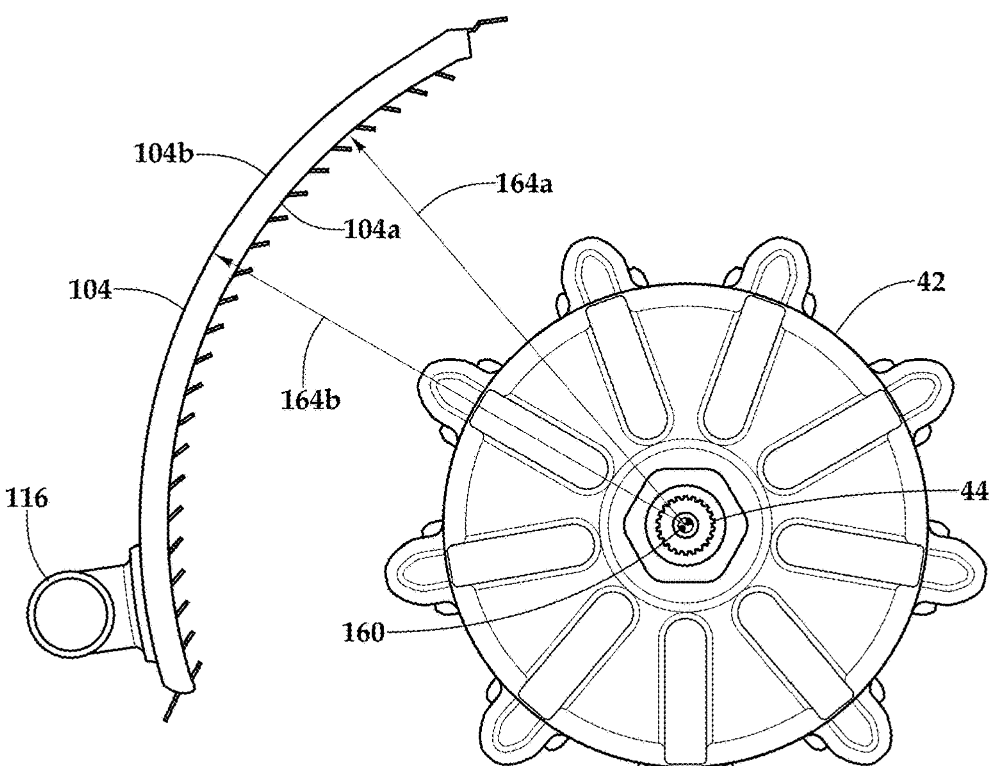
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Fig.4B

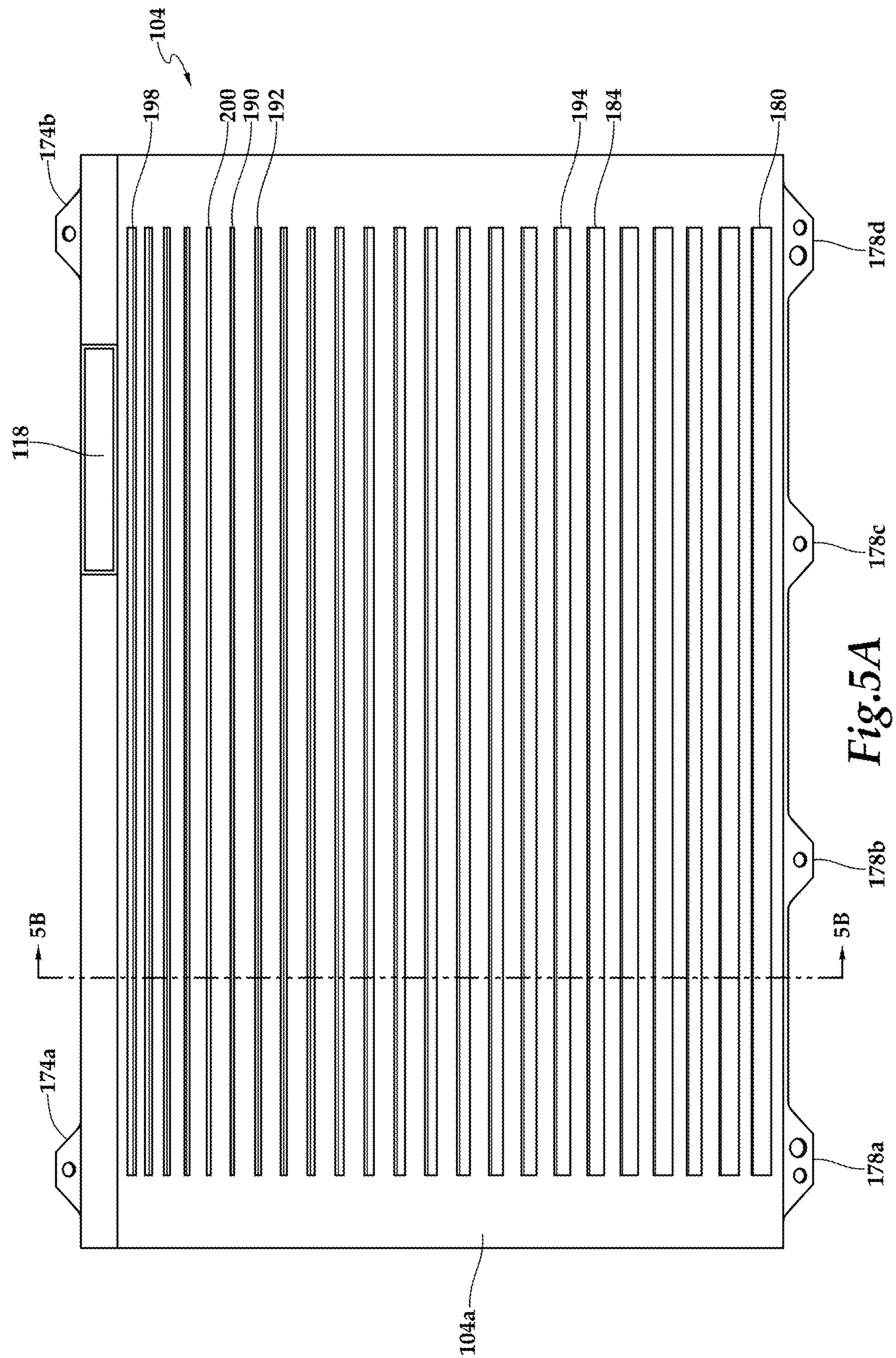
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Fig.5A

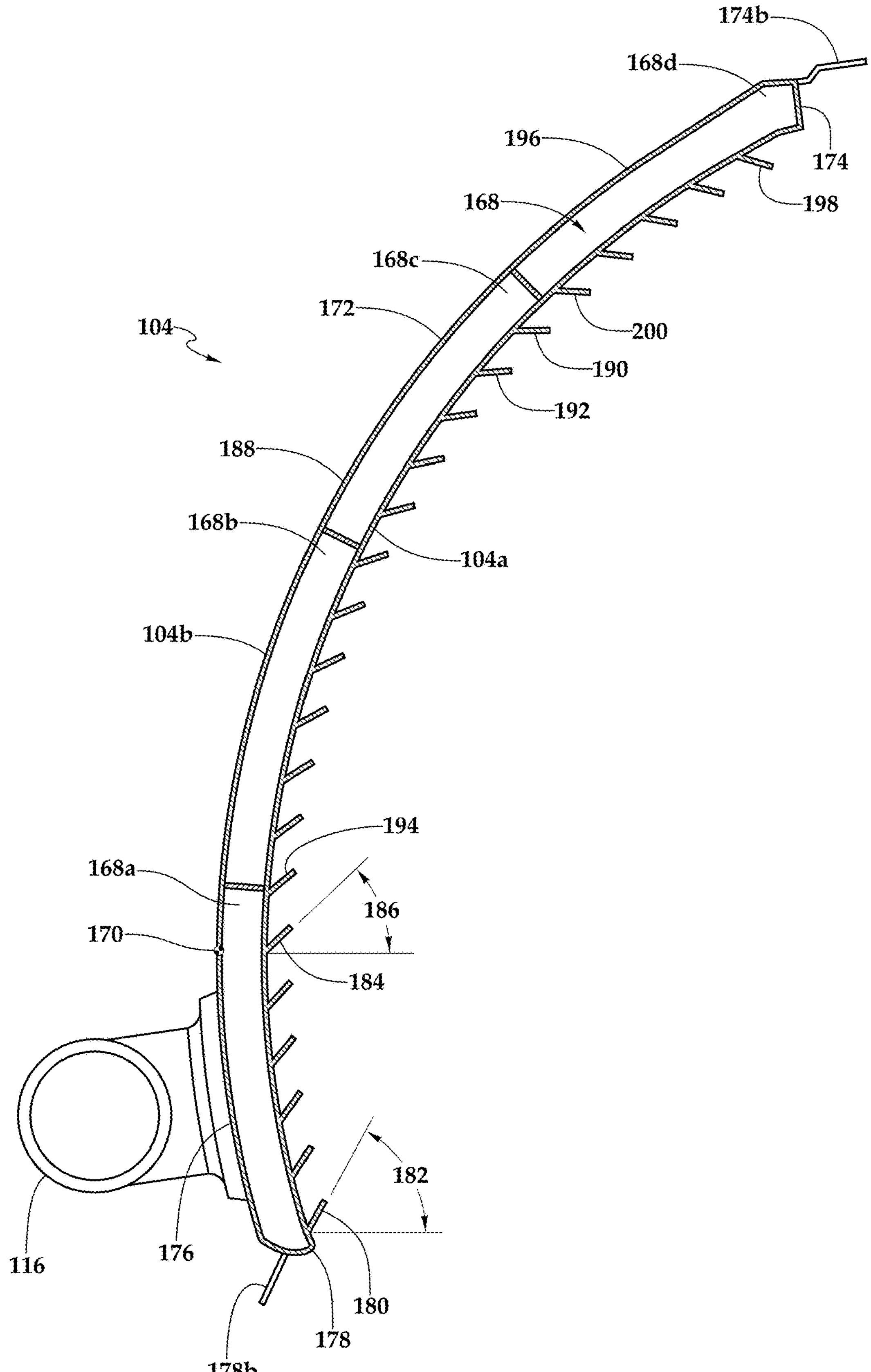
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Fig.5B

