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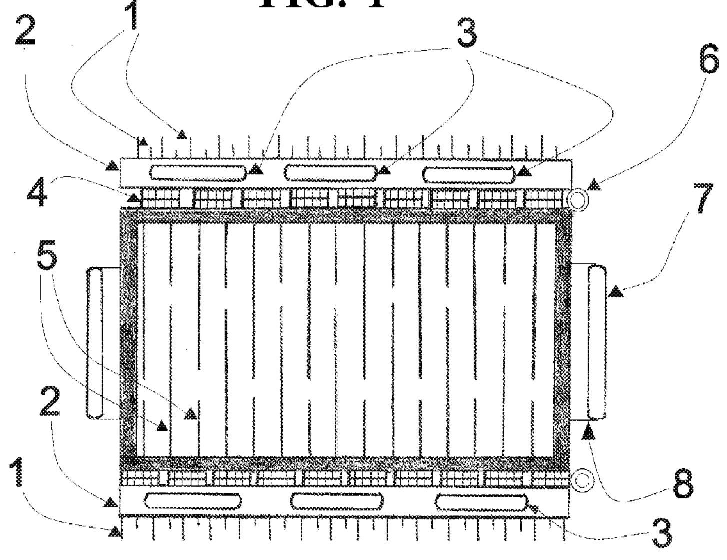
(54) Title: THERMOELECTRIC HEAT ENERGY RECOVERY MODULE GENERATOR FOR APPLICATION IN A STIRLING-ELECTRIC HYBRID AUTOMOBILE

FIG. 1



(57) Abstract: This embodiment is a Stirling-Electric Hybrid automotive exhaust module generator device for converting waste heat energy into electrical energy by employing the Seebeck Effect. The disclosure herein describes how the invention converts heat energy, from hot exhaust gases, from the operation of an automotive external combustion engine (e. g. Stirling Cycle engine), into electrical energy which is fed back into the electrical system of the Stirling-Electric Hybrid Automobile (Patent Number 7,726, 130 B2) minimizing losses due to the second law of thermodynamics. The improvements on the art in this disclosure focuses on employing a plurality of thermopiles and materials with improved coefficients of thermal conductivity and increasing residence time of the hot exhaust gases by inducing turbulent flow through the module generator device in conjunction with external cooling plate(s), heat sink(s); in the form of a plurality of pin(s), on the interior and exterior surface(s) of the module generator device.

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THERMOELECTRIC HEAT ENERGY RECOVERY MODULE GENERATOR FOR APPLICATION IN A STIRLING-ELECTRIC HYBRID AUTOMOBILE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority from U.S. patent application number 13/330,341, filed September 1, 2016, having the same title, and the same inventors, and which is incorporated herein by reference in its entirety.

TECHNICAL FIELD OF THE DISCLOSURE

[0001] The present invention pertains generally to hybrid vehicles, and more particularly to a Stirling electric hybrid vehicle equipped with a thermoelectric heat energy recovery module.

BACKGROUND OF THE DISCLOSURE

[0002] Thermopile technology is based upon the thermoelectric effect, or Seebeck effect. By applying a temperature difference to a pair of dissimilar metallic junctions in an electrical circuit, an electrical voltage is generated.

[0003] The practice of using thermopiles to generate electrical power via a variety of heat sources, including radio isotopes, has been employed by both the U.S. Department of Energy and the National Aeronautics and Space Administration (NASA). These applications include radio-thermal generators (i.e. RTGs) for remote power supplies for equipment deployed in Antarctica, and spacecraft power supplies (i.e., the Pioneer 10 Spacecraft). Thermopiles have been shown to be more efficient as ΔT increases.

[0004] Information disclosed in this Background of the Invention section, is only for enhanced and detailed understanding of the general background of the invention and should not be taken as an acknowledgement nor any form of suggestion that this information forms the prior art already known to a person skilled in the art.

SUMMARY OF THE INVENTION

[0005] Preferred embodiments of the systems and methodologies disclosed herein provide a thermoelectric module generator device which employs the Seebeck effect to convert waste heat energy from exhaust gases produced by an automotive external combustion Stirling Cycle engine into electrical energy.

[0006] The technical problems that the preferred embodiments of the systems and methodologies disclosed herein set out to resolve are not limited to the ones mentioned herein, and those technical problems that are not mentioned shall be clearly understood by a person skilled in the art by examining the present disclosure.

[0007] In one aspect, a thermoelectric generator module of a Stirling-Electric Hybrid Automobile may include an inlet conduit to transfer the flow of exhaust gases from the exhaust system (be it an exhaust manifold or exhaust pipe) into the module generator device where heat sink pins, which may be of varying lengths, may be arranged in a plurality of alternating offset, overlapping rows, such that there is no direct line of sight path to create turbulent flow of the exhaust gases as the gases flow from the inlet to the outlet. The overall geometric shape of the device may be such that the surface area of the top surface and the bottom surface of the device exceeds the surface area of the side surface(s) of the device by a factor of two or higher. The rows of heat sink pins may be affixed to the top and bottom interior surfaces of the device to absorb heat energy from the exhaust gases and to thermally conduct the heat energy to the top and bottom interior surfaces of the module generator device. The volumetric dimensions of the module generator device may be constructed to accommodate twice the volumetric capacity of the exhaust pipe or manifold, thereby minimizing exhaust system backpressure. A plurality of heat sink pins may be arranged geometrically to provide for a fluid dynamic porosity and permeability of 50% or higher.

