



(11)

EP 4 509 701 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.02.2025 Bulletin 2025/08

(51) International Patent Classification (IPC):
F01K 25/08^(2006.01)

(21) Application number: **23191346.8**

(52) Cooperative Patent Classification (CPC):
F01K 25/08

(22) Date of filing: **14.08.2023**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **Rotmanas, Algimantas**
Vilnius (LT)
• **Rotmanas, Mantas**
Vilnius (LT)
• **Regimantas, Bareikis**
Vilnius (LT)
• **Gedzevicius, Irmantas**
Vilnius (LT)

(71) Applicant: **Vilniaus Gedimino technikos universitetas**
10223 Vilnius (LT)

(74) Representative: **Pakeniene, Ausra**
AAA Law
A. Gostauto street 40B
03163 Vilnius (LT)

(54) **OPPOSED COLD STEAM ENGINE AND METHOD OF OPERATION**

(57) Opposed cold steam engine according to the invention comprises: a first refrigerant and a second refrigerant; a first circuit with the first refrigerant absorbing thermal energy; a first refrigerant compressor; a second heat exchanger of the first refrigerant; an expansion valve of the first refrigerant; a heat exchanger of an injected fraction of a second refrigerant; a circuit of the second refrigerant; a reservoir of the second refrigerant; valves of condensate of the second refrigerant; a mem-

brane; a chamber for the membrane accommodation and operation; two membrane chamber cavities; cyclically opening valves of the second refrigerant inlet to cavities of the membrane chamber; a second refrigerant condensate discharge/separation reservoir; a crankshaft with a flywheel; valves of the second refrigerant nozzles; nozzles of the second refrigerant; a second refrigerant nozzle pump.

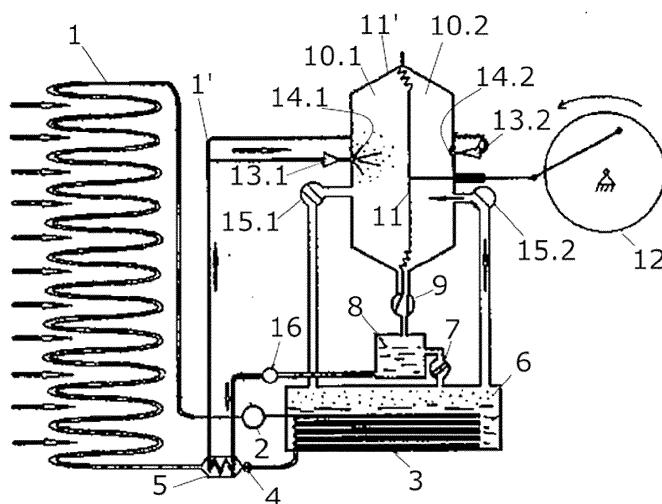


Fig. 1

Description

Field of the invention

[0001] The invention relates to energy transformation machines, and, more specifically, to machines that convert thermal energy into mechanical energy.

Background of the invention

[0002] Among thermodynamic energy transformation machines using low-temperature, from 0°C to 90°C, thermal energy as the main or additional energy source, heat pump is best known and most widely used. However, heat pump does not generate mechanical energy. Prevailing heat engines and generators in the industry transform only thermal energy of relatively high temperatures, from a few hundred to a thousand and more degrees Celsius into mechanical or other type of energy. Chemical energy from burning fuel is used as main energy source. Low-temperature thermal energy is usually released into the environment as waste. Almost all modern heat engines work according to the direct Carnot cycle, i.e. work in a temperature range that is very far from temperature of a used material, energy carrier, and phase transitions. For example, in an internal combustion engine, which is still very widely used, the energy source is burning hydrocarbon fuel. In principle, it is a hot expanding gas of which only a small part of the energy is used as a mechanical energy. Rest of the energy is emitted in the form of thermal energy. Steam turbines in thermal and nuclear power plants work similarly.

