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(54) **An apparatus for converting waste heat from a production process into electrical energy**

(57) An apparatus for converting the waste heat from a production process into electrical energy, whereby the production process comprises a number of sub-processes, in which the waste heat from at least two sub-processes is simultaneously extracted from the production process by a single closed work-producing cooling circuit (1), and in which there is at least one heat exchanger (3,4) for each sub-process in the form of an evaporator, with a primary section incorporated into the closed cooling circuit (1) and a secondary section through which a fluid is taken from the sub-process concerned to evaporate the coolant in the closed cooling circuit (1), whereby

at least one of the aforementioned heat exchangers (3,4) has its secondary section incorporated into a cooling circuit of a sub-process that uses the same coolant, and such that after cooling in the heat exchanger concerned the coolant is mixed with the coolant in the closed cooling circuit by means of a mixer (11) followed by a closed mixing vessel (12) in which the fluid and gas phases of the coolant are separated, and there is a closed mixing vessel (12) in the closed cooling circuit (1) after the mixer (11) in which the liquid and gas phases of the coolant are separated, and coolant is tapped off from this for use in the aforementioned cooling circuit of the sub-process.

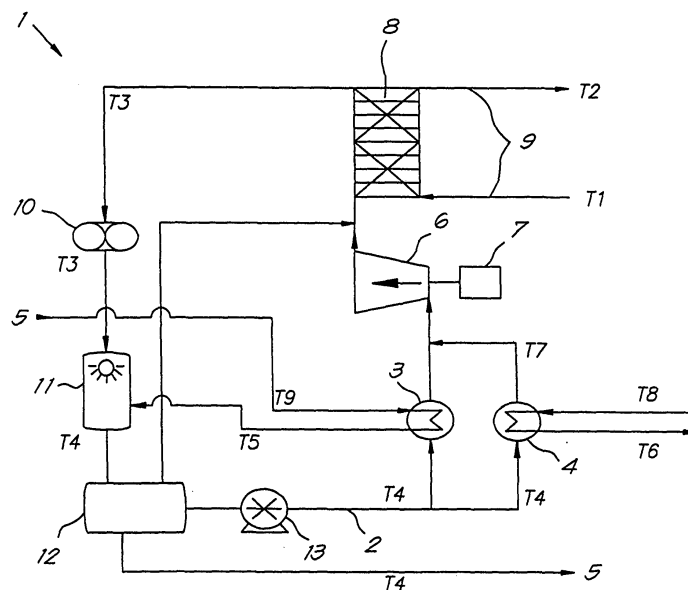


Fig. 1

Description

[0001] An apparatus for converting waste heat from a production process into electrical energy.

[0002] It is known that heat is produced in a number of industrial production processes that is emitted as waste heat into the environment without further utilisation.

[0003] A disadvantage of this situation is the waste of a quantity of energy in the form of waste heat which increases the energy costs of the production process.

[0004] Another disadvantage of this situation is that the environment can be taken out of equilibrium by this waste heat, with the attached costs for the environment.

[0005] The purpose of the present invention is to use the waste heat from industrial processes more efficiently by generating electrical energy without fossil fuels or emissions, whereby this electrical energy can be used in the same production process or in another application.

[0006] To this end the invention relates to an apparatus for converting waste heat from a production process into electrical energy, where the production process comprises a number of sub-processes, in which the waste heat from at least two sub-processes is simultaneously extracted from the production process by a single closed work-producing cooling circuit, and in which there is at least one heat exchanger for each sub-process in the form of an evaporator, with a primary section incorporated into the closed cooling circuit and a secondary section through which a fluid is taken from the sub-process concerned to evaporate the coolant in the closed cooling circuit, where at least one of the aforementioned heat exchangers has its secondary section incorporated into a cooling circuit of a sub-process that uses the same coolant, and whereby after cooling in the heat exchanger concerned the coolant is mixed with the coolant in the closed cooling circuit by means of a mixer followed by a closed mixing vessel (12) in which the fluid and gas phases of the coolant are separated, and there is a closed mixing vessel (12) in the closed cooling circuit (1) after the mixer (11) in which the liquid and gas phases of the coolant are separated, and coolant is tapped off from this for use in the aforementioned cooling circuit of the sub-process.

[0007] Preferably there is a power source in the closed cooling circuit, such as a turbine, to which a generator is connected to supply electrical energy, a condenser for cooling and condensing the coolant, and a drive means to circulate the coolant.

[0008] An advantage of the present invention is that it is a reliable technology by which up to 25% of the waste heat can be converted into electrical energy by means of a single cooling circuit for a number of waste heat sources. Another advantage of the present invention is that no fossil fuels such as petroleum or natural gas are required to generate this electrical energy.