[0008] The outlet of the device may have affixed to the outside surface(s) edge, an aerodynamically contoured air foil affixed at an angle at the edge of the outlet where the outlet is vented to the atmosphere. The air foil may take advantage of the air movement under the frame of the automobile such that the forward motion of the automobile will force air past the air foil, to create a Venturi effect to assist in drawing the exhaust gases out of the device to further minimize exhaust system back pressure.

[0009] The outer surfaces of the top and bottom of the device may have a plurality of layers of thermopiles in an array affixed to the surface via a thermally conductive adhesive and/or fixture. The thermopile array may be wired in series and/or parallel in wiring harnesses, which may be shielded in a conduit, to satisfy the specifications of the electrical system of the Stirling-Electric Hybrid Automobile. The heat energy from the heat sink pins on an interior surface of the module generator device may be conducted through the surface of the module generator device to the outer surfaces of the module generator device to the hot side of the thermopiles in the thermopile array.

[0010] A cooling plate made of a thermally conductive material, may be affixed to the cold side of the thermopiles in the thermopile array via a thermally conductive adhesive and/or fixture. This thermally conductive material may include, but is not limited to, one or more materials selected from the group consisting of ceramics, ceramic composites, metallic alloys and metallic alloy composites. A cooling fluid may circulate through a channel in a pattern to circulate the fluid to and from a radiator device to expel excess waste heat energy. This pattern may include, but is not limited to, a serpentine pattern.

[0011] The radiator device may be constructed of one or more materials selected from the group consisting of thermally conductive ceramics, ceramic composites, metallic alloys and metallic alloy composites. The radiator device may be affixed with at least one fan which is driven by electricity or by mechanical means. Such mechanical means may include, but is not limited to, mechanical means which provide motive power to the fan for the purpose of forcing ambient air over, and/or through, the radiator device to expel excess waste heat energy conducted to the surfaces of the radiator device from the cooling fluid. These mechanical means may include at least one mechanical means selected from the group consisting of belts, cog wheels and other such devices. The radiator device may be part of the overall cooling radiator system of the Stirling-Electric Hybrid Automobile, or may be separate from the overall radiator cooling system.

[0012] An outer surface of the cooling plate may be affixed with a plurality of heat sink pins by a thermally conductive adhesive and/or fixture such that passive transfer of heat energy from a surface of the cooling plate to the heat sink pins is accomplished. The heat sink pins may expel excess waste heat energy passively via air movement the under the frame generated by the forward motion of the automobile forcing air over and/or through the arrangement of heat sink pins.

BRIEF DESCRIPTION OF THE DISCLOSURE

[0013] For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numerals indicate like features.

[0014] FIG. 1 is a diagrammatic view of the outlet end of the Thermoelectric Heat Energy Recovery Module (THERMO) Generator device for application in a Stirling-Electric Hybrid vehicle in accordance with the teachings herein.

[0015] Figure 2 is a lateral view of a diagrammatic representation of a module generator device.

[0016] Figure 3 is a diagrammatic representation of the plurality of thermopile arrays affixed to an outer surface of a module generator device which is wired in series, and/or parallel, to meet the electrical specifications of the electrical system of the Stirling-Electric Hybrid Automobile.

[0017] Figure 4 is a diagrammatic representation of a cooling plate with a tubular channel therein for the circulation of cooling fluid.

[0018] Figure 5 is a layered, cut away diagrammatic representation of an outlet surface of a module generator device which is in direct contact with thermopiles arrayed in a plurality of layers.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0019] Automotive applications of thermopiles have been limited, in part, because the temperatures of exhaust gases from internal combustion engines can reach 800° C when measured at the exhaust manifold. Conventional heat sink materials, stable at these high temperatures, are not as thermally conductive as they are at lower temperatures, thus resulting in less favorable ΔT across the thermopile for the generation of electrical voltage. These high temperatures limit the types of materials that can be employed to maintain favorable rates of efficient heat energy transfer. Additionally, previous designs have not employed both active, and passive, heat energy transfer techniques, and more effective heat energy transfer methodologies as disclosed herein the present invention, such as heat sink(s) pin(s), rather than less efficient heat transfer fins. None of the previous designs were specific to a series hybrid electric automotive application employing an external combustion Stirling Cycle engine. The operation of an automotive Stirling Cycle engine produces exhaust gases at significantly lower temperatures than exhaust gas temperatures produced by current internal combustion engines. These lower temperatures provide for more efficient application of thermopile technology, since a broader range of more effective heat sink materials are stable at these lower temperature ranges. Generally speaking, heat sinks have a greater coefficient of thermal conductivity at lower temperatures. There is roughly a 50% loss in thermal conductivity of a heat sink composed of Iron at 800°C when compared to the thermal conductivity of the same material at 200°C.

[0020] An example of a heat sink material available for use with the external combustion Stirling Cycle engine is Aluminum. Aluminum, when employed as a heat sink material, has superior coefficient of thermal conductivity to that of Iron. However, Aluminum cannot be used at the higher exhaust gas temperatures produced by internal combustion engines, since exhaust gas temperatures are well above the melting point of 660°C. These physical properties of Aluminum make it unsuitable as a heat sink material at the higher temperatures found in the exhaust gases of the internal combustion engine, but make it an ideal material to be employed when recovering heat energy from the exhaust gases produced by an external combustion Stirling Cycle engine.

