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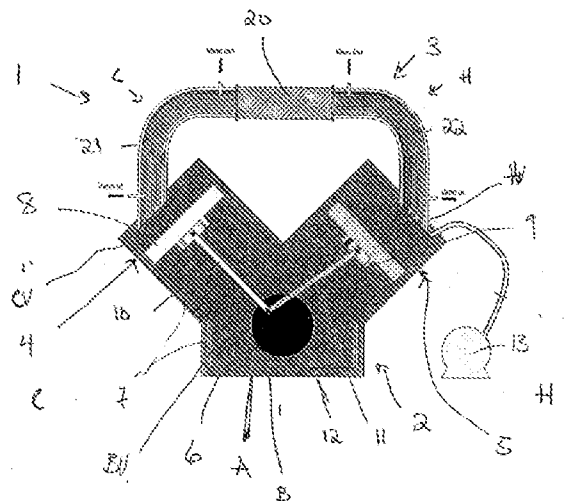
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(54) Title **Heat pump**
(57) Abstract

The invention relates to a heat pump device (1) comprising a heat exchanger arrangement (3) and a driving unit (2, 40, 50). The driving unit (2, 40, 50) comprises a housing (2a, 40a, 50a) having an expansion volume (CV), a compression volume (HV) and a base volume (BV), at least one piston arrangement comprising each a piston (4, 5, 42, 52) being fluidly connected to the expansion volume (CV) and/or the compression volume (HV) at one side, and fluidly connected to the base volume (BV) at the opposite side, the piston (4, 5, 42, 52) comprises an oil scraper ring (31) and a compression ring (30), -the driving unit (3, 40, 50) further comprises a device for supplying working fluid into the expansion and/or compressor volume (CV, HV) during operation of the heat pump (1) in order to maintain a higher pressure in the expansion and/or compressor volume (CV, HV) than in the base volume (BV).



HEAT PUMP

Technical Field

- 5 This invention relates to a heat pump and more particularly a heat pump using an engine based on the stirling cycle principle for transferal of heat.

Background Art

- 10 A stirling cycle is a thermodynamic cycle in which air or other gaseous working fluid undergoes a cyclic compression and expansion. If the cycle is applied to a heat hump, there is a net conversion of mechanical work to heat energy and also absorption of heat from the surroundings. This heat may be used in heat exchangers to heat exchange the hot working fluid to an area or substance that requires heating. On the opposite side the cold expanded fluid may be heat
15 exchanged with a source that requires cooling.

- Existing prior art machines often use Helium or other noble gases as working fluid. Such gases have the advantage of providing a low internal friction in a driving unit. However, the use of helium requires the use of expensive and complicated sealing mechanisms to avoid the helium to escape from the
20 system.

The heat pump according to the invention provides a simple driving unit that is easy to assemble and requires less maintenance than prior art heat pumps.

The heat pump according to the invention further provides a cost-effective heat exchanger maintaining a high efficiency of heat transferal in the system.

- 25 The use of oil lubricated pistons that have one or several compression rings is adapted to reduce the leakage of working fluid from the process to the environment and one or several oil scraper rings is adapted to facilitate effective lubrication of the piston assembly without allowing excessive oil flow to the process/heat exchanger side of the pistons.

- 30 An oil pump facilitates the circulation of oil to the reciprocating and/or rotating components.

A pressurised Stirling process where the process pressure is always higher than the crank case pressure, reduces the oil migration past the pistons into the process side of the pistons.

- 5 A compressor which replaces working fluid that leaks out of the process provides that the pressure in the process is continuously higher than the pressure of the surroundings.

Further and other advantages will be apparent by the detailed description and the accompanying drawings.

10

Summary of invention

- The invention relates to a heat pump device comprising a heat exchanger arrangement and a driving unit. The heat pump being distinctive in that
- the driving unit comprises a housing having an expansion volume, a
 - 15 compression volume and a base volume,
 - at least one piston arrangement comprising each a piston being fluidly connected to the expansion volume and/or the compression volume at one side, and fluidly connected to the base volume at the opposite side, the piston comprises an oil scraper ring and a compression ring,
 - 20 -the driving unit further comprises a device for supplying working fluid into the expansion and/or compressor volume during operation of the heat pump in order to maintain a higher pressure in the expansion and/or compressor volume than in the base volume.
- 25 The provides a cost-effective heat pump that maintain a high efficiency of the heat transferal in the system. By using pistons with less "sealing requirements" and maintain overpressure in the system, the heat pump will operate efficiently.

- It is important to maintain an overpressure in the compress and/or expansion volume compared to the base volume as this reduces at the same time the risk
- 30 of leaking oil into the heat exchanger part of the system.

The pressure of the compression (hot) volume and expansion (cold) volume is

thus exceeding the pressure of the base volume, in order to prevent oil migration from the base volume to the compression and/or expansion volume.

Preferably, the working fluid is air.

5 Preferably, the driving unit further comprising an oil pump arranged in the base volume adapted to circulate oil to reciprocating and/or rotating parts of the driving units.

Preferably, excessive oil is adapted to be collected at the bottom of the base volume of the housing.

10 Preferably, the pressure of the hot and cold volume is exceeding the pressure of the main volume, in order to prevent oil migration from the main volume to the hot and/or cold volume.

