(19) DANMARK

(10) **DK/EP 3486564 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: *F 22 B 37/36 (2006.01)* *F 25 B 49/00 (2006.01)*

(45) Oversættelsen bekendtgjort den: **2020-08-10**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2020-05-13**

(86) Europæisk ansøgning nr.: **18198588.8**

(86) Europæisk indleveringsdag: **2018-10-04**

(87) Den europæiske ansøgnings publiceringsdag: **2019-05-22**

(30) Prioritet: **2017-11-16 DE 102017126947**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **Vaillant GmbH, Berghauser Strasse 40, 42859 Remscheid, Tyskland**

(72) Opfinder: **Lingk, Tobias, Oberbüscherhof 13, 42799 Leichlingen, Tyskland**
Spahn, Hans-Josef, Nordstraße 10, 40699 Erkrath, Tyskland
Salg, Frank, Königsberger Strasse 12, 42897 Remscheid, Tyskland
Badenhop, Thomas, Breslauer Str. 12, 51688 Wipperfürth, Tyskland

(74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**

(54) Benævnelse: **INDRETNING TIL SIKKER UDFØRELSE AF EN VENSTREDREJENDE TERMODYNAMISK CLAUSIUS-RANKINE-PROCES BASERET PÅ ARBEJDSFLUIDADSORPTION MED FORTRÆNGNING AF INERT GAS**

(56) Fremdragne publikationer:
EP-A1- 3 106 780
DE-A1-102011 116 863
JP-A- 2000 105 003

Description

The invention relates to irregular states in cooling circuits, in which a working fluid acting as a refrigerant is guided in a thermodynamic cyclic process, such as for example the Clausius-Rankine cyclic process. These are predominantly heat pumps, air conditioning units and cooling devices such are used in residential buildings. The term “residential buildings” here denotes private houses, rental house complexes, hospitals, hotel premises, restaurant premises and combined residential and business houses and business premises, in which people permanently live and work, in contrast to mobile devices such as vehicle air conditioning units or transport boxes, or also industrial plants or devices used in the medical branch. It is common to these cyclic processes that they use energy to generate useful heat or useful cooling and form heat transfer systems.

The invention relates to a device for the secure implementation of a left-turning thermodynamic Clausius-Rankine cyclic process by means of an inflammable working fluid.

The thermodynamic cyclic processes which are employed have been known for a long time, as have been the safety problems which can result when using suitable working fluids. Apart from water, the working fluids which are most well-known at the present time are inflammable and poisonous. In the last century they resulted in the development of the safety refrigerants which consisted of fluorinated hydrocarbons. It was, however, proved that these safety refrigerants damage the ozone layer, result in global warming, and that their safety-related harmlessness resulted in constructive carelessness. Up to 70% of the turnover resulted from the need to refill leaking assemblies and their leakage losses, which was accepted as long as this was considered to be reasonable on a case-by-case basis and promoted the need for the purchase of replacements.

The use of these refrigerants was for this reason subjected to restrictions, in the European Union for example by the F-Gas-Regulation (EU) 517/2014.

It is thus on the one hand extremely difficult to adopt the constructive principles for refrigerant-carrying thermodynamic processes which have apparently proved to be useful in the case of safety refrigerants, on the other hand to revert to system concepts from the time prior to the introduction of the safety refrigerants. Another reason for this is that in the meantime individual devices have turned into complex systems, which has multiplied the number of possibilities for malfunctions and their consequences. This results, for example, in the following requirements being made of the safety concept:

- The system must be absolutely leakproof during normal operation.
- Working fluid may not penetrate into the coupled useful heat circuit or useful cool circuit either in the case of a leak in the condenser or in the case of a leak in the liquefier.
- No working fluid may escape unobserved from the cooling circuit.
- In the compressor, the working fluid may not escape through the mounting.
- In the relaxation system, the working fluid may not diffuse through the valve seat or result in leakages by cavitation.
- Encapsulated parts must remain accessible for servicing and control purposes.
- There must be no danger in emergency situations.
- The system must able to be integrated into present premises.
- The refrigerant should be able to be drained and filled up.

The term “emergency situation” must be viewed broadly. Conceivable are power outages, earthquakes, landslides, floods, fires, technical faults and climate-related extreme conditions. Inasmuch as the systems are operated in a network, also a network outage or a network fault are to be considered as an emergency situation. The device should be inherently safe when faced with such dangers or faults. However, also an outage of the available primary energy can be a cause for an emergency situation and may not result in any danger. All these emergency situations can also occur combined.

Here, the different constructional forms and application cases for thermodynamic cyclic processes of this sort are to be taken into consideration separately: in the case of stationary systems for residential buildings, for example, the following:

- household refrigerators,
- household freezers,
- household dryers,
- household refrigerator/freezer combinations,
- refrigeration rooms for hotels and restaurants,
- freezing rooms for hotels and restaurants,
- air conditioning systems for household, hotels and restaurants,
- warm water production for household, hotels and restaurants,

- heating for household, hotels and restaurants,
- sauna/swimming pool systems for household, hotels and restaurants,
- combined systems for the above-mentioned applications,

wherein this list is incomplete.