[0021] The application of a thermopile module generator device to generate electrical energy from waste heat energy carried by exhaust gases from an external combustion Stirling-Electric Hybrid Automobile is novel. Additionally, previous designs of automotive thermoelectric generators did not take advantage of both active and passive systems of heat energy transfer. Previous designs did not employ a plurality of heat sink pins which have superior heat transfer characteristics to those of heat transfer fins, due to a more favorable surface area to mass ratio typically found in the design of heat sink pins. Additionally, heat sink pins do not inhibit heat transfer by boundary layer effects as is typical with the laminar fluid flow with the employment of heat transfer fins.

[0022] Previous automotive applications could not take advantage of more efficient heat sink materials such as Aluminum, because such materials would melt at the higher temperatures of operation typically found in the exhaust manifold of an internal combustion engine. Additionally, the geometric configuration of the heat sink pins improves heat energy transfer rates from the exhaust gases to a thermopile array by creating micro turbulent flow within the exhaust module generator device. This increases residence time of the exhaust gas molecules, allowing for a more complete heat energy transfer to the thermopile array, while minimizing back pressure within the exhaust system.

[0023] Exhaust gas temperatures from an external combustion automotive Stirling Cycle engine typically range from 150° C to 250° C when measured at the exhaust manifold. The current state of the art on thermopile power generation requires at least a 50° C temperature difference (ΔT) to generate power at optimum efficiencies. Preferred embodiments of the systems and methodologies disclosed herein utilize a Stirling Cycle engine, which has significantly lower exhaust gas temperature ranges than conventional combustion engines. This represents a significant improvement in the art, since high temperature range thermopiles are not as efficient as lower temperature range thermopiles. This is due, in part, to the greater ability to maintain more favorable thermal gradients from the hot side of the thermopile to the cold side of the thermopile at lower temperatures. The coefficients of thermal conductivity for materials, which are stable at high temperatures, have a lower rate of heat energy transfer at high temperatures than the same material has at a lower temperatures. Essentially, there is an inverse relationship in the rate heat energy transfer such that, as temperatures drop, the coefficient of thermal conductivity of materials increases.

[0024] The technical problems that may be solved with the systems and methodologies disclosed herein are not limited to those mentioned above, and those that are not mentioned shall be clearly understood by a person skilled in the art upon examining the present disclosure.

[0025] Figure 1 is a diagrammatic view of the outlet end of a Thermoelectric Heat Energy Recovery Module (THERMO) Generator device for application in a Stirling-Electric Hybrid automotive application in accordance with a preferred embodiment of the systems and methodologies disclosed herein. The Thermoelectric Heat Energy Recovery Module Generator device may include a conduit which allows for the flow of exhaust gases through the interior of the module generator device from the inlet to the outlet for venting to the atmosphere. This conduit is preferably tubular, but may have various other geometric shapes.

[0026] Opposite of the outlet, the inlet of the module generator device may be connected to the exhaust manifold (or to the exhaust pipe and/or other conduit) to transfer the exhaust gases of the module generator device before venting to the atmosphere. The outlet of the module generator device may be vented to the atmosphere, or may be connected to other Thermoelectric Heat Energy Recovery Module Generator device in series before venting to the atmosphere. An interior surface (which may be an upper or lower interior surface) of the module generator device may have a plurality of varying length heat sink pins (5) affixed thereto. These pins may eb arranged in a plurality of offset overlapping rows such that there is no direct line of sight flow path as the exhaust gases move from the inlet to the outlet of the module generator device. The geometric arrangement of the plurality of heat sink(s) pin(s) may be designed in such a manner as to achieve a porosity and permeability of 50% or higher from the inlet to the outlet.

[0027] A plurality of thermopile(s) array(s) (4) may be affixed, via a thermally conductive adhesive and/or fixture, to an outer surface of the module generator device to absorb heat energy from an outer surface of the module generator device. The plurality of thermopiles may be arrayed in various geometric arrangements and may be in a plurality of layers, may be wired in series, and/or may be wired parallel in accordance with the voltage specifications of the electrical system of the Stirling-Electric Hybrid Automobile. The wiring may be bundled into a conduit and/or wiring harness (6) to connect the wiring to the electrical system of the Stirling-Electric Hybrid Automobile.

[0028] A cooling plate(s) (2) may be affixed via thermally conductive adhesive and/or fixture(s) to the outer most surface(s) of the thermopile(s) array(s) (4) in such a manner as to absorb heat energy from the surface(s) of the thermopile(s) arrayed on the surface(s) of the module generator device. The cooling plate(s) may have a plurality of tubular channels, both internal and external, (3) through which cooling fluid may flow in a pattern similar to, but not limited to, a serpentine pattern such that the cooling fluid circulates through the majority of the mass, and/or area, of the cooling plate(s). This circulation of cooling fluid will be augmented by external tubular return loops (3) to conduct the cooling fluid through the cooling plate(s). The circulating fluid may be pumped actively to and from the radiator through the cooling plate(s) via a cooling fluid inlet and a cooling fluid outlet, which may be part of the overall radiator cooling system, or separate from the overall radiator cooling system.

