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(54) APPARATUS FOR CONVERTING THERMAL ENERGY

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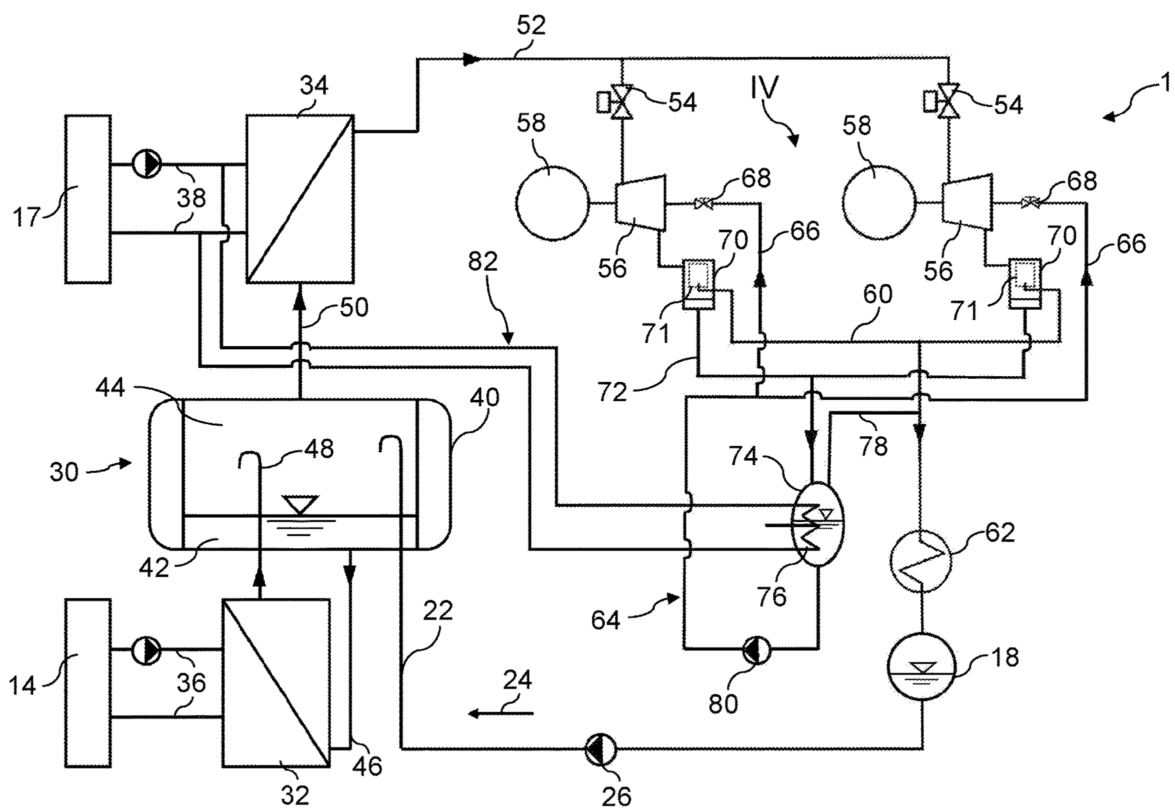
(57) **ABSTRACT**

In an apparatus for converting thermal energy from a heat source into mechanical energy by means of a thermodynamic cycle using a working medium which is guided in the cycle and in that context experiences a changing pressure, wherein a saturated steam temperature value of the working medium is associated with the respective pressure, and an expansion device for expanding the working medium from an elevated pressure to a lower pressure, wherein after expansion to the lower pressure the working medium has a waste steam temperature, there is provided an adjustment device for setting the waste steam temperature to a defined waste steam temperature value above the saturated steam temperature value associated with the lower pressure.