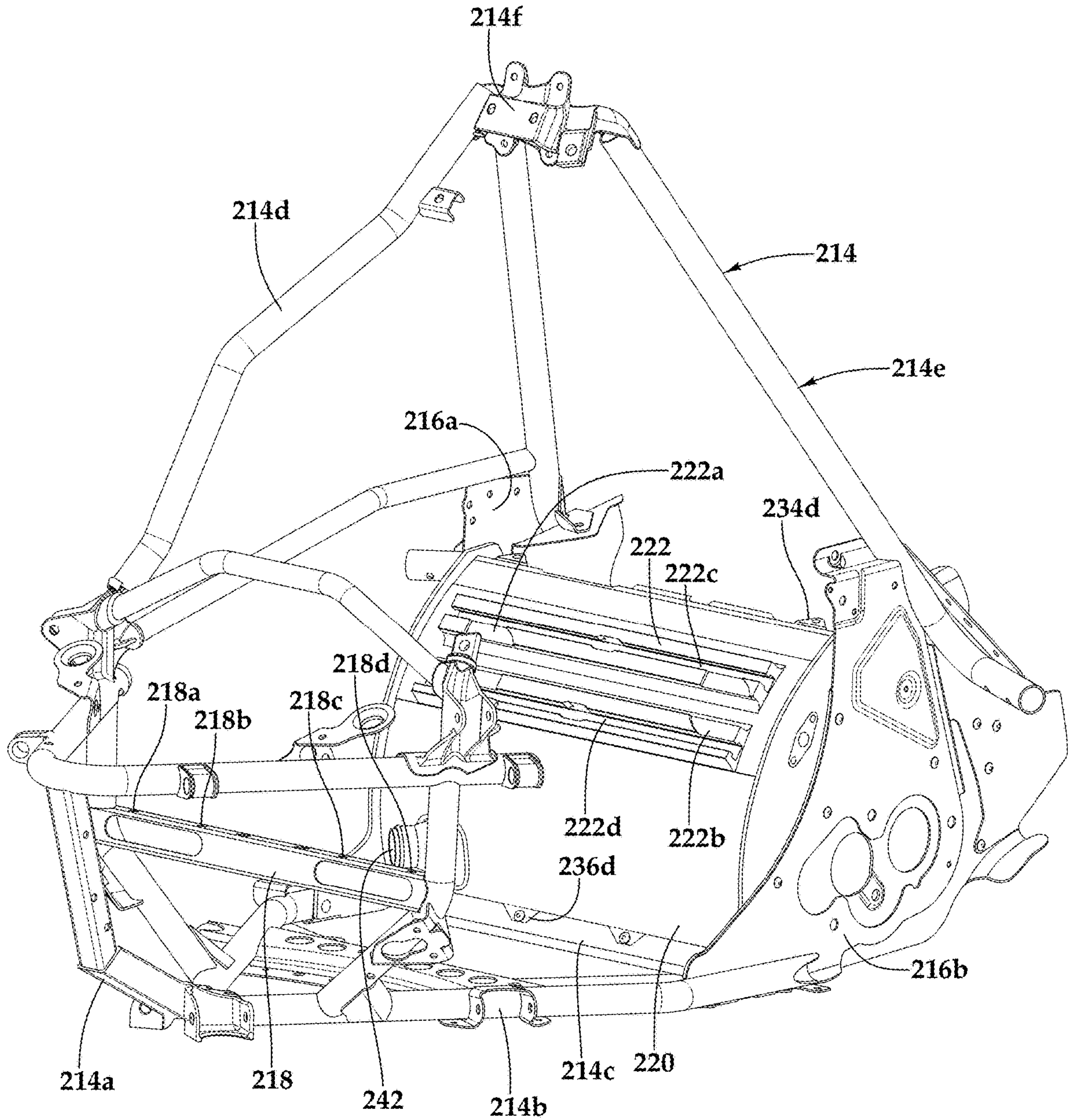
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Fig.6A

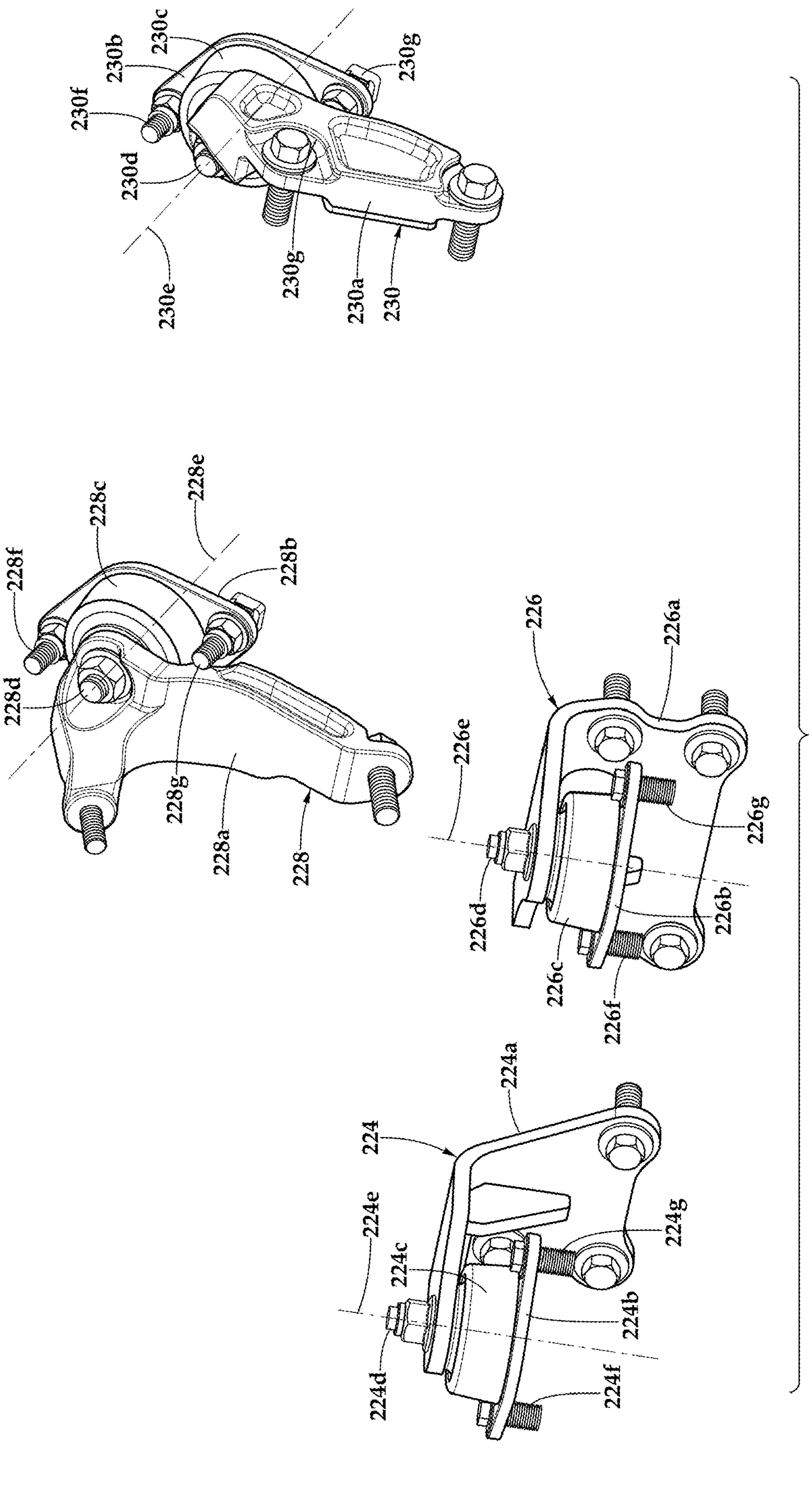
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Fig.6B