[0029] A plurality of heat sink(s) pin(s) (1), of varying length, may be affixed to the outer surface(s) of the cooling plate(s) and geometrically arranged in offset overlapping rows and of varying lengths, to take advantage of air movement under the frame of the Stirling-Electric hybrid Automobile (ibid) as the vehicle moves forward to expel heat energy derived from the module generator device to the ambient air.

[0030] Attached to the side(s) of the module generator device may be air foil(s) to direct air flow past the outlet end of the module generator device (7) which is affixed to the outermost surface of the module generator device via a bracket (8) and/or other fixture to allow for air flow past the air foil(s).

[0031] Figure 2 is a lateral view of a diagrammatic representation of the module generator device. The inlet end (10) of the module generator device is to be affixed to an exhaust pipe, exhaust manifold and/or other conduit device, to transfer the hot exhaust gases to the interior of the module generator device for venting to the atmosphere via the outlet (9) of the device. Affixed to the outermost surface(s) of the module generator device are the thermopile(s) array(s) (4). Affixed to the outermost surface(s) of the thermopile(s) array(s) (4) is the cooling plate(s) (2) via thermally conductive adhesive and/or fixture(s). The cooling Plate(s) has a tubular return loop(s) (3) to conduct circulating fluid through the tubular channel(s) of the cooling plate(s) via the circulating fluid inlet (11) and then via the tubular return loop(s) (3) to the fluid outlet (12). An air foil (7) is attached to the side of the module generator device to direct air flow past the outlet end of the module generator device.

[0032] Figure 3 is a diagrammatic representation of the plurality of thermopile(s) array(s) affixed to the outer surface(s) of the module generator device wired in series, and/or parallel to meet the electrical specifications of the electrical system of the Stirling-Electric Hybrid Automobile (ibid). The wiring may be bundled into a conduit to carry the electrical power to the electrical system of the Stirling-Electric Hybrid Automobile (ibid). The plurality of thermopile(s) array(s) may be arranged in a plurality of layers.

[0033] Figure 4 is a diagrammatic representation of the cooling plate(s) (2) with a tubular channel(s) for the circulation of cooling fluid which may circulate in a pattern to include, but not limited to a serpentine pattern, to circulate the fluid to and from a radiator device via the cooling fluid inlet(s) (11) and cooling fluid outlet(s) (12) of the cooling plate(s) to expel excess waste heat energy. The pattern of serpentine circulation of the cooling fluid within the cooling plate(s) (2) is augmented by return loop(s) tube(s) (3) at either end of the cooling plate(s) (2) until the cooling fluid exits the cooling plate(s) (2) via the cooling fluid outlet(s) (12).

[0034] Figure 5 is a layered cut away diagrammatic representation of the outlet (14) surface(s) of the module generator device in direct contact with the thermopile(s) (4) arrayed in a plurality of layers. The cut away diagrammatic representation of the cooling plate(s) (2) are in direct contact with the thermopile(s) array(s) (4). The wiring of the thermopile(s) array(s) may be bundled into a conduit(s) and/or wiring harness (6) to connect with the electrical system of the Stirling-Electric Hybrid Automobile (ibid). Heat sink(s) pin(s) (1) are diagrammatically represented having direct contact with the outer surface(s) of the cooling plate(s) (2) which have tubular channels (13) for the circulation of cooling fluid. In direct contact with the cooling plate(s) (2) are the outmost surfaces of the thermopile(s) array(s) (4) which are affixed to the outermost surface layer(s) between the interior and exterior of the module generator device. Affixed to the lateral side of the module generator device is an air foil (7) which is affixed with a bracket and/or fixture (8) to direct air flow past the outlet of the module generator device. The interior surfaces(s) of the module generator device are affixed with a plurality of heat sink(s) pin(s) (5) of varying length, arranged in a plurality of rows with each row offset one from the other.

