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(54) **Stirling engine including a recuperative heater**

Stirling-Motor einschließend Rekuperatorhitzer

Moteur stirling comprenant un réchauffeur à récuperation

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Description

TECHNICAL FIELD

[0001] The present invention relates generally to a stirling engine including a recuperative heater, and more particularly a recuperative heater with an exhaust gas heat exchanger. Most particularly the invention relates to a heater for supplying operating heat to a Stirling engine used in a cogeneration system.

BACKGROUND ART

[0002] A number of closed-cycle thermodynamic machines operate with heat from a high-grade source, typically in the form of a fossil fuel burner, to directly heat a heat exchanger or heater head integral with the machine. A Stirling engine is an example of such an external combustion thermodynamic machine.

[0003] Stirling engines are well suited to cogeneration (or combined heat and power) applications and offer significant potential advantages. Stirling engines have a low emission external combustion system, thereby allowing multiple fuels to be used, preventing internal parts becoming fouled by the combustion products and providing quiet operation. However to realize these advantages in systems for the mass market, not only are issues of working lifespan, noise and emissions important but efficiency of fuel use and maintaining a cool engine compartment are key considerations. For maximum efficiency it is necessary to recover a portion of the latent, as well as the sensible heat of the water vapor formed in the combustion process. Moreover, particularly for domestic applications, size, cost, simplicity of construction and maintenance of the systems become very significant considerations.

[0004] A burner of the applicant's design, for use in a Stirling engine, is described in WO/9940309. The heating system used therein is one in which the combustion products from the burner are first sent through a heat exchanger or heater head for transferring heat to the working fluid of the Stirling engine. This compact burner provides recuperative heat exchange means in a device that can be economically manufactured. When used in a micro-cogeneration system, the exhaust gases from the burner pass to a separate (preferably condensing) exhaust gas heat exchanger for the production of hot water for space and potable water heating.

[0005] However, this type of configuration poses disadvantages in this and other systems utilizing a conventional exhaust gas heat exchanger. The disadvantages largely stem from the incorporation of the heat exchanger as a subsequent addition to the engine rather than as an integral engine design element. In particular, disadvantages in conventional systems include:

- The heat exchanger requires connection to the engine exhaust via some form of coupling or duct. In a typical configuration, a rigidly mounted heat exchanger is connected to an engine mounted on vibration isolators and thus a flexible exhaust coupling is required.
  The complexity and cost of producing a reliable exhaust coupling are increased by the harsh environmental conditions including the effects of corrosive high temperatures exhaust gases.
- Heat is lost directly from the coupling. The inherent design constraints of a nonintegrated flexible exhaust coupling hinder the efficient prevention of heat losses.
- Constrained and/or uneven gas flow.
- Increased manufacturing and operational system complexity and thus cost.
- Heat is only recovered from the exhaust gases and not from other heated engine surfaces/components.
- Separate thermal insulation surrounding the engine is required to prevent heat losses and undesirably high exterior surface temperatures.
- Additional heat exchanger fluid connections are necessary.
- Increased system dimensions
- Increase system weight

[0006] US Patent No. 3,717,993 discloses an air preheater for an external combustion engine in which a multiwalled heat exchanger around the combustion chamber preheats inlet air to the combustion chamber.

[0007] It is an object of the present invention to address the foregoing problems or at least to provide the public with a useful choice.

[0008] Further aspects and advantages of the present invention will become apparent from the ensuing description which is given by way of example only.

DISCLOSURE OF THE INVENTION

[0009] According to one aspect of the present invention there is provided a Stirling engine including a recuperative heater as defined in claim 1.

[0010] It will be further appreciated that said fluid may be any flowable gas or liquid capable of effecting thermal heat transfer of heat away from the heated combustion portion, including, but not restricted to water, oil and air.

[0011] By incorporating the exhaust gas heat exchanger in a Stirling engine according to the above configuration, numerous advantages are realised.

[0012] Firstly, virtually all the heat generated in the combustion portion can flow into the exchanger fluid and thereby increasing efficiency of energy recovered from the fuel significantly.

[0013] Secondly, as the heat exchanger may be formed as a rigidly fixed portion of the engine structure, there is no requirement for a flexible coupling between the heat exchanger and the combustion products outlet from the combustion portion. This can reduce manufacturing and system costs and complexity, whilst improving reliability.

[0014] Furthermore, instead of an asymmetrical weight loading imposed on the engine by the connection of an external heat exchanger to the high temperature combustion exhaust outlet with or without a flexible coupling, the heat exchanger may be configured to place an even load on the engine.

[0015] Thus, according to a further aspect, said fluid heat exchanger is located about said combustion portion to place a symmetrical gravitational load on the engine.

[0016] Further advantages of the present invention over the prior art include;

- the exhaust gases exiting the heat exchanger are at a low temperature and any flexible duct/coupling still required may be formed from cheap adaptable materials such as flexible polymer;

- the flow of the combustion exhaust gases may be configured to be evenly distributed; and

- a recuperator (i.e. a heat exchanger utilising the combustions products to preheat one or more of the pre-combustion constituents e.g. air) may be readily incorporated into the engine design.

[0017] By at least partially surrounding the combustion chamber and the recuperative heat exchanger, the fluid in the jacket is able to absorb heat that my otherwise be lost. The fluid is preferably a liquid (e.g. water) circulated through the jacket. The exhaust gas heat exchange takes place during a single axial pass, before the combustion products pass to the flue. Preferably this single pass approximates a contra-flow action with the fluid flow through the jacket. The combustion products preferably pass in a cylindrical passage adjacent the inner wall of the jacket. Means are provided for improving the heat transfer from the combustion products, preferably comprising fins formed in the inner wall of the water jacket and projecting into the exhaust gas passage.

[0018] Preferably the recuperative heat exchanger includes a plurality of parallel elongate channels comprising alternating combustion product channels and inlet air channels adjacent thereto for heat exchange therebetween. The channels at least partially surround the combustion chamber and a first end of each combustion product channel receives combustion products from the combustion chamber and an opposing end of each combustion product channel provides the combustion products to the exhaust gas heat exchanger. The channels are formed between two coaxial cylindrical surfaces that abut the crests of a corrugated thin heat-conductive guide.

[0019] Preferably, the exhaust gas heat exchanger is separated from the recuperator axial flow section by an insulator.

[0020] Preferably the recuperative heat exchanger further includes an outer space or plenum positioned adjacent to an outer surface of the heater and adapted such that inlet air introduced into the outer plenum cools the outer surface. The outer surface may be a top cover opposing the heater heads or hot end of the engine, the water jacket bounding the sides and the cover the top of the heater. Preferably the recuperative heat exchanger also includes an inner enclosure or plenum separated from the outer plenum by a heat conductive wall, the inner plenum being positioned inwardly of the outer plenum in a space substantially bounded by a wall of the combustion chamber and the heat conductive wall and adapted such that inlet air form the outer plenum passes through the channels into the inner plenum, from which it passes into the combustion chamber. Pairs of flow paths, between combustion air in the outer plenum and the inner plenum, and between the combustion air in the inner plenum and the combustion products in the combustion chamber approximate to contra-flow passes.