[0003] Heat pumps as mechanisms are special in that they consume several times less energy than they collect from the environment and serve to the user. For example, in the most common compressor heat pumps, heat of material phase transitions is purposefully used - the material is cyclically changed from liquid phase to gas phase and back. This is done by changing pressure in circuits in which refrigerant circulates. When the refrigerant gas is compressed by the compressor, it heats up, but changes its aggregate state from gaseous to liquid, condenses, and at a higher temperature gives thermal energy to the user. After losing thermal energy, the liquid phase of the refrigerant passes to another expansion circuit. After reducing pressure in it the refrigerant boils and evaporates: it changes its aggregate state from liquid to gas and absorbs the heat required for phase transformation from the environment, the medium in which the expansion circuit is placed. Temperature of this medium can be significantly lower than that of the environment to which the condensation thermal energy is transferred. Many modern heat pumps have a coefficient of transformation (COP) of 4 or even higher. This means that the device provides the user with 4 times more thermal energy than the electricity consumed by its compressor.

[0004] The heat pump supplies thermal energy to the consumer as a product.

[0005] European patent No. EP3457052 discloses a device designed to transform waste or natural low-temperature energy accumulated in nature not only into thermal but also into mechanical energy. An atmospheric pressure cold steam engine is described for generating mechanical energy using ambient thermal energy or excess low temperature thermal energy released during manufacturing processes. The working principle of the atmospheric pressure cold steam engine is based on the ability of materials to absorb or release thermal energy when they change from liquid to gas phase and vice versa. Main structural unit in which mechanical energy is generated is a cavity with a membrane. The engine is named atmospheric because mechanical energy generated by condensation of liquid in a membrane cavity is generated by the atmospheric pressure acting on the membrane. Although it is mentioned that not only atmospheric pressure can be used as an accumulator. When the membrane moves under atmospheric pressure, the engine generates energy, and when the membrane returns to its original position under the inertia of the flywheel, the engine stores potential energy. Therefore, its operation is cyclic and only half of the revolution of the shaft (theoretically 180° out of 360°) generates mechanical energy. Main disadvantage of the atmospheric pressure cold steam engine is that relatively little mechanical energy is generated, considering mass and dimensions of the mechanism - in other words, a poor mass-to-power ratio.

[0006] The invention does not have the above-mentioned disadvantages related to the small angle of rotation of the motor shaft in the generation of mechanical energy, and includes additional advantages.

Summary of the invention

[0007] The invention is an opposed cold steam engine. The invention comprises: a first refrigerant and a second refrigerant, a thermal energy absorbing first circuit with the first refrigerant; a first refrigerant compressor; a second heat exchanger of the first refrigerant; expansion valve of the first refrigerant; a heat exchanger of injected fraction of the second refrigerant; circuit of the second refrigerant; a reservoir of the second refrigerant; valves of condensate of the second refrigerant; a membrane; the membrane accommodating and operation chamber; two membrane chamber cavities; cyclically opening valves of the second refrigerant inlet to cavities of the membrane chamber; the second refrigerant condensate discharge-separation reservoir; a crankshaft with a flywheel; valves of second refrigerant nozzles; nozzles of the second refrigerant; the second refrigerant nozzle pump.

[0008] Structure of the opposed cold steam engine according to the invention allows to avoid using atmospheric pressure or another accumulator to generate mechanical energy. The gas phase of the refrigerant liquid, the vapor, is not used as a means of storing potential energy by overcoming atmospheric pressure,

but as a means of doing mechanical work of expansion. Therefore, it becomes possible to carry out both steam filling on one side of the membrane and condensation on the other side of the membrane in half a revolution of the shaft, i.e., 180°. Through 360°, i.e. two power generation cycles, a complete revolution occur. During generation of the mechanical energy the area of the membrane is affected by the refrigerant vapor pressure, which can be made from 10% to 50% higher than the atmospheric one, while obtaining a greater pressure difference on the opposite sides of the membrane.

[0009] Since the membrane is cyclically affected from both sides, i.e. the engine is a two-cycle engine - mechanical energy is generated by a 360° rotation of the shaft, and the pressure difference becomes greater than the difference between the atmospheric pressure and the pressure of the condensing liquid. These factors increase the power by more than 100%.

Short Description of Drawings

[0010] Features of the invention believed to be novel and inventive are set forth with particularity in the appended claims. The invention itself, however, may be best understood by reference to the following detailed description of the invention, which describes exemplary embodiments, given in non-restrictive examples, of the invention, taken in conjunction with the accompanying drawings, in which:

Fig. 1 shows principal scheme of the opposed cold steam engine according to the invention.