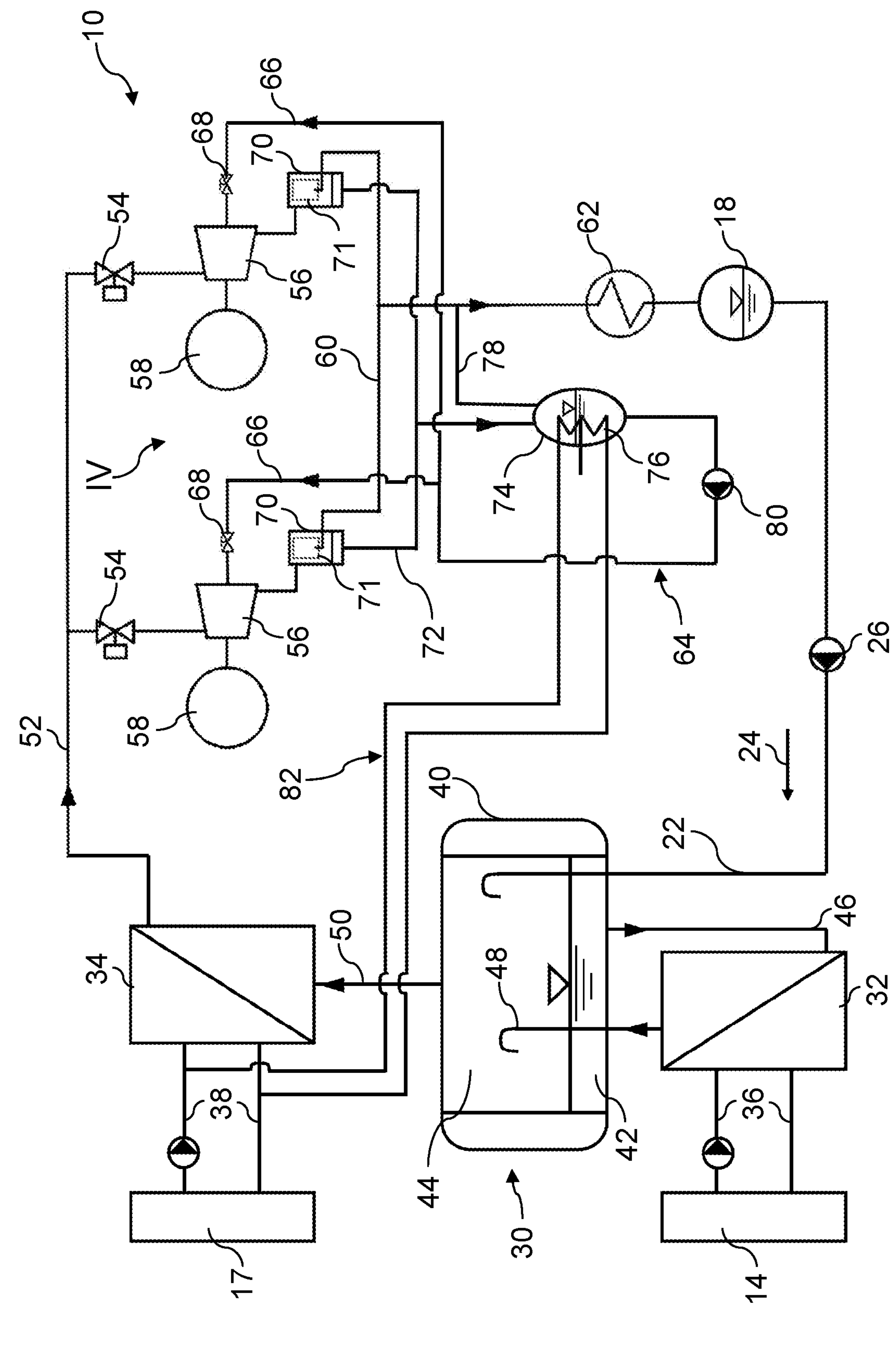

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Fig. 1

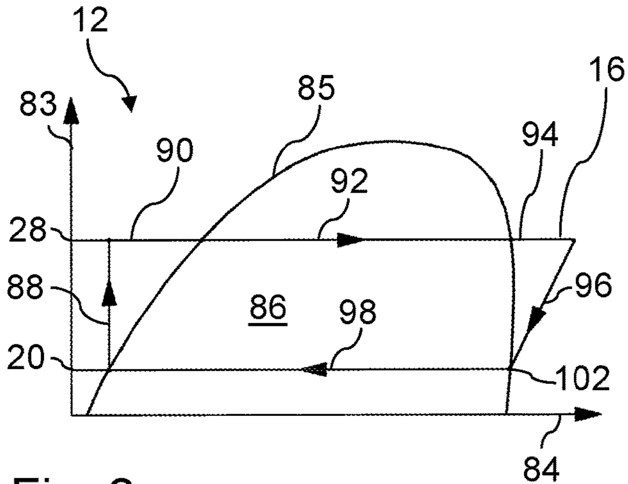


Fig. 2

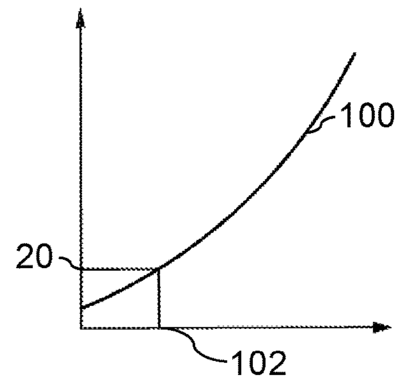
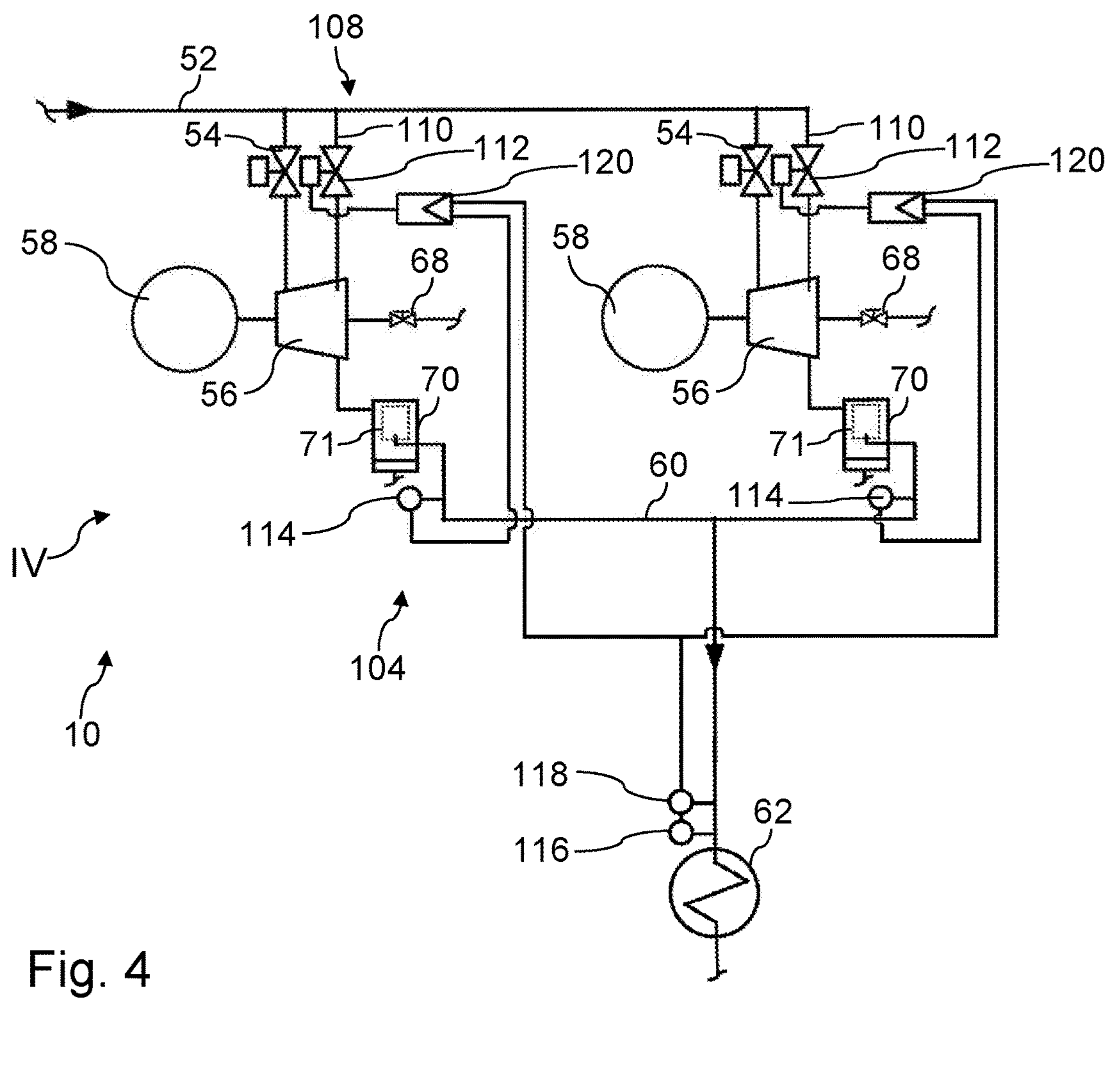


Fig. 3



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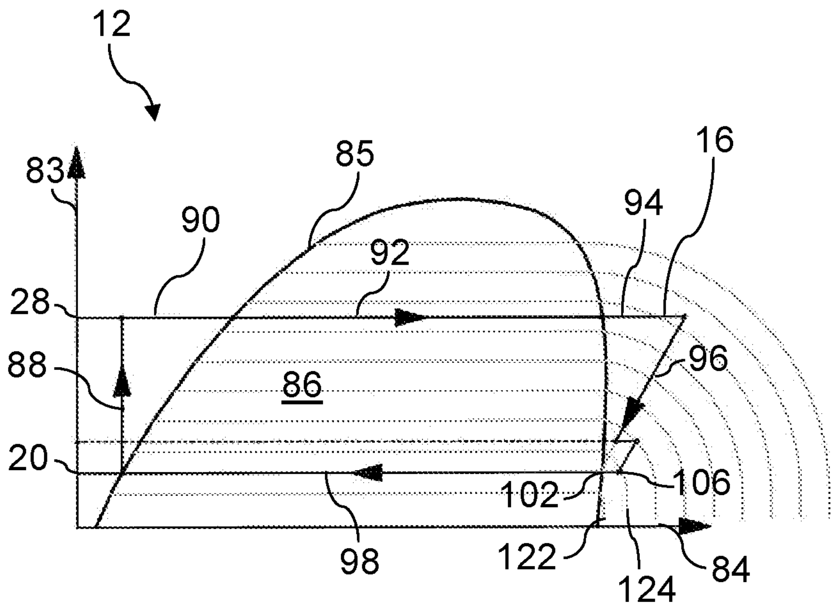
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Fig. 5

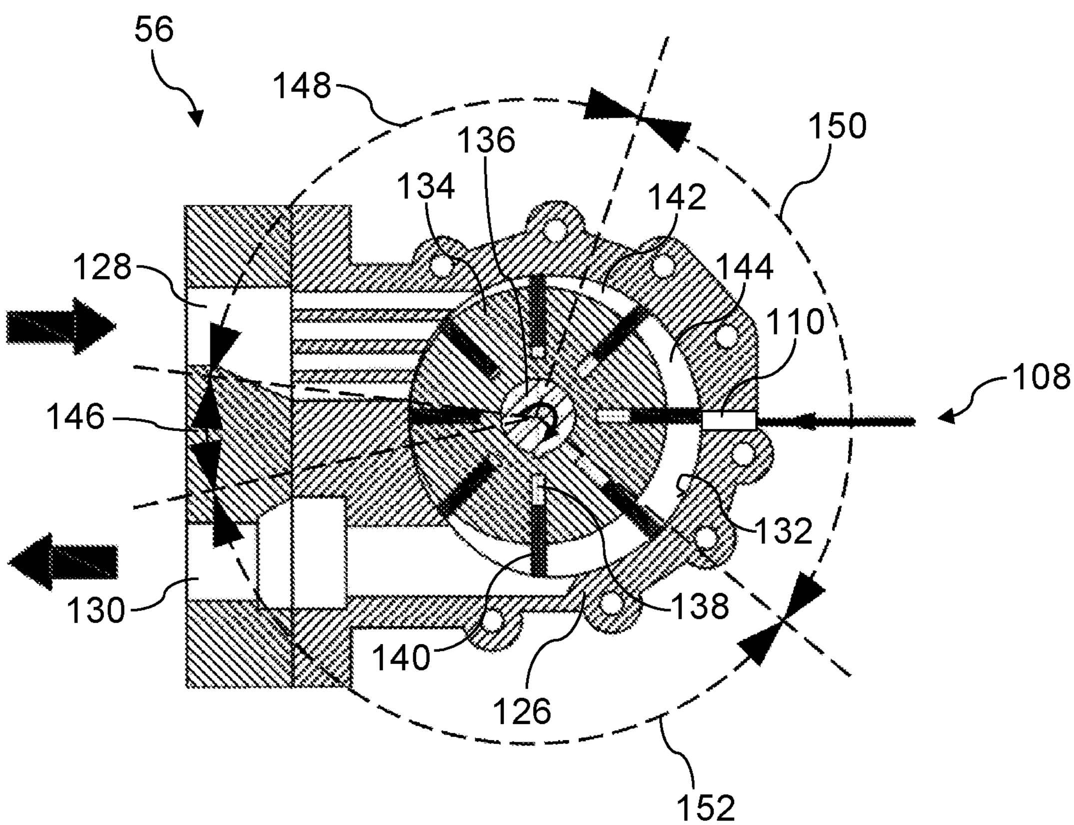
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Fig. 6