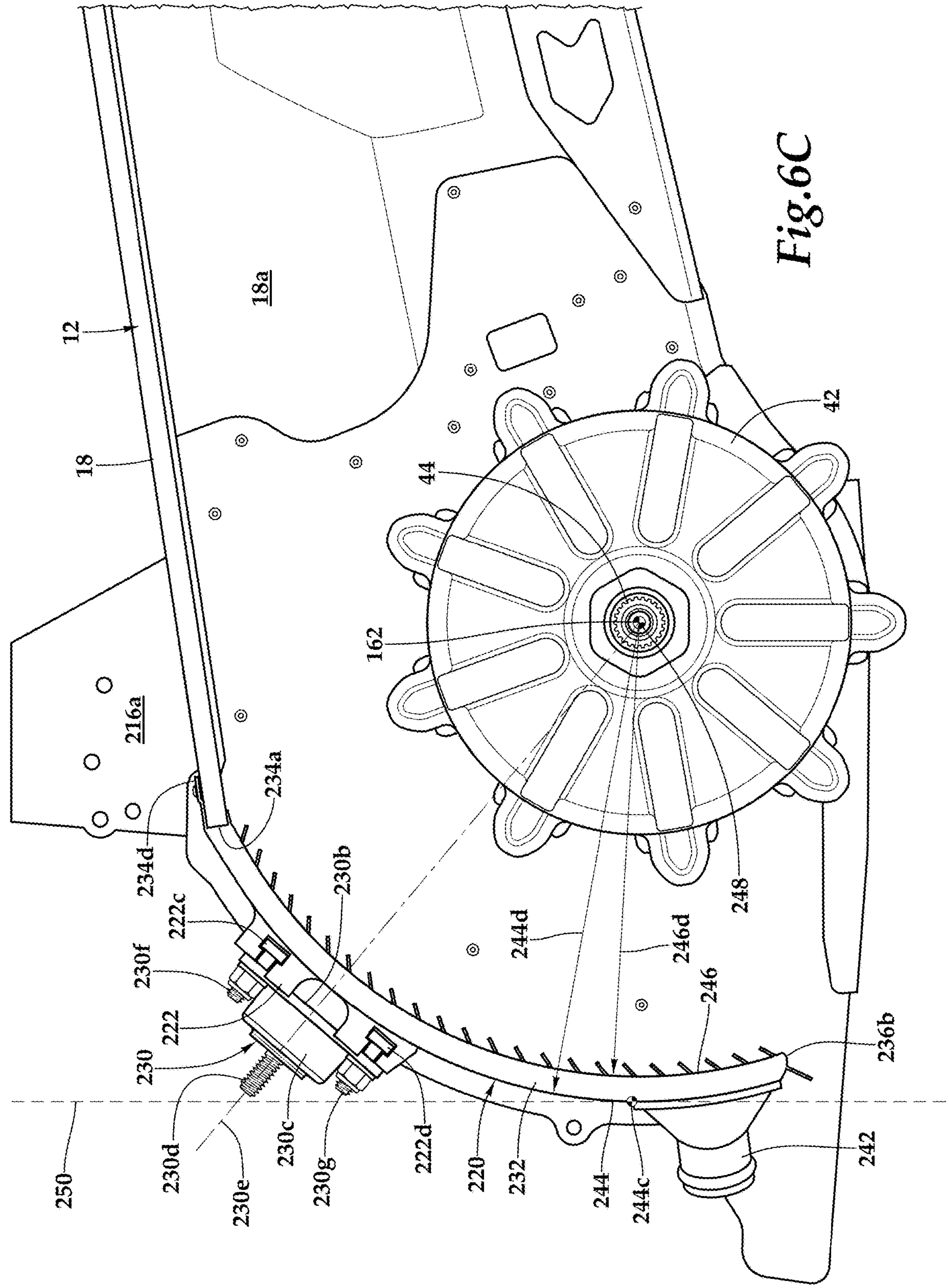
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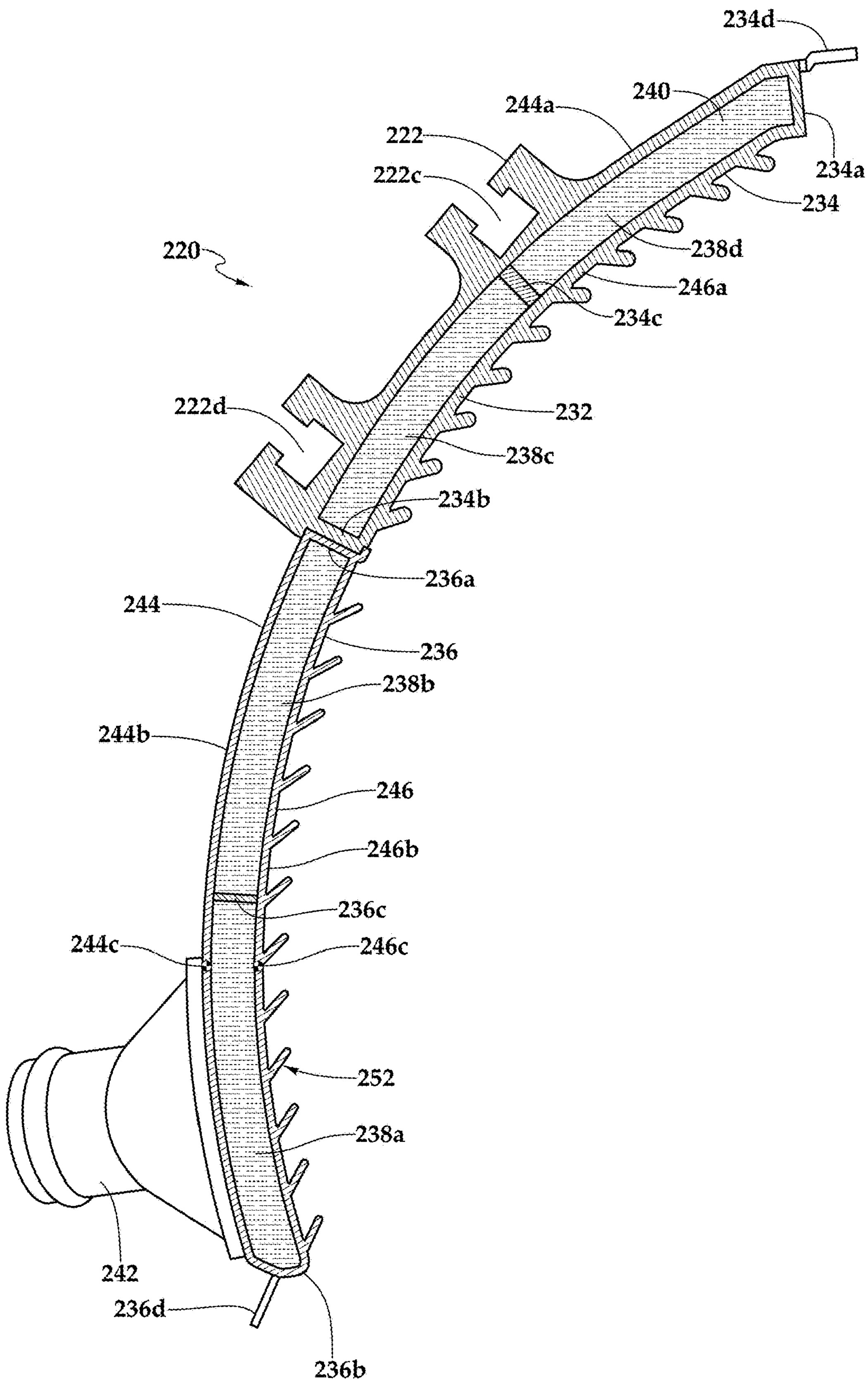
Fig.6C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238b
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246b
236c
244c
246c
252
238a
242
236d
236b

Fig.6D

ENGINE COOLING SYSTEMS FOR SNOWMOBILES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Application No. 63/528,411, filed Jul. 23, 2023 and U.S. Provisional Application No. 63/537,179, filed Sep. 7, 2023, the entire contents of each is hereby incorporated by reference.

TECHNICAL FIELD OF THE DISCLOSURE

[0002] The present disclosure relates, in general, to engine cooling systems for use on land vehicles and, in particular, to engine cooling systems for use on snowmobiles that include a heat exchanger having a body with an arcuate section that expands the engine bay to accommodate a larger four-stroke engine in a chassis designed for a two-stroke engine.

BACKGROUND

[0003] Snowmobiles are popular land vehicles used for transportation and recreation in cold and snowy conditions. Certain snowmobiles are designed for specific applications such as trail, utility, mountain, race and crossover applications, to name a few. Snowmobiles typically include a chassis that supports various components of the snowmobile such as an engine, a transmission and a ground-engaging endless drive track disposed in a longitudinally extending tunnel. The engine and transmission power the drive track to enable ground propulsion for the vehicle. A rider controls the operation of the snowmobile using a steering system including a handlebar assembly that is operatively linked to a pair of ski assemblies that provide flotation for the front of the snowmobile over the snow.

[0004] The engine used in snowmobiles is typically a naturally aspirated internal combustion engine. For example, some snowmobiles utilize a two-stroke internal combustion engine due to the compact size, efficient design and high power-to-weight ratio of such engines. Other snowmobiles utilize a four-stroke internal combustion engine due to the high fuel efficiency, low noise, reduced emissions and simplified refueling process. To increase the power output of a snowmobile without increasing the size of the engine, certain snowmobiles add a forced induction system to the engine such as a turbocharger. Snowmobile engines are typically cooled by circulating a coolant through an engine cooling system that receives warmed coolant from the engine, passes the warmed coolant through one or more heat exchangers to remove heat and then returns cooled coolant back to engine, thereby forming a cooling circuit. One type of heat exchanger found on snowmobiles is a radiator that cools the circulating coolant with air passing therethrough. Another type of heat exchanger found on snowmobiles is a tunnel heat exchanger that cools the circulating coolant due to snow present in the tunnel during snowmobile operations.

SUMMARY

[0005] In a first aspect, the present disclosure is directed to an engine cooling system for a snowmobile that has a forward frame assembly, an engine cooled by a fluid, a tunnel and a track driveshaft having an axis of rotation. The cooling system includes a radiator, a heat exchanger and a tunnel heat exchanger. The radiator is coupled to the forward frame assembly and is positioned forward of the engine. The radiator is configured to remove heat from the fluid responsive to air passing therethrough. The heat exchanger is coupled to a forward portion of the tunnel and is positioned aft of the engine. The heat exchanger is configured to remove heat from the fluid responsive to snow in the tunnel. The heat exchanger has a substantially constant radius of curvature with a center of curvature proximate the axis of rotation of the track driveshaft. The tunnel heat exchanger is positioned along a top portion of the tunnel. The tunnel heat exchanger is configured to remove heat from the fluid responsive to snow in the tunnel. The radiator, the heat exchanger and the tunnel heat exchanger are in fluid communication with the engine forming a cooling circuit through which the fluid circulates such that heat extracted from the engine by the fluid is removed from the fluid in the cooling circuit as the fluid circulates therethrough.

[0006] In some embodiments, the radiator may be positioned above and coupled to a nose portion of the forward frame assembly. In certain embodiments, the radiator may be tilted forward such that an upper portion of the radiator is forward of a lower portion of the radiator. In some embodiments, the heat exchanger may have a forward apex, an upper arcuate section extending upward and aftward from the forward apex and a lower arcuate section extending downward and aftward from the forward apex. In such embodiments, the upper arcuate section may have a distal end that is coupled to the forward portion of the tunnel. Also, in such embodiments, the lower arcuate section may have a distal end that includes a snow retaining fin extending therefrom wherein, the snow retaining fin may have a positive snow retention angle configured to enhance a dwell time of snow thereon. In certain embodiments, the lower arcuate section may have an inner surface including a plurality of snow retaining fins extending therefrom wherein, each of the snow retaining fins may have a positive snow retention angle configured to enhance the dwell time of snow thereon. In some embodiments, the lower arcuate section may have an inner surface including a plurality of snow retaining fins extending therefrom wherein, the snow retaining fins having progressively increasing positive snow retention angles from an upper snow retaining fin to a lower snow retaining fin with each of the snow retaining fins configured to enhance the dwell time of snow thereon. In certain embodiments, the lower arcuate section and a lower portion of the upper arcuate section may have an inner surface including a plurality of snow retaining fins extending therefrom wherein, each of the snow retaining fins may have a positive snow retention angle configured to enhance the dwell time of snow thereon. In some embodiments, the heat exchanger may have an inner surface including a plurality of snow retaining fins extending therefrom wherein, at least some of the snow retaining fins have a positive snow retention angle configured to enhance the dwell time of snow thereon. In certain embodiments, the heat exchanger may have an inner surface including a plurality of snow retaining fins extending therefrom wherein, the snow retaining fins having progressively increasing snow retention angles from an upper snow retaining fin to a lower snow retaining fin.

[0007] In some embodiments, the tunnel heat exchanger may include a longitudinally extending outbound channel and a longitudinally extending inbound channel that are substantially parallel with each other. In certain embodiments, the tunnel heat exchanger may extend substantial the entire length of the tunnel. In other embodiments, the tunnel heat exchanger may extend only a portion of the length of the tunnel. In some embodiments, the radiator may be fluidically positioned between the engine and the heat exchanger, the heat exchanger may be fluidically positioned between the radiator and the tunnel heat exchanger, the tunnel heat exchanger may be fluidically positioned between the heat exchanger and the engine, and the engine may be fluidically positioned between the tunnel heat exchanger and the radiator. In certain embodiments, the radiator may be coupled between the engine and the heat exchanger, the heat exchanger may be coupled between the radiator and the tunnel heat exchanger, the tunnel heat exchanger may be coupled between the heat exchanger and the engine, and the engine may be coupled between the tunnel heat exchanger and the radiator. In some embodiments, the fluid may circulate through the cooling circuit sequentially from the radiator to the heat exchanger then to the tunnel heat exchanger. In certain embodiments, the cooling system may include an expansion chamber fluidically positioned between the tunnel heat exchanger and the engine. In certain embodiments, the cooling system may include a thermostat and a bypass system wherein, the thermostat is configured to monitor a temperature of the fluid and regulate fluid flow between the bypass system and the cooling circuit.