[0021] Preferably, in the exhaust gas heat exchanger the combustion products are cooled to cause at least a portion of the combustion products to condense.

[0022] Most preferably the heater is installed on a Stirling engine forming part of a cogeneration system for providing heat and electricity, the engine driving an electrical generator and supplying a liquid heated by the engine and the exhaust gas heat exchanger to a heating circuit. Alternatively, the heater may be used in other external combustion engines for providing improved energy efficiency within a single compact device.

[0023] The heater is compact and may be readily fabricated. Without external insulation, all the outer components present no danger of burning the user, the water jacket cooling the sides and the plenum arrangement cooling the top cover. It is effective and efficient in operational use, may be economically constructed and has an overall simple design that minimizes manufacturing costs and maximizes performance, and simplifies maintenance by offering an essentially modular design.

[0024] In an alternative embodiment, the additional heated products (typically air and/or combustion products) sourced externally from the engine may be introduced into the flow from the engine combustion products passing from the recuperator to the exhaust heat exchanger.

[0025] Such a configuration is particularly suited to domestic environments where the heated fluid generated by the exhaust heat exchanger requires supplementation by an additional burner to provide the total household needs..

BRIEF DESCRIPTION OF DRAWINGS

[0026] Further aspects of the present invention will become apparent from the following description which is given by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a half-sectional elevation through a central plane of the recuperative heater of the present invention; and

Figure 2 is a scrap section along line XX of Fig. 1.

BEST MODES FOR CARRYING OUT THE INVENTION

[0027] Referring to Figs 1 and 2, a first preferred embodiment of the recuperative heater 100 of the present invention is installed on a Stirling engine 2.

[0028] The exact configuration shown in the preferred embodiment is but one example of numerous costs and maximizes performance, and simplifies maintenance by offering an essentially modular design.

[0029] In an alternative embodiment, the additional heated products (typically air and/or combustion products) sourced externally from the engine may be introduced into the flow from the engine combustion products passing from the recuperator to the exhaust heat exchanger.

[0030] Such a configuration is particularly suited to domestic environments where the heated fluid generated by the exhaust heat exchanger requires supplementation by an additional burner to provide the total household needs..

BRIEF DESCRIPTION OF DRAWINGS

[0031] Further aspects of the present invention will become apparent from the following description which is given by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a half-sectional elevation through a central plane of the recuperative heater of the present invention; and

Figure 2 is a scrap section along line XX of Fig. 1.

BEST MODES FOR CARRYING OUT THE INVENTION

[0032] Referring to Figs 1 and 2, a first preferred embodiment of the recuperative heater 100 of the present invention is installed on a Stirling engine 2.

[0033] It will be appreciated that while a Stirling engine is shown in the preferred embodiment, the present invention is not necessarily restricted to same. It can be seen by one skilled in the art that the concept of integrating an exhaust heat exchanger into the structure of a combustion engine may be equally applied to internal and external combustion engines. Furthermore, the exact configuration shown in the preferred embodiment is but one example of numerous possible implementations which also fall within the scope of the invention.

[0034] As shown in the drawings, the present invention is integrated into the structure of a Stirling engine 2 having an axis A, with four vertical cylinders 30 in a square arrangement. The principal components of the heater 100 are generally symmetrical about axis A, which extends parallel to the axes C of the cylinders 30. The heater 100 surrounds the hot end or heater heads 3 of the engine 2 and serves for heating a combustion chamber 1 for supplying operating heat to the engine 2. Preferably the heater 100 forms part of a micro-cogeneration system (not shown) whereby electrical power is derived from the engine 2 and the heater 100 also supplies heat to a load (not shown).

[0035] Centrally positioned at the top of the heater 100, a fuel distributor 4 (illustrated schematically) is provided, through which fuel (e.g. natural gas, diesel oil or the like) can be supplied to the combustion chamber 1. The combustion chamber 1 is bounded outwardly by a domed combustion chamber wall 5a and inwardly by the heater head 3 of the engine 2 and a centrally positioned insulator 31. The combustion chamber wall 5a is a section of a shell 5 which also includes an intermediate cylindrical portion 5b surrounded by a larger diameter coaxial peripheral portion 5c.

[0036] A recuperative heat exchanger (not numbered separately) through which the inlet air passes as it is preheated includes an inner chamber or plenum 6, an outer housing or plenum 18 and an axially extending single pass air/exhaust contra-flow section comprising alternating inlet air and exhaust gas channels 11 and 12 respectively (best seen in Fig. 2).

[0037] The inner plenum 6 is a space positioned outwardly from the combustion chamber 1. A cylindrical wall 8 of the inner channels 11 is radially spaced from the cylindrical portion 5c, and is joined to an upright conical plenum wall 7, to divide the wall 8 into lower and upper sections 8a and 8b respectively. The inner plenum 6 is bounded generally by shell sections 5a and 5b, the lower cylindrical section 8a and the conical plenum wall 7.

[0038] The inlet air and exhaust gas channels 11 and 12 are formed by a corrugated guide 26 received in a space between the cylindrical wall 8 and a radially separated cylindrical insulator 27. The inlet air channels 11 are formed on the inner side of the guide 26, the crests of the corrugations being in contact with the cylindrical wall 8 to enclose passages 11 therebetween. The combustion product channels 12 are similarly formed on the outer side of the guide 26 and bounded by the insulator 27 such that the channels 11 and 12 alternate in the radial direction and form a ring encircling the combustion chamber 1. The upper end of the corrugated guide 26 is fixed to a disc-like top cover 17 and its lower end is connected by a ring 9 to the lower peripheral edge of the shell 5.

[0039] The outer plenum 18 is a space formed between the conical plenum wall 7, the upper cylindrical section 8b and a top cover 17. The top cover 17 encloses the top of the heater 100 and receives the fuel distributor 4. The top cover 17 extends between the inner water jacket walls 13 and is provided with a seal 19 around its perimeter. Combustion air is supplied through an opening 20 in the top cover 17 and into the outer plenum 18.

[0040] An exhaust gas heat exchanger (not numbered separately) for extracting heat from the exhaust gases is in the form of an axially extending single pass exhaust/water contra-flow section comprising a finned exhaust passage 15 and an adjacent cylindrical water jacket 16. The exhaust gas heat exchanger at least partially surrounds the combustion chamber 1 and the recuperative heat exchanger to capture the heat flowing radially outward.

[0041] The combustion chamber 1 and recuperative heat exchanger are within the water jacket 16 which partially surrounds them. The cylindrical water jacket 16 rings the heater 100, and has inner and outer walls 13 and 14 respectively. Water inlet 23 and water outlet 24 are positioned at the lower and upper ends of the water jacket 16 respectively. The water inlet and outlet 23, 24 are connected to a circuit (not shown) for supplying heat to the load (e.g. for space or potable water heating). Baffles (not shown) direct water flow evenly through the water jacket 16.

[0042] The annular passage 15 is formed between the inner water jacket wall 13 and a cylindrical exhaust passage wall 10 which abuts the outer face of the insulator 27. Heat exchange fins 25 are formed on the inner water jacket wall 13 extend into the passage 15. Ringing the heater 100 at the base of the passage 15 is a condensate and exhaust chamber 21 having a flue 22.