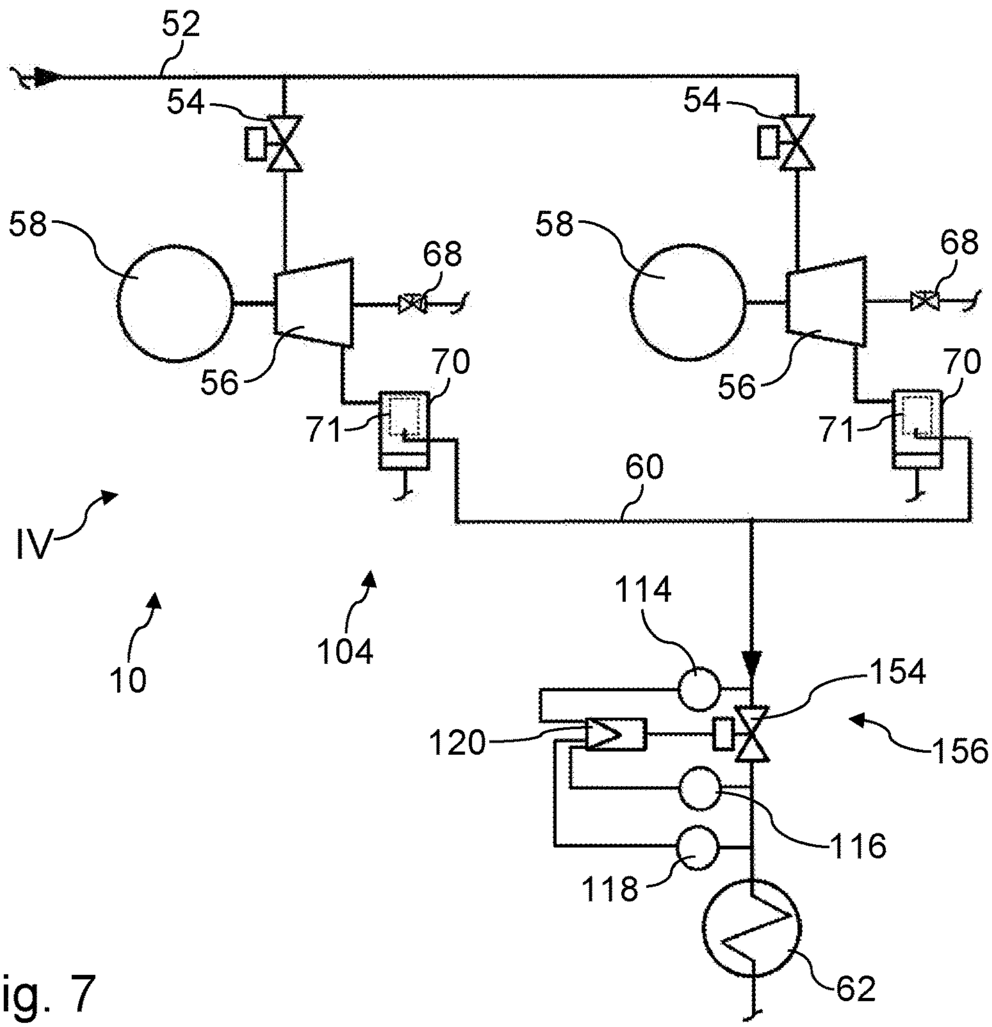
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Fig. 7

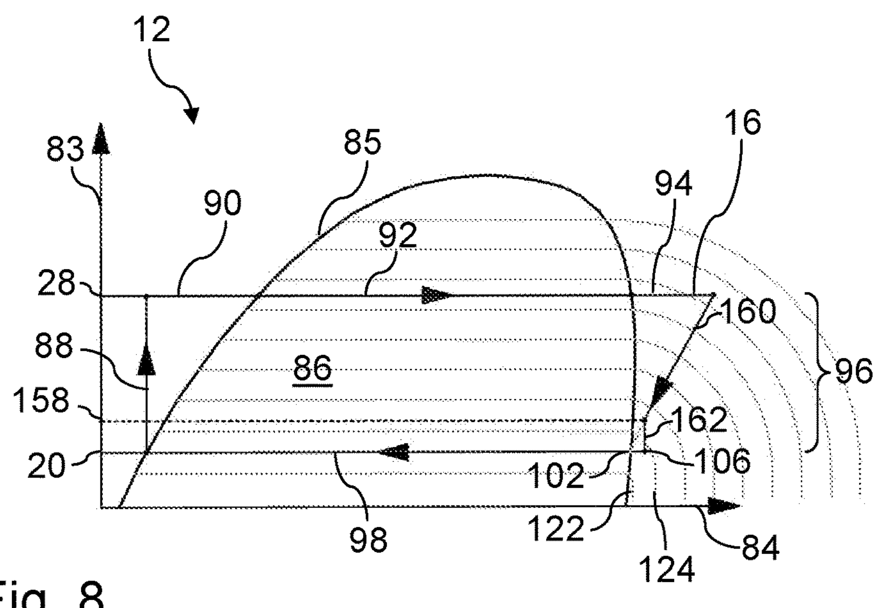
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Fig. 8

APPARATUS FOR CONVERTING THERMAL ENERGY

TECHNICAL FIELD

[0001] The disclosure concerns an apparatus for converting thermal energy from a heat source into mechanical energy by means of a thermodynamic cycle using a working medium. Furthermore, the disclosure relates to a corresponding method for converting thermal energy into mechanical energy.

BACKGROUND

[0002] Generic apparatuses and methods are used to generate electrical energy from thermal energy in what is known as power generation by heat. As a thermodynamic cycle, a Clausius-Rankine cycle is usually carried out, which is widely used in steam power plants with water as a working medium. The water is heated to about 600° C. by means of high temperature heat sources such as coal, natural gas, petroleum and nuclear energy. If an organic working medium is used instead of water, this is called the ORC process (Organic Rankine Cycle). Organic working media can boil at a far lower temperature than water and evaporate at lower temperatures. Therefore, ORC processes are used to recover thermal energy from low temperature heat sources that have temperatures of 60° C. to 200° C. Such heat sources are solar thermal or geothermal sources and waste heat from engines, industrial production processes and biogas plants. They can only be used insufficiently with conventional apparatuses and methods.

[0003] In a thermodynamic cycle, the working medium undergoes periodic changes in its thermodynamic state variables such as temperature and pressure. Depending on the change in the state variables, energy can be absorbed by the working medium from the environment or emitted into the environment. In this case, the working medium therefore experiences a changing pressure. It is first placed under an elevated pressure as a liquid working medium and then evaporated and superheated by means of transferring thermal energy from the heat source. The result is a high-energy compressed working medium vapor, which can again emit its absorbed energy during expansion from the elevated pressure to a lower pressure by means of an expansion device. The emitted energy can drive a generator to generate electrical energy in the form of mechanical energy.

[0004] After the expansion or the expansion process, the working medium vapor in the form of exhaust vapor often has a proportion of liquid working medium. This proportion of liquid working medium lowers the efficiency and service life of many expansion devices. A major reason for this is that most expansion devices, such as positive displacement machines and in particular rotary vane expanders, usually require oil lubrication with a lubricating oil. By means of the lubricating oil, friction between moving parts of the expansion device can be kept low and leak gaps can be sealed in an expansion chamber carrying the working medium. If, on the other hand, the lubricating oil accumulates with the proportion of liquid working medium, then the lubricating properties and sealing capabilities of the lubricating oil decrease. Lower lubricating properties increase wear on the moving parts. Lower sealing capabilities lead to a higher leakage of the working medium in the expansion device and therefore to a lower efficiency. Furthermore, an additional heating energy for a subsequent thermal expulsion of liquid working medium from a recirculated lubricating oil is necessary, which further reduces the efficiency.

SUMMARY

[0005] The problem addressed by the disclosure is that of providing an apparatus and method for a thermodynamic cycle using a working medium for the conversion of thermal energy. In this case, the thermodynamic cycle is intended to be optimized, especially in terms of the service life and efficiency of the expansion device and the expansion process.

[0006] This problem is solved by an apparatus for converting thermal energy from a heat source into mechanical energy by means of a thermodynamic cycle using a working medium which is carried in the cycle and in the process experiences a changing pressure, wherein a saturated vapor temperature value of the working medium is associated with the particular pressure in each case, and an expansion device for expanding the working medium from an elevated pressure to a lower pressure, wherein, after expansion to the lower pressure, the working medium has an exhaust vapor temperature. In this case, an adjustment device is provided for adjusting the exhaust vapor temperature to a defined exhaust vapor temperature value above the saturated vapor temperature associated with the lower pressure.

[0007] By means of the apparatus, the working medium carried in the cycle experiences a changing pressure, which is in particular subject to periodic changes. In this case, a saturated vapor temperature value of the working medium is associated with each pressure experienced by the working medium. The saturated vapor temperature value is the temperature value at which liquid working medium is in equilibrium with gaseous working medium. It depends on the particular pressure in each case, which is called the saturated vapor pressure value. The dependency on the saturated vapor pressure value and the saturated vapor temperature value can be represented in a vapor curve as a phase boundary line between the liquid and gaseous working medium. The vapor curve is specific to each working medium.

[0008] If the working medium has a temperature below the saturated vapor temperature value of the particular pressure currently experienced thereby, then the working medium is liquid. If the working medium has a temperature above the saturated vapor temperature value of the particular pressure, then the working medium is gaseous. When cooling the gaseous working medium, first condensation drops of the working medium are formed once the saturated vapor temperature value is reached.