[0008] In a second aspect, the present disclosure is directed to a snowmobile including a forward frame assembly, a tunnel coupled to the forward frame assembly, a powertrain coupled to the forward frame assembly and including an engine cooled by a fluid, and a drive track system disposed at least partially below the tunnel. The drive track system includes a track driveshaft having an axis of rotation. The track driveshaft receives rotational energy from the powertrain such that the drive track system is configured to provide ground propulsion for the snowmobile. A radiator is coupled to the forward frame assembly and is positioned forward of the engine. The radiator is configured to remove heat from the fluid responsive to air passing therethrough. A heat exchanger is coupled to a forward portion of the tunnel and is positioned aft of the engine. The heat exchanger is configured to remove heat from the fluid responsive to snow in the tunnel. The heat exchanger has a substantially constant radius of curvature with a center of curvature proximate the axis of rotation of the track driveshaft. A tunnel heat exchanger is positioned along a top portion of the tunnel. The tunnel heat exchanger is configured to remove heat from the fluid responsive to snow in the tunnel. The radiator, the heat exchanger and the tunnel heat exchanger are in fluid communication with the engine forming a cooling circuit through which the fluid circulates such that heat extracted from the engine by the fluid is removed from the fluid in the cooling circuit as the fluid circulates therethrough.

[0009] In a third aspect, the present disclosure is directed to a snowmobile including a tunnel and a drive track system that is at least partially disposed within the tunnel. The drive track system includes a track driveshaft having an axis of rotation. A heat exchanger is coupled to a forward end of the tunnel. The heat exchanger includes a substantially constant radius of curvature with respect to the axis of rotation of the track driveshaft.

[0010] In some embodiments, a forward frame assembly may be coupled to the tunnel and an engine may be coupled to the forward frame assembly. The engine may be aftwardly tilted and may include a crankshaft having an axis of rotation. In certain embodiments, the engine may include a pump that is in fluid communication with a fluid inlet port positioned on a forward side of the engine. In some embodiments, the engine may include an exhaust outlet positioned on the forward side of the engine and an air intake inlet positioned on an aftward side of the engine. In certain embodiments, the engine may include an oil sump positioned below the crankshaft. In some embodiments, the pump may be positioned forward of the axis of rotation of the crankshaft. In certain embodiments, an air plenum may be positioned on top of the engine.

[0011] In a fourth aspect, the present disclosure is directed to an engine cooling system for a snowmobile that including a forward frame assembly, an engine, a tunnel and a track driveshaft having an axis of rotation. The cooling system includes a heat exchanger that is coupled to the forward frame assembly and to the tunnel. The heat exchanger is positioned aft of the engine and is configured to transfer heat from a coolant fluid circulated through the engine and the heat exchanger. The heat exchanger includes a body having an arcuate section with a substantially constant radius of curvature and with a center of curvature proximate the axis of rotation of the track driveshaft.

[0012] In some embodiments, the body may have a forward wall, an aft wall, an upper end and a lower end with the forward and aft walls each having a forward apex. In certain embodiments, the arcuate section may include an upper portion that extends upward and aftward from the forward apexes and a lower portion that extends downward and aftward from the forward apexes. In some embodiments, the upper end may be coupled to the tunnel and the lower end may be coupled to the forward frame assembly. In certain embodiments, the lower end may be positioned aft of the forward apex of the aft wall. In some embodiments, the heat exchanger may include an engine mounting assembly positioned on the forward wall at a location that is closer to the upper end than to the lower end. In such embodiments, the arcuate section of the body may extend from the lower end to at least the engine mounting assembly. In certain embodiments, the heat exchanger may include a lowermost chamber disposed within the lower portion of the arcuate section and a fluid port that is positioned on the forward wall and is in fluid communication with the lowermost chamber. In such embodiments, the fluid port may extend forward and downward from the forward wall.

[0013] In a fifth aspect, the present disclosure is directed to a snowmobile including a forward frame assembly, a tunnel coupled to the forward frame assembly and a drive track system disposed at least partially below the tunnel and including a track driveshaft having an axis of rotation. A heat exchanger has a body with a forward wall, an aft wall, an upper end and a lower end. The upper end is coupled to the tunnel and the lower end is coupled to the forward frame assembly. The heat exchanger includes an engine mounting assembly positioned on the forward wall between the upper and lower ends. The body has an arcuate section with a substantially constant radius of curvature and with a center of curvature proximate the axis of rotation of the track driveshaft. The arcuate section extends from the lower end of the body to at least the engine mounting assembly.

[0014] In some embodiments, the heat exchanger may define at least first and second chambers with a partition therebetween that extends between the forward wall and the aft wall behind the engine mounting assembly. In certain embodiments, the body may include an upper housing that defines the first and second chambers with the engine mounting assembly integrally formed with the upper housing. In some embodiments, the body may have a length in the lateral direction of the snowmobile and the engine mounting assembly may include mounting rails that have a length in the lateral direction of the snowmobile that is more than half the length of the body. In certain embodiments, a vibration damper having a mount axis that extends through the body may be coupled to the engine mounting assembly. In such embodiments, the arcuate section of the body may extend from the lower end of the body to at least the mount axis of the vibration damper. Also, in such embodiments, the mount axis of the vibration damper may extend in a radial direction of the track driveshaft.

[0015] In a sixth aspect, the present disclosure is directed to a snowmobile including a forward frame assembly, a tunnel coupled to the forward frame assembly and a drive track system disposed at least partially below the tunnel and including a track driveshaft having an axis of rotation. A heat exchanger has a body including an upper housing with an upper end and a lower housing with a lower end. The upper end is coupled to the tunnel and the lower end is coupled to the forward frame assembly. The heat exchanger includes an engine mounting assembly positioned on a forward side of the upper housing and a fluid port positioned on a forward side of the lower housing. The body has an arcuate section with a substantially constant radius of curvature and a center of curvature proximate the axis of rotation of the track driveshaft. The arcuate section extends at least between the fluid port and the engine mounting assembly.

[0016] In some embodiments, the upper housing may have a forward wall having a first thickness and the lower housing may have a forward wall having a second thickness that is less than the first thickness. In certain embodiments, the body may have a forward apex, the upper end may be positioned aft and above the forward apex and/or the lower end may be positioned aft and below the forward apex. In some embodiments, the forward apex may be located on the lower housing. In certain embodiments, a vibration damper may be coupled to the engine mounting assembly such that the vibration damper is positioned aft of a plane that is tangent to the forward apex. In some embodiments, the lower end may be positioned aft at least a portion of the vibration damper. In certain embodiments, a vibration damper having a mount axis that extends through the body may be coupled to the engine mounting assembly. In such embodiments, the arcuate section of the body may extend at least between the fluid port and the mount axis of the vibration damper.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] For a more complete understanding of the features and advantages of the present disclosure, reference is now made to the detailed description along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0018] FIGS. **1**A-**1**E are schematic illustrations of a snowmobile having an engine cooling system in accordance with embodiments of the present disclosure;

[0019] FIGS. **2**A-**2**B are isometric views of an engine cooling system for a snowmobile in accordance with embodiments of the present disclosure;

[0020] FIG. **3** is an isometric view of an engine cooling system for a snowmobile in accordance with embodiments of the present disclosure;

[0021] FIGS. **4**A-**4**B are side views of a forward portion of the tunnel including a heat exchanger and a tunnel heat exchanger of an engine cooling system for a snowmobile in accordance with embodiments of the present disclosure;

[0022] FIGS. **5**A-**5**B are rear elevation and cross sectional views of a heat exchanger of an engine cooling system for a snowmobile in accordance with embodiments of the present disclosure; and

[0023] FIGS. **6**A-**6**D are various views of a heat exchanger including an engine mounting system for a snowmobile in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

[0024] While the making and using of various embodiments of the present disclosure are discussed in detail below, it should be appreciated that the present disclosure provides many applicable inventive concepts, which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative and do not delimit the scope of the present disclosure. In the interest of clarity, all features of an actual implementation may not be described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0025] In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as the devices are depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the present disclosure, the devices, members, apparatuses, and the like described herein may be positioned in any desired orientation. Thus, the use of terms such as "above," "below," "upper," "lower" or other like terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, as the devices described herein may be oriented in any desired direction. As used herein, the term "coupled" may include direct or indirect coupling by any means, including by mere contact or by moving and/or non-moving mechanical connections.

[0026] Referring to FIGS. **1**A-**1**E in the drawings, a land vehicle depicted as a snowmobile is schematically illustrated and generally designated **10**. Structural support for snowmobile **10** is provided by a chassis **12** that includes a forward frame assembly **14** and a longitudinally extending tunnel **18**. In the illustrated embodiment, forward frame assembly **14** (see also FIG. **2**A) is formed from interconnected tubular members such as round and hollow tubular members comprised of metal, metal alloy, polymeric materials, fiber reinforced polymer composites and/or combinations thereof that are coupled together by welds, bolts, pins or other suitable fastening means. A right plate member **16***a* and a left plate member **16***b* may be coupled to and preferably welded to forward frame assembly **14** such that forward frame assembly **14** and plate members **16***a*, **16***b* form a welded frame assembly. Tunnel **18** is coupled to forward frame assembly **14** and/or plate members **16***a*, **16***b* with welds, bolts, rivets or other suitable means. In the illustrated embodiment, tunnel **18** includes a right sidewall **18***a*, a left sidewall **18***b* and a top panel **18***c*. Tunnel **18** may be integrally formed or may consist of multiple members that are coupled together with welds, bolts, rivets or other suitable means. Plate members **16***a*, **16***b* and tunnel **18** may be formed from sheet metal, metal alloy, fiber reinforced polymer or other suitable material or combination of materials.

[0027] Various components of snowmobile **10** are assembled on or around forward frame assembly **14**. One or more body panels **20** cover and protect the various components of snowmobile **10** including parts of forward frame assembly **14**. For example, a hood panel **20***a*, a nose panel **20***b*, an upper right side panel **20***c* and a lower right side panel **20***d* shield underlying componentry from the snow and terrain. Similarly, an upper left side panel and a lower left side panel (not visible) also shield underlying componentry from the snow and terrain. In the illustrated embodiment, snowmobile **10** has a windshield **22** that shields the rider of snowmobile **10** from snow, terrain and frigid air during operation. Even through snowmobile **10** has been described and depicted as including specific body panels **20**, it should be understood by those having ordinary skill in the art that a snowmobile of the present disclosure may include any number of body panels in any configuration to provide the shielding functionality. In addition, it should be understood by those having ordinary skill in the art that the right side and the left side of snowmobile **10** will be with reference to a rider of snowmobile **10** with the right side of snowmobile **10** corresponding to the right side of the rider and the left side of snowmobile **10** corresponding to the left side of the rider.