[0043] The exhaust gas heat exchanger is mounted on the top of the engine 2 and is assembled from the cast aluminium water jacket 16 and the separately fabricated exhaust passage wall 10. The recuperative heat exchanger is a weldment, with the shell 5, cylindrical wall 8, ring 9 and corrugated guide 26 being formed from stainless steel plate. This assembly is then received axially within the exhaust gas heat exchanger, supported on a shoulder formed between portions 5b and 5c upon the outer ring of insulator 31 sealed about the heater head 3.

[0044] Proceeding from the cold rest state, first in the starting operation, fuel is supplied through the fuel distributor 4 along path F at the base of the fuel distributor 4 the fuel and air are mixed and directed to the combustion chamber 1 where the air/fuel mixture is ignited and burned.

[0045] Inlet combustion air flows into the recuperative heat exchanger and follows the path schematically represented by line I in Fig. 1. Air supplied through opening 20 enters the outer plenum 18, cooling the conical plenum wall 7 and top cover 17 and passing through the circumferentially extending gap between the guide 26 and the top of the cylindrical wall section 8b into the passages 11. In the passages 11 the air is heated by contra-flow exhaust gases passing in the passages 12. At the lower end of the passages 11, the air passes through a circumferential opening between the lower wall section 8a and shell portion 5c into the inner plenum 6. The air in the inner plenum 6 passes over one side of the combustion chamber wall 5a applying a cooling effect to the wall. The air is partly heated through the combustion chamber wall 5a and is then directed through openings in the base of the fuel distributor 4, where it is mixed with the fuel before passing into the combustion chamber 1 where it is burned.

[0046] The line E in Fig. 1 schematically represents the path followed by the combustion products. After flowing over the heater head (3), combustion products flow first though the recuperative heat exchanger and then through the exhaust gas heat exchanger. From the combustion chamber 1, the combustion products flow out radially, then axially, applying a heating effect to the heater head 3 of the engine 2 before passing into plenum 32 and then through a circumferential gap between the insulation 27 and the guide 26 into the lower end of the channels 12. The pleneum 32 is located immediately above a lower ceramic insulator 33 spanning the width of the combustion chamber 1 and acts to protect the engine from the corrosive combustion products and high temperatures.

[0047] The upper end of the wall 10 is axially separated from the top cover 17, providing a space through which the exhaust passes into the passage 15. Flowing downwardly through the passage 15, water vapour in the exhaust is at least partially condensed by the cooling action of water in the water jacket 16. Condensate (not shown) and exhaust gases are collected in the plenum chamber 21, from which they are withdrawn through the flue 22.

[0048] Water flows through the water jacket 16 in a circuit (e.g. to a load - not shown) its path schematically represented by the line W extending between the inlet and outlet 23, 24.

[0049] It will be appreciated that the radiative and convective heat transfers in the heater 100, occur in approximately contra-flow arrangements in both the recuperative and exhaust gas heat exchangers, with heat flowing from the inner plenum 6 to the outer plenum 18, from the combustion chamber to the inner plenum 6 and from channels 11 to channels 12 (for recuperatively heating the inlet air) and from passage 15 to the water jacket (for recovering heat from the exhaust).

[0050] Although illustrated as substantially enclosing the top portion of the engine 2, it should be understood this is primarily due to the configuration of further components present in the applicant's own Stirling engine design (as described in WO/9940309). Consequently, the exhaust heat exchanger may be designed to substantially envelop a larger portion of the engine or even completely enclose same. The greatest heat is naturally generated in the regions adjacent the combustion portion of the engine, though it is still possible to recover heat from areas located more distally to the combustion process.

[0051] Aspects of the present invention have been described by way of example only and it should be appreciated that modifications and additions may be made thereto without departing from the scope thereof defined in the claims.

Claims

Claims for the following Contracting State(s): AT, BE, CH, DK, ES, FR, GB, GR, IT, LI, LU, NL, SE

1. A Stirling engine comprising: means for combusting fuel (4) in a combustion chamber (1) configured to transfer heat to a heater head (3) of the engine;
   a recuperative heat exchanger adapted for receiving combustion products from the combustion chamber (1), the recuperative heat exchanger forcing inlet air into a heat exchange relationship with the combustion products in order to heat the inlet air by thermal transfer from the combustion products before the inlet air is passed to the combustion chamber; and
   an exhaust gas heat exchanger adapted for receiving the combustion products from the recuperative heat exchanger, the exhaust gas heat exchanger forcing another fluid, being a fluid other than said inlet air, into a heat exchange relationship with the combustion products in order to heat the another fluid by thermal transfer from the combusion products, the heater head defining a flow path for said fluid into the heater head, through the exhaust gas heat exchanger, and from the heater head, whereby said another fluid after heating by thermal transfer from combustion products may carry heat to an external load;
   characterised in that the combustion chamber is defined between the heater head (3) of the engine and an inner wall (5a) of the recuperative heat exchanger which extends over the heater head (3) of the engine, the recuperative heat exchanger at least partially surrounds the combustion chamber, and the exhaust gas heat exchanger at least partially surrounds the recuperative heat exchanger, so that combustion products pass from the combustion chamber to the recuperative heat exchanger, to heat the inlet air and then to the exhaust gas heat exchanger to heat said another fluid, and **in that** the exhaust gas heat exchanger includes a jacket (13, 14) through which said another fluid passes which at least partially surrounds an exhaust gas passage (15) through which the combustion products pass to heat the another fluid.

2. A Stirling engine as claimed in claim 1 wherein heat transfer fins (25) are provided in the inner wall (13) of the jacket (13, 14) projecting into the exhaust gas passage (15).

3. A Stirling engine as claimed in any either of the claims 1 and 2 wherein the recuperative heat exchanger includes a plurality of parallel elongate channels (11, 12) comprising alternating combustion product channels (12) and inlet air channels (11) adjacent thereto for heat exchange therebetween.

4. A Stirling engine as claimed in claim 3, wherein the channels (11, 12) at least partially surround the combustion chamber (1) and a first end of each combustion product channel (12) receives combustion products from the combustion chamber and an opposing end of each combustion product channel (12) provides the combustion products to the exhaust gas heat exchanger.

5. A Stirling engine as claimed in any one of claims 1 to 4, wherein in recuperative heat exchanger is at least partially surrounded by an insulator (27).

6. A Stirling engine as claimed in any one of claims 1 to 4 wherein the recuperative heat exchanger further includes an outer plenum (18) positioned adjacent to an outer surface of the heater and adapted such that inlet air introduced into other plenum cools the outer surface.

7. A Stirling engine as claimed in claim 6, further including an inner plenum (6) separated from the outer plenum (18) by a heat conductive wall (7), the inner plenum being positioned inwardly of the outer plenum in space substantially bounded by a wall of the combustion chamber (5a, 5b,5c)and the heat conductive wall (7) and adapted such that inlet air from the outer plenum (18) passes through the channels (11, 12) into the inner plenum (6), from which it passes into the combustion chamber (1).

8. A Stirling engine as claimed in claim 6 or claim 7, wherein pairs of flow paths, between inlet air in the outer plenum and the inner plenum, and between the inlet air in the inner plenum and the combustion products in the combustion chamber approximate to contra-flow passes.