[0009] By means of the expansion device, the working medium carried in the cycle shall be expanded from an elevated pressure to a lower pressure. During expansion, not only does the pressure of the working medium decrease to the lower pressure, but the temperature of the working medium also decreases. The temperature of the working medium after expanding to the lower pressure is referred to as the exhaust vapor temperature.

[0010] An adjustment device is provided by means of which this exhaust vapor temperature can be adjusted to a defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure. By means of such an adjustment device, the exhaust vapor temperature value of the working medium can be adjusted specifically so as to be above the saturated vapor temperature value associated with the lower pressure. The working medium which has an exhaust vapor temperature value above the saturated vapor temperature is gaseous. The working medium can be reliably prevented from condensing from its gaseous state to its liquid state during and after expansion. Thus, a consistently condensate-free working medium vapor is achieved without a proportion of liquid working medium in the associated expansion device. Lubricant which is provided in and on the expansion device and is usually liquid, such as in particular a lubricating oil, cannot be contaminated with liquid working medium. The lubricant that is therefore kept clean reliably prevents friction between movable components of the expansion device and reliably seals the expansion chamber from leakage of working medium. In addition, a subsequent heating to expel an otherwise occurring liquid working medium in the usually recirculated lubricant is not necessary. Thus, both the efficiency and the service life of the expansion device of the disclosed apparatus are significantly improved by comparison with conventional devices of this type.

[0011] The solution according to the invention is initially surprising, since additional components and additional energy expenditure are required for the adjustment device. In addition, there is a higher exhaust vapor temperature value by comparison with conventional devices of this type. Such a higher exhaust vapor temperature value results in an energy loss. A relatively small amount of energy can be released during the expansion, which can be reused as mechanical energy. According to the invention, however, it has surprisingly been found that the advantage of the consistently condensate-free working medium vapor in the expansion device far outweighs the additional energy expenditure and the resulting energy loss.

[0012] Furthermore, with the solution according to the invention, the gaseous working medium can be prevented from condensing after expansion independently of a wide range of external and internal conditions of the thermodynamic cycle. No matter what thermal energy the heat source has and no matter what temperature and pressure the working medium has on entering the expansion device, the exhaust vapor temperature value of the working medium is always adjusted so as to be above the saturated vapor temperature value associated with the lower pressure. Therefore, the exhaust vapor temperature value is defined as a function of the lower pressure, which may vary depending on the inlet temperature and inlet pressure of the working medium in the expansion device. The inlet temperature and the inlet pressure are often dependent on the thermal energy of the heat source. In addition, the exhaust vapor temperature value is defined as a function of the saturated vapor temperature value associated with the lower pressure. This saturated vapor temperature value is specific to each working medium, so that the gaseous working medium can also always be reliably prevented from condensing after expansion, regardless of the type of working medium.

[0013] The defined exhaust vapor temperature value is preferably kept constant above the saturated vapor temperature value associated with the lower pressure. With the exhaust vapor temperature value kept constant in this way, the expansion and condensation following the expansion in the cycle can be carried out particularly uniformly without large temperature fluctuations. In particular, only a small amount of internal friction losses in the working medium and a small amount of external friction losses occur with respect to a line carrying the working medium. Otherwise occurring energy losses can be reduced.

[0014] Advantageously, the defined exhaust vapor temperature value is between 2 K and 12 K, preferably between 4 K and 8 K, and particularly preferably between 5 K and 6 K above the saturated vapor temperature value associated with the lower pressure. It has been found that even such a small difference between the exhaust vapor temperature value and the relevant saturated vapor temperature value is sufficient to reliably prevent the working medium vapor from condensing during expansion to the lower pressure. For a larger difference, a higher exhaust vapor temperature value would have to be set, which would cause unnecessary energy loss.

[0015] Furthermore, it is advantageous to increase a temperature of the working medium by means of the adjustment device such that the exhaust vapor temperature has the defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure. Such a temperature increase is easy to carry out.

[0016] As is known, the working medium carried in a thermodynamic cycle in its liquid state is shall be transferred from a lower pressure to an elevated pressure. Thereafter, the working medium placed under the elevated pressure shall be isobarically evaporated and superheated. The temperature of the working medium increases in the process. When the compressed and superheated working medium vapor expands to the lower pressure, the temperature of the working medium vapor drops to the exhaust vapor temperature.

[0017] The temperature of the working medium carried in the cycle shall now preferably be increased by means of the adjustment device after evaporation and before or during expansion such that the exhaust vapor temperature then has the defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure.

[0018] The temperature of the working medium within the expansion device shall be particularly preferably increased by means of the adjustment device. Thus, the temperature during the expansion process can be increased, which is more energy efficient than a temperature increase of the superheated working medium vapor before expansion. In particular, the temperature of the working medium shall be increased in this case toward the end of the expansion process. Toward the end of the expansion process, the temperature of the expanding working medium vapor is lower than at the beginning or in the middle of the expansion process. Therefore, the temperature of the working medium can be increased in an energy-efficient manner from a relatively low temperature to the required temperature value, at which the defined exhaust vapor temperature value should be achieved after expansion.

[0019] Furthermore, the adjustment device advantageously comprises a vapor supply for supplying vapor to the working medium, wherein the vapor is in particular superheated vapor. Vapor molecules which form the vapor move quickly and transmit their movement in a collision correspondingly fast to the working medium vapor molecules, which increases the temperature of the working medium vapor correspondingly fast. In addition, depending on the temperature and amount of vapor to be supplied, the temperature of the working medium vapor can be adjusted in a very purposeful way to the defined exhaust vapor temperature value. If the vapor is overheated, the temperature increase is even faster.

[0020] The vapor supply is preferably adapted to supply the vapor to the expansion device, in particular after supplying the working medium vapor carried in the cycle to the expansion device. This allows the temperature of the working medium vapor to be increased during expansion in an energy-efficient manner. A vapor supply leading into the expansion device preferably toward the end of expansion is particularly energy-efficient in accordance with the embodiments described above.

[0021] In addition, the vapor supply to the expansion device has the advantage that the vapor supplied can expand as additional vapor. This results in additional expansion capacity of the additional vapor, which can be delivered to the expansion device in the form of additional mechanical power. Higher power and associated higher efficiency of the expansion device can be achieved, which increases the efficiency of the entire apparatus.

[0022] Furthermore, the vapor is advantageously a vapor of the working medium. Therefore, despite the supply of additional vapor, the working medium remains a pure working medium that is not contaminated with the vapor of another medium. Preferably, the vapor of the working medium comes from the same cycle as the working medium vapor itself, which is to be conducted to the expansion device at the beginning of expansion. Only a single vapor generation process is then required so as to save on energy and components, and as a result of which thermal energy can be transferred from the heat source particularly efficiently.

[0023] The expansion device is advantageously designed as a positive displacement machine for passing the working medium through at least one expansion chamber or volume chamber which increases in size when said medium passes therethrough. In this case, an inlet for introducing the working medium vapor placed under the elevated pressure is provided in the expansion chamber. The introduced working medium vapor then displaces a component that delimits the expansion chamber. This increases the size of the expansion chamber and at the same time moves the component to perform mechanical work. Increasing the size of the expansion chamber causes expansion of the working medium vapor from the elevated pressure to the lower pressure.

[0024] In such a positive displacement machine, the working medium vapor can be carried through the inlet and the additional vapor through a vapor supply positioned between the inlet and the outlet in the expansion chamber. In this case, the working medium vapor can expand when passing through the expansion chamber which is increasing in size and can be reheated by means of the supplied vapor through the expansion chamber increasing in size. Along with the supplied vapor, the reheated working medium vapor may continue to expand toward the outlet.

[0025] The vapor supply of such a positive displacement machine can be designed in a particularly purposeful way to comprise two or more expansion chambers. The vapor supply may in this case be designed such that additional vapor is to be conducted to the expansion chamber in a targeted manner when the expansion chamber has reached a desired size. According to this size, there is then correspondingly expanded and cooled working medium vapor, which can then be heated in a targeted manner. The heated working medium vapor can then expand further in the expansion chamber that continues to increase in size until an outlet is reached in the expansion chamber, from which the working medium vapor and the additional vapor can escape. In this case, at least the inlet for the working medium vapor is arranged spatially far enough away from the vapor supply that an expansion chamber located at the inlet is spatially separate from an expansion chamber located at the vapor supply. Preferably, the outlet is arranged spatially far enough away from the vapor supply that an expansion chamber located at the outlet is spatially separate from the expansion chamber located at the vapor supply. This allows for a particularly purposeful increase in temperature during expansion in a defined expansion zone. The defined expansion zone corresponds to the size of the expansion chamber at the vapor supply.

[0026] In addition, a counterpressure shall be generated on the working medium in an advantageous manner by means of the adjustment device in such a way that the exhaust vapor temperature has the defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure. A structure with such a counterpressure is particularly energy-efficient.

[0027] With this kind of counterpressure, the lower pressure is not reached at first during expansion. Instead, a lower pressure increased according to the counterpressure is reached. The increased lower pressure is associated with a correspondingly increased saturated vapor temperature value of the working medium. By means of the counterpressure, the working medium vapor is initially kept at the increased lower pressure and has an exhaust vapor temperature which corresponds to this increased saturated vapor temperature value. Upon further expansion, the lower pressure increased according to the counterpressure shall then be expanded to the lower pressure. After the remaining expansion, the working medium vapor has an exhaust vapor temperature that corresponds to the defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure. The working medium vapor is reliably prevented from condensing throughout the entire expansion process.