Preferably, the driving unit comprises a first piston arrangement in connection with the compression volume and a second piston arrangement in connection with the expansion volume.

15 Preferably, the first and second piston arrangements comprises a respectively a first piston and a second piston connected to a crankshaft arranged in the main volume via piston rods. Said piston rods being connected to the crankshaft at the same position off center of the center axis of the crankshaft.

20 Preferably, the driving unit comprises a one piston arrangement in connection with the compression and expansion volume, said compression and expansion volume being divided by a displacer.

Preferable the driving piston and the displacer being connected to a common crankshaft.

25 A use of an oil lubricated piston having one or more compression rings and one or more oil scraper rings as a piston in a heat pump operated by a stirling cycle driving unit.

Brief description of drawings

Figure 1 shows a cross sectional view of an embodiment of the invention with an alfa configuration of the driving unit.

Figure 2 shows a detailed view of the pistons that are arranged within a driving unit of the heat exchanger according to an alfa configuration from figure 1.

Figure 3 shows a detailed view of a driving unit according to a further embodiment of the invention with a beta configuration.

Figure 4 shows a detailed view of a driving unit according to another embodiment of the invention with a gamma configuration.

Figure 5 shows a detailed view of the piston of the driving unit according to the embodiments shown in figure 1-4.

Detailed description of the invention

Figure 1 shows a cross sectional view of an embodiment of a heat pump according to the invention.

The heat pump 1 comprises a driving unit 2 and a heat exchanger arrangement 3. The driving unit 2 is based on a stirling cycle principle with an alpha configuration. This process will be further described below.

The driving unit 2 comprises a housing 7. The housing having further a cold side C and a hot side H, as indicated in figure 1.

A working fluid undergoes a cyclical compression and expansion by a cyclic movement between the cold side C and the hot side H of the driving unit 2. The driving unit 2 as shown in the figure comprises a cold cylinder 4 and a hot cylinder 5 arranged on the respective cold and hot side C, H of the driving unit 2. The cylinders 4, 5 extends into a common base part 6 as shown in figure 1. The cylinders 4, 5 and the base part 6 forming a Y-shaped design or housing 7 of the driving unit 2. This is commonly known as the alpha-type stirling configuration.

The process can be carried out by using a hot piston 9 and a cold piston 8 that is adapted to move with approximately 90° phase angle in hot and cold cylinders

5, 4, respectively.

The hot piston 9 and cold piston 8 are respectively connected to a crankshaft 12 through a piston rod 11, 10. The piston rod 11 of the hot piston 9 and the piston rod 10 of the cold piston 8 are connected to the same position A in the crankshaft 12. The piston rods 10, 11 of the respective pistons 8, 9 are connected to the crankshaft 12 through a crank pin 14 (fig. 2) and a bearing (not shown). However, this is only an example of possible piston operating arrangements. Other mechanisms for operating the pistons 8, 9 being alternative embodiments of the invention, such as the beta and gamma configuration as shown in figure 3 and 4.

It is to be mentioned that the piston arrangement at the hot side and the piston arrangement on the cold side is substantially equal in design.

The position A is eccentric of a centre axis B of the crankshaft 12. This eccentric position A results in the phase angle movement of the hot and cold pistons 8, 9 in the respective cylinder 4, 5 as defined above.

The crankshaft 12 is as shown in the figure 1 arranged in the common base part 6 or the housing 7. The crank shaft 12 is rotated by an electrical motor (not shown) or other devices providing a rotation of the crankshaft 12.

The volume defined by the hot piston 9 and the hot cylinder 5 is defined as a compression (hot) volume HV. The volume defined by the cold piston 8 and the cold cylinder 4 is defined as the expansion (cold) volume CV.

The remaining volume defined by the cold piston 8 and the hot piston 9 and the housing part between the underside of the cold and hot piston 8, 9 is defined as a base volume BV.

This driving unit 2 is adapted to industrial use. The driving unit 2 in connection with the heat exchanger arrangement 3 is illustrated in figure 1. The heat exchanger arrangement 3 has a hot side H correspondent and in connection with the compression (hot) volume HV of the driving unit 2. This hot side H having a hot heat exchanger 22 that typically produce steam or hot water ie the heat exchanger transfer heat to the area or substance to be heated. However, these are only examples of possible heating possibilities. Other possibilities for heating being alternative embodiments of the invention.

The heat exchanger arrangement 3 has also a cold side C correspondent and in connection with the expansion (cold) volume CV of the driving unit 2. This cold side C having a cold heat exchanger 21 that typically absorb waste heat from an industrial process, ie receive heat from an area or substance. However, these are only examples of possible cooling possibilities of the heat exchanger arrangement 3. Other possibilities for cooling being alternative embodiments of the invention.

- 10 The heat exchanger arrangement 3 further comprising a regenerator 20. This regenerator 20 is arranged between the cold heat exchanger 21 and the hot heat exchanger 22.

The purpose of the regenerator 20 is to store heat between the hot side of the heat exchanger arrangement 22 and the cold side of the heat exchanger arrangement 21 and thus reuse heat on the hot side of the heat exchanger arrangement 3. The regenerator is known per se.