[0035] This embodiment of the invention is Stirling-Electric Hybrid automotive exhaust module generator device for converting waste heat energy into electrical energy by employing the Thermoelectric Effect, also known as the Seebeck Effect. The disclosure herein describes how the invention converts heat, from hot exhaust gases, from the operation of an automotive external combustion engine (e. g. Stirling Cycle engine), into electrical energy which is fed back into the electrical system of the Stirling-Electric Hybrid Automobile (Patent Number 7,726,130 B2) minimizing losses due to the second law of thermodynamics. The improvements on the art in this disclosure focus on taking advantage of the first law of thermodynamics by increasing residence time of the hot exhaust gases through the module generator device by employing heat sink(s), in the form of a plurality of pins, on the interior surface(s) of the module generator device. additional improvements may be implemented by employing materials with higher coefficients of thermal conductivity such as ceramic, ceramic composite(s), metal alloys and/or metal alloy composite(s), for the module generator device, the overall rate of heat transfer of the module generator device surface(s) may be improved. As exhaust gases move from the inlet of the module generator device to the outlet, the plurality of pin(s) of the heat sink(s) create micro-turbulences such that micro-vortices and turbulent flow move the exhaust gas molecules over more heat transfer surface(s) area(s) of the module with a resultant improvement in heat energy transfer than can be currently attained with heat transfer fins due to the boundary layer effect typical in laminar fluid flow. Additionally, this configuration of the plurality of heat sink(s) pin(s) will resolve the problem of creating back-pressure in the exhaust system that is inherent in heat transfer fin designs due to laminar fluid flow boundary layer effects. The plurality of the heat sink(s) pin(s) transfers the heat energy to the outer surface(s) of the module where, a plurality of thermopile(s), are wired in both series and/or parallel bundles, to meet the voltage specifications of the electrical system. The plurality of the thermopile(s) composes an array(s) which may be affixed to the hot outer surface(s) of the exhaust module device such that the thermopile(s) are in direct contact with the outer surface(s) of the module device via thermally conductive adhesives and/or fixtures to provide for heat energy transfer via thermal conduction. The thermopile(s) array(s) may be in a plurality of layers, each layer in direct contact with the adjacent layer to transfer heat energy, one from the other, by thermal conduction. Cooling plate(s) may be affixed in direct contact to the outer surface(s) of the thermopile(s) array(s) with a thermally conductive adhesive and or fixture(s) to provide for heat energy transfer via thermal conduction. The cooling plate(s) may be composed of a thermally conductive material to include, but not limited to ceramic, ceramic composite(s), metal alloy and/or metal alloy composite(s). The cooling plate(s) is to provide for a significant ΔT between the surface(s) of the thermopile(s) array(s), which are in direct contact with the outer surface(s) of the module generator device and the cooling plate(s) surface(s) such that an electrical voltage is generated when a minimum threshold ΔT is achieved. The cooling plate(s) may transfer heat energy from the thermopile(s) array(s) to the ambient air, both actively and passively. The active cooling may be provided by the employment of a serpentine arrangement of a tubular channel(s) in the cooling plate(s) through which cooling fluid circulates to and from the cooling plate via a radiator to expel heat energy from the circulating fluid to the ambient air. The passive cooling may be accomplished by affixing a plurality of heat sink(s) pin(s) to the outer surface(s) of the cooling plate(s) to take advantage of the air movement under the vehicle frame, to expel heat to the ambient air, as the automobile moves along the roadway.

[0036]

[0037] In order to facilitate a better understanding of the systems, devices, methodologies and platforms disclosed herein, specific embodiments of platforms and FPGAs have been disclosed herein, and specific components of these devices have been identified including, in some instances, specific models and types of these components, and specific attributes or performance characteristics possessed by these components. However, unless otherwise indicated, the systems, devices, methodologies and platforms disclosed herein are not limited to these specific models or types, or to components having the specific recited attributes or performance characteristics.

[0038] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0039] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0040] Unless otherwise indicated, the use herein of the conjunctive “or” shall be construed inclusively. Thus, for example, the phrase “A or B” shall be construed to include only A, only B, and A and B.

[0041] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

[0042] In the following claims, unless indicated otherwise in the specification, the elements in different dependent claims may be combined without departing from the scope of the invention. For example, if claim X has claims X1 and X2 dependent thereon, and if claims X1 and X2 recite, respectively, elements A and B, then both of elements A and B may be added to claim X without departing from the scope of the invention.

WHAT IS CLAIMED IS:

1. A hybrid electric vehicle, comprising:

a Sterling engine;

an exhaust system; and

a Thermoelectric Heat Energy Recovery Module (THERMO) module generator device attached to said exhaust system;

wherein said module generator device has an interior space which is equipped with an array of heat sink pins, and wherein said heat sink pins are in direct contact with an interior surface of said module generator device.

2. The vehicle of claim 1, wherein said heat sink pins are arranged in rows, and wherein the heat sink pins in adjacent rows are offset from each other.

3. The vehicle of claim 1, wherein said module generator device has first and second opposing interior surfaces, wherein said array of heat sink pins includes a first array of heat sink pins disposed on, and in direct contact with, said first interior surface, and a second array of heat sink pins disposed on, and in direct contact with, said second interior surface, wherein said first and second arrays of heat sink pins are disposed in an overlapping manner, and wherein the heat sink pins in the first array of heat sink pins do not contact the heat sink pins ion the second array of heat sink pins.

4. The vehicle of claim 1, wherein said module generator device is equipped with an inlet and an outlet disposed in an opposing relation to each other.

5. The vehicle of claim 4, wherein the inlet is connected to said exhaust system.

6. The vehicle of claim 1, wherein said module generator device has volumetric dimensions which accommodate at least twice the volumetric capacity of the exhaust system.

7. The vehicle of claim 3, wherein the inlet is connected to said exhaust system, and wherein the array of heat sink pins has a porosity and permeability of at least 50% throughout a portion of the interior space which extends from the inlet to the outlet.

8. The vehicle of claim 1, wherein the heat sink pins are affixed to the interior surface of said module generator device with an attaching means selected from the group consisting of thermally conductive adhesives and fixtures.

9. The vehicle of claim 1, further comprising a cooling plate.

10. The vehicle of claim 9, wherein an outer surface of the module generator device is equipped with a plurality of thermopiles that are in direct contact with the outer surface.

11. The vehicle of claims 9 or 10, wherein an outer surface of the module generator device is equipped with a plurality of layers of thermopiles, wherein a first of the plurality of layers is in direct contact with the outer surface of the module generator device, and wherein a second of the plurality of layers is in direct contact with said cooling plate.