[0028] For this purpose, an expansion device is preferably provided for expanding the working medium from an elevated pressure to a lower pressure, in which the lower pressure is to be achieved by means of a two-stage expansion process. The elevated pressure is to be expanded in a first expansion stage, first by means of the generation or build-up of counterpressure, to a first lower pressure. Thereafter, the first lower pressure is to be expanded in a second expansion stage to a second lower pressure, the second lower pressure corresponding to the above-mentioned lower pressure after expansion.

[0029] In this case, the first and the second expansion stages can take place in a single expansion device. Particularly preferably, the first expansion stage is to be carried out in a first expansion unit and the second expansion stage is to be carried out separately in a second expansion unit. The first expansion unit is designed in particular having a positive displacement machine and the second expansion unit is designed in a structurally simple manner to be a line element within a line carrying the working medium. The first and second expansion units then constitute the expansion device as a whole.

[0030] In addition, the adjustment device advantageously comprises a blocking element for generating the counterpressure on the working medium, which blocking element is designed in particular having a valve for selectively opening and closing a line carrying the working medium. By means of the blocking element, a working medium flow of the working medium carried in the cycle can be shut off in a structurally particularly simple and rapid manner. After this kind of shut-off, the desired counterpressure builds up on the working medium. The counterpressure can be relieved again with short reaction times when needed, by the blocking element being designed having a valve that can be easily opened again.

[0031] Preferably, the blocking element is arranged within the expansion device between the first and second expansion units, as a result of which the described two-stage expansion process is made possible.

[0032] In addition, advantageously, the working medium is carried in a circulation direction and a condensation device for condensing the expanded working medium is provided downstream of the expansion device in the circulation direction, wherein the adjustment device comprises a temperature measuring element for measuring a temperature of the working medium after expansion and before condensation in the circulation direction and/or a pressure measuring element for measuring the pressure of the working medium after expansion and before condensation in the circulation direction. With this kind of temperature measuring element and/or pressure measuring element, a control device is created by means of which the adjustment device shall be controlled according to the measured temperature and/or the measured pressure. This type of control allows the exhaust vapor temperature to always be reliably adjusted to the desired defined exhaust vapor temperature value as required by means of the adjustment device.

[0033] In particular, the temperature measuring element measures the exhaust vapor temperature of the working medium after expansion. The exhaust vapor temperature is also dependent on the temperature of an inlet vapor of the working medium when entering the expansion device. In addition, the temperature of the working medium before condensation or the condensation temperature can be determined. The condensation temperature value corresponds in particular to the saturated vapor temperature value associated with the lower pressure. By means of the pressure measuring element, a currently valid saturated vapor pressure value or condensation pressure value of the working medium can be measured, in particular shortly before condensation, which is dependent on a cooling capacity of the condensation device.

[0034] Furthermore, the disclosure is directed to a method for converting thermal energy from a heat source into mechanical energy by means of a thermodynamic cycle using a working medium which is carried in the cycle and in the process experiences a changing pressure, wherein a saturated vapor temperature value of the working medium is associated with the particular pressure in each case, and a step of expanding the working medium from an elevated pressure to a lower pressure, wherein, after expansion to the lower pressure, the working medium has an exhaust vapor temperature. The exhaust vapor temperature is adjusted to a defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure.

[0035] The advantages of such a method are apparent from the advantages already described in the description of the disclosed apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] In the following, embodiments of a solution are explained in more detail on the basis of the appended schematic drawings, in which:

[0037] FIG. **1** is a simplified process diagram of an apparatus for converting thermal energy according to the prior art.

[0038] FIG. **2** is a schematic log pressure-enthalpy diagram of the thermodynamic cycle from FIG. **1**.

[0039] FIG. **3** is a vapor curve of a working medium carried in the cycle.

[0040] FIG. **4** shows the detail IV according to FIG. **1** of a first embodiment of an apparatus according to the invention.

[0041] FIG. **5** is a schematic log pressure-enthalpy diagram of the thermodynamic cycle from FIG. **4**.

[0042] FIG. **6** is a cross section of a positive displacement machine of the apparatus according to FIG. **4**.

[0043] FIG. **7** shows the detail IV according to FIG. **1** of a second embodiment of an apparatus for converting thermal energy.

[0044] FIG. **8** is a schematic log pressure-enthalpy diagram of the thermodynamic cycle from FIG. **7**.

DETAILED DESCRIPTION

[0045] In the figures, an apparatus **10** and an associated method **12** for converting thermal energy from a heat source **14** are shown. The apparatus **10** forms a closed system of a process plant in which a thermodynamic cycle **16** is to be completed by means of a working medium carried in the cycle **16**.

[0046] The illustrated thermodynamic cycle **16** is a modified Organic Rankine Cycle (ORC) in which the working medium is an organic working medium. In the present case, the working medium is designed having ammonia, preferably anhydrous ammonia (NH_3, R 717) in a concentration of over 99.6% by mass. With such an almost pure ammonia, the physical and thermodynamic properties of ammonia can be exploited without disturbing influences of other substances. Liquid ammonia has, for example, a high evaporation enthalpy, which means that a relatively large amount of energy has to be used to convert ammonia from its liquid state to its gaseous state. This means that a correspondingly high amount of energy can be stored in gaseous ammonia and then converted into mechanical energy during expansion.

[0047] Low temperature heat sources are used as the heat source **14**. The heat source **14** can be a single heat source **14** or have two different heat sources **14** and **17**. In the embodiments shown, two different heat sources are used to generate energy, where heat source **14** has a lower temperature than heat source **17**. Heat source **14** is engine waste heat, and heat source **17** is exhaust gas waste heat of an internal combustion engine of a combined heat and power plant.

[0048] The working medium is provided in the form of a pressure-liquefied gas in a collecting tank **18** which is part of the cycle **16**. In this case, the working medium is under a pressure which represents a lower pressure level of the thermodynamic cycle **16** as a lower pressure **20**. Starting from the collecting tank **18**, a line **22** carries the working medium in a circulation direction **24** to a pressure increasing device **26**. By means of the pressure increasing device **26**, the pressure experienced by the working medium shall be increased from the lower pressure **20** to a pressure which represents an upper pressure level of cycle **16** as an elevated pressure **28**.

[0049] In circulation direction **24**, the liquid working medium is then pumped from the pressure increasing device **26** through line **22** to a heat transfer device **30**. The heat transfer device **30** comprises a first heat exchanger **32** and a second heat exchanger **34** connected in series. The first heat exchanger **32** is coupled to heat source **14** so as to transmit heat by means of a transfer medium carried through a line **36**. Accordingly, the second heat exchanger **34** is coupled to heat source **17** by means of a transfer medium carried through a line **38**.

[0050] Between the two heat exchangers **32** and **34** there is a separator **40** having a lower region **42** and an upper region **44**. In the upper region **44**, the liquid working medium is carried by means of line **22**. The liquid working medium separates itself from any gaseous working medium present and sinks into the lower region **42**. From there, a line **46** carries the liquid working medium separated in this way into the first heat exchanger **32**, which serves as a preheater and evaporator. There, the liquid working medium is preheated by transferring thermal energy from the first heat source **14** and is largely evaporated. A working medium vapor generated in this way is a wet vapor. This means that even small drops and finely distributed liquid working medium are present in the gaseous working medium as a condensate portion. The wet vapor is carried out of the first heat exchanger **32** through a line **48** into the upper region **44** of the separator **40**. The condensate portion sinks into the lower region **42** and accumulates there as a liquid working medium, whereas only gaseous working medium remains in the upper region **44**. A particularly dry gaseous working medium can therefore be produced. The liquid working medium flows from the lower region **42** through line **46** back into the first heat exchanger **32** for reheating.

[0051] By means of the separator **40**, the lines **22** and **48** leading into its upper region **44** and the line **46** leading out of its lower region **42**, evaporation according to a thermosiphon principle is made possible. This principle is based on the fact that, during evaporation in the first heat exchanger **32**, the density of the working medium located therein is reduced due to the wet vapor formed. Thus, the wet vapor pushes through line **48** into the separator **40**. In addition, the same amount of liquid working medium always flows from the lower region **42** of the separator **40** through line **46** into the heat exchanger **32** as is required for evaporation. In the separator **40** a level controller (not shown) is provided by means of which the pressure increasing device **26** shall be controlled in such a way that only as much working medium is pumped to the first heat exchanger **32** as can also be evaporated.

[0052] From the separator **40**, the gaseous working medium from the upper region **44** is carried through a line **50** into the second heat exchanger **34**. The second heat exchanger **34** serves as a superheater by means of which the gaseous working medium shall be superheated when transferring thermal energy from heat source **17**. The superheated working medium vapor is then carried out of the second heat exchanger **34** through a line **52** by means of an inlet valve **54** into an expansion device **56**.

