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(54) **EXTERNAL HEAT ENGINE OF THE ROTARY VANE TYPE AND COMPRESSOR/EXPANDER**

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(57) **ABSTRACT**

A heat engine of the rotary vane type and thermodynamic cycle is disclosed. The engine converts thermal energy contained within relatively low temperature hot gasses into mechanical energy. The engine operates by expanding a hot gas to a sub-atmospheric pressure, cooling the gas at a roughly constant volume and then cooling the gas further while compressing it back to atmospheric pressure. Possible sources of hot gasses for powering the engine include exhaust gasses from other engines and air heated by solar collectors. A novel compressor and expander comprised of the primary components of the engine is also disclosed.

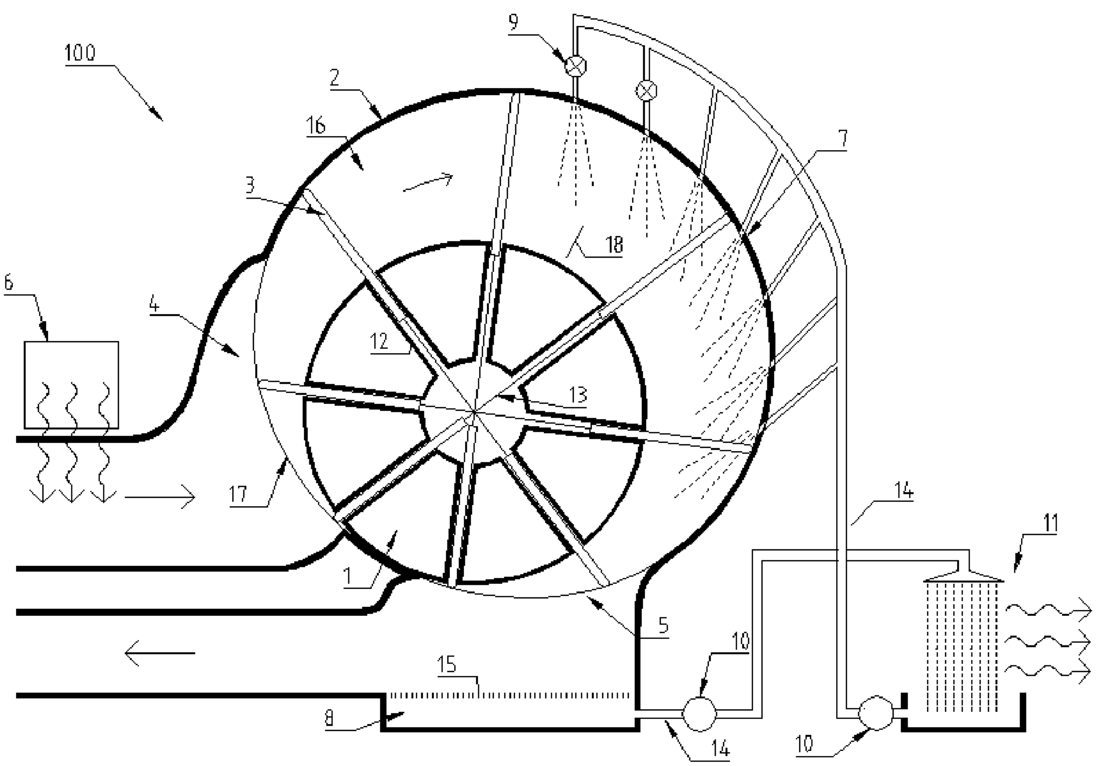


FIG. 1

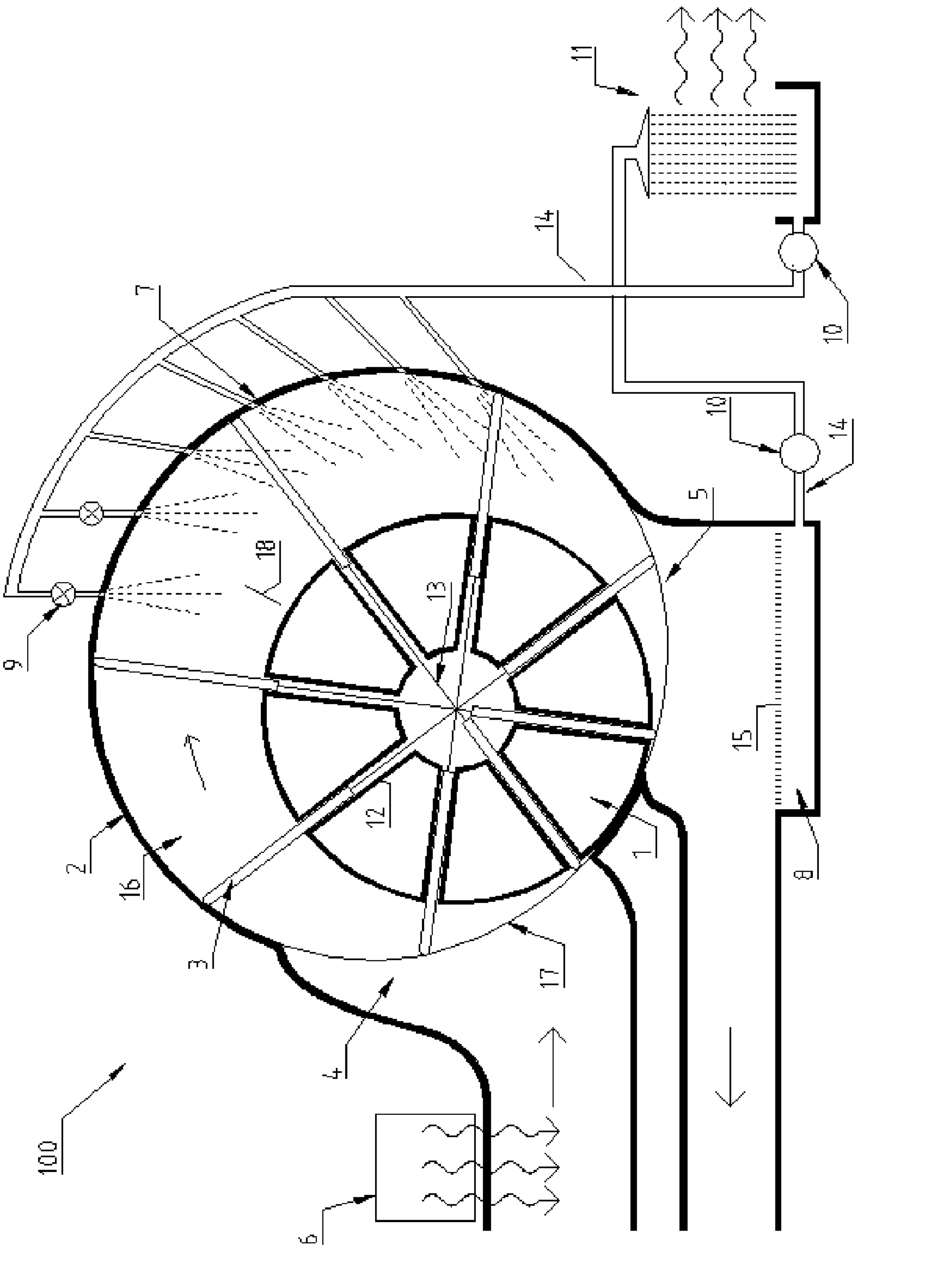


FIG. 2

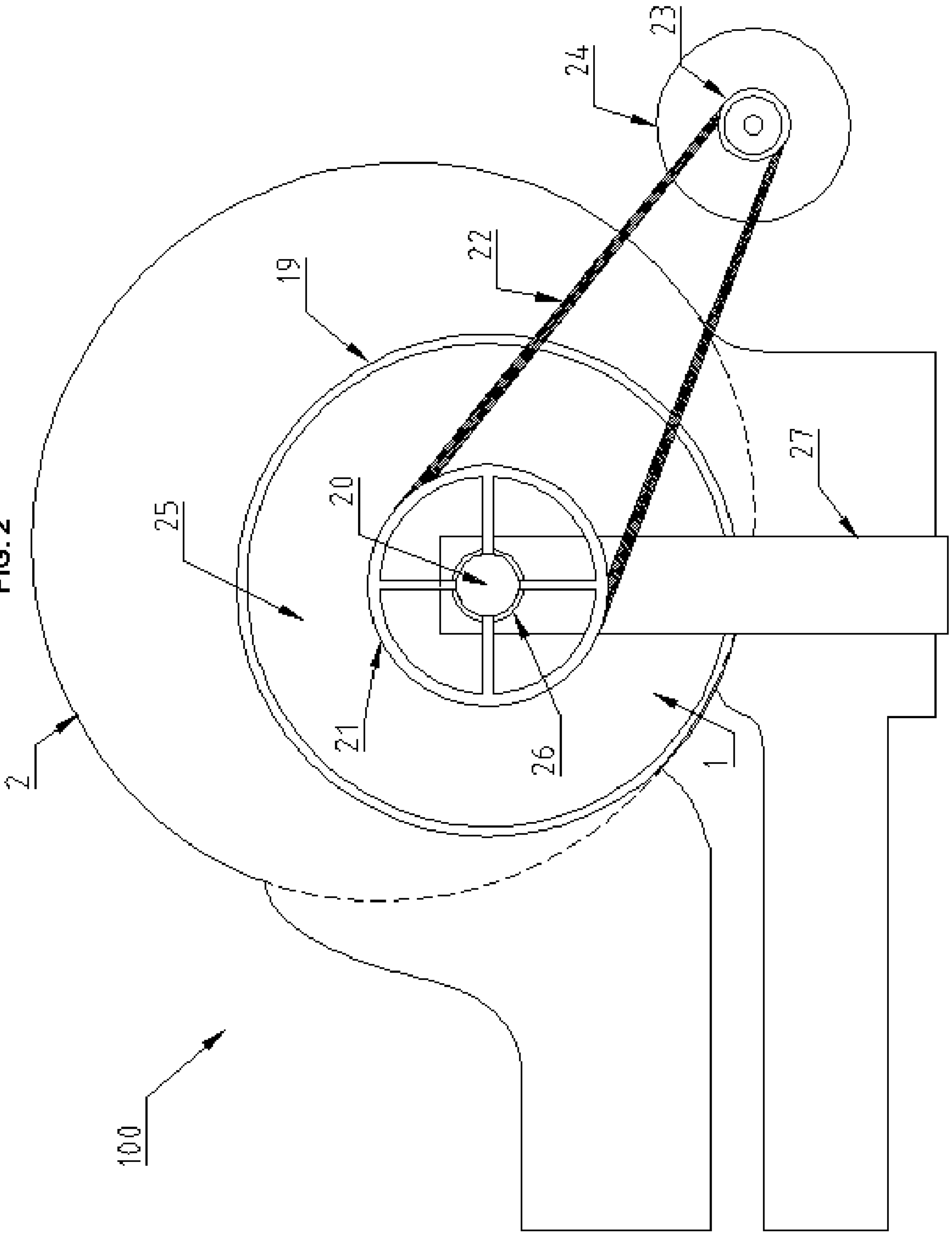


FIG. 3

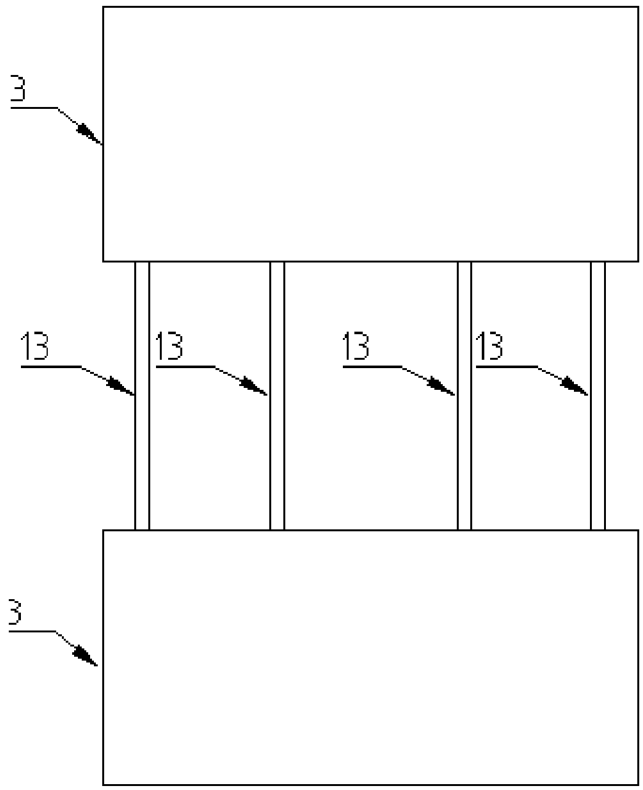


FIG. 4

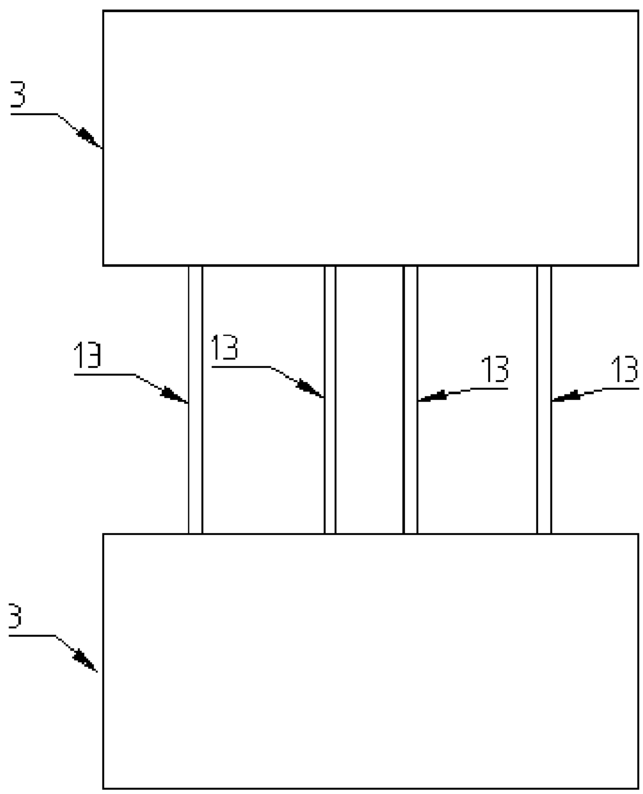


FIG. 5

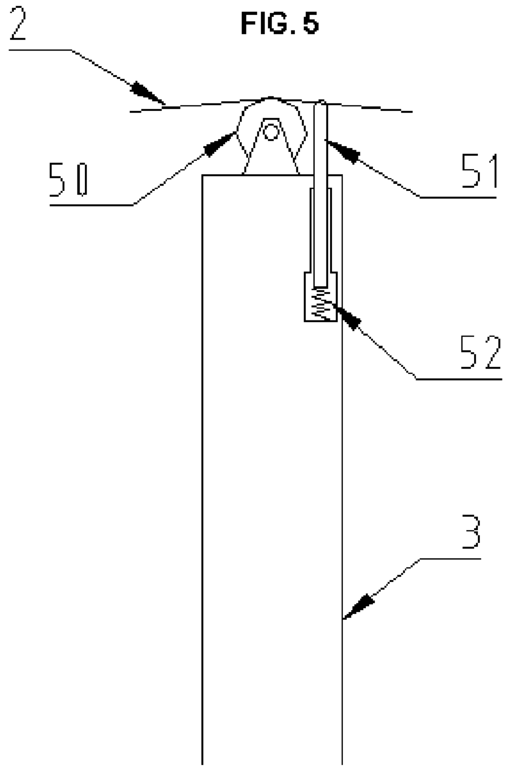


FIG. 6

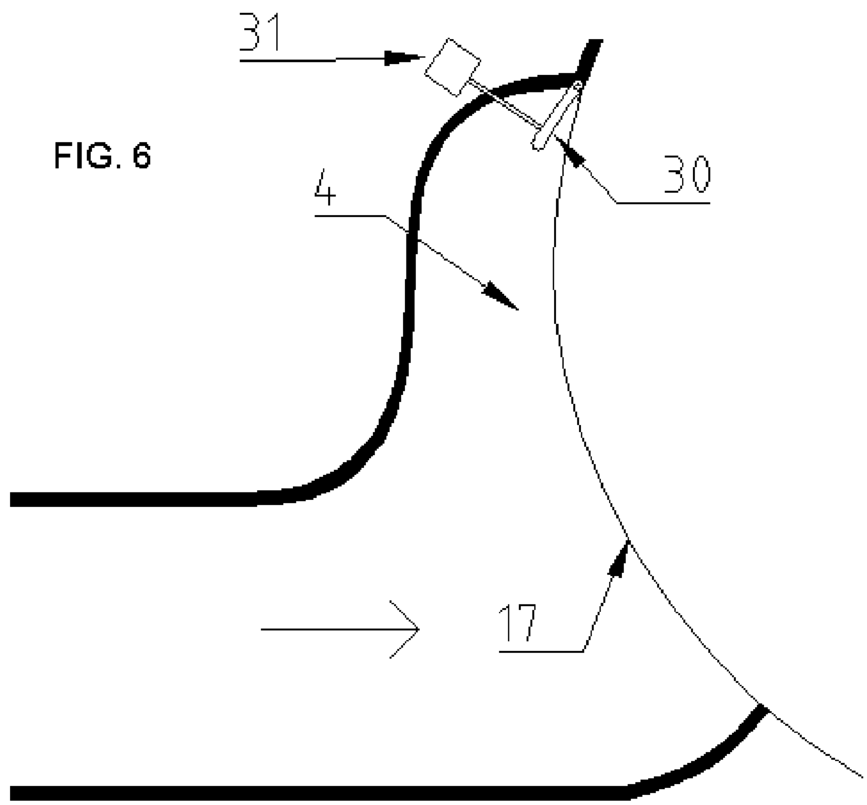


FIG. 7

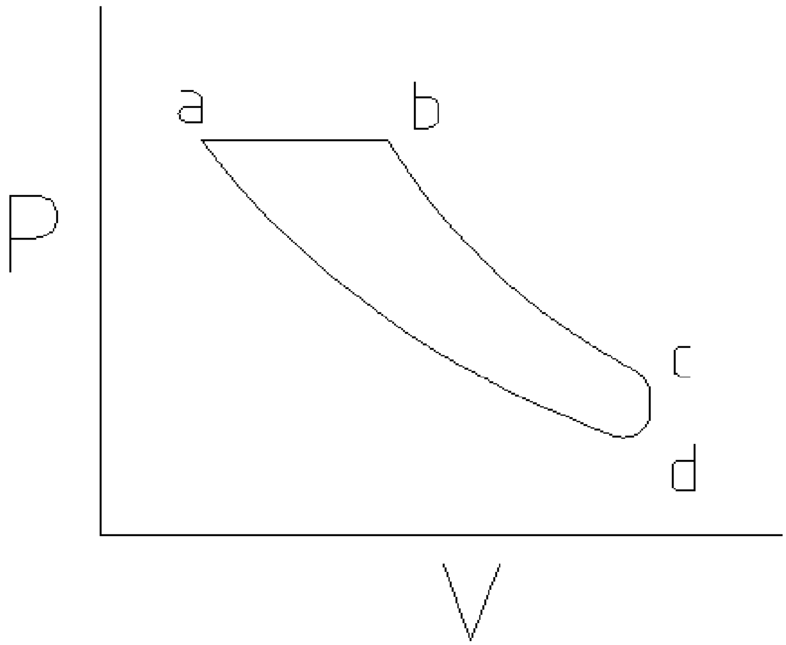
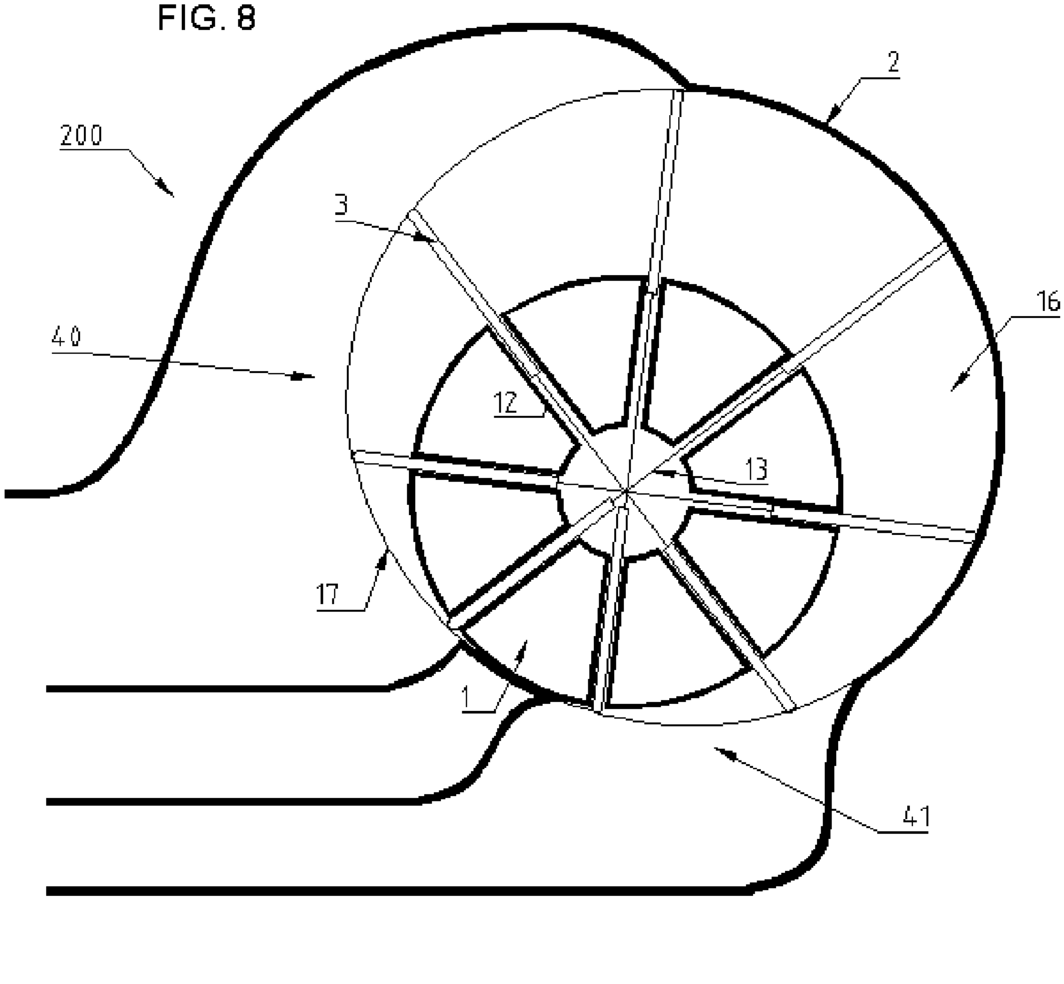