[0028] Body panels **20** have been removed from snowmobile **10** in FIGS. **1**B-**1**E to reveal the underlying components of snowmobile **10**. For example, snowmobile **10** has a powertrain **24** that includes an engine **26** and a drivetrain **28** both of which are coupled to forward frame assembly **14**. Engine **26** resides in an engine bay formed within forward frame assembly **14**. In the illustrated embodiment, engine **26** is a four-stroke, three cylinder internal combustion engine such as a naturally aspirated internal combustion engine or a forced induction internal combustion engine that includes, for example, one or more turbochargers and/or superchargers that is aftwardly tilted and has air intake inlets on the aftward side of engine **26** and exhaust outlets on the forward side of engine **26**. In other embodiments, an engine of the present disclosure may be a two-stroke engine, an electric motor, a hybrid engine or other prime mover. In addition, an engine of the present disclosure may have more than or less than three cylinders, may be vertically mounted or mounted with a forward tilt and/or may have air intake inlets or exhaust outlets in other locations. In one example, engine **26** may be an engine of the type disclosed in co-owned U.S. patent application 63/468,357, filed May 23, 2023, the entire contents of which is hereby incorporated by referenced. Engine **26** includes a crankshaft **26***a* (see also FIG. **2**A) that has an axis of rotation. Crankshaft **26***a* is coupled to drivetrain **28** and specifically to a transmission **30** of drivetrain **28** such as a continuously variable transmission, an electrically variable transmission or other suitable transmission type for varying the ratio of the engine output speed to the drive track input speed. Engine **26** includes an oil sump **26***b* positioned below crankshaft **26***a*. Engine **26** has an air intake system that includes an air plenum **26***c* positioned on top of engine **26**. In the illustrated embodiment, engine **26** is supported by forward frame assembly **14** and a heat exchanger **104** (see also FIG. **2**A). More specifically, a right forward engine mount **26***d* and a left forward engine mount **26***e* couple engine **26** to a cross member **14***b* of forward frame assembly **14**. In addition, a right aftward engine mount (not visible) and a left aftward engine mount **26***f* couple engine **26** to heat exchanger **104** via mounting brackets or mounting rails that are integral with and/or coupled to a forward wall of heat exchanger **104**.

[0029] A drive track system **32** is at least partially disposed within and/or below tunnel **18** and is in contact with the ground to provide ground propulsion for snowmobile **10**. Torque and rotational energy are provided to drive track system **32** from engine **26** via drivetrain **28**. Drive track system **32** includes a track frame **34**, an internal suspension **36**, a plurality of idler wheels **38** such as idler wheels **38***a*, **38***b*, **38***c*, **38***d* and an endless track **40**. Track frame **34** may be coupled to forward frame assembly **14** via a swing arm having a coil spring, a rigid strut, a torsion spring, an elastomeric member or any other suitable coupling configuration. Endless track **40** is driven by a track drive sprocket **42** via a track driveshaft **44** (see also FIGS. **4**A-**4**B) that is rotated responsive to torque provided from powertrain **24**. Endless track **40** rotates around track frame **34** and idler wheels **38** to propel snowmobile **10** in either the forward direction, as indicated by arrow **46***a*, or the backwards direction, as indicated by arrow **46***b* in FIG. **1**B. When viewed from the right side of snowmobile **10**, endless track **40** rotates around track frame **34** and idler wheels **38** in the clockwise direction, as indicated by arrow **48***a*, to propel snowmobile **10** in the forward direction **46***a*. Endless track **40** rotates around track frame **34** and idler wheels **38** in the counterclockwise direction, as indicated by arrow **48***b*, to propel snowmobile **10** in the backward direction **46***b*. The forward and backward directions also represent the longitudinal direction of snowmobile **10** with the lateral direction of snowmobile **10** being normal thereto and represented by the rightward direction, as indicated by arrow **50***a*, and the leftward direction, as indicated by arrow **50***b* in FIG. **1**E. The backward direction may also be referred to herein as the aftward direction.

[0030] Snowmobile **10** has a ski system **52** and a front suspension assembly **54** that provide front end support for snowmobile **10**. Ski system **52** includes a right ski **52***a* that is coupled to forward frame assembly **14** by upper and lower A-arms **52***b*, **52***c* and right spindle **52***d*. Ski system **52** also includes a left ski **52***e* that is coupled to forward frame assembly **14** by upper and lower A-arms **52***f*, **52***g* and left spindle **52***h*. Skis **52***a*, **52***e* are interconnected to a steering system **56** including a handlebar assembly **56***a*, a steering column **56***b*, a right tie rod **56***c* and a left tie rod **56***d* that enable the rider to steer snowmobile **10**. For example, when handlebar assembly **56***a* is rotated, skis **52***a*, **52***e* responsively pivot to turn snowmobile **10**. The rider controls snowmobile **10** from a seat **58** that is position atop a fuel tank **60**, above tunnel **18**, aft of handlebar assembly **56***a* and aft of forward frame assembly **14**. Snowmobile **10** has a lift bumper **62** that is coupled to an aft end of tunnel **18** that enables a person to lift the rear end of snowmobile **10** in the event snowmobile **10** becomes stuck or needs to be repositioned when it is not moving. Snowmobile **10** has a snow flap **64** that deflects snow emitted by endless track **40**. In the illustrated embodiment, snow flap **64** is coupled to lift bumper **62**. In other embodiments, a snow flap may be coupled directly to tunnel **18**. A taillight housing **66** is also coupled to lift bumper **62** and houses a taillight of snowmobile **10**. Snowmobile **10** has an exhaust system **70** that includes an exhaust manifold **72** that is coupled to engine **26**, an exhaust duct **74** and a muffler **76**. Exhaust system **70** is configured to direct high-temperature exhaust gases away from engine **26** and the rider of snowmobile **10**. As exhaust system **70** including exhaust manifold **72** is coupled to the forward side of engine **26**, the forward side of engine **26** may be referred to herein as the hot side of engine **26** due to the hot temperatures associated with engine exhaust. The aftward side of engine **26** is concomitantly considered the cool side of engine **26** as hot exhaust system components are located opposite and/or remote therefrom.

[0031] It should be appreciated that snowmobile **10** is merely illustrative of a variety of vehicles that can implement the embodiments disclosed herein. Other vehicle implementations can include motorcycles, snow bikes, all-terrain vehicles (ATVs), utility vehicles, recreational vehicles, scooters, automobiles, mopeds, straddle-type vehicles and the like. As such, those skilled in the art will recognize that the embodiments disclosed herein can be integrated into a variety of vehicle configurations. It should be appreciated that even though ground-based vehicles are particularly well-suited to implement the embodiments of the present disclosure, airborne vehicles and devices such as aircraft can also implement the embodiments.

[0032] Referring additionally to FIGS. **2**A-**2**B of the drawings, details of an engine cooling system **100** of snowmobile **10** will now be discussed. In the illustrated embodiment, engine cooling system **100** includes a radiator **102** that is coupled to forward frame assembly **14**. In other embodiments, an engine cooling system for a snowmobile may not include a radiator, may have an intercooler instead of a radiator or may have both a radiator and an intercooler. In the illustrated embodiment, radiator **102** is coupled to and positioned above a nose portion **14***a* of forward frame assembly **14**. In this location, radiator **102** is positioned forward of engine **26** and is tilted forward such that an upper portion of radiator **102** is forward of a lower portion of radiator **102**. Radiator **102** is configured to remove heat from a coolant fluid circulating therethrough responsive to air passing through radiator **102** from the front side of radiator **102** to the rear side of radiator **102**. In the illustrated embodiment, radiator **102** includes a fan **102***a* that may be selectively operated to help air move through radiator **102**. Engine cooling system **100** also includes heat exchanger **104**. An upper end of heat exchanger **104** is coupled to a forward portion of tunnel **18**, the end caps of heat exchanger **104** are coupled to plate members **16***a*, **16***b* and a lower end of heat exchanger **104** is coupled to forward frame assembly **14** via a cross member of a belly pan. In this location, heat exchanger **104** is positioned aft of engine **26**. Heat exchanger **104** is configured to remove heat from a coolant fluid circulating therethrough responsive to snow in tunnel **18**. For example, during operation of snowmobile **10**, endless track **40** kicks snow toward an inner surface **104***a* (see FIG. **5**A) of heat exchanger **104** which is configured to retain at least a portion of this snow. Heat from the coolant fluid circulating through heat exchanger **104** is transferred to the retained snow causing the retained snow to melt. Engine cooling system **100** further includes a tunnel heat exchanger **106** that is positioned along a top portion of tunnel **18**. Tunnel heat exchanger **106** is configured to remove heat from a coolant fluid circulating therethrough responsive to snow in tunnel **18**. For example, during operation of snowmobile **10**, endless track **40** kicks snow toward an upper surface of tunnel **18**, a portion of which sticks to this surface which is in thermal communication with tunnel heat exchanger **106**. Heat from the coolant fluid circulating through tunnel heat exchanger **106** is transferred to the retained snow causing the retained snow to melt. It is noted that snow flap **64** helps to retain snow in tunnel **18** which aids in the snow sticking to the upper surface of tunnel **18**.

[0033] In the illustrated embodiment, radiator **102**, heat exchanger **104** and tunnel heat exchanger **106** form a cooling circuit that is in fluid communication with engine **26**. In other embodiments, a cooling circuit for engine **26** may include fewer, additional or different components such as a cooling circuit including only heat exchanger **104** and tunnel heat exchanger **106**. In the illustrated embodiment, radiator **102** is fluidically positioned between engine **26** and heat exchanger **104**. In addition, heat exchanger **104** is fluidically positioned between radiator **102** and tunnel heat exchanger **106**. Also, tunnel heat exchanger **106** is fluidically positioned between heat exchanger **104** and engine **26**. Finally, engine **26** is fluidically positioned between tunnel heat exchanger **106** and radiator **102**. More specifically, radiator **102** is coupled engine **26** via a fluid discharge port on the aftward side (not visible) of engine **26**, a fluid conduit **108** and a fluid inlet port **110** of radiator **102**. Radiator **102** is also coupled to heat exchanger **104** via a fluid discharge port **112** of radiator **102**, a fluid conduit **114** and a fluid inlet port **116** of heat exchanger **104**. Heat exchanger **104** is coupled to tunnel heat exchanger **106** via a direct coupling of a fluid discharge port **118** (see FIG. **5**A) of heat exchanger **104** and an inlet of a longitudinally extending outbound channel **106***a* of tunnel heat exchanger **106** which is in fluid communication with and substantially parallel with a longitudinally extending inbound channel **106***b* of tunnel heat exchanger **106**. A laterally extending channel **106***c* fluidically couples outbound channel **106***a* and inbound channel **106***b* of tunnel heat exchanger **106**. Tunnel heat exchanger **106** is coupled engine **26** via a fluid discharge port **120** of inbound channel **106***b*, a fluid conduit **122** and a fluid inlet port **124** on the forward side of engine **26**. Fluid inlet port **124** is in fluid communication with a pump **126** that circulates the coolant fluid through engine **26** and the cooling circuit.