[0053] By means of the expansion device **56**, the superheated working medium vapor shall be expanded from the elevated pressure **28** to the lower pressure **20**, at the same time reducing the temperature of the working medium. The energy released in the process is transferred as mechanical energy to the expansion device **56**, which serves as the drive unit for a generator **58** coupled to the expansion device **56**, so as to generate electrical energy.

[0054] In the present case, a further expansion device connected in parallel with the expansion device **56** is provided into which the compressed and superheated working medium vapor is carried by means of an associated further inlet valve. For a better overview, the further expansion device together with its associated components is designated by the same reference numerals as the expansion device **56**. With such a parallel connection of the expansion devices **56**, a particularly uniform expansion of the superheated working medium vapor without large pulsations is possible over time. In addition, a larger amount of working medium vapor can be expanded if necessary. Thus, overall, a uniform and high output can be drawn from the cycle **16**. To improve this effect, more than two expansion devices **56** connected in parallel may be provided.

[0055] Downstream of the expansion device **56** in circulation direction **24**, the expanded working medium vapor is carried through a line or exhaust vapor line **60** out of the expansion device **56** and conducted through a condensation device **62**. By means of the condensation device **62**, the expanded working medium vapor is cooled and condensed. The condensed working medium is conducted into the collecting tank **18**, which is arranged in line **22** downstream of the condensation device **62** in circulation direction **24**. With condensation, the thermodynamic cycle **16** is closed and can be repeated as often as required.

[0056] Furthermore, the apparatus **10** has an oil supply circuit **64** having an oil supply line **66**, through which an oil shall be carried by means of an associated oil inlet valve **68** into the respectively associated expansion device **56**. The oil is used for sealing and lubricating components of the expansion device **56**. During the expansion of the working medium vapor, the oil in the expansion device **56** can get into the working medium vapor. For this reason, the expanded working medium vapor together with the oil from each expansion device **56** is carried through the associated exhaust vapor line **60** into an associated oil separator **70**. By means of the oil separator **70**, the oil shall be separated from the expanded working medium vapor. For this purpose, a separating element **71** is arranged at the top of the oil separator **70** and designed as a mechanical oil separator. The separating element **71** separates the oil as liquid from the expanded working medium vapor as gas mechanically and due to different densities of liquid and gas.

[0057] The expanded working medium vapor cleaned in this way is carried out of the oil separator **70** through the exhaust vapor line **60** to the condensation device **62** in the cycle **16**.

[0058] The separated oil is conducted from each oil separator **70** through an associated oil discharge line **72** into an oil collecting tank **74**. In this case, the separated oil may contain a proportion of liquid working medium, which has formed during expansion of the working medium vapor in a conventional manner. To remove this proportion of liquid working medium, an oil heater **76** is provided in the oil collecting tank **74**. By means of the oil heater **76**, the separated oil is heated until the proportion of liquid working medium is almost completely evaporated or expelled from the oil. Between the oil separator **70** and the condensation device **62** in circulation direction **24**, a working medium vapor produced in this way is carried from the oil collecting tank **74** back into the exhaust vapor line **60** and thus into the cycle **16** by means of a vapor line **78**.

[0059] An oil pump **80** is also arranged in the oil supply line **66**, by means of which pump the separated oil cleaned of liquid working medium is carried through the oil supply line **66** again into the expansion device **56**. In addition, the oil heater **76** comprises a heating circuit line **82** which carries a heating medium and is coupled to the second heat source **17** so as to transmit heat.

[0060] FIG. **2** is a schematic log pressure-enthalpy diagram of the thermodynamic cycle **16** of the method **12** which can be carried out by means of the apparatus **10** according to FIG. **1**. In this figure, the logarithm of the pressure **83** is plotted on the axis of ordinates, and the enthalpy **84** is plotted on the axis of abscissas. The illustrated curved line represents a phase boundary line **85** of the working medium. As long as the phase boundary line **85** increases, this is the bubble line at which a transition from saturated liquid working medium to wet vapor takes place. If the phase boundary line **85** falls, it represents the dew line marking a transition from the wet vapor to a saturated working medium vapor. In a transition of this kind, the vapor is also referred to as saturated vapor. An area enclosed by the phase boundary line **85** and the axis of abscissas is a wet vapor region **86** of the working medium, in which working medium vapor as gaseous phase and liquid working medium as liquid phase are present at the same time.

[0061] Starting from the liquid working medium which is placed under the lower pressure **18**, the working medium is placed under the elevated pressure **28** by means of the pressure increasing device **26** in one method step or step **88** of increasing pressure. Ammonia is adjusted from a lower pressure **18** of about 8.4 bar and a temperature of about 23° C. to an elevated pressure **28** of about 37 bar and a temperature of about 30° C.

[0062] All pressure values given here should be understood to be absolute pressure values.

[0063] By means of the first heat exchanger **32**, in a preheating step **90**, the working medium under the elevated pressure **28** is heated isobarically to an evaporation temperature value associated with the elevated pressure **28**. For ammonia this value is about 76° C. Subsequently, in an evaporation step **92**, the working medium, which is still liquid and preheated to the evaporation temperature value, is isobarically evaporated. During step **92**, the main component of the thermal energy is supplied to the working medium. During evaporation, the temperature of the working medium remains the same.

[0064] Subsequently, by means of the second heat exchanger **34**, in a superheating step **94**, the working medium vapor produced in step **92** is isobarically superheated to a final temperature. The final temperature for ammonia is about 120° C.

[0065] The working medium vapor superheated in this way is adiabatically expanded as superheated ammonia gas in an expansion step **96** by means of the two expansion devices **56** connected in parallel. Adiabatic means that no heat is exchanged with the environment during expansion. During expansion, the actual conversion of thermal energy into mechanical energy takes place. In this case, the working medium entering expansion device **56** has the elevated pressure **28** as the inlet pressure and the temperature of the superheated working medium vapor as the inlet temperature. The working medium leaving the expansion device **56** then has the lower pressure **20** as the exhaust vapor pressure and an exhaust vapor temperature which is lower than the inlet temperature. Incoming ammonia has the elevated pressure **28** of about 37 bar and the inlet temperature of about 120° C., and outgoing ammonia has the lower pressure **20** of about 8.4 bar and the exhaust vapor temperature of about 23° C. A liquid proportion is contained in the exhaust vapor in the outgoing working medium vapor, since both the inlet temperature and the exhaust vapor temperature are subject to certain tolerances. Even at a slightly lower inlet temperature, condensate forms in the exhaust vapor. The exhaust vapor temperature then reached, i.e. the end point of expansion step **96**, is in the wet vapor region **86**.

[0066] Subsequently, the expanded working medium leaving the expansion device **56** is isobarically condensed in a condensation step **98** by means of the condensation device **62** and thus again reaches its initial state in the cycle **16**.

[0067] FIG. **3** shows a saturation vapor pressure curve or vapor pressure line or vapor curve **100** of the working medium carried in the cycle **16**, in this case the vapor curve **100** of ammonia. In this figure, the pressure is plotted on the axis of ordinates and the temperature is plotted on the axis of abscissas. The curved line represents the vapor curve **100** of the working medium and is the phase boundary line between liquid and gaseous working medium. Accordingly, the vapor curve **100** shows which saturated vapor temperature value is associated with a particular pressure of the working medium at which the gaseous working medium begins to condense. The lower pressure **20** is associated with the saturated vapor temperature value **102**, which has a value of 23° C. for ammonia at a lower pressure **20** of 8.4 bar.

[0068] FIG. **4** and FIG. **7** show a detail of the apparatus **10** where, in contrast to the apparatus **12** according to FIG. **1**, an adjustment device **104** is provided for adjusting the exhaust vapor temperature of the working medium after the expansion step **96**. By means of the adjustment device **104**, the exhaust vapor temperature is adjusted to a defined exhaust vapor temperature value **106** above the saturated vapor temperature value **102** associated with the lower pressure **20**. The defined exhaust vapor temperature value **106** is between 4 K and 8 K above the saturated vapor temperature value **102** associated with the lower pressure **20**.

[0069] According to FIG. **4**, the adjustment device **104** comprises a vapor supply **108** for supplying vapor during the expansion step **96** to each expansion device **56**. This type of vapor supply is also referred to as intermediate injection. By means of a vapor supply **108** of this kind, the temperature of the working medium vapor can be increased during expansion in such a way that the exhaust vapor temperature of the working medium has the defined exhaust vapor temperature value **106** after step **96**.

[0070] For this purpose, the vapor supply **108** is designed having in each case a vapor supply line **110** and an additional inlet valve **112** arranged therein, which lead into the associated expansion device **56** downstream of the inlet valve **54** in circulation direction **24**. In addition, the vapor supply line **110** is fluidically connected to line **52**. With such a connection, the working medium vapor from line **52**, which is superheated by means of the second heat exchanger **34**, can be conducted through the additional inlet valve **112** into the expansion device **56**. The superheated working medium vapor is conducted into the expansion device **56** at an advanced stage, especially toward the end of the expansion step **96**.