The heat pump 1 uses preferable air as a working fluid in the heat exchanger 2. The invention is however not limited to air as working fluid. This working fluid is however highly advantage as working fluid in the heat pump 1 as this is a resource that has low cost and that also has no environmental hazard in the event of leakage. The heat pump 1 further comprise an air compressor 13 for refilling air to the system if air leak into the system. The air compressor 13 is arranged in connection with the hot volume to supply air into the compression (hot) volume HV from the upper side of the pistons 8, 9. The air is supplied through a compressor tube 13a into the compression (hot) volume HV. The air compressor 13 may however be arranged differently as long as it is supplying air into the area of the working fluid in the system. There may also be other sources than a compressor for supply of air into the system.

- 30 Calculations indicate that use of air as working fluid in a Stirling cycle heat pump does not prevent the machine from reaching acceptable performance, despite higher friction losses and lower heat transfer coefficients than for a helium filled machine. This observation is mostly related to Stirling process

heat pumps as opposed to Stirling engines. This is due to the friction in a heat pump being converted to useful heat whereas in a Stirling engine it will be converted to waste heat.

5 The use of air as working fluid also increases the leak tolerance, since the lost fluid is replaced by the air supply system, such as the air compressor 13. The reduced leak tolerance and friction tolerance enable that components commonly used in engines to be used also in the process with the heat pump. These components are otherwise not acceptable due to strict tolerances for
10 leak of the prior art heat pumps.

Figure 2 shows the driving unit 2 in greater detail. Each of the pistons on the hot and cold side have one or more compression rings 30 and one or more oil scraper rings 31 as indicated by the figure. These rings 30, 31 are arranged on
15 the side of the respective pistons 8, 10 facing the compression (hot) and expansion (cold) volume HV, CV, respectively.

The pistons 8, 9 of the invention are oil lubricated pistons. This means that the pistons 8, 9 have with one or compression rings 30 and one or more oil scraper
20 rings 31 as shown in fig. 2 and 3. The compression ring 30 are adapted to reduce the leakage of working fluid from the compression (hot) volume HV or expansion (cold) volume CV to the base volume BV. The oil scraper ring 31 facilitate effective lubrication of the piston assembly without allowing excessive oil flow into the compression (hot) volume HV or the expansion (cold) volume
25 CV of the driving unit 2.

The compressor or air supply that is continuously supplying air to the compression (hot) volume HV and expansion (cold) volume CV system, provides an overpressure at this side of the pistons, 8, 9. This overpressure
30 prevents further any leakage of oil into the heat exchanger unit 3. Oil that otherwise leak into heat exchanger parts and the regenerator would highly decrease the efficiency of the heat exchanger parts 21, 22 or the regenerator
20.

The air supply system of the invention prevent such incident and make it possible to use the lubricated pistons in the heat pump systems as the air supply and the created overpressure prevents the oil to leak into the heat exchanger parts 21, 22, 20 .

5

A further advantage with the air supply is that the pressure is maintain at the sufficiently level without the necessity of keeping the compression (hot) volume HV and expansion (cold) volume completely airtight. This means that the piston with oil scraper and compression rings provide an acceptable sealing system for the pistons which result in less friction between the pistons 8,9 and respective cylinders 4, 5.

10

In addition, there is an oil pump 35 arranged in the bottom of the base volume BV to collect any oil 34 that has leaked from the system. The oil may be supplied to the parts that require oil in the unit 2.

15

Figure 3 shows a cross sectional view of an alternative embodiment of a driving unit 40 of a second embodiment of a heat pump according to the invention. The driving unit 40 according to the second embodiment operates in line with a beta (β) configuration. The driving unit 40 may in a similar way as in figure 1 be connected to the heat exchanger arrangement 3, through the compression (hot) volume HV and expansion (cold) volume CV indicated in figure 3.

20

The driving unit 40 comprises a housing 49. The housing 49 is divided into a cylinder 41 and a crank case 49. The housing comprises the compression volume HV, expansion volume CV and base volume BV.

25

The cylinder 41 has a piston 42 arranged inside the cylinder 41. The piston 42 divides the cylinder 41 further into a compression (hot) volume HV, an expansion (cold) volume CV arranged above the piston 42 and a base volume below the piston 42. The piston 42 is oil lubricated pistons and has one or several oil-scraper rings 31 and compression rings 30 (see fig. 5). This is the same types of piston as used in the configuration of figure 1. The piston 42 is connected to a crank shaft 44 or other driving mechanism through a piston rod

30

43. A displacer 45 moves cyclically between the compression (hot) volume HV and the expansion (cold) volume CV above the piston 42. The displacer 45 is attached to the crank shaft 44 through a displacer rod 46. The displacer rod 46 is extending through an opening 42a in the piston 42 substantially in the center position of the piston 42. The displacer 45 movement is approximately 90° out of phase with the movement of the piston. This is provided by the design of the crankshaft 44 causing the piston 42 and displacer to move in opposite directions as shown in figure 3. This ensures that the working fluid undergoes a cyclical compression and expansion cycle where heat is exchanged through the hot and cold surfaces of the machine respectively. A compressor 13 or other source of pressurised working fluid ensures that the pressure above the piston 42 is sufficiently high, during all parts of the cycle, to prevent excessive lubrication oil from reaching the process side, ie the side containing the compression (hot) volume HV and the expansion (cold) volume CV of the piston 42. Oil for the rotating and reciprocating components is supplied by an oil pump 48 and by oil splashing from the volume 47 in the lower part of a crank case 49. The crank case 49 is in this embodiment containing a base volume BV similar as defined in the embodiment of figure 1.