9. A Stirling engine as claimed in any one of claims 1 to 8 further including a coupling connectable to a heat source external to said engine, said coupling allowing externally heated products to be added to said combustion products from the combustion chamber entering the fluid heat exchanger.

10. A cogeneration system for providing heat and electricity, the system including: a Stirling engine as claimed in any one of claims 1 to 9 wherein the sys-

tem includes an outlet from the exhaust gas heat exchanger for supplying the another fluid to a heating circuit and an inlet in the exhaust gas heat exchanger for receiving the another fluid from the circuit, and a generator operatively connected to the Stirling engine for generating electrical power.

Claims for the following Contracting State(s): DE

1. A Stirling engine comprising: means for combusting fuel (4) in a combustion chamber (1) configured to transfer heat to a heater head (3) of the engine;
a recuperative heat exchanger adapted for receiving combustion products from the combustion chamber (1), the recuperative heat exchanger forcing inlet air into a heat exchange relationship with the combustion products in order to heat the inlet air by thermal transfer from the combustion products before the inlet air is passed to the combustion chamber; and
an exhaust gas heat exchanger adapted for receiving the combustion products from the recuperative heat exchanger, the exhaust gas heat exchanger forcing another fluid, being a fluid other than said inlet air, into a heat exchange relationship with the combustion products in order to heat the another fluid by thermal transfer from the combusion products, the heater head defining a flow path for said fluid into the heater head, through the exhaust gas heat exchanger, and from the heater head, whereby said another fluid after heating by thermal transfer from combustion products may carry heat to an external load;
characterised in that the combustion chamber is defined between the heater head (3) of the engine and an inner wall (5a) of the recuperative heat exchanger which extends over the heater head (3) of the engine, the recuperative heat exchanger surrounds and extends over the combustion chamber, and the exhaust gas heat exchanger at least partially surrounds the recuperative heat exchanger, so that combustion products pass from the combustion chamber to the recuperative heat exchanger, to heat the inlet air and then to the exhaust gas heat exchanger to heat said another fluid, and **in that** the exhaust gas heat exchanger includes a jacket (13, 14) through which said another fluid passes which at least partially surrounds an exhaust gas passage (15) through which the combustion products pass to heat the another fluid.

2. A Stirling engine as claimed in claim 1 wherein heat transfer fins (25) are provided in the inner wall (13) of the jacket (13, 14) projecting into the exhaust gas passage (15).

3. A Stirling engine as claimed in any either of the claims 1 and 2 wherein the recuperative heat exchanger includes a plurality of parallel elongate channels (11, 12) comprising alternating combustion product channels (12) and inlet air channels (11) adjacent thereto for heat exchange therebetween.

4. A Stirling engine as claimed in claim 3, wherein the channels (11, 12) at least partially surround the combustion chamber (1) and a first end of each combustion product channel (12) receives combustion products from the combustion chamber and an opposing end of each combustion product channel (12) provides the combustion products to the exhaust gas heat exchanger.

5. A Stirling engine as claimed in any one of claims 1 to 4, wherein in recuperative heat exchanger is at least partially surrounded by an insulator (27).

6. A Stirling engine as claimed in any one of claims 1. to 4 wherein the recuperative heat exchanger further includes an outer plenum (18) positioned adjacent to an outer surface of the heater and adapted such that inlet air introduced into other plenum cools the outer surface.

7. A Stirling engine as claimed in claim 6, further including an inner plenum (6) separated from the outer plenum (18) by a heat conductive wall (7), the inner plenum being positioned inwardly of the outer plenum in space substantially bounded by a wall of the combustion chamber (5a, 5b,5c)and the heat conductive wall (7) and adapted such that inlet air from the outer plenum (18) passes through the channels (11, 12) into the inner plenum (6), from which it passes into the combustion chamber (1).

8. A Stirling engine as claimed in claim 6 or claim 7, wherein pairs of flow paths, between inlet air in the outer plenum and the inner plenum, and between the inlet air in the inner plenum and the combustion products in the combustion chamber approximate to contra-flow passes.

9. A Stirling engine as claimed in any one of claims 1 to 8 further including a coupling connectable to a heat source external to said engine, said coupling allowing externally heated products to be added to said combustion products from the combustion chamber entering the fluid heat exchanger.

10. A cogeneration system for providing heat and electricity, the system including: a Stirling engine as claimed in any one of claims 1 to 9 wherein the system includes an outlet from the exhaust gas heat exchanger for supplying the another fluid to a heating circuit and an inlet in the exhaust gas heat exchanger for receiving the another fluid from the circuit, and a generator operatively connected to the Stirling en-

gine for generating electrical power.

Patentansprüche

Patentansprüche für folgende(n) Vertragsstaat(en): AT, BE, CH, DK, ES, FR, GB, GR, IT, LI, LU, NL, SE

1. Stirlingmotor, der Folgendes umfasst: ein Mittel zur Verbrennung von Kraftstoff (4) in einer Verbrennungskammer (1), die zur Übertragung von Wärme zu einem Heizkopf (3) des Motors konfiguriert ist;
einen rekuperativen Wärmetauscher, der zum Empfang von Verbrennungsprodukten aus der Verbrennungskammer (1) ausgelegt ist, wobei der rekuperative Wärmetauscher Einlassluft in ein Wärmeaustauschverhältnis mit den Verbrennungsprodukten drückt, um die Einlassluft durch Wärmeübertragung von den Verbrennungsprodukten zu erwärmen, bevor die Einlassluft zu der Verbrennungskammer geleitet wird; und
einen Abgaswärmetauscher, der zum Empfang der Verbrennungsprodukte von dem rekuperativen Wärmetauscher ausgelegt ist, wobei der Abgaswärmetauscher ein anderes Fluid, das ein anderes Fluid als die Einlassluft ist, in ein Wärmeaustauschverhältnis mit den Verbrennungsprodukten drückt, um das andere Fluid durch Wärmeübertragung von den Verbrennungsprodukten zu erwärmen, wobei der Heizkopf einen Strömungspfad für das Fluid in den Heizkopf, durch den Abgaswärmetauscher und aus dem Heizkopf abgrenzt, wodurch das andere Fluid nach der Erwärmung durch die Wärmeübertragung von den Verbrennungsprodukten Wärme zu einer externen Last befördern kann;
dadurch gekennzeichnet, dass die Verbrennungskammer zwischen dem Heizkopf (3) des Motors und einer inneren Wand (5a) des rekuperativen Wärmetauschers abgegrenzt ist, die sich über den Heizkopf (3) des Motors erstreckt, der rekuperative Wärmetauscher die Verbrennungskammer mindestens teilweise umgibt und der Abgaswärmetauscher den rekuperativen Wärmetauscher mindestens teilweise umgibt, so dass Verbrennungsprodukte aus der Verbrennungskammer zu dem rekuperativen Wärmetauscher geleitet werden, um die Einlassluft zu erwärmen, und daraufhin zu dem Abgaswärmetauscher geleitet werden, um das andere Fluid zu erwärmen, sowie **dadurch**, dass der Abgaswärmetauscher einen Mantel (13, 14) umfasst, durch den das andere Fluid hindurchgeleitet wird und der mindestens teilweise einen Abgasdurchgang (15) umgibt, durch den die Verbrennungsprodukte geleitet werden, um das andere Fluid zu erwärmen.