[0071] In addition, the adjustment device **104** according to FIG. **4** comprises a temperature measuring element **114** associated with each expansion device **56**, which element is arranged, after expansion, slightly behind each oil separator **70** in circulation direction **24**. With such an arrangement, the exhaust vapor temperature of the working medium can be determined by means of the temperature measuring element **114**. In addition, a temperature measuring element **116** arranged slightly ahead of the condensation device **62** in circulation direction **24** and a pressure measuring element **118** arranged slightly ahead of said temperature measuring element are provided.

[0072] The pressure measuring element **118** and temperature measuring element **116** associated with the condensation device **62** are each coupled to the temperature measuring element **114** associated with an expansion device **56**. For this purpose, the measured values can be transferred to a control device **120** associated with each expansion device **56**. The control device **120** then opens and closes the additional inlet valve **112** for supplying vapor to the expansion device **56** according to the measurement result.

[0073] For this purpose, a pressure value of the lower pressure **20** that is currently valid in the cycle **16** is measured by the pressure measuring element **118** slightly ahead of the condensation device **62**. The lower pressure **20** can vary depending on the inlet pressure value of the elevated pressure **28** into the expansion device **56** and depending on the condensation temperature of the condensation device **62**.

[0074] According to the measured pressure value of the lower pressure **20**, the corresponding currently valid saturated vapor temperature value **102** is obtained according to the vapor curve **100** stored in the control device **120**. Depending on the valid saturated vapor temperature value **102**, the additional inlet valve **112** is opened by means of the control device **120** until the defined exhaust vapor temperature value **106** is measured by the temperature measuring element **114**. Depending on the duration and opening width of the inlet valve **112**, a corresponding amount of additional vapor is supplied until the defined exhaust vapor temperature value **106** is reached and, in particular, kept constant.

[0075] Alternatively or additionally, the temperature value of the working medium ahead of the condensation device **62** can be determined by the temperature measuring element **116**. This measured temperature value corresponds to a currently valid saturated vapor temperature value **102**, which depends on a cooling capacity of the condensation device **62**. The cooling capacity may vary depending on the temperature of the coolant. In particular, if, in a manner which is particularly simple and cost-effective in terms of construction, the coolant is air from the environment, the cooling capacity is directly dependent on the prevailing outside temperature. Depending on the measured, currently valid saturated vapor temperature value **102**, the additional inlet valve **112** is opened by means of the control device **120** until the defined exhaust vapor temperature value **106** is measured by the temperature measuring element **114**.

[0076] Depending on the measured, currently valid saturated vapor temperature value **102**, the corresponding saturated vapor pressure value can be determined according to the vapor curve **100**. This saturated vapor pressure value corresponds to the current lower pressure **20**.

[0077] In FIG. **5**, in contrast to the diagram according to FIG. **2**, there are additional lines which correspond to the isotherms, i.e. lines of the same temperature. **122** denotes the 20° C. isotherm **122**, and **124** denotes the 30° C. isotherm **124**. In addition, step **96** shows how the temperature of the working medium increases when superheated working medium vapor is supplied toward the end of expansion by means of the vapor supply **108**. When the lower pressure **20** is reached, the working medium has the defined exhaust vapor temperature value **106** above the saturated vapor temperature value **102** associated with the lower pressure **20**. This means that the end point of step **96** is relatively far outside the wet vapor region **86**, such that a condensate is reliably prevented from occurring in the exhaust vapor. For ammonia, the defined exhaust vapor temperature value **106** has a temperature of about 28° C. and is thus about 5 K above the saturated vapor temperature value **102** of about 23° C. at the lower pressure **20** of about 8.4 bar.

[0078] FIG. **6** shows the expansion device **56** which is used in the apparatus **10** according to FIG. **4** and is designed having a rotary valve machine in the form of a positive displacement machine. The rotary valve machine is a rotary piston expander which operates in the opposite manner to a rotary piston compressor and is in this case a rotary vane expander.

[0079] Such a rotary vane expander has an annular housing **126** comprising an inlet **128** and an outlet **130**. The inlet **128** is used for admitting the working medium vapor under the elevated pressure **28** and the outlet **130** is used for discharging the expanded working medium vapor. In this case, each flow direction of the working medium vapor is indicated by a flow arrow. The annular housing **126** is formed having a cylindrical hollow cylinder whose inner lateral face forms an inner annular wall **132**. A rotary piston **134** is mounted in the annular housing **126** eccentrically to the axis of the hollow cylinder so as to be rotatable centrally around a shaft **136**. The rotary piston **134** has eight grooves **138** along its longitudinal extension, in each of which a corresponding slide **140** is mounted so that it can be moved radially back and forth.

[0080] To delimit the annular housing **126**, two opposite delimiting surfaces (not shown) are provided in the axial direction. Together with the rotary piston **134**, the inner annular wall **132** and the eight gate valves **140**, the two delimiting surfaces define eight cells **142**, each having a variable volume **144**.

[0081] The individual variable volume **144** is formed by the fact that the relevant slide **140** is pressed in a sealing manner against the annular wall **132** in the course of a rotation by effective centrifugal forces. As the rotary piston **134** is eccentrically mounted in the annular housing **126**, the distance between the rotary piston **134** and the annular wall **132** varies during the rotational movement. For this reason, the relevant slide **140** is pushed back and forth in the corresponding groove **138** when turning. When the distance increases, the slide **140** is pushed out of the corresponding groove **138** until the maximum distance and thus also the maximum volume of the volume **144** is reached. Then the distance decreases again and, when sliding along the annular wall **132**, the slide **140** is pushed from the annular wall **132** into the corresponding groove **138** until the minimum distance and thus also the volume minimum of the volume **144** is reached.

[0082] The variable volume **144** increases during the rotational movement from the inlet **128** toward the outlet **130**, so that when the working medium vapor under the elevated pressure **28** passes through, this working medium vapor expands. When expanding, the working medium vapor presses against a slide **140** in the direction of rotation, so that the rotational movement is started and maintained. This drives the shaft **136**, which in turn drives the generator **58** for generating electric current.

[0083] The size of the variable volume **144** of each cell **142** depends on a rotation angle associated with the rotational movement, which angle can be divided into individual successive rotation angle zones. The volume **144** has its minimum volume in a rotation angle zone **146**. At the inlet **128**, the volume **144** slowly increases in a rotation angle zone **148** during the inflow of the compressed working medium vapor and is expanded to its maximum volume in the rotation angle zone **150**. During expansion, the temperature of the working medium vapor drops. Before the maximum volume is reached, superheated working medium vapor is supplied or fed by intermediate injection into each cell **142** through the vapor supply line **110** by means of the vapor supply **108**. Due to the working medium vapor fed in by intermediate injection, the temperature of the expanding working medium vapor is raised to such an extent that the exhaust vapor temperature of the working medium vapor exiting through the outlet **130** has the defined exhaust vapor temperature value **106**. The working medium vapor reheated in this manner and expanded to the maximum volume then flows out of the outlet **130** in a rotation angle zone **152**, except for a small residual volume. The working medium vapor exiting through the outlet **130** of each cell **142** is the working medium vapor introduced through the inlet **128** together with the working medium vapor fed in by intermediate injection. The residual volume remains in the relevant cell **142** and is compressed via the rotation angle zone **146** until compressed working medium vapor flows in again at the inlet **128**. This process is repeated periodically.

[0084] The expansion ratio, i.e. the ratio between the volume **144** at the inlet **128** and the volume **144** at the outlet **130**, is set at from 1:3 to 1:4 and thus is specially adapted to the working medium ammonia.

[0085] For sealing and lubricating the radial and axial slide gaps occurring between a particular groove **138** and the corresponding slide **140**, the oil supply line **66** is provided for supplying oil (FIG. **4**). The oil also specifically seals and lubricates the running surface of the slide **140** along the annular wall **132**. When the working medium vapor expands, the oil mixes with the working medium vapor as described above and must be discharged from the expansion device **56** through the exhaust vapor line **60** via the oil separator **70**. In the oil separator **70**, the oil separates again around the working medium vapor. Since a proportion of liquid working medium is reliably prevented from occurring in the separated oil by means of the apparatuses **10** according to FIG. **4** and FIG. **7**, the oil heater **76** otherwise required according to FIG. **1** can be omitted so as to save on cost and energy.

[0086] In the apparatus **10** according to FIG. **7**, a counterpressure shall be generated on the working medium by means of the adjustment device **104** in such a way that the exhaust vapor temperature of the expanded working medium has the defined exhaust vapor temperature value **106** above the saturated vapor temperature value **102** associated with the lower pressure **20**. For this purpose, a valve or exhaust vapor control valve **154** is provided as a blocking element **156** by means of which the exhaust vapor line **60** can be shut off. With this kind of shut-off, pressure relief of the working medium in circulation direction **24** is prevented. The working medium is accumulated in the exhaust vapor line **60** against the circulation direction **24** or the flow direction, as a result of which the desired counterpressure can be generated. By opening the exhaust vapor control valve **154**, the counterpressure can be relieved again if necessary.