FIG. 8



EXTERNAL HEAT ENGINE OF THE ROTARY VANE TYPE AND COMPRESSOR/EXPANDER

BACKGROUND OF THE INVENTION

[0001] Heat engines that convert thermal energy into mechanical energy by cycling a working fluid through a suitable thermodynamic cycle have been around for a very long time and come in countless varieties. To maximize efficiency heat engines are typically designed to heat their working fluid to a high temperature. The higher the temperature reached by the working fluid the more efficient the engine can become.

[0002] However, heat engines that are designed to operate at high temperatures and high efficiencies typically cannot effectively or economically convert thermal energy from low temperature heat sources into other usable forms of energy.

[0003] Given the rising cost of fuel and a relative abundance of low cost and environmentally friendly low temperature heat sources, the economic viability of an engine that can effectively harness the energy of low temperature heat sources is greater than ever.

[0004] The Ranking Vapor Compression cycle if often used to harness power from low temperature heat sources. However the ranking cycle does not efficiently harness thermal energy from gasses at temperatures above or below the boiling point of its working fluid.

[0005] Gas turbines that follow the Inverted Brayton cycle have been proposed to harness waste heat from exhaust gasses. However the high cost of manufacturing gas turbines has prevented such engines from being used on a large scale.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of this invention to provide an engine capable of effectively converting thermal energy contained within relatively low temperature hot gasses into mechanical energy at the lowest possible cost. The invention can be used in addition to or as a replacement for the ranking vapor compression cycle commonly used for such purposes.