Figure 4 shows a cross sectional view of an alternative embodiment of a driving unit 50 of a third embodiment of a heat pump according to the invention. The driving unit 50 according to the third embodiment operates in line with a gamma (γ) configuration. The driving unit 50 may in a similar way as in figure 1 and 3, be connected to the heat exchanger arrangement 3, through the compression (hot) volume HV and expansion (cold) volume CV indicated in figure 4.

The heat pump comprises a first cylinder 51 with a piston 52 arranged inside. The piston 52 is oil lubricated and has one or several oil-scraper rings 30 and compression rings 31 (fig. 5). It is connected to a crank shaft 54 or other driving mechanism through a piston rod 53. The first cylinder 51 is fluid connected to a second cylinder 49 which contains a displacer 55. The displacer 55 is adapted to move approximately 90° out of phase with the movement of the piston. This is provided by the design of the crankshaft 54 causing the piston 52 and displacer

55 to move in different directions through a displacer rod 56 and piston rod 53 as shown in the figure. The cylinder 49 further has a lower wall 49a with elements to provide a sealing against the displacer rod 56.

This ensures that the working fluid undergoes a cyclical compression and
 5 expansion cycle where heat is exchanged through the (compression) hot and (expansion) cold surfaces of the machine respectively. A compressor 13 or other source of pressurised working fluid ensures that the pressure above the piston 52 is sufficiently high, during all parts of the cycle, to prevent excessive lubrication oil from reaching the process side of the piston 52. The air or
 10 working fluid may be supplied through compressor tubes 13a to the system. The process side is the side of the piston in fluid connection with compression (hot) volume HV and expansion (cold) volume CV of the driving unit 50. Oil for the rotating and reciprocating components is supplied by an oil pump 58 and by oil splashing from the volume 57 in the lower part of the crank case 59. The
 15 crank case 59 is in this embodiment containing a base volume BV similar as defined in the embodiment of figure 1.

Figure 5 shows a further detailed view of one of the pistons 8, 9, 42, 52 according to any of the embodiments shown in figure 1-4. The hot and cold
 20 pistons 9, 8 and the gamma piston 52 are equal. The piston 42 of the beta configuration differs only in that it has a through hole adapted to receive the crankshaft, otherwise the components are equal. The piston 8, 9, 42, 52 illustrated in figure 5 has two compression rings 30 arranged above one oil scraper ring 31. Other arrangements may however be possible, such as one
 25 compression ring and one or two oil rings.

The heat exchanger process by the heat pump 1 will be further described in the following: For simplicity the heat exchanger process with the alpha configuration according to fig 1 and 2 is described below. However, this process is equally
 30 applicable to the heat exchanger process with the beta and gamma configuration disclosed in fig. 3 and 4 as well.

The working fluid adapted to flow between the compression (hot) volume HV

and the expansion (cold) volume CV, through the cold heat exchanger 21, regenerator 20 and the hot heat exchanger 22.

5 The phase angle between the movement of the two pistons 8, 9 will ensure that the working fluid is compressed, expanded and moved between the respective parts of the machine, as outlined in the text below. The pistons are single acting pistons.

10 During the compression phase the air temperature will increase. The opposite will take place during the expansion phase. Due to the cyclical movement of the working fluid, most heat will be released through the hot heat exchanger 22 and most of the heat that the machine absorbs from the environment will be absorbed through the cold heat exchanger 21. This principle is general to Stirling cycle machines.