[0011] Preferred embodiments of the invention are described below with reference to the drawings. Each figure has the same numbering for the same or equivalent feature.

Detailed description of the methods of implementation of the invention

[0012] It should be understood that numerous specific details are presented in order to provide a complete and comprehensible description of the invention embodiment. However, the person skilled in art will understand that the embodiment examples do not limit the application of the invention which can be implemented without these specific instructions. Well-known methods, procedures and components have not been described in detail for the embodiment to avoid misleading. Furthermore, this description should not be considered to be constraining the invention to given embodiment examples but only as one of possible implementations of the invention. While the examples of the invention, or aspects thereof, as shown and described, include a plurality of components depicted in a particular common space or location, some components may be remote. Scale of elements in relation to other elements is not accurate, the aim is only to show the basic functional relationships between the elements. Materials that are presented as one of the

possibilities can also be replaced by materials with similar functional properties. It should be understood that the examples provided are not limited to the components described and include other elements necessary for their functioning and interaction with other components, the presence of which is self-evident and therefore not detailed.

[0013] According to the exemplary embodiment of the invention and as shown in Figure 1, the opposed cold steam engine comprises a first refrigerant and a second refrigerant, absorbing thermal energy in a first circuit (1) with the first refrigerant; a first refrigerant compressor (2); a second heat exchanger (3) of the first refrigerant; a first refrigerant expansion valve (4); a heat exchanger (5) of injected fraction of the second refrigerant; a circuit (1') of the second refrigerant; a reservoir (6) of the second refrigerant; second refrigerant condensate valves (7, 9); cyclically opening valves (15.1, 15.2) for the second refrigerant inlet to membrane chamber cavities; a second refrigerant condensate discharge-separation reservoir (8); a membrane housing and operation chamber (11'); two membrane chamber (11') cavities (10.1, 10.2); the membrane (11); a crankshaft with a flywheel (12); valves of the second refrigerant nozzles (13.1, 13.2); second refrigerant nozzles (14.1, 14.2); a second refrigerant nozzle pump (16). Operation of the opposed cold steam engine comprises two main working stages and two different refrigerants circulating in these stages. Hereafter concepts of "the first refrigerant" and "the second refrigerant" will be used assuming that the first refrigerant circulates in the first working stage and the first circuit (1), while the second refrigerant circulates in the second working stage and the second circuit (1').

[0014] In the first stage, which is similar to operation of a typical compressor heat pump, in the first circuit (1), the first refrigerant, such as R410, R32, R290 or others common for compressor heat pumps, boils and evaporates due to pressure reduced by the compressor (2). For evaporation it uses thermal energy of its own and that of the surrounding structures, i.e., the first circuit (1). When the temperature of the first refrigerant drops below that of the environment, i.e., medium in which the first circuit (1) is placed, thermal energy from this medium passes to structures of the first circuit (1), and these, due to their thermal conductivity, transmit heat to the first refrigerant circulating in the first circuit (1). Next, the first refrigerant, in the gaseous phase, entering the compressor (2), is compressed to the pressure at which condensation takes place. For example, when the temperature of the medium from which the thermal energy is absorbed is between 10°C and 20°C, the common refrigerant R32 can be used as the first refrigerant. From the compressor (2) of the first refrigerant the compressed vapor of the first refrigerant enters the second heat exchanger (3) of the first refrigerant. There, the first refrigerant, when condensed into a liquid, significantly reduces its volume, thermal energy concentrates, temperature rises, and thermal energy is transferred to the second refrigerant reservoir (6) through

walls of the second heat exchanger (3) of the first refrigerant. Cycle of the first refrigerant ends when the first refrigerant returns to the first circuit (1) through the expansion valve of the first refrigerant (4) and the heat exchanger (5) of the second refrigerant injection fraction.

[0015] The absorption of thermal energy takes place at lower temperatures than the transfer thereof. Elements that have to absorb thermal energy from the heat source must be maximally conductive to heat, and elements that have a different temperature compared to the environment must be thermally insulated. The amount of energy consumed by the compressor (2), as in conventional compressor heat pumps, is on average 4 times lower than the amount of energy absorbed in the first circuit (1) and concentrated in the second heat exchanger (3) of the first refrigerant and transferred to the reservoir (6) of the second refrigerant.