[0007] Briefly described in a preferred embodiment, the invention is a heat engine of the rotary vane type. The engine requires a source of hot gas and a source of cool liquid to operate. The thermodynamic cycle of the engine begins as a gas is heated by a heat source external to the engine. Possible sources of hot gasses to power the engine include exhaust gasses from gas turbine or diesel engines, and air heated by solar collectors. It is even possible that warm atmospheric air located near a cold body of water could be used to power the engine. Although the efficiency of the engine decreases as the temperature difference between the gas and the water decreases.

[0008] After the gas is heated it enters the engine through the inlet port into the spaces between the engines vanes, rotor and housing. As the gas moves past the inlet port it enters the expansion section of the engine where the gas expands adiabatically to a sub-atmospheric pressure. Just before the gas leaves the expansion section a cooling liquid is injected into the gas through holes in the walls of the engine housing further reducing its temperature and pressure.

[0009] Next the gas leaves the expansion section of the engine it enters the compression section. Here more cooling liquid is injected into the gas, which absorbs heat generated by the compression process. This reduces the amount of work required to compress the gas back to atmospheric pressure. Finally, the working gas and the cooling liquid leave the engine through the outlet port at the bottom of the engine.

[0010] Because the expansion process occurs at a higher temperature than the compression process, more work is created by expanding the gas than is consumed by compressing it and a net work output is produced by the engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will be better understood by reading the Detailed Description of the Preferred and Alternate Embodiments with reference to the accompanying drawing figures, in which like reference numerals denote similar structure and refer to like elements throughout, and in which:

[0012] FIG. **1** is a cross section schematic illustration of the present engine;

[0013] FIG. **2** is a side view schematic illustration of the engine showing a preferred power transfer means;

[0014] FIG. **3** is a schematic illustration of two of the engines sliding vanes connected by four connecting linkages;

[0015] FIG. **4** is a schematic illustration of another pair of the engines sliding vanes connected by four connecting linkages offset from the connecting linkages in FIG. **3**;

[0016] FIG. **5**. is a side view schematic illustration of the tip of an engine vane;

[0017] FIG. **6**. is a schematic illustration of an alternative embodiment of the engine inlet port.

[0018] FIG. **7**. is a pressure-volume diagram of the thermodynamic cycle of the present engine;

[0019] FIG. **8**. is a schematic illustration of a novel compressor/expander comprised of the primary components of the present engine.

DETAILED DESCRIPTION

[0020] In describing the preferred and alternate embodiments of the present invention, as illustrated in FIGS. **1-8**, specific terminology is employed for the sake of clarity. The invention, however, is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner to accomplish similar functions.

[0021] Referring now to FIG. **1**, illustrated therein is heat engine **100**, having an outer housing **2** and a rotor **1** that rotates within the housing. Contained within the rotor **1** are a plurality of slots **12** and a plurality of sliding vanes **3** residing within the slots **12**. The vanes **3** extend outwards to make contact with the inner walls of the housing **2**.

[0022] Each vane **3** is connected to another vane **3** on the opposite side of the rotor **1** by one or more connecting linkages **13**. The connecting linkages **13** that connect a pair of vanes **3** are horizontally offset from other connecting linkages **13** that connect other pairs of vanes **3**. This allows the linkages to slide past each other through the rotor's axis of rotation. The shape of the housing **2** is such that the distance from one point on the surface of the inner wall of the housing **2** to another point on the opposite side of the housing through the axis of rotation of the rotor is always the same. This allows the vanes **3** to be connected by connection linkages **13** of fixed length.

[0023] The space between the engine vanes **3**, the rotor **1** and the housing **2** define variable volume gas chambers **16**. The volume of the gas chambers **16** change as the rotor **1** rotates within the housing **2** and the distance between the rotor **1** and the inner wall of the housing **2** changes.

[0024] A heat source external to the engine **100** heats a gas, which is supplied to the engine **100**. This hot gas is both the energy source and working fluid of the engine. The thermodynamic cycle begins as the engine **100** draws in the hot gas through the inlet port **4** into the space between the rotating vanes **3**. A guide rail **17** traverses the inlet port **4** keeping the vanes **3** in the proper position as they move past the inlet port **4** while allowing the hot gas to flow around it.

[0025] As the vanes **3** move past the inlet port **4** they enter the expansion section of the engine. In this section the vanes **3** slide outwards from the rotor **1** and the volume of the gas chambers **16** increases. The expansion section of the engine extends from the point where a trailing vane **3** of a gas chamber **16** passes the inlet port until the center of the gas chamber **16** reaches the midpoint of the engine **18**. This expansion lowers the pressure and temperature of the working gas.

[0026] Just before the gas chamber **16** reaches the end of the expansion section, a cooling liquid, such as water, is injected into the gas chambers **16** through a plurality of nozzles **7** in the wall of the housing **2**. This further reduces the temperature and pressure of the working gas. A plurality of valve means **9** can be utilized to control the timing of the injection of the cooling liquid into the gas chambers.