[0009] Another advantage is that an investment according to the present invention in an industrial process

can pay for itself in one to two years, depending on the dimensions of the production unit and the attainable efficiency of the waste heat conversion.

[0010] A preferable embodiment is one that can be applied in the vegetable oil industry.

[0011] The energy consumption, in the form of steam and electricity, in the vegetable oil refining process has already been minimised, but nevertheless the energy consumption continues to constitute an important proportion of the variable costs.

[0012] In the vegetable oil extraction and refining processes, two waste sources have been identified: the cooling of the hot end product, the refined vegetable oil, and the condensation of the steam used. This condensation can be done by using an ice condenser, in which steam is condensed into ice during the vegetable oil refining process, and in which ammonia is used as a coolant. Instead of an ice condenser, an alkaline vacuum system with a cooling unit can also be used to condense the steam, in which cold barometric alkaline water is used as a primary coolant/condensation means, and a glycol/water mixture is used as an intermediate coolant, which in turn is cooled by another coolant such as freon or ammonia. In any case waste heat is released from this condensation process.

[0013] Preferably the waste heat is recovered from both waste heat sources in a closed cooling circuit where, in parallel for each sub-process, one heat exchanger in the form of an evaporator with a primary section incorporated in the cooling circuit and a secondary section through which a fluid is guided, originating from the sub-process concerned, to evaporate the coolant in the cooling circuit.

[0014] The cooling circuit contains a turbine as a power source, to which a generator is connected, a condenser for cooling and condensing the coolant, and a drive means to circulate the coolant, and to partly convert the waste heat into electrical energy.

[0015] To better demonstrate the characteristics of the invention, a preferred embodiment is described below, as an example without any limiting nature, of an apparatus for converting waste heat according to the invention, with reference to the accompanying drawings, in which:

Figure 1 schematically shows an apparatus for converting waste heat into electrical energy according to the invention, applied in a production process for refining vegetable oil; and

figure 2 shows a graphic presentation of the efficiency of the apparatus according to figure 1.

[0016] The apparatus shown in figure 1 consists of a cooling circuit 2 with ammonia as a coolant, for example, that contains an evaporator 3 and a heat exchanger 4, a turbine 6 connected to an electrical power source 7, and further a condenser 8. The ammonia circuit is connected via a mixer 11 and a mixing vessel 12. From the mixing vessel 12 ammonia is pumped back 13 to the heat ex-

changer 4, but is also taken further to an ice condenser 5, via a compressor (not shown). The temperatures given in figure 1 are indicated with symbols. These symbols indicate the following temperatures in this case, but these symbols are not limited to these temperatures:

T1 = 18°C
 T2 = 22°C
 T3 = 25°C
 T4 = 38°C
 T5 = 50°C
 T6 = 62°C
 T7 = 72°C
 T8 = 120°C
 T9 = 217°C

[0017] The apparatus for converting waste heat from a production process is used in the vegetable oil production process, where the operation of the integrated waste heat conversion of two waste heat sources can be explained as follows.

[0018] The production process is a process for producing vegetable oil, in which the oil extracted from plants is refined in a first sub-process at high temperature by passing steam in a deodoriser through the oil, whereby the heat released by cooling the deodorised oil is at least partly converted into electrical energy via a first heat exchanger 4, and whereby the steam used for deodorising is taken from the deodoriser to an ice condenser that condenses the steam supplied to ice via a second sub-process that exchanges heat with the closed cooling circuit 2 via a second heat exchanger 3.

[0019] The deodoriser raises the vegetable oil to a temperature of around 250°C. After refinement, the vegetable oil has to be cooled to a temperature of 30°C for soft oils or to 50°C for palm oil to enable transport and storage.

[0020] Ammonia is heated and evaporated with the waste heat from both sources, after which the two ammonia flows of 72°C are combined to drive a turbine 6 connected to an electrical power source 7 for electricity generation. The spent ammonia is brought back to its low output temperature via a condenser 8, connected to an external coolant 9, and recycled as a coolant for both cooling processes, i.e. the cooling of the ammonia from the ice condenser, and the cooling of the refined vegetable oil, the end product of the industrial process.

[0021] Figure 2 shows the efficiency of the waste heat conversion in the form of a graph, in which the efficiency is expressed as the percentage of the waste heat that is converted to electrical energy at different temperatures of the waste heat sources and at different temperatures of the coolant in the closed cooling circuit.

[0022] The efficiency, i.e. the percentage of the waste heat that is recovered as electrical energy, of this conversion circuit 1 depends on the temperature of the waste heat sources and the temperature of the cooled coolant. For example, the efficiency of the circuit for a waste heat source of 100°C is already 18% if the temperature of the

coolant is brought to -30°C, and it rises to 22% for a waste heat source of 150°C in the same conditions, as shown in figure 2.