[0016] The second stage of work begins in the reservoir (6) of the second refrigerant. Properties of the second refrigerant - boiling point, heat capacity, specific heat of vaporization, vapor pressure in the working temperature range - are such that the second refrigerant boils and evaporates after absorbing concentrated thermal energy of the first refrigerant in the second heat exchanger (3) during the first cycle. Next, the vapors of the second refrigerant rise towards the cyclically opening valves (15.1, 15.2). These cyclically opening valves (15.1, 15.2) open cyclically depending on the position of the membrane (11) in the membrane chamber (11'). The membrane (11) is connected to the crankshaft with a flywheel (12), so the membrane in the chamber (11') can move cyclically from one extreme position to another (from the left end to the right end and back). Fig. 1 shows position of the membrane (11) in the membrane chamber (11') when, after the membrane (11) passes the right extreme position, the second cyclically opening valve (15.2) opens and the vapor of the second refrigerant fills the second cavity (10.2) of the membrane chamber (11'), located behind the membrane (11). The vapor of the second refrigerant in the second cavity (10.2) presses the membrane (11) and performs mechanical work. A pressure difference occurs because in the first cavity (10.1) of the membrane chamber (11') in front of the membrane at the same time an opposite process takes place - condensation of vapor of the second refrigerant.

[0017] For example, using a solution of ammonia and water as the second refrigerant, the pressure difference between the first cavity (10.1) of the membrane chamber (11') and the second cavity (10.2) of the membrane chamber (11') is about 120 kPa, when the temperature difference of $\Delta t = 40^\circ\text{C}$. Condensation in the first cavity (10.1) of the membrane chamber (11') is induced by injecting the same second refrigerant, or, partially, its components, through the first nozzle (14.1) for injecting the second refrigerant into the membrane chamber (11'). The said fractions have different boiling temperatures and are rectified during the process. When the membrane (11) reaches the extreme left position, the con-

densate from the first cavity (10.1) of the membrane chamber (11') is discharged to the condensate collection reservoir (8) through the valve (9) for the condensate outflow from the membrane chamber (11'). In the condensate collection reservoir (8), the second refrigerant is separated - the heavier fraction, such as water, goes to the heat exchanger (5) of the second refrigerant injection fraction, and the lighter fraction, which evaporates more easily, such as ammonia, to the reservoir (6). As the flywheel (12) rotates, the cycle that took place on the right side of the membrane (11), in the second cavity (10.2) of the membrane chamber (11'), is repeated on the left side, in the first cavity (10.1) of the membrane chamber (11'). The first cyclically opening valve (15.1) opens and steam fills the first cavity (10.1) of the membrane chamber (11'). And at the same time, on the right side, in the second cavity (10.2) of the membrane chamber (11'), condensation takes place.

[0018] The first cavity (10.1) of the said membrane chamber (11') and the second cavity (10.2) of the membrane chamber (11') are tightly separated from each other by means of the membrane (11).

[0019] Mechanical energy is generated during the entire revolution of the flywheel (12), 360° shaft rotation, as the membrane (11) moves to the left extreme position and to the right extreme position, in the membrane chamber (11').

[0020] When generating mechanical energy, it is important to have the pressure difference between the opposed sides of the membrane (11) as large as possible. One side of the membrane (11) is affected by the vapor pressure of the second refrigerant, which can be significantly higher than the atmospheric pressure. On the other, the opposite side of the membrane (11), the pressure of the condensing steam of the second heat exchanger acts, which may be lower than atmospheric, but not necessarily. The pressure difference generates mechanical power.

[0021] The opposed cold steam engine according to the invention can generate more mechanical energy than the atmospheric pressure cold steam engine for the same membrane area.

[0022] The conditions for the formation of a significantly larger pressure difference on the opposite sides of the membrane (11) occur because the mechanical work is performed by the pressure of the refrigerant prepared in the second refrigerant reservoir (6), and not atmospheric pressure or another energy accumulator.

[0023] Both from physical and technical point of view, it is possible to prepare a higher than atmospheric pressure in the second refrigerant reservoir (6). For example, the vapor pressure of an ammonia-water solution at the beginning of the membrane cavity filling cycle is about 170 kPa, at the end of the filling cycle is about 120 kPa, and the average pressure is about 140 kPa, which is 40 percent higher than the atmospheric pressure.