[0034] In the illustrated embodiment, fluid circulates through the cooling circuit sequentially from engine **26** to radiator **102** then to heat exchanger **104** then to tunnel heat exchanger **106** before returning to engine **26**. More specifically, warmed fluid that has extracted heat from engine **26** exits engine **26** via the fluid discharge port (not visible) of engine **26** and flows to radiator **102** via fluid conduit **108** and fluid inlet port **110**. The fluid then flows through radiator **102** as cool air passes through radiator **102** removing some of the heat from the fluid. The fluid now exits radiator **102** via fluid discharge port **112** and flows to heat exchanger **104** via fluid conduit **114** and fluid inlet port **116**. It is noted that a portion of fluid conduit **114** and fluid inlet port **116** are positioned between heat exchanger **104** and engine **26** including a substantially horizontal section **114***a* and a substantially vertical section **114***b* of fluid conduit **114**. The fluid then flows through multiple stages (see FIG. **5**B) within heat exchanger **104** as snow retained on inner surface **104***a* is melted which removes some of the heat from the fluid. The fluid now exits heat exchanger **104** via fluid discharge port **118** (see FIG. **5**A) and flows into tunnel heat exchanger **106** via the direct coupling. The fluid then flows through outbound channel **106***a*, laterally extending channel **106***c* and inbound channel **106***b* of tunnel heat exchanger **106** as snow retained on an upper surface of tunnel **18** is melted which removes some of the heat from the fluid. The cooled fluid now exits tunnel heat exchanger **106** via fluid discharge port **120** and returns to engine **26** via fluid conduit **122** and fluid inlet port **124**. In this manner, heat from the warmed fluid from engine **26** is removed in the cooling circuit formed by radiator **102**, heat exchanger **104** and tunnel heat exchanger **106**.

[0035] In the illustrate embodiment, engine cooling system **100** includes a thermostat **128** that monitors the temperature of the fluid exiting engine **26** to determine whether the fluid should be circulated through the cooling circuit. If the temperature of the fluid is below a predetermined threshold, thermostat **128** signals a valve to remain closed such that the fluid exiting engine **26** bypasses the cooling circuit via bypass conduit **130** and returns directly to engine **26**. If the temperature of the fluid is above a predetermined threshold, thermostat **128** signals the valve to open which routes the fluid exiting engine **26** to the cooling circuit for heat removal, as discussed herein. Also, in the illustrated embodiment, engine cooling system **100** includes an expansion chamber **132** that is fluidically positioned between tunnel heat exchanger **106** and engine **26**.

[0036] Even though tunnel heat exchanger **106** has been depicted and described as having longitudinally extending outbound channel **106***a* that is substantially parallel with longitudinally extending inbound channel **106***b*, each of which extends substantially the entire length of tunnel **18**, it should be understood by those having ordinary skill in the art that a tunnel heat exchanger could have other configurations. For example, as best seen in FIG. **3**, an engine cooling system **150** for snowmobile **10** has a cooling circuit that includes radiator **102**, heat exchanger **104** and a tunnel heat exchanger **152**. Similar to engine cooling system **100**, in engine cooling system **150**, fluid circulates through the cooling circuit sequentially from engine **26** to radiator **102** then to heat exchanger **104** then to tunnel heat exchanger **152** before returning to engine **26**. Tunnel heat exchanger **152** has a longitudinally extending outbound channel **152***a* that is in fluid communication with and substantially parallel with a longitudinally extending inbound channel **152***b* that are fluidically coupled together by a laterally extending channel **152***c*. Inboard channel **152***b* has a fluid discharge port **154** that communicates fluid to engine **26**. In the illustrated embodiment, however, longitudinally extending outbound channel **152***a* and longitudinally extending inbound channel **152***b* do not extend substantially the entire length of tunnel **18** but rather, extend only a portion of the length of tunnel **18** such as between about twenty-five percent and seventy-five percent of the length of tunnel **18** or between about thirty-three percent and sixty-six percent of the length of tunnel **18** such as about fifty percent of the length of tunnel **18**.

[0037] Referring now to FIGS. **4**A-**4**B of the drawings, certain details of heat exchanger **104** will now be discussed. In the illustrated embodiment, heat exchanger **104** is coupled to a forward portion of tunnel **18**. Note that in FIG. **4**A, the left end cap of heat exchanger **104**, left sidewall **18***a* and most of drive track system **32** except for track drive sprocket **42** and track driveshaft **44** have been removed. In addition, only the body of heat exchanger **104** without the end caps, track drive sprocket **42** and track driveshaft **44** are presented in FIG. **4**B. Heat exchanger **104** is positioned relative to track drive sprocket **42** such that heat exchanger **104** has a center of curvature **160** (see FIG. **4**B) that is at least proximate to, and in the illustrated embodiment coincident with, an axis of rotation **162** (see FIG. **4**A) of track driveshaft **44**. In addition, inner surface **104***a* of heat exchanger **104** has a substantially constant radius of curvature **164***a* and outer surface **104***b* of heat exchanger **104** has a substantially constant radius of curvature **164***b*. Having substantially constant radii of curvature **164***a*, **164***b* and having center of curvature **160** coincident with axis of rotation **162** of track driveshaft **44** not only improves the snow receiving and retention functionality of heat exchanger **104** but also minimizes the space requirements of heat exchanger **104** which enlarges the engine bay. For example, the enlarged engine bay accommodates a larger four-stroke engine in a chassis designed for a two-stroke, allows the engine to be positioned lower in the engine bay which lowers the center of gravity of the snowmobile, allows the engine to have reduced aftward tilt and/or provides space for additional snowmobile components to be positioned between the engine and the lower portion of heat exchanger **104** such as fluid inlet port **116** and the substantially horizontal section **114***a* of fluid conduit **114** or an oil tank such as that disclosed in copending U.S. application Ser. No. 18/650,021 filed Apr. 29, 2024, the entire contents of which are hereby incorporated by reference.

[0038] Referring additionally to FIGS. **5**A-**5**B of the drawings, further details of heat exchanger **104** will now be disclosed. In FIG. **5**A, inner surface **104***a* of the body of heat exchanger **104** is revealed including fluid discharge port **118** that is directly coupled to the inlet of longitudinally extending outbound channel **106***a* of tunnel heat exchanger **106**. In FIG. **5**B, a cross section view of the body of heat exchanger **104** taken along line **5**B-**5**B in FIG. **5**A is presented. As best seen in FIG. **5**B, heat exchanger **104** has a plurality of chambers **168** including a first or lowermost chamber **168***a*, a second chamber **168***b*, a third chamber **168***c* and a fourth or uppermost chamber **168***d* that function as heat exchanger stages. Fluid from fluid inlet port **116** enters first chamber **168***a* of heat exchanger **104** and travels laterally and upwardly through the first stage before entering second chamber **168***b* in which the fluid travels laterally and upwardly through the second stage before entering third chamber **168***c* in which the fluid travels laterally and upwardly through the third stage before entering fourth chamber **168***d* in which the fluid travels laterally and upwardly through the fourth stage before exiting fluid discharge port **118** and entering tunnel heat exchanger **106**. Even though heat exchanger **104** has been depicted and described as having a particular number of chambers and stages, it should be understood by those having ordinary skill in the art that a heat exchanger of the present disclosure could have other numbers of chambers and stages either less than or greater than four.

[0039] In the illustrated embodiment, heat exchanger **104** has a forward apex **170** that is located adjacent to first chamber **168***a* which represents the forwardmost point of the cooling portion of heat exchanger **104**. In other embodiments, a forward apex of a heat exchanger of the present disclosure could be located adjacent to another chamber such as second chamber **168***b*. Heat exchanger **104** includes an upper arcuate section **172** that extends upward and aftward from forward apex **170**. Upper arcuate section **172** has a distal end **174** that is coupled to the forward portion of tunnel **18** such as by coupling tabs **174***a*, **174***b* to tunnel **18** using bolts, rivet or other suitable fastening means. Heat exchanger **104** also includes a lower arcuate section **176** extending downward and aftward from forward apex **170**. Lower arcuate section **176** has a distal end **178** that is coupled to forward frame assembly **14** such as by coupling tabs **178***a*, **178***b*, **178***c*, **178***d* to a cross member of a belly pan of forward frame assembly **14** using bolts, rivet or other suitable fastening means. Distal end **178** of lower arcuate section **176** includes a snow retaining fin **180** that extends upward and aftward from inner surface **104***a* of heat exchanger **104**. Snow retaining fin **180** has a positive snow retention angle such that snow kicked up by endless track **40** is captured and retained by snow retaining fin **180**. The length and angle of snow retaining fin **180** is configured to enhance the dwell time of snow thereon which enhances the heat removal capacity of heat exchanger **104**. As used herein, the term "positive snow retention angle" refers to a snow retaining fin that has an angle above the horizontal such that snow contacting inner surface **104***a* adjacent thereto tends to be captured and retained therein resulting in melting snow rather than the snow slide off and thus provides significant heat removal capacity due to the state change of the snow from frozen water to liquid water. In the illustrated embodiment, snow retaining fin **180** has a positive snow retention angle **182** of about sixty degrees.

[0040] In addition to snow retaining fin **180**, lower arcuate section **176** includes a plurality of additional snow retaining fins including snow retaining fin **184** which represents the uppermost snow retaining fin of lower arcuate section **176**. In the illustrated embodiment, snow retaining fin **184** has a positive snow retention angle **186** of about forty-five degrees. From snow retaining fin **184** to snow retaining fin **180**, the snow retaining fins of lower arcuate section **176** have progressively increasing positive snow retention angles. More specifically, from snow retaining fin **184** to snow retaining fin **180**, the positive snow retention angle of each subsequent snow retaining fin progressively increases by about three degrees. In other embodiments, the snow retaining fins of lower arcuate section **176** could have other configurations including having progressively increasing positive snow retention angles that increase by more or less than three degrees, having snow retaining fins with nonuniformly progressively increasing positive snow retention angles or having snow retaining fins with constant positive snow retention angles. In the illustrated embodiment, each of the snow retaining fins of lower arcuate section **176** including snow retaining fins **180**, **184** is configured to enhance the dwell time of snow thereon.