[0023] The present invention is not in any way limited to the embodiment described as examples and shown in the drawings, but a production process according to the invention can be realised in all kinds of forms and dimensions, without exceeding the scope of the invention.

Claims

1. An apparatus for converting the waste heat from a production process to electrical energy, whereby the production process comprises a number of sub-processes, and in which the waste heat from at least two sub-processes is simultaneously extracted from the production process by a single closed work-producing cooling circuit (1), and in which there is at least one heat exchanger (3,4) for each sub-process in the form of an evaporator, with a primary section incorporated into the closed cooling circuit (1) and a secondary section through which a fluid is taken from the sub-process concerned to evaporate the coolant in the closed cooling circuit (1), **characterised in that** at least one of the aforementioned heat exchangers (3,4) has its secondary section incorporated into a cooling circuit of a sub-process that uses the same coolant, and **in that** after cooling in the heat exchanger concerned the coolant is mixed with the coolant in the closed cooling circuit by means of a mixer (11) followed by a closed mixing vessel (12) in which the fluid and gas phases of the coolant are separated, and **in that** there is a closed mixing vessel (12) in the closed cooling circuit (1) after the mixer (11) in which the liquid and gas phases of the coolant are separated, and coolant is tapped off from this for use in the aforementioned cooling circuit of the sub-process.
2. An apparatus according to claim 1, **characterised in that** a power source (6) is incorporated into the closed work-producing cooling circuit (1) to which an electricity generator (7) is connected to supply electrical energy.
3. An apparatus according to claim 1, **characterised in that** the cooling circuit (1) successively contains a turbine as a power source (6), to which the generator (7) is connected, a condenser (8) for cooling and condensing the coolant, and a drive means (10) in order to circulate the coolant.
4. An apparatus according to claim 3, **characterised in that** the condenser (8) for cooling/condensing the coolant is connected to an external cooling fluid (9).
5. An apparatus according to one of the foregoing

claims, **characterised in that** a first waste heat source is formed by the cooling process of an end product of the production process.

6. An apparatus according to one of the foregoing claims, **characterised in that** the production process is a process for the production of a vegetable oil, whereby the oil that has been extracted from plants, is refined in a first sub-process at high temperature by passing steam through it in a deodoriser, whereby the heat released by the cooling of the deodorised oil is at least partly converted into electrical energy via a first heat exchanger (4), and whereby the steam used for deodorising is taken through an ice condenser, that sublimates the steam supplied to ice. The cooling in the ice condenser is achieved by evaporating ammonia, which is then compressed and then exchanges heat with the closed cooling circuit (1).
7. An apparatus according to claim 1, **characterised in that** the temperature of the coolant in the cooling circuit (2), in order to convert waste heat into electrical energy, is kept below 40°C, and preferably below -5°C, and most preferably below -30°C.