[0027] When the center of a gas chamber passes the midpoint of the engine **18** it leaves the expansion section of the engine and enters the compression section of the engine. Cooling liquid is continuously injected into the lower portion of the compression section of the engine through nozzles **7**. A lubricant could be injected into the engine along with the cooling liquid to lubricate the engine. Additionally a chemical solution capable of absorbing pollutants within the working gas could be injected into the engine along with the cooling liquid.

[0028] When the leading vane **3** of a gas chamber **16** reaches the outlet port **5** the compression process is complete and the working gas and cooling liquid are expelled from the engine through the outlet port **5**. The outlet port **5** is positioned at the bottom of the engine **100** allowing gravity to assist in expelling the cooling liquid from the engine **100**.

[0029] A catch basin **8** is positioned beneath the outlet port **5** to collect the cooling liquid expelled from the engine **100**. A metal grate **15** covers the catch basin. A pump means **10** pumps water through a pipe **14** from the catch basin **8** through an evaporative heat exchanger **11** then back to the engine **100**. The heat exchanger **11** expels heat from the cooling liquid before it returns to the engine **100**.

[0030] Referring now to FIG. **2** illustrated therein is a side view of engine **100** illustrating the power transfer means of a preferred embodiment. The rotor **1** extends outward through a circular hole **19** in the sidewall of the housing **2**. A shaft **20** is attached to the sidewall **25** of the rotor **1** and extends away from the rotor **1**. A bearing means **26** mounted on a supporting structure **27** supports the rotor **1** and allows it rotate about its axis of rotation.

[0031] A pulley **21** is coupled to the shaft **20** on the opposite side of the supporting structure **27** from the rotor **1**. A belt **22** transfers mechanical power from the pulley **21** to another pulley **23** coupled to a generator **24**.

[0032] Referring now to FIG. **3** illustrated therein is a front view of a pair of engine vanes **3** connected by four connecting linkages **13**.

[0033] Referring now to FIG. **4** illustrated therein is a front view of another pair of engine vanes **3** connected by four connecting linkages **13**. The connecting linkages **13** illustrated in FIG.**4** are horizontally offset from the connecting linkages **13** illustrated in FIG. **3**. This allows the connecting linkages **13** to slide past each other through the axis of rotation of the rotor **1**. The connection linkages **13** connecting other pairs of engine vanes **3** would also be horizontally offset from the connecting linkages illustrated in FIG. **3** and FIG. **4**.

[0034] Referring now to FIG. **5** illustrated therein is a side view schematic of the tip of an engine vane. Attached to the tip of the vane **3** is a rolling element **50**. This rolling element **50** reduces friction as the vane moves along the inner surface of the housing **2**. A floating seal **51** is housed within the tip of a vane. A spring **52** exerts a force on the floating seal **51** keeping it on contact with the inner wall of the housing **2**. The floating seal **51** is designed to minimize gas leakage from one gas chamber to another.

[0035] Referring now to FIG. **6** illustrated therein is a cross section schematic of an alternate embodiment of the engine inlet port **4**. This alternative embodiment has a movable member **30** and an actuator **31** connected to the movable member. The actuator can move the movable member into a position along the guide rail **17**. This decreases the size of the inlet port and changes the pressure ratio of the engine. A similar configuration can be used to change the size of the engine outlet port providing an additional means to alter the pressure ratio of the engine.

[0036] Referring now to FIG. **7** illustrated therein is a pressure-volume diagram of the thermodynamic cycle of the present engine **100**. The pressure of the working gas is plotted on the vertical axis and the volume is plotted on the horizontal axis. Line a-b is a constant pressure heat addition line representing the working gas of the engine being heated and expanded by some process external to the engine. Line b-c is an adiabatic expansion line representing the working gas being expanded adiabatically in the expansion section of the engine. Line c-d is a constant volume heat rejection line representing the working gas being cooled at a roughly constant volume while cooling liquid is being injected into the working gas as the working gas begins to leave the expansion section and enter the compression section. Line d-a is an isothermal compression line representing the working gas being simultaneously compressed and cooled in the compression section of the engine.

[0037] Referring now to FIG. **8**, illustrated therein is a novel machine **200** of the rotary vane type that can be used as either a compressor or an expander. The machine **200** is comprised of the main components of engine **100**. It has an outer housing **2** and a rotor **1** that rotates within the housing. Contained within the rotor **1** are a plurality of slots **12** and a plurality of sliding vanes **3** residing within the slots **12**. The vanes **3** extend outwards to make contact with the inner walls of the housing **2**.

[0038] Each vane **3** is connected to another vane **3** on the opposite side of the rotor **1** by one of more connecting linkages **13**. The connecting linkages **13** that connect a pair of vanes **3** are horizontally offset from other connecting linkages **13** that connect other pairs of vanes **3**. This allows the linkages to slide past each other through the rotor's axis of rotation. The shape of the housing **2** is such that the distance from one point on the surface of the inner wall of the housing **2** to another point on the opposite side of the housing through the axis of rotation of the rotor is always the same. This allows the vanes **3** to be connected by connection linkages **13** of constant length. Utilizing the connecting linkages **13** to connect the vanes reduces the centrifugal force exerted by the vanes on the wall of the housing, improving the efficiency and durability of the machine **200** over existing compressors and expanders of the rotary vane type.