[0041] In addition to having positive snow retention angles for the snow retaining fins of lower arcuate section **176**, a lower portion **188** of upper arcuate section **172** also has snow retaining fins that have positive snow retention angles. Specifically, for the plurality of snow retaining fins between snow retaining fin **184** and snow retaining fin **190**, each has a positive snow retention angle. Similar to the snow retaining fins of lower arcuate section **176**, the snow retaining fins of lower portion **188** of upper arcuate section **172** have progressively increasing positive snow retention angles from snow retaining fin **192** to snow retaining fin **194**. As such, each of the snow retaining fins of lower portion **188** of upper arcuate section **172** including snow retaining fins **192**, **194** is configured to enhance the dwell time of snow thereon. Importantly, as the fluid entering heat exchanger **104** is warmest in first chamber **168***a*, having snow retaining fins adjacent thereto that have significantly positive snow retention angles enhances the heat removal capacity of heat exchanger **104**. Likewise, as the fluid in second chamber **168***b* is the second warmest, having snow retaining fins adjacent thereto that have positive snow retention angles enhances the heat removal capacity of heat exchanger **104**.

[0042] In the illustrated embodiment, an upper portion **196** of upper arcuate section **172** has snow retaining fins that have negative snow retention angles wherein the snow retaining fins extend downward and aftward from inner surface **104***a* and thus have angles below the horizontal. The snow retaining fins of upper portion **196** of upper arcuate section **172** from snow retaining fin **198** to snow retaining fin **200** have progressively increasing snow retention angles. In addition, while the snow retaining fins of upper portion **196** of upper arcuate section **172** have negative snow retention angles, they may nonetheless enhance the dwell time of snow thereon relative to an embodiment in which inner surface **104***a* entirely lacks snow retaining fins in this region. It is noted that from uppermost snow retaining fin **198** to lowermost snow retaining fin **180** the snow retaining fins have progressively increasing snow retention angles.

[0043] Referring next to FIGS. **6**A-**6**D of the drawings, a heat exchanger incorporating an engine mounting assembly will now be discussed. FIG. **6**A depicts a forward frame assembly **214** that is representative of forward frame assembly **14** discussed herein. Forward frame assembly **214** includes nose frame assembly **214***a*, a base frame assembly **214***b* including a cross member **214***c*, which may be a component of a belly pan, a right side frame assembly **214***d* and a fixed portion of a left side frame assembly **214***e* as well as a steering column mount **214***f*. Welded to forward frame assembly **214** are right side plate member **216***a* and left side plate member **216***b*. Nose frame assembly **214***a* includes a nose cross member **218** that includes a pair of right openings **218***a*, **218***b* and a pair of left openings **218***c*, **218***d* for receiving bolts therethrough that couple the right and left forward engine mounts to nose cross member **218**. A heat exchanger **220** is representative of heat exchanger **104** discussed herein. An upper end of heat exchanger **220** is coupled to a forward portion of tunnel **18**, the end caps of heat exchanger **220** are coupled to plate members **216***a*, **216***b* and a lower end of heat exchanger **220** is coupled to forward frame assembly **14** via cross member **214***c*. As best seen in FIG. **6**D, heat exchanger **220** has a body **232** including an upper housing **234** and a lower housing **236** that may be joined together by welding or other suitable connecting means. Upper housing **234** has an upper end **234***a* and a lower end **234***b*. Lower housing **236** has an upper end **236***a* and a lower end **236***b*. Upper end **234***a* includes one or more coupling tabs **234***d* used to couple heat exchanger **220** to tunnel **18** using rivets or other suitable fasteners. Lower end **236***b* includes one or more coupling tabs **236***d* used to couple heat exchanger **220** to base cross member **214***c* of forward frame assembly **214** using rivets or other suitable fasteners.

[0044] Heat exchanger **220** has a plurality of chambers including a first chamber **238***a* also referred to herein as lowermost chamber **238***a*, a second chamber **238***b*, a third chamber **238***c* and a fourth chamber **238***d* also referred to herein as uppermost chamber **238***d* that act as heat exchanger stages. In one example, a heated coolant fluid **240** that has extracted heat from engine **26**, enters heat exchanger **220** at a fluid port **242**. Fluid **240** enters lowermost chamber **238***a* in which fluid **240** travels laterally and upwardly through the first stage before entering second chamber **238***b* in which fluid **240** travels laterally and upwardly through the second stage before entering third chamber **238***c* in which the fluid travels laterally and upwardly through the third stage before entering uppermost chamber **238***d* in which the fluid travels laterally and upwardly through the fourth stage before exiting a fluid discharge port (not visible) at upper end **234***a* and entering, for example, tunnel heat exchanger **106**. In other implementations, a heated coolant fluid could instead enter heat exchanger **220** at the upper fluid port then sequentially pass through uppermost chamber **238***d*, third chamber **238***c*, second chamber **238***b* and lowermost chamber **238***a* before exiting heat exchanger **220** at fluid port **242**.

[0045] As should understood by those having ordinary skill in the art, fluid port **242** is in fluid communication with lowermost chamber **238***a* which is in fluid communication with second chamber **238***b* which is in fluid communication with third chamber **238***c* which is in fluid communication with uppermost chamber **238***d* which is in fluid communication with the upper fluid port. In the illustrated embodiment, lowermost chamber **238***a* and second chamber **238***b* are positioned within lower housing **236** with third chamber **238***c* and uppermost chamber **238***d* positioned within upper housing **234**. In other embodiments, a heat exchanger of the present disclosure could have other numbers of chambers both less than and greater than four. Likewise, in other embodiments, an upper housing or a lower housing of a heat exchanger could have other numbers of chambers both less than and greater than two including embodiment in which an upper housing and a lower housing of a heat exchanger have different numbers of chambers.

[0046] Body **232** of heat exchanger **220** has a forward wall **244** and an aft wall **246**. In the illustrated embodiment, forward wall **244** has an upper section **244***a* that is formed by upper housing **234** and a lower section **244***b* that is formed by lower housing **236**. Likewise, aft wall **246** has an upper section **246***a* that is formed by upper housing **234** and a lower section **246***b* that is formed by lower housing **236**. The wall thickness of upper section **244***a* is greater than the wall thickness of lower section **244***b*. For example, the thickness of lower section **244***b* may be between twenty-five and seventy-five percent of the thickness of upper section **244***a*, such as between forty and sixty percent of the thickness of upper section **244***a* or about fifty percent of the thickness of upper section **244***a*. Likewise, the wall thickness of upper section **246***a* is greater than the wall thickness of lower section **246***b*. For example, the thickness of lower section **246***b* may be between twenty-five and seventy-five percent of the thickness of upper section **246***a*, such as between forty and sixty percent of the thickness of upper section **246***a* or about fifty percent of the thickness of upper section **246***a*. The nonuniform thickness of forward wall **244** has the benefit of providing maximum support for engine **26** when engine **26** is mounted to heat exchanger **220** at mounting rails **222**. In addition, the nonuniform thickness of aft wall **246** has the benefit of providing maximum heat transfer relative to lowermost chamber **238***a* and second chamber **238***b* where coolant fluid **240** is warmest. Forward wall **244** has a forward apex **244***c* which also represents the forwardmost point of body **232**. Aft wall **246** has a forward apex **246***c*. In the illustrated embodiment, forward apexes **244***c*, **246***c* are formed as part of lower housing **246** and are adjacent to lowermost chamber **238***a*. Upper end **234***a* is positioned aft and above forward apexes **244***c*, **246***c*. In this illustrated embodiment, lower end **236***b* is positioned aft and below forward apexes **244***c*, **246***c*. In other embodiments, lower end **236***b* could have an aftwardly extending shelf that curves upward for snow retention.

[0047] Body **232** of heat exchanger **220** has an arcuate section with a substantially constant radius of curvature and with a center of curvature proximate axis of rotation **162** of track driveshaft **44**. The arcuate section may extend the entire length of body **232** from lower end **236***b* to upper end **234***a* or may extend for only a portion of the entire length. The arcuate section of body **232** includes an upper portion that extends upward and aftward from forward apexes **244***c*, **246***c* and a lower portion that extends downward and aftward from forward apexes **244***c*, **246***c*. As best seen in FIG. **6**C, forward wall **244** has a substantially constant radius of curvature **244***d* and aft wall **246** has a substantially constant radius of curvature **246***d*. Radii of curvature **244***d*, **246***d* share a common center of curvature **248** that is coincident with axis of rotation **162** of track driveshaft **44** and track drive sprocket **42**.

[0048] In this illustrated embodiment, heat exchanger **220** includes an engine mounting assembly depicted as mounting rails **222** that are preferably formed integrally with upper housing **234** using, for example, an extrusion process followed by a machining process. Mounting rails **222** include a right mounting location **222***a* and a left mounting location **222***b* may be machined into mounting rails **222** to receive the right and left aftward engine mounts therein. Mounting rails **222** also include upper and lower slots **222***c*, **222***d* sized to receive and secure bolt heads therein such that the right and left aftward engine mounts can be coupled thereto. As best seen in FIG. **6**B, an engine mount system compatible with mounting rails **222** includes a right forward engine mount **224**, a left forward engine mount **226**, a right aftward engine mount **228** and a left aftward engine mount **230**. In the illustrated embodiments, right forward engine mount **224** includes an angled bracket **224***a* that is bolted to a forward side of engine **26**. A mounting flange **224***b* with a vibration damper **224***c* are secured to angled bracket **224***a* by a bolt **224***d*. Mounting flange **224***b* is coupled to nose cross member **218** with bolts **224***f*, **224***g* that extend through right openings **218***a*, **218***b* to resiliently secure right forward engine mount **224** to nose cross member **218** such that mount axis **224***e* extends in a direction that is substantially parallel to the aftward tilt angle of engine **26**. Left forward engine mount **226** includes an angled bracket **226***a* that is bolted to a forward side of engine **26**. A mounting flange

226*b* with a vibration damper **226***c* are secured angled bracket **226***a* by a bolt **226***d*. Mounting flange **226***b* is coupled to nose cross member **218** with bolts **226***f*, **226***g* that extend through left openings **218***c*, **218***d* to resiliently secure left forward engine mount **226** to nose cross member **218** such that mount axis **226***e* extends in a direction that is substantially parallel to the aftward tilt angle of engine **26**. Due to the resilient nature of vibration dampers **224***c*, **226***c*, vibration transfer from engine **26** to nose cross member **218** is reduced and/or eliminated.