12. The vehicle of claim 11, wherein the first of the plurality of layers is affixed to the outer surface of the module generator device with a connecting means selected from the group consisting of thermally conductive adhesives and fixtures.

13. The vehicle of claim 9, wherein the plurality of thermopiles are wired in series and/or in parallel and are connected to the electrical system of the vehicle by means of a conduit or other shielding device.

14. The vehicle of claim 11, wherein the cooling plate is directly attached to the second of the plurality of layers with an attaching means selected from the group consisting of thermally conductive adhesives and fixtures.

15. The vehicle of claim 11, wherein said cooling plate has a plurality of tubular channels which extend through it.

16. The vehicle of claim 15, wherein the tubular channels are geometrically arranged to maximize the area and/or mass of the cooling plate.

17. The vehicle of claim 15, wherein said plurality of tubular channels is equipped with an inlet and an outlet, and further comprising:

a circulating system for circulating a cooling fluid to and from the cooling plate by way of the inlet and outlet, respectively.

18. The vehicle of claim 17, further comprising:

a radiator; and

a conduit in fluidic communication with the circulating system.

19. The vehicle of claim 18, wherein the circulating system comprises a pump which circulates the cooling fluid between the cooling plate and the radiator.

20. The vehicle of claim 17, further comprising:

a fan which forces air over or through surfaces of the radiator.

21. The vehicle of claim 20, wherein the fan is driven mechanically or electrically.

22. The vehicle of claim 19, wherein the pump is driven mechanically or electrically.

22. The vehicle of claim 11, wherein said cooling plate has an outermost surface which is in direct contact with a plurality of heat sink pins.

23. The vehicle of claim 11, further comprising a plurality of the heat sink pins attached to said outermost surface with an attaching means selected from the group consisting of thermally conductive adhesives and fixtures.

24. The vehicle of claim 23, wherein said plurality of heat sink pins are arranged in rows, and wherein the heat sink pins in adjacent rows are offset from each other.

25. The vehicle of claim 4, further comprising an air foil, wherein said airfoil is affixed to said outlet.

26. The vehicle of claim 25, wherein said air foil is disposed at an angle to direct air toward the outlet end such that, when there is forward motion of the vehicle, air is forced air past the outlet end of the module generator device.