[0039] The rotor **1** rotates clockwise when the machine **200** is operating as a compressor and counterclockwise when it is operating as an expander. A large port **40** is used as the inlet port when the machine **200** is operating as a compressor and as the outlet port when it is operating as an expander. A small port **41** is used as the inlet port when the machine **200** is operating as an expander and as the outlet port when it is operating as a compressor.

[0040] A cooling liquid could be injected into machine **200** like it is in engine **100** when it is operating as a compressor to cool the gas while it is being compressed. Alternatively a hot liquid could be injected into the machine **200** like it is in engine **100** when it is operating as an expander to increase the power output of the expander. However in this arrangement the locations of the large port **40** and the small port **41** should be reversed to allow gravity to assist in expelling the heating liquid from the machine **200**.

[0041] Having thus described exemplary embodiments of the present invention, it should be noted by those skilled in the art that the within disclosures are exemplary only, and that various other alternatives, adaptations, and modifications may be made within the scope of the present invention. Accordingly, the present invention is not limited to the specific embodiments illustrated herein, but is limited only by the following claims.

What is claimed is:

1. A heat engine comprising:

a housing enclosing a cavity, said housing having an inner and outer wall surface;

a rotatable rotor mounted within the cavity of said housing;

a plurality of slots contained within said rotor;

a plurality of sliding vanes mounted within said slots extending outwards towards the inner surface of said housing;

a plurality of variable volume gas chambers defined by the regions between said rotor, said sliding vanes and said housing;

an inlet port wherein a high temperature working gas enters said variable volume gas chambers moving past said inlet port;

an expansion section in fluid communication with said inlet port wherein said vanes moving through said expansion section slide outwards away from said rotor increasing the volume and decreasing the pressure of the gas within said section;

a compression section in fluid communication with said expansion section wherein said vanes moving through said compression section slide inwards toward said rotor decreasing the volume and increasing the pressure of the gas within said section;

a means for injecting a cooling liquid into said working gas moving through said compression section of said engine;

an outlet port in fluid communication with said compression section wherein said working gas and said cooling liquid injected into said working are expelled from said engine;

a means for transferring mechanical energy from the spinning rotor to an external apparatus.

2. An engine according to claim **1** having cooling liquid passageways within the walls of said housing wherein cooling liquid is injected in said engine.

3. An engine according to claim **1** having cooling liquid pumped through said rotor and into said engine through nozzles located on said rotor.

4. An engine according to claim **1** wherein each vane is connected to another vane on the opposite side of said rotor by a connecting linkage wherein each connecting linkage is offset from the other connecting linkages through a distance parallel to said rotors axis of rotation.

5. An engine according to claim **1** having a means to change the size of the inlet port.

6. An engine according to claim **1** having a means to change the size of the outlet port.

7. An engine according to claim **1** wherein a lubricant is injected into said engine along with said cooling liquid.

8. An engine according to claim **1** wherein the cooling liquid contains a solution capable of absorbing pollutants from said working gas.

9. An engine according to claim **1** having a section in between said expansion and said compression sections wherein said variable volume gas chambers moving through said section maintain a generally constant volume.

10. An engine according to claim **1** having a plurality of friction reducing roller means at the tips of said engine vanes in contact with the inner wall of said housing.

11. An engine according to claim **1** having a plurality of floating seals at the tips of said engine vanes making contact with the inner wall of said housing.

12. A machine for changing the volume of a gas comprising:

a housing enclosing a cavity, said housing having an inner and outer wall surface;

a rotatable rotor eccentrically mounted within the cavity of said housing;

a plurality of slots contained within said rotor;

at least four sliding vanes mounted within said slots extending outwards towards the inner surface of said housing wherein each of said vanes is connected to another vane on the opposite side of said rotor by a connecting linkage wherein each connecting linkage is offset from the other connecting linkages by a distance parallel to the axis of rotation of said rotor;

a plurality of variable volume gas chambers defined by the regions between said rotor, said sliding vanes and said housing;

a relatively large port wherein a gas enters said variable volume gas chambers moving past said relatively large port when said machine is being used to decrease the volume of a gas and wherein a gas leaves said variable volume gas chambers moving past said relatively large port when said machine is being used to increase the volume of a gas;

a relatively small port wherein a gas enters said variable volume gas chambers moving past said relatively small port when said machine is being used to increase the volume of a gas and wherein a gas leaves said variable volume gas chambers moving past said relatively small port when said machine is being used to decrease the volume of a gas;

a volume changing section in fluid communication with each of said ports wherein said vanes moving through said section slide outwards away from said rotor increasing the volume of the gas within said section when said machine is used to increase the volume of a gas and wherein said vanes moving through said section slide inwards toward said rotor decreasing the volume of the gas within said section when said machine is being used to decrease the volume of a gas;

a means for transferring rotational mechanical energy between the spinning rotor and an external apparatus.

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