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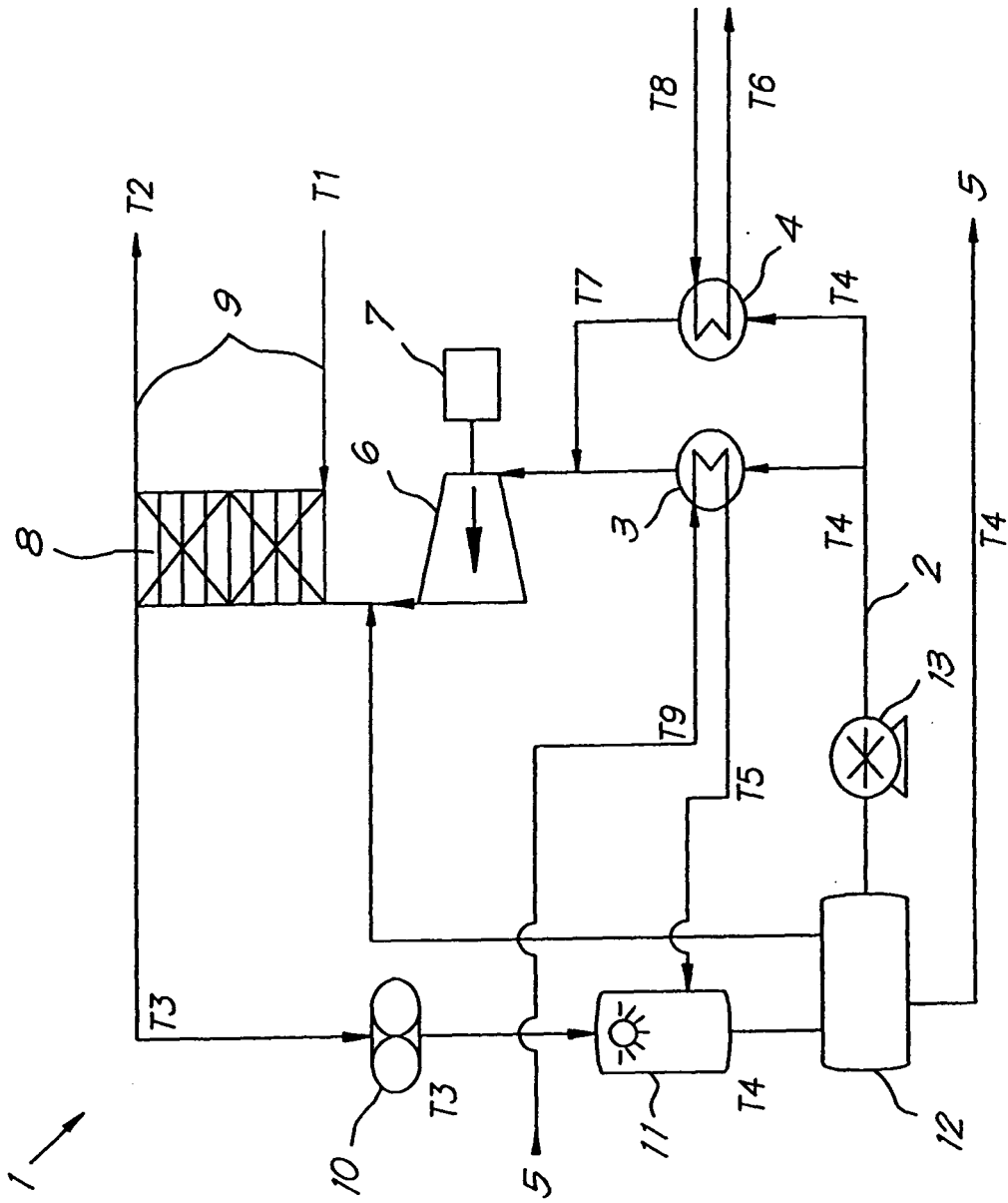


Fig. 1

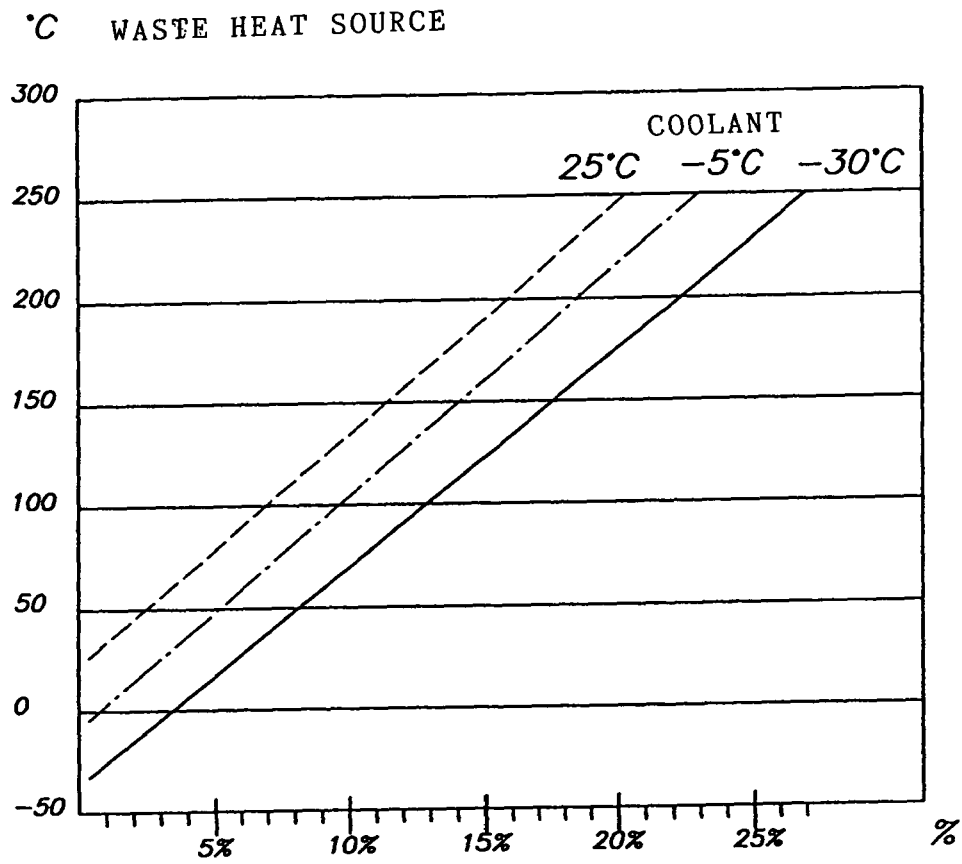


Fig. 2