[0024] In the opposed cold steam engine, on the op-

posite side of the membrane (11), the pressure of the condensing vapors of the second refrigerant is only 5-10 percent higher than the atmospheric pressure in the cold steam engine. This results in a greater pressure difference on the opposite sides of the membrane (11) and more mechanical energy per 180° shaft rotation. The solution of ammonia and water is presented here only as an example of substances well known to everyone, and using other, more purposefully selected substances, it is possible to obtain several times higher pressure differences on the opposite sides of the membrane in the opposed engine than in the atmospheric pressure cold steam engine.

[0025] In the opposed cold steam engine, mechanical energy is generated during 360° of shaft rotation, so it is theoretically possible to obtain more than twice the mechanical energy using a membrane of the same area, compared to when mechanical energy is generated during 180° of shaft rotation.

[0026] Although the present description includes numerous characteristics and advantages of the invention together with structural details and features, the description is given as an example of the invention embodiment. There may be changes in the details, especially in the form, size and layout of materials without departing from the principles of the invention, in accordance with the widely understood definition of terms used in claims.

Claims

1. Opposed cold steam engine, comprising a thermal energy absorbing circuit, a first refrigerant compressor, a second heat exchanger of the first refrigerant, an expansion valve of the first refrigerant, a heat exchanger of injected fraction of a second refrigerant, the second refrigerant reservoir; the second refrigerant condensate valves, a membrane, cyclically opening valve for the injection of the second refrigerant into cavity in front of the membrane, reservoir for the second refrigerant condensate discharge/separation, injection cavity for the second refrigerant injected fraction in front of the membrane, crankshaft with a flywheel, a the nozzle valve for injecting the second refrigerant into the cavity in front of the membrane, pump for the second refrigerant injector, **characterized in that** it further comprises a chamber (11') for containing and operating the membrane (11), the chamber (11') comprising a first cavity (10.1) for injecting the second refrigerant, located on one side of the membrane (11), in front of the membrane (11) intended to fill with the vapor of the second refrigerant, and a second cavity (10.2) for the injection of the second refrigerant, located on the other - opposite - side of the membrane (11), behind the membrane (11), intended to be filled with the vapor of the second refrigerant, where the first cavity (10.1) and the second cavity (10.2) are separated cavities,

sealed from each other by the membrane (11), the chamber (11') further comprises a second nozzle (13.2) for injecting the second refrigerant into the second cavity (10.2), a second nozzle valve (14.2) and a second cyclic opening valve (15.2).

2. The method of operation of the opposed cold steam engine according to claim 1, comprising two stages of operation with different refrigerants in separate circuits, wherein first stage of operation comprises transferring the ambient heat of a first refrigerant for heating a second refrigerant in a heat exchanger, and a second stage of operation comprises converting the second refrigerant to vapor, wherein the second refrigerant, in form of vapor, is supplied to a cavity in front of a membrane to change position of the membrane, wherein change of membrane position moves a crankshaft with a flywheel, **characterized in that** properties of the second refrigerant - boiling point, heat capacity, specific heat of vaporization, vapor pressure in the operating temperature range - are such that the second refrigerant boils and evaporates after absorbing concentrated thermal energy from a first refrigerant in a second heat exchanger (3) during the first stage of work, and

in that vapors of a second refrigerant rises towards a first cyclically opening valve (15.1) and separately towards a second cyclically opening valve (15.2), which open cyclically depending on the position of the membrane (11) in a membrane chamber (11'), wherein after the membrane (11) passes the right extreme position in the membrane chamber (11'), the second cyclically opening valve (15.2) opens and the vapor of the second refrigerant fills a second cavity (10.2) located in the membrane chamber (11') behind the membrane (11), at the same time pressurizing membrane (11) and performing mechanical work, where in a first cavity (10.1), located in the membrane chamber (11') in front of the membrane (11), condensation takes place at the same time, triggered by the injection of the same second refrigerant or, partially, its components through a nozzle (14.1) of the first cavity (10.1), after the membrane (11) reaches the extreme left position in the membrane chamber (11'), the condensate of the second refrigerant from the first cavity (10.1) is discharged through a condensate valve (9) into a condensate collection reservoir (8) and there the second refrigerant is separated, where heavier fraction goes to a heat exchanger of the second refrigerant and the injected fraction (5) which is lighter and easier to evaporate goes to the reservoir of the second refrigerant (6), as the flywheel (12) rotates, the cycle that took