2. Stirlingmotor nach Anspruch 1, wobei Wärmeübertragungsrippen (25) in der inneren Wand (13) des Mantels (13,14) bereitgestellt sind, die in den Abgasdurchgang (15) vorstehen.

3. Stirlingmotor nach einem der Ansprüche 1 und 2, wobei der rekuperative Wärmetauscher eine Vielzahl von parallelen länglichen Kanälen (11, 12) umfasst, die abwechselnd Verbrennungsproduktkanäle (12) und Einlassluftkanäle (11) benachbart dazu für einen Wärmeaustausch zwischen diesen uznfassen.

4. Stirlingmotor nach Anspruch 3, wobei die Kanäle (11, 12) die Verbrennungskammer (1) mindestens teilweise umgeben und ein erstes Ende jedes Verbrennungsproduktkanals (12) Verbrennungsprodukte aus der Verbrennungskammer erhält und ein gegenüberliegendes Ende jedes Verbrennungsproduktkanals (12) die Verbrennungsprodukte dem Abgaswärmetauscher zuführt.

5. Stirlingmotor nach einem der Ansprüche 1 bis 4, wobei der rekuperative Wärmetauscher mindestens teilweise von einem Isolator (27) umgeben ist.

6. Stirlingmotor nach einem der Ansprüche 1 bis 4, wobei der rekuperative Wärmetauscher des Weiteren eine äußere Kammer (18) umfasst, die benachbart zu einer äußeren Fläche der Heizvorrichtung angeordnet und so ausgelegt ist, dass die Einlassluft, die in die andere Kammer eingeführt wird, die Außenfläche kühlt.

7. Stirlingnaotor nach Anspruch 6, der des Weiteren eine innere Kammer (6) umfasst, die von der äußeren Kammer (18) durch eine wärmeleitende Wand (7) getrennt ist, wobei die innere Kammer einwärts von der äußeren Kammer im Raum angeordnet ist, der im Wesentlichen durch eine Wand der Verbrennungskammer (5a, 5b, 5c) und die wärmeleitende Wand (7) begrenzt wird, und so ausgelegt ist, dass die Einlassluft von der äußeren Kammer (18) durch die Kanäle (11, 12) in die innere Kammer (6) strömt, aus der sie in die Verbrennungskammer (1) geleitet wird.

8. Stirlingmotor nach Anspruch 6 oder Anspruch 7, wobei sich Paare von Strömungspfaden zwischen der Einlassluft in der äußeren Kammer und der inneren Kammer und zwischen der Einlassluft in der inneren Kammer und den Verbrennungsprodukten in der Verbrennungskammer Gegenströmungsdurchläufen nähern.

9. Stirlingmotor nach einem der Ansprüche 1 bis 8, der des Weiteren eine Kupplung umfasst, die mit einer Wärmequelle verbunden werden kann, die sich außerhalb des Motors befindet, wobei die Kupplung

ermöglicht, dass extern erwärmte Produkte zu den Verbrennungsprodukten aus der Verbrennungskammer hinzugefügt werden, die in den Fluidwärmetauscher eintreten.

10. Kraft-Wärme-Kopplungssystem zur Bereitstellung von Wärme und Elektrizität, wobei das System einen Stirlingmotor nach einem der Ansprüche 1 bis 9 umfasst, wobei das System Folgendes umfasst: einen Auslass aus dem Abgaswärmetauscher, um das andere Fluid einem Wärmekreislauf zuzuführen, einen Einlass in dem Abgaswärmetauscher, um das andere Fluid aus dem Kreislauf aufzunehmen, sowie einen Generator, der betriebsfähig an den Stirlingmotor angeschlossen ist, um elektrischen Strom zu erzeugen.

Patentansprüche für folgende(n) Vertragsstaat(en): DE

1. Stirlingmotor, der Folgendes umfasst: ein Mittel zur Verbrennung von Kraftstoff (4) in einer Verbrennungskammer (1), die zur Übertragung von Wärme zu einem Heizkopf (3) des Motors konfiguriert ist;
einen rekuperativen Wärmetauscher, der zum Empfang von Verbrennungsprodukten aus der Verbrennungskammer (I) ausgelegt ist, wobei der rekuperative Wärmetauscher Einlassluft in ein Wärmeaustauschverhältnis mit den Verbrennungsprodukten drückt, um die Einlassluft durch Wärmeübertragung von den Verbrennungsprodukten zu erwärmen, bevor die Einlassluft zu der Verbrennungskammer geleitet wird; und
einen Abgaswärmetauscher, der zum Empfang der Verbrennungsprodukte von dem rekuperativen Wärmetauscher ausgelegt ist, wobei der Abgaswärmetauscher ein anderes Fluid, das ein anderes Fluid als die Einlassluft ist, in ein Wärmeaustauschverhältnis mit den Verbrennungsprodukten drückt, um das andere Fluid durch Wärmeübertragung von den Verbrennungsprodukten zu erwärmen, wobei der Heizkopf einen Strömungspfad für das Fluid in den Heizkopf, durch den Abgaswärmetauscher und aus dem Heizkopf abgrenzt, wodurch das andere Fluid nach der Erwärmung durch die Wärmeübertragung von den Verbrennungsprodukten Wärme zu einer externen Last befördern kann;
dadurch gekennzeichnet, dass die Verbrennungskammer zwischen dem Heizkopf (3) des Motors und einer inneren Wand (5a) des rekuperativen Wärmetauschers abgegrenzt ist, die sich über den Heizkopf (3) des Motors erstreckt, der rekuperative Wärmetauscher die Verbrennungskammer umgibt und sich über diese erstreckt und der Abgaswärmetauscher den rekuperativen Wärmetauscher mindestens teilweise umgibt, so dass Verbrennungsprodukte aus der Verbrennungskammer zu dem rekuperativen Wärmetauscher geleitet werden, um die Einlassluft zu erwärmen, und daraufhin zu dem Abgaswärmetauscher geleitet werden, um das andere Fluid zu erwärmen, sowie **dadurch**, dass der Abgaswärmetauscher einen Mantel (13, 14) umfasst, durch den das andere Fluid hindurchgeleitet wird und der mindestens teilweise einen Abgasdurchgang (15) umgibt, durch den die Verbrennungsprodukte geleitet werden, um das andere Fluid zu erwärmen.

2. Stirlingmotor nach Anspruch 1, wobei Wärmeübertragungsrippen (25) in der inneren Wand (13) des Mantels (13, 14) bereitgestellt sind, die in den Abgasdurchgang (15) vorstehen.

3. Stirlingmotor nach einem der Ansprüche 1 und 2, wobei der rekuperative Wärmetauscher eine Vielzahl von parallelen länglichen Kanälen (11, 12) umfasst, die abwechselnd Verbrennungsproduktkanäle (12) und Einlassluftkanäle (11) benachbart dazu für einen Wärmeaustausch zwischen diesen umfassen.