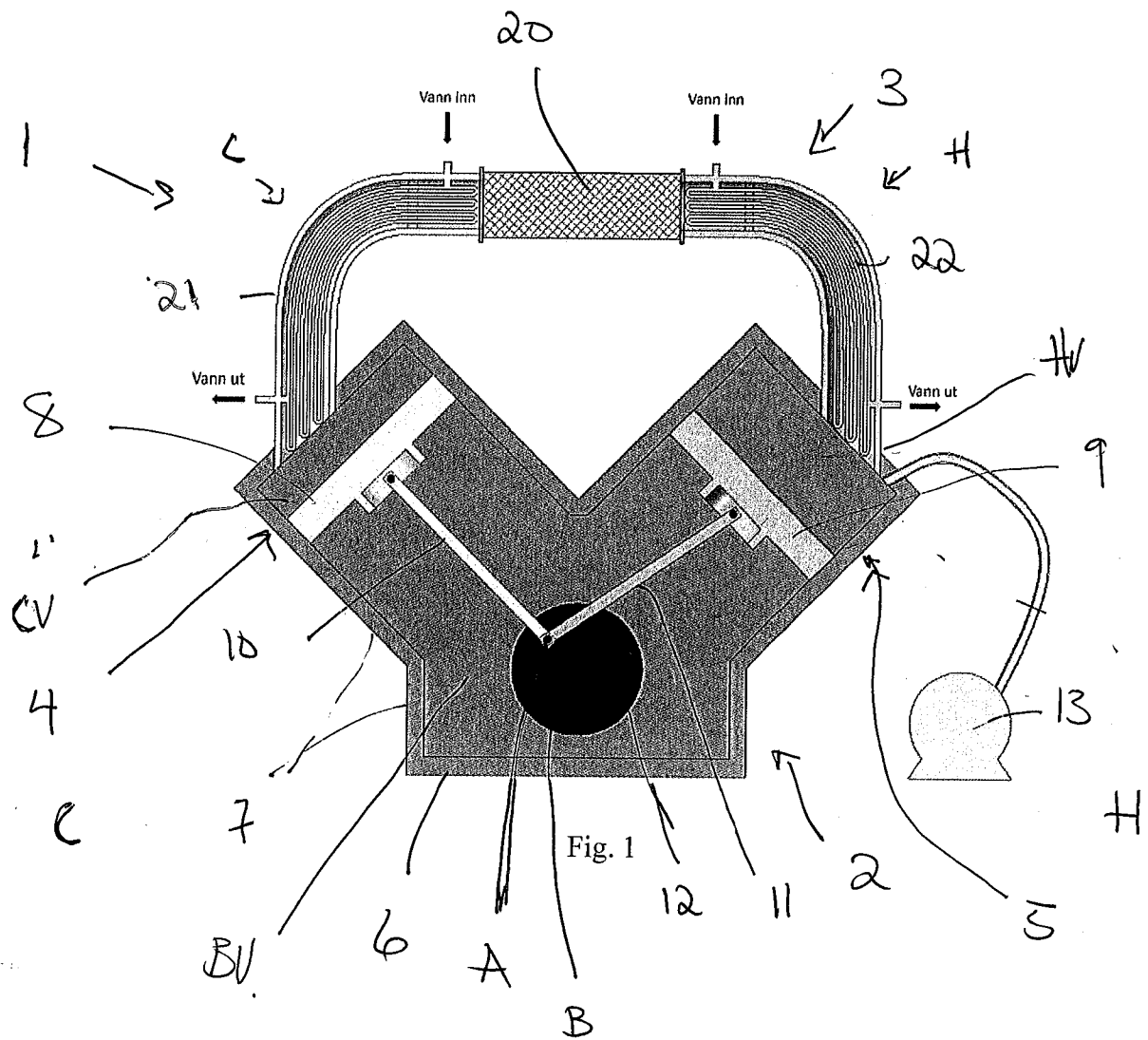
15 The use of this pressurized Stirling process according to the invention, the pressure in the compression (hot) volume HV and expansion (cold) volume CV are always higher than the base volume BV. This ensures that the pressure in the process is continuously higher than the pressure in the surroundings.

20 The present invention has been described with reference to a preferred embodiment and some drawings for the sake of understanding only and it should be clear to persons skilled in the art that the present invention includes all legitimate modifications within the ambit of what has been described
25 hereinbefore and claimed in the appended claims.

Claims

1. A heat pump device (1) comprising a heat exchanger arrangement (3) and a driving unit (2, 40, 50) **characterised in that**
 - 5 -the driving unit (2, 40, 50) comprises a housing (2a, 40a, 50a) having an expansion volume (CV), a compression volume (HV) and a base volume (BV),
 - at least one piston arrangement comprising each a piston (4, 5, 42, 52) being fluidly connected to the expansion volume (CV) and/or the
 - 10 compression volume (HV) at one side, and fluidly connected to the base volume (BV) at the opposite side, the piston (4, 5, 42, 52) comprises an oil scraper ring (31) and a compression ring (30),
 - the driving unit (3, 40, 50) further comprises a device for supplying working fluid into the expansion and/or compressor volume (CV, HV)
 - 15 during operation of the heat pump (1) in order to maintain a higher pressure in the expansion and/or compressor volume (CV, HV) than in the base volume (BV).
2. The heat pump device (1) according to claim 1, wherein the working fluid is air.
- 20 3. The heat pump device (1) according to any one of the preceding claims wherein the driving unit (3, 40,50) further comprising an oil pump (35, 48, 58) arranged in the base volume (BV) adapted to circulate oil to reciprocating and/or rotating parts of the driving units (2).
4. The heat pump device (1) according to any one of the proceeding claims,
- 25 wherein excessive oil is adapted to be collected at the bottom of the base volume (BV) of the housing.
5. The heat pump device (1) according to any one of the preceding claims wherein the driving unit comprises a first piston arrangement (5) in connection with the compression volume (HV) and a second piston
- 30 arrangement (4) in connection with the expansion volume (CV).

6. The heat pump device (1) according to claim 6, wherein the first and second piston arrangements comprises a respectively a first piston (9) and a second piston (8) connected to a crankshaft (12) arranged in the base volume (BV) via piston rods (10, 11),
- 5 7. The heat pump device according to claim 7, wherein said piston rods (10, 11) being connected to the crankshaft (12) at the same position off center (A) of a center axis (B) of the crankshaft.
8. The heat pump device according to any one of the claims 1-5, wherein the driving unit (40) comprises one piston arrangement (41) in
10 connection with the compression and expansion volume (HV, CV), said compression and expansion volume (HV, CV) being divided by a displacer (45, 55).
9. A use of an oil lubricated piston having one or more compression rings (30) and one or more oil scraper rings (31) as a piston (8, 9, 41, 52) in a
15 stirling cycle driving unit (2, 40, 50) operating a heat pump (1).