place on the right side of the membrane (11), in the second cavity (10.2) of the membrane chamber (11'), is repeated on the left side, in the first cavity (10.1) of the membrane chamber (11'), the first valve (15.1) of the second refrigerant 5 opens and steam fills the first cavity (10.1) of the membrane chamber (11'), and at the same time condensation takes place in the second cavity (10.2) of the membrane chamber (11') on the right side, thus generating mechanical energy 10 through the complete rotation of the flywheel (12), 360° shaft rotation, while the membrane (11) moves to the left extreme position and to the right extreme position in the membrane chamber (11'). 15

20

25

30

35

40

45

50

55

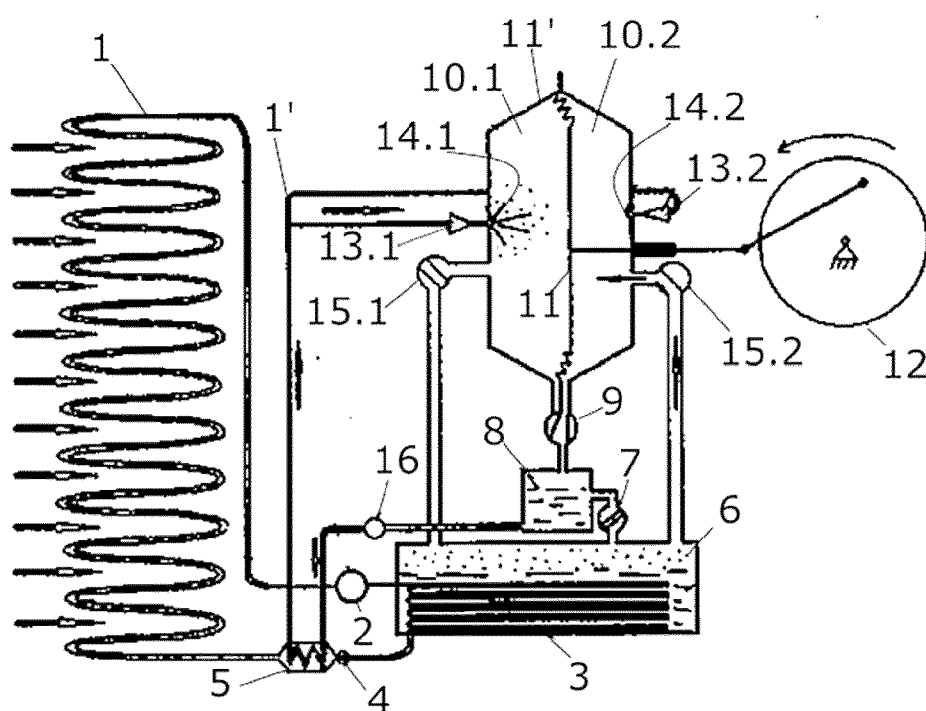


Fig. 1



EUROPEAN SEARCH REPORT

Application Number

EP 23 19 1346

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	EP 3 457 052 A1 (UNIV VILNIAUS GEDIMINO TECH [LT]) 20 March 2019 (2019-03-20) * abstract; figures 1, 2 * * paragraphs [0014] - [0029] * -----	1,2	INV. F01K25/08
A	FR 2 547 399 A1 (ANCET VICTOR [FR]) 14 December 1984 (1984-12-14) * figures 1-3 * * page 3, line 3 - page 4, last line * -----	1,2	
A	US 2015/377496 A1 (CHO YOUNG I [US]) 31 December 2015 (2015-12-31) * abstract * * paragraphs [0011], [0012] * -----	1,2	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01K
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		2 February 2024	Varelas, Dimitrios
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 23 19 1346

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

02-02-2024

10

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 3457052	A1	20-03-2019	EP LT	3457052 A1 6635 B	20-03-2019 25-06-2019

FR 2547399	A1	14-12-1984	NONE		

US 2015377496	A1	31-12-2015	US	2013025300 A1	31-01-2013
			US	2015377496 A1	31-12-2015
			WO	2011130162 A2	20-10-2011

15

20

25

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 3457052 A [0005]