4. Stirlingmotor nach Anspruch 3, wobei die Kanäle (11, 12) die Verbrennungskammer (1) mindestens teilweise umgeben und ein erstes Ende jedes Verbrennungsproduktkanals (12) Verbrennungsprodukte aus der Verbrennungskammer erhält und ein gegenüberliegendes Ende jedes Verbrennungsproduktkanals (12) die Verbrennungsprodukte dem Abgaswärmetauscher zuführt.

5. Stirlingmotor nach einem der Ansprüche 1 bis 4, wobei der rekuperative Wärmetauscher mindestens teilweise von einem Isolator (27) umgeben ist.

6. Stirlingmotor nach einem der Ansprüche 1 bis 4, wobei der rekuperative Wärmetauscher des Weiteren eine äußere Kammer (18) umfasst, die benachbart zu einer äußeren Fläche der Heizvorrichtung angeordnet und so ausgelegt ist, dass die Einlassluft, die in die andere Kammer eingeführt wird, die Außenfläche kühlt.

7. Stirlingmotor nach Anspruch 6, der des Weiteren eine innere Kammer (6) umfasst, die von der äußeren Kammer (18) durch eine wärmeleitende Wand (7) getrennt ist, wobei die innere Kammer einwärts von der äußeren Kammer im Raum angeordnet ist, der im Wesentlichen durch eine Wand der Verbrennungskammer (5a, 5b, 5c) und die wärmeleitende Wand (7) begrenzt wird, und so ausgelegt ist, dass die Einlassluft von der äußeren Kammer (18) durch die Kanäle (11,12) in die innere Kammer (6) strömt, aus der sie in die Verbrennungskammer (1) geleitet wird.

8. Stirlingmotor nach Anspruch 6 oder Anspruch 7, wobei sich Paare von Strömungspfaden zwischen der Einlassluft in der äußeren Kammer und der inneren Kammer und zwischen der Einlassluft in der inneren Kammer und den Verbrennungsprodukten in der Verbrennungskammer Gegenströmungsdurchläufen nähern.

9. Stirlingmotor nach einem der Ansprüche 1 bis 8, der des Weiteren eine Kupplung umfasst, die mit einer Wärmequelle verbunden werden kann, die sich außerhalb des Motors befindet, wobei die Kupplung ermöglicht, dass extern erwärmte Produkte zu den Verbrennungsprodukten aus der Verbrennungskammer hinzugefügt werden, die in den Fluidwärmetauscher eintreten.

10. Kraft-Wärme-Kopplungssystem zur Bereitstellung von Wärme und Elektrizität, wobei das System einen Stirlingmotor nach einem der Ansprüche 1 bis 9 umfasst, wobei das System Folgendes umfasst: einen Auslass aus dem Abgaswärmetauscher, um das andere Fluid einem Wärmekreislauf zuzuführen, einen Einlass in dem Abgaswärmetauscher, um das andere Fluid aus dem Kreislauf aufzunehmen, sowie einen Generator, der betriebsfähig an den Stirlingmotor angeschlossen ist, um elektrischen Strom zu erzeugen.

Revendications

Revendications pour l'(les) Etat(s) contractant(s) suivant(s): AT, BE, CH, DK, ES, FR, GB, GR, IT, LI, LU, NL, SE

1. Moteur Stirling comportant : un moyen de combustion de combustible (4) dans une chambre de combustion (1) dont la configuration permet de transférer de la chaleur à une tête de réchauffeur (3) du moteur ;
un échangeur à récupérateur de chaleur adapté pour recevoir des produits de combustion en provenance de la chambre de combustion (1), l'échangeur à récupérateur de chaleur forçant de l'air d'admission en une relation d'échange de chaleur avec les produits de combustion afin de chauffer l'air d'admission par transfert thermique en provenance des produits de combustion avant que l'air d'admission ne passe dans la chambre de combustion ; et
un échangeur de chaleur de gaz d'échappement adapté pour recevoir les produits de combustion en provenance de l'échangeur à récupérateur de chaleur, l'échangeur de chaleur de gaz d'échappement forçant un autre fluide, à savoir un fluide autre que ledit air d'admission, en une relation d'échange de chaleur avec les produits de combustion afin de chauffer l'autre fluide par transfert thermique en provenance des produits de combustion, la tête de réchauffeur définissant une trajectoire d'écoulement pour ledit fluide dans la tête de réchauffeur, au travers de l'échangeur de chaleur de gaz d'échappement, et en provenance de la tête de réchauffeur, ce par quoi ledit autre fluide après chauffage par transfert thermique en provenance des produits de combustion peut transporter de la chaleur jusqu'à une charge externe ;
caractérisé en ce que la chambre de combustion est définie entre la tête de réchauffeur (3) du moteur et une paroi intérieure (5a) de l'échangeur à récupérateur de chaleur qui se prolonge au-dessus de la tête de réchauffeur (3) du moteur, l'échangeur à récupérateur de chaleur entoure au moins partiellement la chambre de combustion, et l'échangeur de chaleur de gaz d'échappement entoure au moins partiellement l'échangeur à récupérateur de chaleur, de telle manière que les produits de combustion passent de la chambre de combustion à l'échangeur à récupérateur de chaleur, pour chauffer l'air d'admission, puis à l'échangeur de chaleur de gaz d'échappement pour chauffer ledit autre fluide, et **en ce que** l'échangeur de chaleur de gaz d'échappement comprend une chemise (13, 14) au travers de laquelle ledit autre fluide passe qui entoure au moins partiellement un passage de gaz d'échappement (15) au travers duquel les produits de combustion passent pour chauffer l'autre fluide.

2. Moteur Stirling selon la revendication 1, dans lequel des ailettes de transfert de chaleur (25) sont mises en oeuvre dans la paroi intérieure (13) de la chemise (13, 14) à des fins de projection dans le passage de gaz d'échappement (15).

3. Moteur Stirling selon l'une quelconque des revendications 1 et 2, dans lequel l'échangeur à récupérateur de chaleur comprend une pluralité de canalisations allongées parallèles (11, 12) comportant de manière alternée des canalisations de produits de combustion (12) et des canalisations d'air d'admission (11) adjacentes à celles-ci à des fins d'échange de chaleur entre elles.

4. Moteur Stirling selon la revendication 3, dans lequel les canalisations (11, 12) entourent au moins partiellement la chambre de combustion (1) et une première extrémité de chaque canalisation de produits de combustion (12) reçoit des produits de combustion en provenance de la chambre de combustion et une extrémité opposée de chaque canalisation de produits de combustion (12) fournit les produits de combustion à l'échangeur de chaleur de gaz d'échappement.

5. Moteur Stirling selon l'une quelconque des revendications 1 à 4, dans lequel l'échangeur à récupérateur de chaleur est au moins partiellement entouré d'un isolant (27).

6. Moteur Stirling selon l'une quelconque des revendications 1 à 4, dans lequel l'échangeur à récupérateur de chaleur comprend par ailleurs un plénum extérieur (18) positionné de manière adjacente par rapport à une surface extérieure du réchauffeur et adapté de telle manière que l'air d'admission introduit dans l'autre plénum refroidit la surface extérieure.