[0049] Right aftward engine mount **228** has a body **228***a* that is bolted to an aftward side of engine **26**. A mounting flange **228***b* with a vibration damper **228***c* is secured to body **228***a* by a bolt **228***d*. Mounting flange **228***b* is coupled to mounting rails **222** by bolts **228***f*, **228***g*. Left aftward engine mount **230** has a body **230***a* that is bolted to an aftward side of engine **26**. A mounting flange **230***b* with a vibration damper **230***c* is secured to body **230***a* by a bolt **230***d*. Mounting flange **230***b* is coupled to mounting rails **222** by bolts **230***f*, **230***g*. As best seen in FIG. **6**C, the head of bolt **230***f* is received within upper slot **222***c* and the head of bolt **230***g* is received within lower slot **222***d* with mounting flange **230***b* received within left mounting location **222***b*. In this configuration, mounting flange **230***b* is secured to mounting rails **222** with bolts **230***f*, **230***g* such that mount axis **230***e* extends through heat exchanger **220** in a radial direction relative to axis of rotation **162** of track driveshaft **44**. Likewise, when mounting flange **228***b* is secured to mounting rails **222** within right mounting location **222***a* with bolts **228***f*, **228***g*, mount axis **228***e* extends through heat exchanger **220** in a radial direction relative to axis of rotation **162** of track driveshaft **44** (not visible). In the illustrated embodiment, the recessed shape of mounting locations **222***a*, **222***b* conform to the shape of mounting flanges **228***b*, **230***b* to properly locate and retain mounting flanges **228***b* and **230***b* therein during fastening of mounting flanges **228***b*, **230***b* mounting rails **222**. Due to the resilient nature of vibration dampers **228***c*, **230***c*, vibration transfer from engine **26** to heat exchanger **220** is reduced and/or eliminated. In the illustrated embodiment, vibration dampers **228***c*, **230***c* are positioned aft of a plane **250** that is tangent to forward apex **244***c* and lower end **236***b* is positioned aft of at least a portion of vibration dampers **228***c*, **230***c*.

[0050] In the illustrated embodiments, mounting rails **222** are located on the forward side of upper housing **234** such that mounting rails **222** are closer to upper end **234***a* than lower end **236***b*. Mounting rails **222** extend the lateral direction of snowmobile **10** and have a length that is more than half the lateral length of heat exchanger **220** and, in the illustrated embodiment, have a length of about ninety percent of the lateral length of heat exchanger **220**. Disposed within upper housing **234** is a partition **234***c* that extends between forward wall **244***a* and aft wall **246***a* and includes one or more fluid passageways to allow fluid communication between uppermost chamber **238***d* and third chamber **238***c*. Partition **234***c* not only divides upper housing **234** to form uppermost chamber **238***d* and third chamber **238***c* but also provides reinforcement for mounting rails **222** as partition **234***c* sits behind the upper set of rails thus providing added support for engine **26**. Lower end **234***b* also provides reinforcement for mounting rails **222** as lower end **234***b* sits behind the lower set of rails thus providing added support for engine **26**. Lower end **234***b* includes one or more fluid passageways that are aligned with one or more fluid passageways of upper end **236***a* of lower housing **236** to allow fluid communication between second chamber **238***b* and third chamber **238***c*. Disposed within lower housing **236** is a partition **236***c* that extends between forward wall **244***b* and aft wall **246***b* and includes one or more fluid passageways to allow fluid communication between second chamber **238***b* and lowermost chamber **238***a*. In the illustrated embodiments, fluid port **242** is located on the forward side of lower housing **236** and extends in a forward and downward direction relative to forward wall **244***b*.

[0051] As discussed herein, the arcuate section of body **232** may extend the entire length of body **232** from lower end **236***b* to upper end **234***a* or may extend for only a portion of the entire length. For example, the arcuate section of body **232** may extend from lower end **236***b* to at least the uppermost part of mounting rails **222**. The arcuate section of body **232** may extend from lower end **236***b* to at least mount axis **230***e* of vibration damper **230***c* of left aftward engine mount **230**. The arcuate section of body **232** may extend from lower end **236***b* to at least the lowermost part of mounting rails **222**. In additional examples, the arcuate section of body **232** may extend at least between fluid port **242** and upper end **234***a*. The arcuate section of body **232** may extend at least between fluid port **242** and the uppermost part of mounting rails **222**. The arcuate section of body **232** may extend at least between fluid port **242** and mount axis **230***e* of vibration damper **230***c* of left aftward engine mount **230**. The arcuate section of body **232** may extend at least between fluid port **242** and the lowermost part of mounting rails **222**.

[0052] Heat exchanger **220** has a plurality of snow retaining fins **252** that extends aftward from aft wall **246**. The snow retaining fin **252** that are adjacent to lowermost chamber **238***a*, second chamber **238***b* and third chamber **238***c* each have a positive snow retention angle configured to enhance the dwell time of snow thereon. In the illustrated embodiment, snow retaining fins **252** have a progressively increasing positive snow retention angle from the uppermost snow retaining fin **252** of third chamber **238***c* to the lowermost snow retaining fin **252** of lowermost chamber **238***a*. The snow retaining fin **252** that are adjacent to uppermost chamber **238***d* have a negative snow retention angle configured to enhance the dwell time of snow thereon. In the illustrated embodiment, snow retaining fins **252** have a progressively increasing snow retention angle from the uppermost snow retaining fin **252** of uppermost chamber **238***d* to the lowermost snow retaining fin **252** of uppermost chamber **238***d*.

[0053] The foregoing description of embodiments of the disclosure has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the disclosure. The embodiments were chosen and described in order to explain the principals of the disclosure and its practical application to enable one skilled in the art to utilize the disclosure in various embodiments and with various modifications as are suited to the particular use contemplated. For example, numerous combinations of the features disclosed herein will be apparent to persons skilled in the art including the combining of features described in different and diverse embodiments, implementations, contexts, applications and/or figures. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the embodiments without departing from the scope of the present disclosure. Such modifications and combinations of the illustrative embodiments as well as other embodiments will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. An engine cooling system for a snowmobile including a forward frame assembly, an engine, a tunnel and a track driveshaft having an axis of rotation, the cooling system comprising:

a heat exchanger coupled to the forward frame assembly and to the tunnel, the heat exchanger positioned aft of the engine and configured to transfer heat from a coolant fluid circulated through the engine and the heat exchanger;

wherein, the heat exchanger includes a body having an arcuate section with a substantially constant radius of curvature and with a center of curvature proximate the axis of rotation of the track driveshaft.

2. The cooling system as recited in claim **1** wherein, the body has a forward wall, an aft wall, an upper end and a lower end, the forward and aft walls each having a forward apex; and

wherein, the arcuate section includes an upper portion extending upward and aftward from the forward apexes and a lower portion extending downward and aftward from the forward apexes.

3. The cooling system as recited in claim **2** wherein, the upper end is coupled to the tunnel and the lower end is coupled to the forward frame assembly.

4. The cooling system as recited in claim **2** wherein, the lower end is positioned aft of the forward apex of the aft wall.

5. The cooling system as recited in claim **2** wherein, the heat exchanger includes an engine mounting assembly positioned on the forward wall, the engine mounting assembly located closer to the upper end than the lower end; and

wherein, the arcuate section of the body extends from the lower end to at least the engine mounting assembly.

6. The cooling system as recited in claim **2** wherein, the heat exchanger includes a lowermost chamber disposed within the lower portion of the arcuate section; and

wherein, the heat exchanger includes a fluid port positioned on the forward wall and in fluid communication with the lowermost chamber.

7. The cooling system as recited in claim **6** wherein, the fluid port extends forward and downward from the forward wall.

8. A snowmobile comprising:

a forward frame assembly;

a tunnel coupled to the forward frame assembly;

a drive track system disposed at least partially below the tunnel, the drive track system including a track driveshaft having an axis of rotation; and

a heat exchanger having a body with a forward wall, an aft wall, an upper end and a lower end, the upper end coupled to the tunnel, the lower end coupled to the forward frame assembly, the heat exchanger including an engine mounting assembly positioned on the forward wall between the upper and lower ends;

wherein, the body has an arcuate section with a substantially constant radius of curvature and with a center of curvature proximate the axis of rotation of the track driveshaft, the arcuate section extending from the lower end of the body to at least the engine mounting assembly.

9. The snowmobile as recited in claim **8** wherein, the heat exchanger defines at least first and second chambers with a partition therebetween; and

wherein, the partition extends between the forward wall and the aft wall behind the engine mounting assembly.

10. The snowmobile as recited in claim **9** wherein, the body includes an upper housing that defines the first and second chambers, the engine mounting assembly integrally formed with the upper housing.

11. The snowmobile as recited in claim **8** wherein, the body has a length in the lateral direction of the snowmobile; and

wherein, the engine mounting assembly further comprises mounting rails having a length in the lateral direction of the snowmobile that is more than half the length of the body.

12. The snowmobile as recited in claim **8** further comprising a vibration damper having a mount axis that extends through the body, the vibration damper coupled to the engine mounting assembly;

wherein, the arcuate section of the body extends from the lower end of the body to at least the mount axis of the vibration damper.

13. The snowmobile as recited in claim **12** wherein, the mount axis of the vibration damper extends in a radial direction of the track driveshaft.

14. A snowmobile comprising:

a forward frame assembly;

a tunnel coupled to the forward frame assembly;

a drive track system disposed at least partially below the tunnel, the drive track system including a track driveshaft having an axis of rotation; and

a heat exchanger having a body including an upper housing with an upper end and a lower housing with a lower end, the upper end coupled to the tunnel, the lower end coupled to the forward frame assembly, the heat exchanger including an engine mounting assembly positioned on a forward side of the upper housing and a fluid port positioned on a forward side of the lower housing;

wherein, the body has an arcuate section with a substantially constant radius of curvature and a center of curvature proximate the axis of rotation of the track driveshaft, the arcuate section extending at least between the fluid port and the engine mounting assembly.

15. The snowmobile as recited in claim **14** wherein, the upper housing has a forward wall having a first thickness; and

wherein, the lower housing has a forward wall having a second thickness that is less than the first thickness.

16. The snowmobile as recited in claim **14** wherein, the body has a forward apex;

wherein, the upper end is positioned aft and above the forward apex; and

wherein, the lower end is positioned aft and below the forward apex.

17. The snowmobile as recited in claim **16** wherein, the forward apex is located on the lower housing.

18. The snowmobile as recited in claim **17** further comprising a vibration damper coupled to the engine mounting assembly;

wherein, the vibration damper is positioned aft of a plane that is tangent to the forward apex.

19. The snowmobile as recited in claim **18** wherein, the lower end is positioned aft at least a portion of the vibration damper.

20. The snowmobile as recited in claim **14** further comprising a vibration damper having a mount axis that extends through the body, the vibration damper coupled to the engine mounting assembly;

wherein, the arcuate section of the body extends at least between the fluid port and the mount axis of the vibration damper.

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