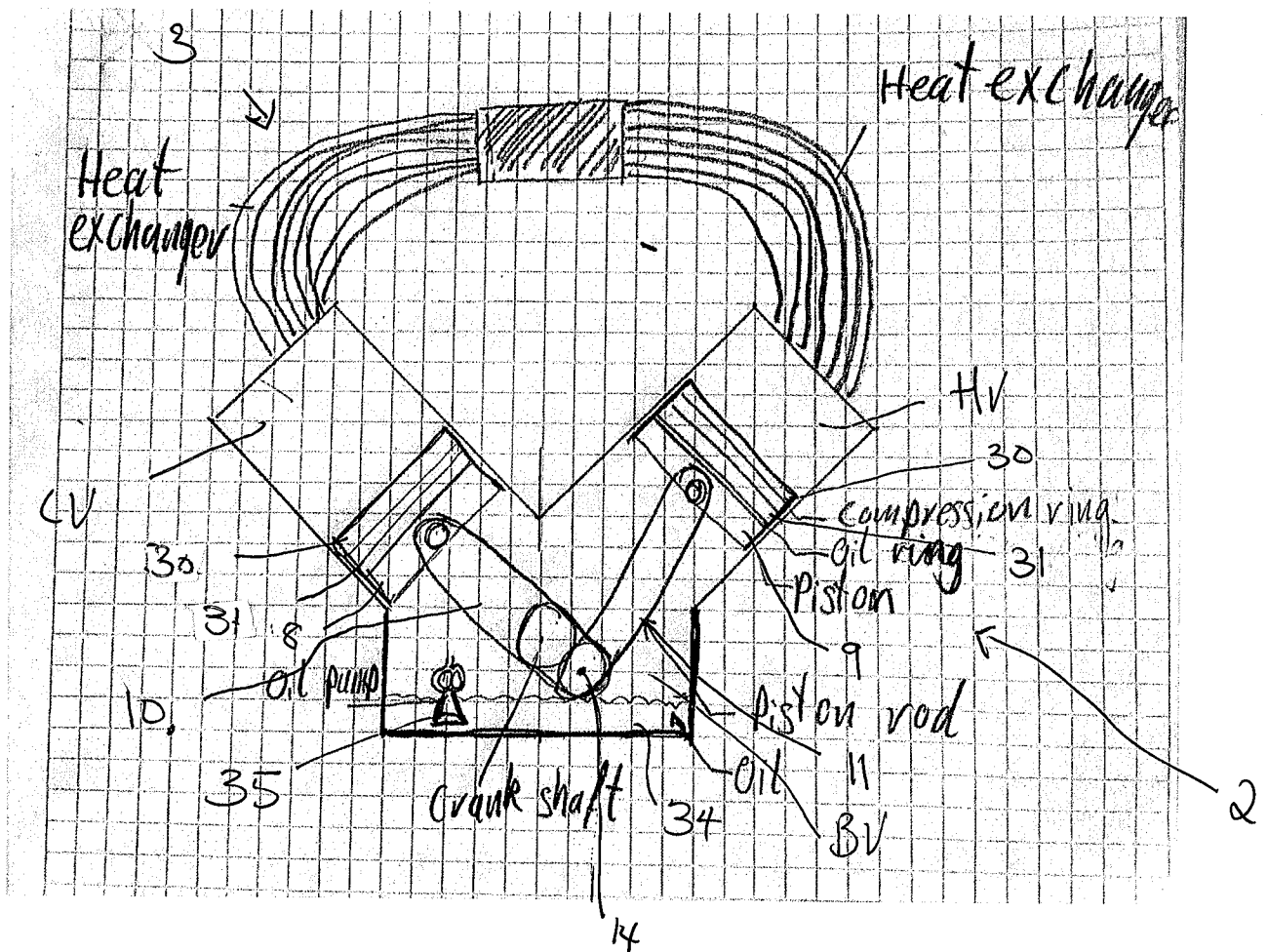


Fig. 2

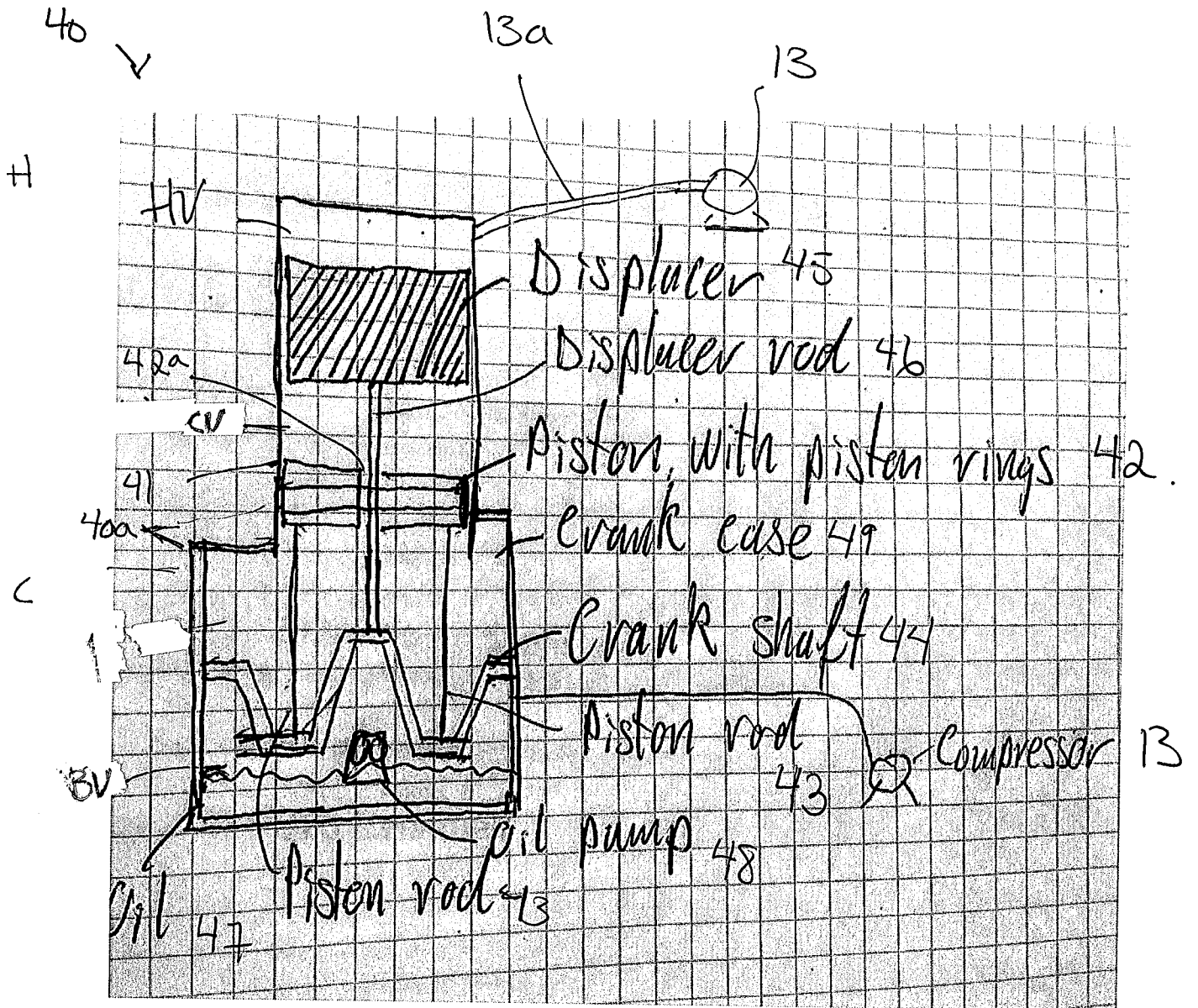