[0087] For controlling the exhaust vapor control valve **154**, the adjustment device **104** of the apparatus **10** according to FIG. **7** comprises, after expansion, the temperature measuring element **114** slightly ahead of the exhaust vapor control valve **154** in circulation direction **24**. The temperature measuring element **116** is arranged downstream of the exhaust vapor control valve **154** and slightly ahead of the condensation device **62**, using which element the currently valid saturated vapor temperature value **102** of the working medium (as described with regard to FIG. **4**) can be determined. In addition, the pressure measuring element **118** is provided downstream of the exhaust vapor control valve **154** and slightly ahead of the condensation device **62** in circulation direction **24**. By means of the pressure measuring element **118**, a pressure value of the lower pressure **20**, currently valid in the cycle **16**, can be measured slightly ahead of the condensation device **62** according to the comments made with regard to FIG. **4**.

[0088] The temperature measuring elements **114** and **116** as well as the pressure measuring element **118** are coupled to the control device **120** in order to transmit the measured values, which control device closes or opens the exhaust vapor control valve **154** depending on the measurement result. According to the measured pressure value of the lower pressure **20** and thus the currently valid saturated vapor pressure, the corresponding currently valid saturated vapor temperature value **102** is obtained according to the vapor curve **100** stored in the control device **120**. Depending on the valid saturated vapor temperature value **102**, the exhaust vapor control valve **154** is closed by means of the control device **120** until the defined exhaust vapor temperature value **106** is measured by the temperature measuring element **114** or **116**.

[0089] FIG. **8** shows that the exhaust vapor pressure is increased to a first lower pressure **158**, which is slightly higher than the lower pressure **20**, by means of the exhaust vapor control valve **154**. In a first expansion stage **160**, the superheated working medium vapor is thus initially expanded to the first lower pressure **158** by means of the expansion device **56**. For ammonia, this first lower pressure **158** is about 12 bar. This first lower pressure **158** is associated with a saturated vapor temperature of about 33° C. according to the vapor curve **100**.

[0090] Downstream of the exhaust vapor control valve **154** in circulation direction **24**, the first lower pressure **158** is then expanded further in a second expansion stage **162** to a second lower pressure corresponding to the lower pressure **20**. The lower pressure **20** is the condensation pressure of the working medium, i.e. the pressure at which the working medium is condensed in the condensation device **62**. FIG. **8** shows that the temperature of the working medium after the further expansion at the lower pressure **20** has the defined exhaust vapor temperature value **106** above the saturated vapor temperature value **102** associated with the lower pressure **20**. The end point of step **96** is thus outside the wet vapor region **86**, which prevents condensation of the working medium vapor.

[0091] In another embodiment not shown, the pressure increasing device **26** is designed having a vapor pump. The vapor pump is used to increase the pressure on the working medium under the influence of vapor on the working medium. For this purpose, the vapor pump is coupled to heat source **14** by means of the heat transfer device **30** and a vapor transfer medium. The working medium vapor formed by the heat transfer device **30** is partially transferred from the vapor transfer medium to the vapor pump. This allows the thermal energy of heat source **14** to be utilized particularly well and also saves the electrical energy otherwise required for the pressure increasing device **26**. Overall, the efficiency can be increased further.

[0092] In addition, a drying process for drying a substance can also be optimized in terms of energy by means of the solution according to the invention. The energy released in step **98** of condensing the working medium is coupled to the drying process so as to transmit energy. In addition, the engine waste heat and the exhaust gas waste heat from an internal combustion process of fuel, in particular biogas, are used as further heat sources **14** and **17** to dry the substance.

LIST OF REFERENCE NUMERALS

[0093] **10** Apparatus for converting thermal energy
[0094] **12** Method
[0095] **14** Heat source
[0096] **16** Thermodynamic cycle
[0097] **17** Heat source
[0098] **18** Collecting tank
[0099] **20** Lower pressure
[0100] **22** Line
[0101] **24** Circulation direction
[0102] **26** Pressure increasing device
[0103] **28** Elevated pressure
[0104] **30** Heat transfer device
[0105] **32** First heat exchanger
[0106] **34** Second heat exchanger
[0107] **36** Line
[0108] **38** Line
[0109] **40** Separator
[0110] **42** Lower region
[0111] **44** Upper region
[0112] **46** Line
[0113] **48** Line
[0114] **50** Line
[0115] **52** Line
[0116] **54** Inlet valve
[0117] **56** Expansion device
[0118] **58** Generator
[0119] **60** Line or exhaust vapor line
[0120] **62** Condensation device
[0121] **64** Oil supply circuit
[0122] **66** Oil supply line or supply device
[0123] **68** Oil inlet valve
[0124] **70** Oil separator
[0125] **71** Separating element
[0126] **72** Oil discharge line
[0127] **74** Oil collecting tank
[0128] **76** Oil heater
[0129] **78** Vapor line
[0130] **80** Oil pump
[0131] **82** Heating circuit line
[0132] **83** Pressure logarithm
[0133] **84** Enthalpy
[0134] **85** Phase boundary line
[0135] **86** Wet vapor region
[0136] **88** Step of increasing pressure
[0137] **90** Preheating step
[0138] **92** Evaporation step
[0139] **94** Superheating step
[0140] **96** Expansion step
[0141] **98** Condensation step
[0142] **100** Vapor curve
[0143] **102** Saturated vapor temperature value
[0144] **104** Adjustment device
[0145] **106** Defined exhaust vapor temperature value
[0146] **108** Vapor supply
[0147] **110** Vapor supply line
[0148] **112** Inlet valve
[0149] **114** Temperature measuring element
[0150] **116** Temperature measuring element
[0151] **118** Pressure measuring element
[0152] **120** Control device
[0153] **122** Isotherm at 20° C.
[0154] **124** Isotherm at 30° C.
[0155] **126** Annular housing
[0156] **128** Inlet
[0157] **130** Outlet
[0158] **132** Inner annular wall
[0159] **134** Rotary piston
[0160] **136** Shaft
[0161] **138** Groove
[0162] **140** Slide
[0163] **142** Cell
[0164] **144** Volume
[0165] **146** Rotation angle zone
[0166] **148** Rotation angle zone
[0167] **150** Rotation angle zone
[0168] **152** Rotation angle zone
[0169] **154** Valve or exhaust vapor control valve
[0170] **156** Blocking element
[0171] **158** First lower pressure
[0172] **160** First expansion stage
[0173] **162** Second expansion stage

1.-**10**. (canceled)

11. An apparatus for converting thermal energy from a heat source into mechanical energy by means of a thermodynamic cycle using

a working medium which is carried in the cycle and experiences a changing pressure, wherein a saturated vapor temperature value of the working medium is associated with a particular pressure in each case, and

an expansion device for expanding the working medium from an elevated pressure to a lower pressure, wherein, after expansion to the lower pressure, the working medium has an exhaust vapor temperature,

wherein an adjustment device for adjusting the exhaust vapor temperature to a defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure is provided.

12. The apparatus according to claim **11**,

wherein the defined exhaust vapor temperature value is between 2 K and 12 K above the saturated vapor temperature value associated with the lower pressure.

13. The apparatus according to claim **11**,
wherein the defined exhaust vapor temperature value is between 4 K and 8 K above the saturated vapor temperature value associated with the lower pressure.

14. The apparatus according to claim **11**,
wherein the defined exhaust vapor temperature value is between 5 K and 6 K above the saturated vapor temperature value associated with the lower pressure.

15. The apparatus according to claim **11**,
wherein, by means of the adjustment device, a temperature of the working medium is increased such that the exhaust vapor temperature has the defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure.

16. The apparatus according to claim **15**,
wherein, by means of the adjustment device, the temperature of the working medium within the expansion device is increased.

17. The apparatus according to claim **11**,
wherein the adjustment device comprises a vapor supply for supplying vapor to the working medium.

18. The apparatus according to claim **17**,
wherein the vapor is superheated.

19. The apparatus according to claim **17**,
wherein the vapor is a vapor of the working medium.

20. The apparatus according to claim **11**,
wherein a counterpressure is generated on the working medium by means of the adjustment device in such a way that the exhaust vapor temperature has the defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure.

21. The apparatus according to claim **20**,
wherein the adjustment device comprises a blocking element for generating the counterpressure on the working medium, the blocking element having a valve for selectively opening and closing a line carrying the working medium.

21. The apparatus according to claim **11**,
wherein the working medium is carried in a circulation direction, and a condensation device for condensing the expanded working medium is provided downstream of the expansion device in circulation direction,
wherein the adjustment device comprises
a temperature measuring element for measuring a temperature of the working medium after expansion and before condensation in circulation direction and/or
a pressure measuring element for measuring the pressure of the working medium after expansion and before condensation in circulation direction.

22. A method for converting thermal energy from a heat source into mechanical energy by means of a thermodynamic cycle using a working medium which is carried in the cycle and experiences a changing pressure,
wherein a saturated vapor temperature value of the working medium is associated with a particular pressure in each case,
comprising a step of expanding the working medium from an elevated pressure to a lower pressure,
wherein, after expansion to the lower pressure, the working medium has an exhaust vapor temperature, and
wherein the exhaust vapor temperature is adjusted to a defined exhaust vapor temperature value above the saturated vapor temperature value associated with the lower pressure.

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