7. Moteur Stirling selon la revendication 6, comprenant par ailleurs un plénum intérieur (6) séparé du plénum extérieur (18) par une paroi conductrice de chaleur (7), le plénum intérieur étant positionné vers l'intérieur par rapport au plénum extérieur dans un espace dans une large mesure limité par une paroi de la chambre de combustion (5a, 5b, 5c) et la paroi conductrice de chaleur (7) et adapté de telle manière que l'air d'admission en provenance du plénum extérieur (18) passe au travers des canalisations (11, 12) dans le plénum intérieur (6), d'où il passe dans la chambre de combustion (1).

8. Moteur Stirling selon la revendication 6 ou la revendication 7, dans lequel des paires de trajectoires d'écoulement, entre l'air d'admission dans le plénum extérieur et le plénum intérieur, et entre l'air d'admission dans le plénum intérieur et les produits de combustion dans la chambre de combustion sont proches de couloirs à contre-courant.

9. Moteur Stirling selon l'une quelconque des revendications 1 à 8, comprenant par ailleurs un raccord pouvant être raccordé sur une source de chaleur externe audit moteur, ledit raccord permettant aux produits chauffés de manière extérieure d'être ajoutés auxdits produits de combustion en provenance de la chambre de combustion entrant dans l'échangeur de chaleur de fluide.

10. Système de cogénération permettant de fournir de la chaleur et de l'électricité, le système comprenant : un moteur Stirling selon l'une quelconque des revendications 1 à 9, dans lequel le système comprend une sortie en provenance de l'échangeur de chaleur de gaz d'échappement pour alimenter l'autre fluide dans un circuit de chauffage et une admission dans l'échangeur de chaleur de gaz d'échappement pour recevoir l'autre fluide en provenance du circuit, et un générateur raccordé de manière opérationnelle sur le moteur Stirling pour produire de l'énergie électrique.

Revendications pour l'(les) Etat(s) contractant(s) suivant(s): DE

1. Moteur Stirling comportant : un moyen de combustion de combustible (4) dans une chambre de combustion (1) dont la configuration permet de transférer de la chaleur à une tête de réchauffeur (3) du moteur ;
un échangeur à récupérateur de chaleur adapté pour recevoir des produits de combustion en provenance de la chambre de combustion (1), l'échangeur à récupérateur de chaleur forçant de l'air d'admission en une relation d'échange de chaleur avec les produits de combustion afin de chauffer l'air d'admission par transfert thermique en provenance des produits de combustion avant que l'air d'admission ne passe dans la chambre de combustion; et
un échangeur de chaleur de gaz d'échappement adapté pour recevoir les produits de combustion en provenance de l'échangeur à récupérateur de chaleur, l'échangeur de chaleur de gaz d'échappement forçant un autre fluide, à savoir un fluide autre que ledit air d'admission, en une relation d'échange de chaleur avec les produits de combustion afin de chauffer l'autre fluide par transfert thermique en provenance des produits de combustion, la tête de réchauffeur définissant une trajectoire d'écoulement pour ledit fluide dans la tête de réchauffeur, au travers de l'échangeur de chaleur de gaz d'échappement, et en provenance de la tête de réchauffeur, ce par quoi ledit autre fluide après chauffage par transfert thermique en provenance des produits de combustion peut transporter de la chaleur jusqu'à une charge externe ;
caractérisé en ce que la chambre de combustion est définie entre la tête de réchauffeur (3) du moteur et une paroi intérieure (5a) de l'échangeur à récupérateur de chaleur qui se prolonge au-dessus de la tête de réchauffeur (3) du moteur, l'échangeur à récupérateur de chaleur entoure la chambre de combustion et s'étend au-dessus de celle-ci, et l'échangeur de chaleur de gaz d'échappement entoure au moins partiellement l'échangeur à récupérateur de chaleur, de telle manière que les produits de combustion passent de la chambre de combustion à l'échangeur à récupérateur de chaleur, pour chauffer l'air d'admission, puis à l'échangeur de chaleur de gaz d'échappement pour chauffer ledit autre fluide, et **en ce que** l'échangeur de chaleur de gaz d'échappement comprend une chemise (13, 14) au travers de laquelle ledit autre fluide passe qui entoure au moins partiellement un passage de gaz d'échappement (15) au travers duquel les produits de combustion passent pour chauffer l'autre fluide.

2. Moteur Stirling selon la revendication 1, dans lequel des ailettes de transfert de chaleur (25) sont mises en oeuvre dans la paroi intérieure (13) de la chemise (13, 14) à des fins de projection dans le passage de gaz d'échappement (15).

3. Moteur Stirling selon l'une quelconque des revendications 1 et 2, dans lequel l'échangeur à récupérateur de chaleur comprend une pluralité de canalisations allongées parallèles (11, 12) comportant de manière alternée des canalisations de produits de combustion (12) et des canalisations d'air d'admission (11) adjacentes à celles-ci à des fins d'échange de chaleur entre elles.

4. Moteur Stirling selon la revendication 3, dans lequel les canalisations (11, 12) entourent au moins partiellement la chambre de combustion (1) et une première extrémité de chaque canalisation de produits de combustion (12) reçoit des produits de combustion en provenance de la chambre de combustion et une extrémité opposée de chaque canalisation de produits de combustion (12) fournit les produits de combustion à l'échangeur de chaleur de gaz d'échappement.

5. Moteur Stirling selon l'une quelconque des revendications 1 à 4, dans lequel l'échangeur à récupérateur de chaleur est au moins partiellement entouré d'un isolant (27).

6. Moteur Stirling selon l'une quelconque des revendications 1 à 4, dans lequel l'échangeur à récupérateur de chaleur comprend par ailleurs un plénum extérieur (18) positionné de manière adjacente par rapport à une surface extérieure du réchauffeur et adapté de telle manière que l'air d'admission introduit dans l'autre plénum refroidit la surface extérieure.

7. Moteur Stirling selon la revendication 6, comprenant par ailleurs un plénum intérieur (6) séparé du plénum extérieur (18) par une paroi conductrice de chaleur (7), le plénum intérieur étant positionné vers l'intérieur par rapport au plénum extérieur dans un espace dans une large mesure limité par une paroi de la chambre de combustion (5a, 5b, 5c) et la paroi conductrice de chaleur (7) et adapté de telle manière que l'air d'admission en provenance du plénum extérieur (18) passe au travers des canalisations (11,12) dans le plénum intérieur (6), d'où il passe dans la chambre de combustion (1).

8. Moteur Stirling selon la revendication 6 ou la revendication 7, dans lequel des paires de trajectoires d'écoulement, entre l'air d'admission dans le plénum extérieur et le plénum intérieur, et entre l'air d'admission dans le plénum intérieur et les produits de combustion dans la chambre de combustion sont proches de couloirs à contre-courant.

9. Moteur Stirling selon l'une quelconque des revendications 1 à 8, comprenant par ailleurs un raccord pouvant être raccordé sur une source de chaleur externe audit moteur, ledit raccord permettant aux produits chauffés de manière extérieure d'être ajoutés auxdits produits de combustion en provenance de la chambre de combustion entrant dans l'échangeur de chaleur de fluide.