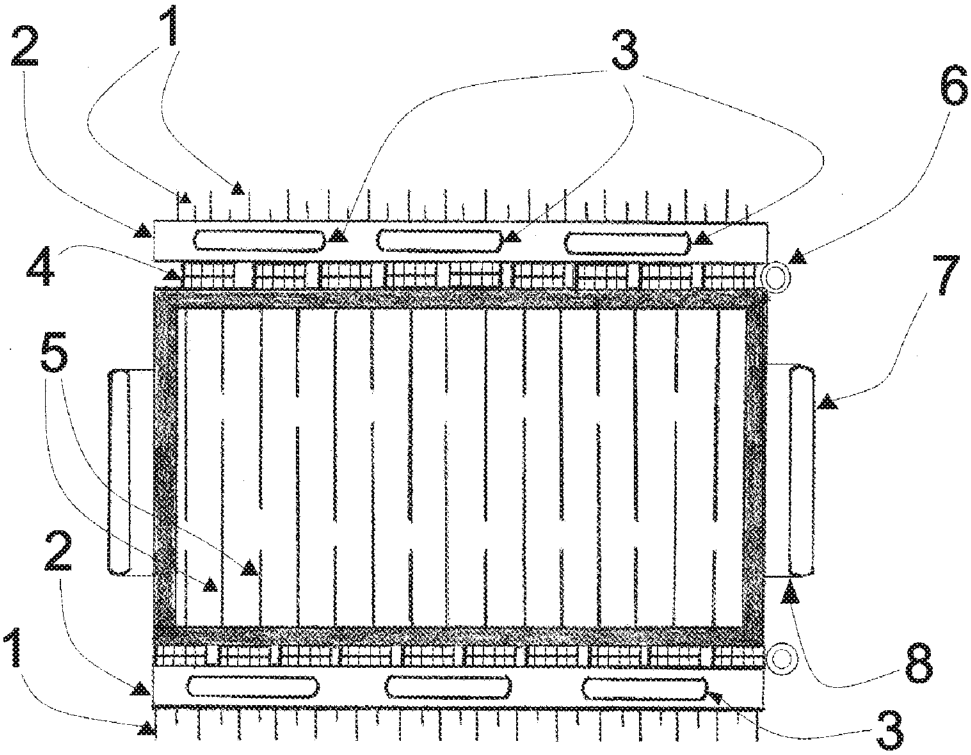

FIG. 1

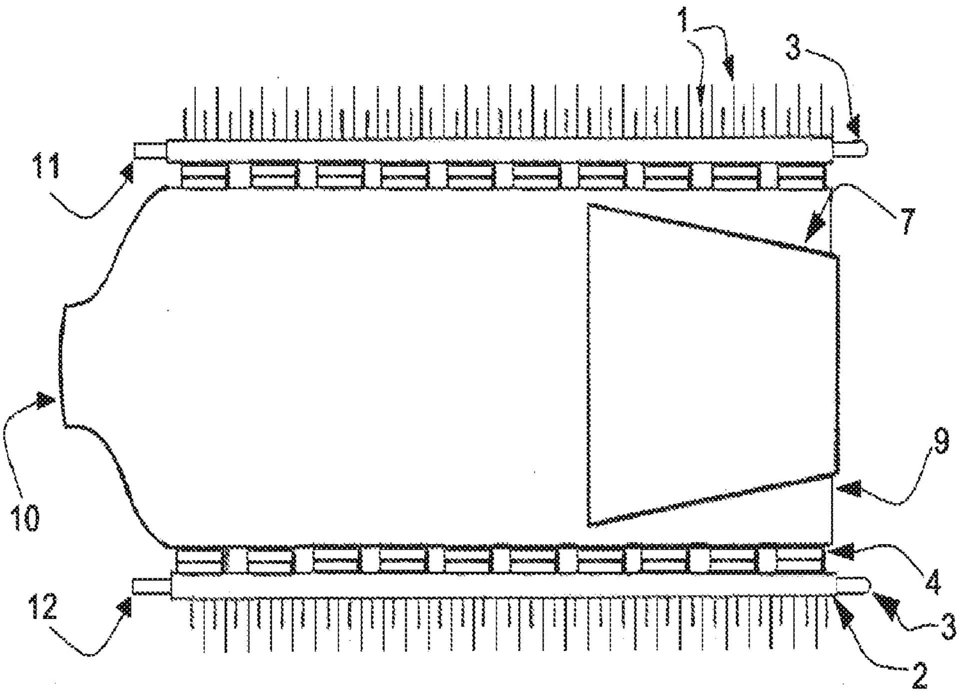

FIG. 2

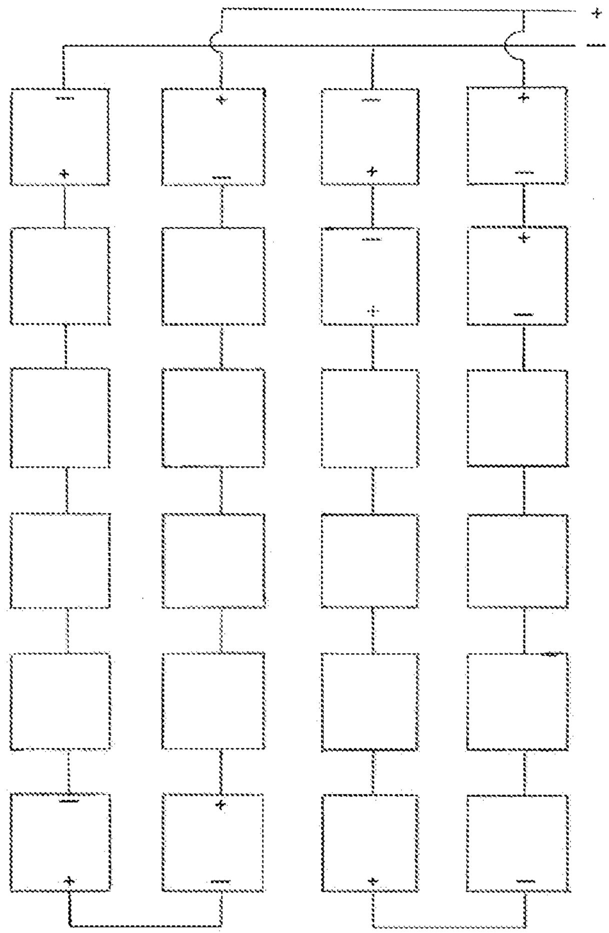

FIG. 3

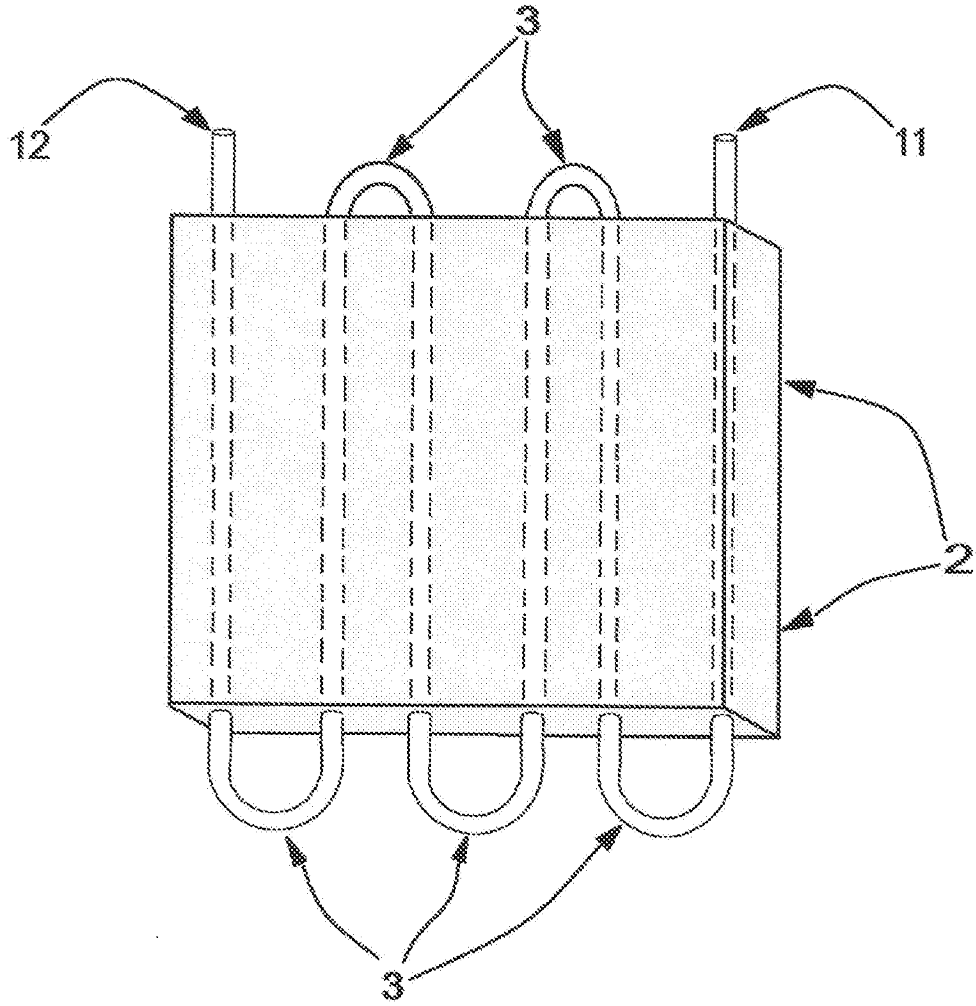

FIG. 4

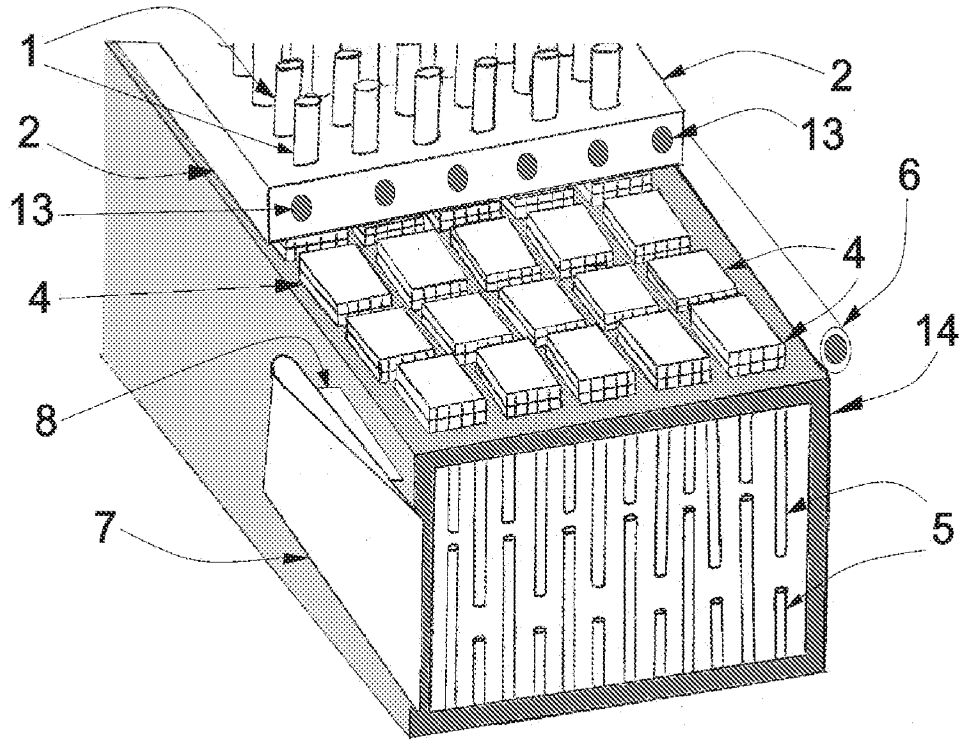

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/49983

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F01N 5/02; F02G 5/02; H01L 35/32 (2017.01)
CPC - F01N 5/025; F02G 5/02; H01L 35/32; Y02T 10/166

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2015-140713 A (SUZUKI MOTOR CORP) 03 August 2015 (03.08.2015), Fig 1-3, 7, abstract, para [0013], [0025]-[0029], [0030], [0033], [0034]	1-21, 22a, 22b, 23-26
Y	US 7,469,760 B2 (KAMEN et al.) 30 December 2008 (30.12.2008), Fig 1, 10a, 10b, abstract, col 1, ln 11-24, col 15, ln 15-60	1-21, 22a, 22b, 23-26
Y	US 2014/0026933 A1 (KELL et al.) 30 January 2014 (30.01.2014), abstract, para [0050], [0087]	8, 12
Y	US 4,463,214 A (LOWTHER) 31 July 1984 (31.07.1984), Fig 7, 8A, 8B, abstract, col 22, ln 39-45	10-21, 22a, 22b, 23, 24
Y	US 4,691,668 A (WEST) 08 September 1987 (08.09.1987), Fig 1, abstract, col 3, ln 4-25	19-21, 22a
Y	US 8,188,359 B2 (CHAKRABORTY) 29 May 2012 (29.05.2012), Fig 1, abstract, col 3, ln 30-36	22b, 23, 24
Y	US 8,713,924 B2 (BRUCK et al.) 06 May 2014 (06.05.2014), Fig 6, abstract, col 12, ln 17-41	25, 26

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 December 2017	29 JAN 2018

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774