Fig. 3

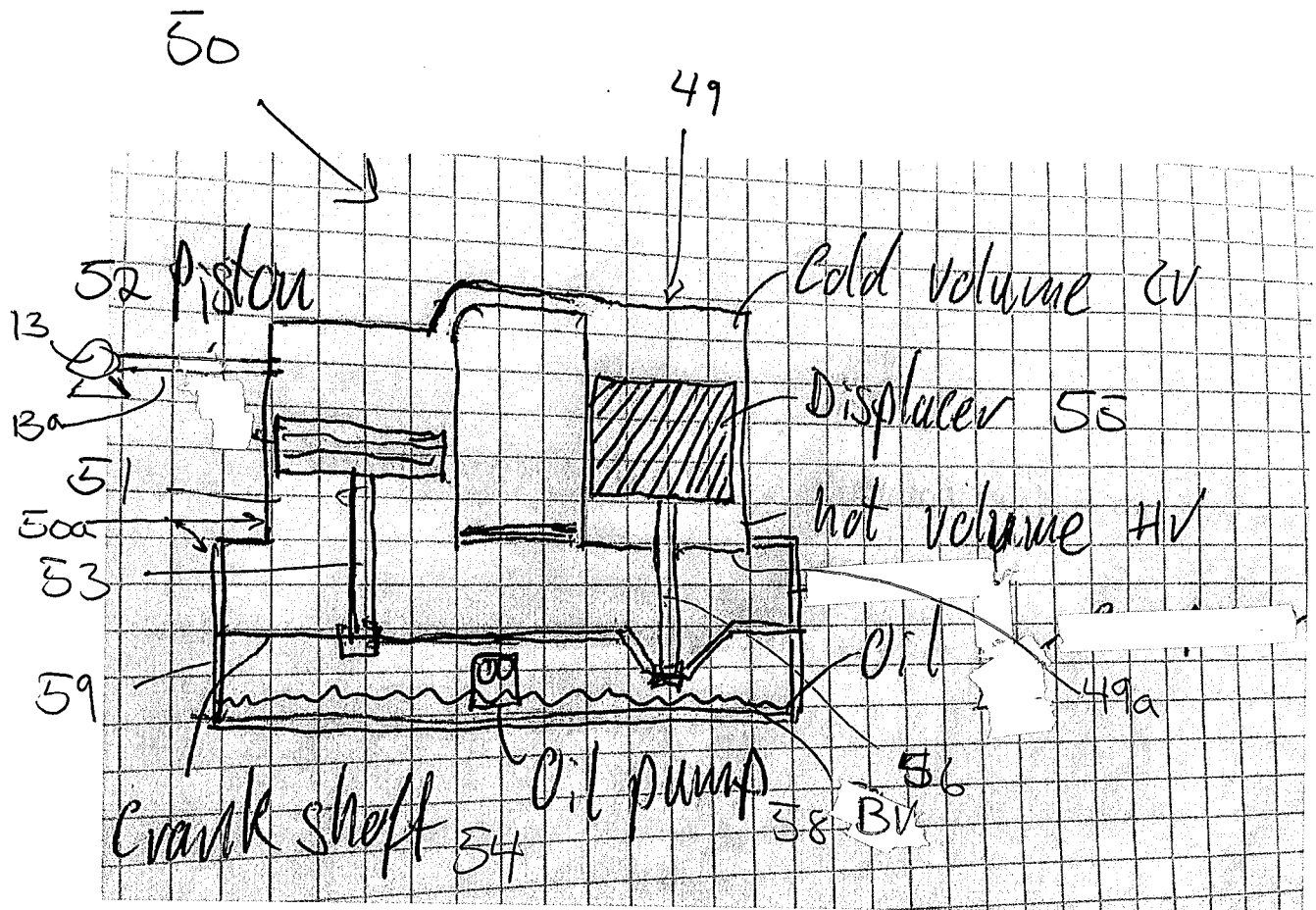


Fig. 4