10. Système de cogénération permettant de fournir de la chaleur et de l'électricité, le système comprenant : un moteur Stirling selon l'une quelconque des revendications 1 à 9, dans lequel le système comprend une sortie en provenance de l'échangeur de chaleur de gaz d'échappement pour alimenter l'autre fluide dans un circuit de chauffage et une admission dans l'échangeur de chaleur de gaz d'échappement pour recevoir l'autre fluide en provenance du circuit, et un générateur raccordé de manière opérationnelle sur le moteur Stirling pour produire de l'énergie électrique.

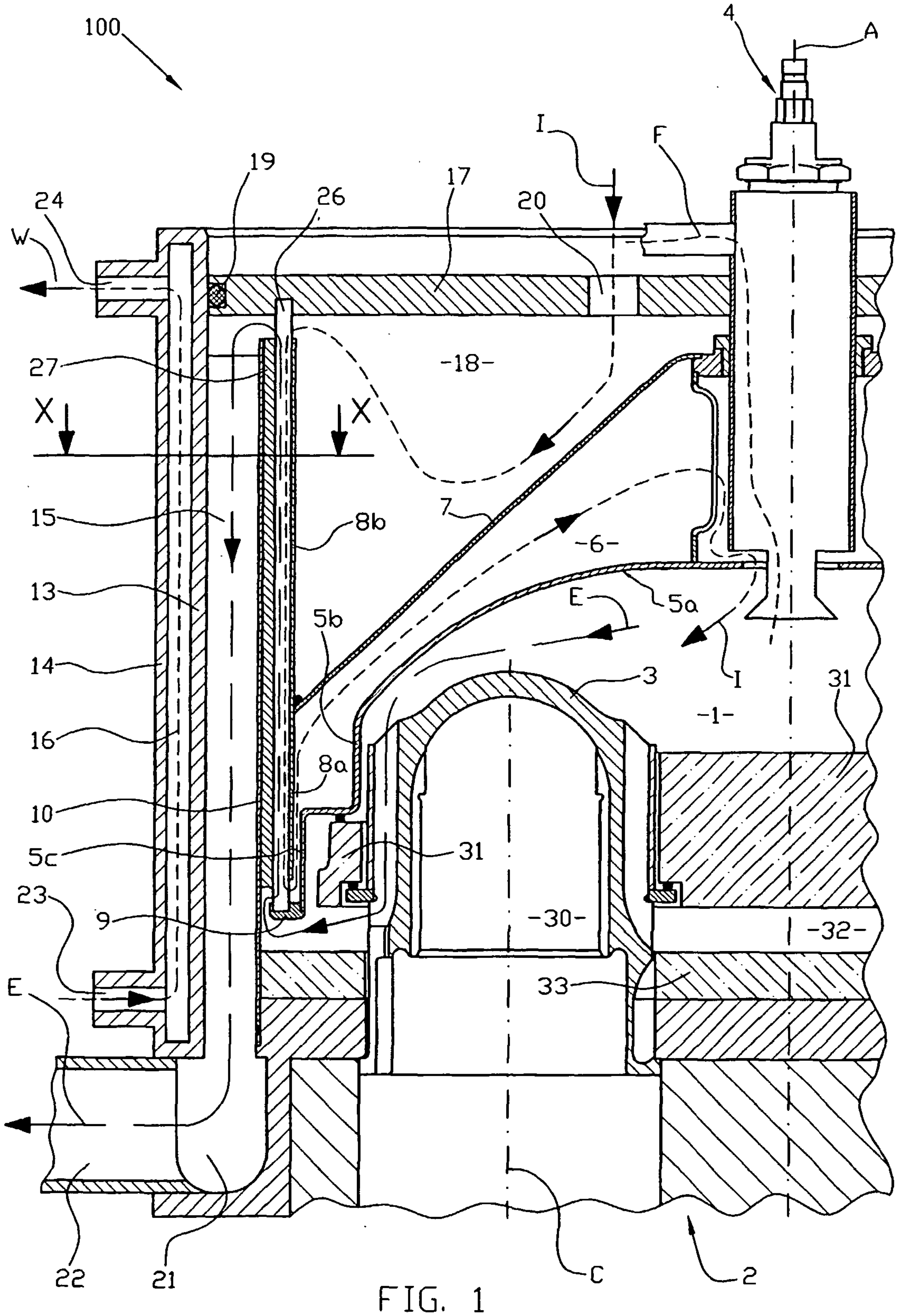
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FIG. 1

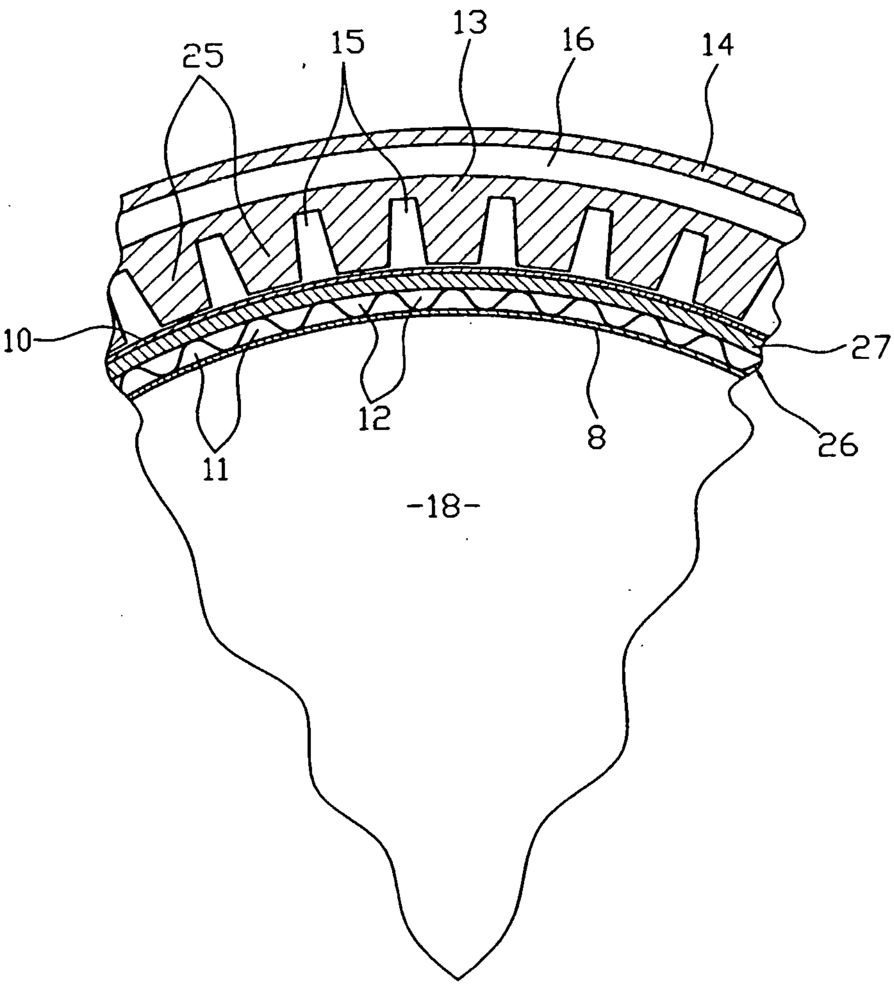

FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 9940309 A **[0004] [0050]**
- US 3717993 A **[0006]**