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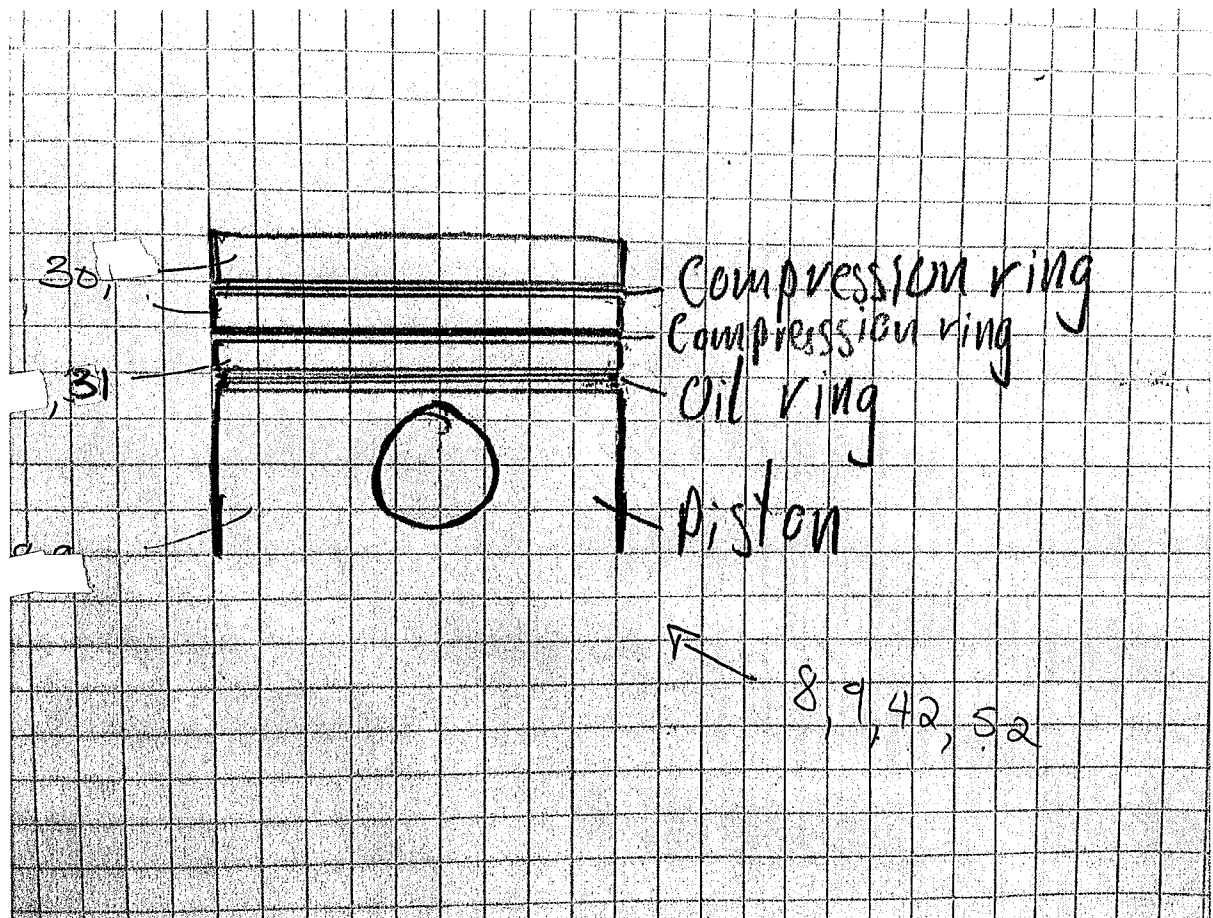


Fig.5