The energy for the operation of the systems including the heat energy to be displaced can originated from different sources:

- ground heat from ground heat accumulators,
- geothermal heating,
- teleheat,
- electrical energy from general power supply,
- electrical solar energy,
- solar heat,
- waste heat,
- hot well,
- ice reservoir,
- latent heat accumulator,
- fossil fuel energy sources such as natural gas, crude oil, coal,
- renewable raw materials such as wood, pellets, biogas,
- combinations of the aforementioned energy sources,

wherein also this list is incomplete.

The problems occurring when designing the safety of such systems are described vividly in WO 2015/032905 A1. Thus the lower ignition limit of propane as a working fluid is approximately at 1.7 volume percent in air, which corresponds to 38 g/m^3 in air. Inasmuch as the refrigerating process is carried out with the working fluid propane in a room which surrounds it and is hermetically sealed, but otherwise filled with air, there arises the problem of the recognition of a critical explosive situation following a fault, in which the working fluid emerges into this hermetically sealed room. It is difficult to design as explosion-proof electrical sensors for the recognition of critical concentrations, for which reason particularly the propane recognition on the part of the sensors itself significantly intensifies the risk of explosion: the exception to this are infrared sensors. Propane is also poisonous: in the case of inhalation above the concentration of approximately 2 g/m^3 narcotic effects, headaches and nausea occur. This concerns persons which are supposed to solve the recognised problem on location even prior to the risk of explosion.

Propane is also heavier than air, thus in still air it sinks to the floor and collects there. If, therefore, a part of the propane were to collect in a low-air-flow zone of the enclosed room in which the faulty unit is located, the local explosion limits can be reached significantly more rapidly than the quotient of total room volume to emerged propane quantity would lead one to expect. WO 2015/032905 A1 seeks to solve this problem in that a generator for electrical current is integrated into the opening of this room, or into its locking mechanism, and when this is actuated, in a first step generates and provides the electrical energy with which the sensor is activated, and the sensor in the case of alarm does not release the locking but rather triggers a ventilation of the closed room and only in a second step permits an unlocking and opening.

Already at the start of the technology of the compression refrigeration machines, it was attempted to create a closed room in which the apparatuses could all be safely accommodated and which encloses these completely. DE-PS 553 295 describes an encapsulated compression refrigeration machine in which the refrigerant compressor 1, its drive motor 2, evaporator 3, condenser 4 and regulating valve 5 are enclosed in a double-walled capsule 6 or 7. In the interspace of the double-walled capsule is applied an underpressure, and leakages which could occur at the breaches for cooling water and brine are suctioned off. The suctioned-off working fluid can thereafter where appropriate be recovered. It is here necessary to note that there is no environmental air within the encapsulated room and by reason of the underpressure in the double shell it cannot penetrate into the encapsulated inner room.

DE 10 2011 116 863 A1 describes a method for securing a device for a thermodynamic cyclic process which is operated with a process fluid, which contains at least one environmentally-hazardous, poisonous and/or inflammable substance or consists thereof. In the case of a leakage in the device for a thermodynamic cyclic process an adsorbent is brought into contact with the process fluid, in particular ammonia, propane or propene, and the substance is selectively bound by the adsorbent. The adsorbent is regenerated after use. As adsorbents are proposed zeolith, also in combination with imidazole or phosphates, furthermore CuBTC, the adsorbent can be in the form of a bulk, a moulded body, a painted coating, a sprayed film or a coating. The support structure of the moulded body can consist of microstructure, lamellar structure, tubular bundle, pipe register and metal sheet and must be mechanically stable as well as strongly surface-increasing. A circulation of the potentially contaminated air takes place normally in a continuous manner, can however also be initiated by a sensor which switches on the ventilation after a threshold value has been reached or in the case of a recognised emergency. The adsorption can be carried out inside or outside a closed room. Moreover, DE 10 2011 116 863 A1 discloses a device according to the preamble of claim 1.

DE 195 26 980 A1 describes a device and a method for purifying air of closed rooms which have a gaseous contamination. After the contamination has been recognised by a gas sensor, this activates a compressor which guides the air through an absorber located in this room, by means of which the contamination is absorbed. The purified air leaves the absorber into the closed room.

DE 195 25 064 C1 describes a cooling machine with a housing which is designed to be gastight which accommodates all refrigerant-conducting components of the machine, a space is provided connecting the interior of the gas tight housing with an outlet, and the space is filled with a material which absorbs the refrigerant. The quantity of the absorbing material is in this regard dimension such that the entire amount of potentially escaping refrigerant can be accommodated and kept away from the environment. The space filled with the absorbing material is open to the environment. In the case of refrigerants which are heavier than air, the space is open downwardly, in the case of such which are lighter than air, it is open upwardly, such that a conveying fan is not necessary. The sorbent is introduced into the housing and encloses the cooling machine or the refrigerant-conducting devices completely. On its path to the outside, chicanes are provided which prevent short-circuit flows and force escaping gas through the sorbent. Possible is also a double-walled embodiment in which the sorbent is arranged in the double shell. At the exit of the space filled with the absorbing material towards the environment can be provided a measuring device for refrigerant.

EP 3 106 780 A1 describes a thermal pump system which is accommodated in an airtight housing lined with a binding agent. Within this housing can be arranged an absorption unit with a forced ventilation device which cleans the air in the housing in air recirculation mode. This air recirculation mode can take place continuously or only in the case of a fault or at regular intervals. Downstream from this absorption stage, also an igniter, a pilot light, a catalytic burner or a heating wire can be arranged which burns any remaining flammable contaminants. Also conceivable is a fresh air supply in connection with the discharge of cleaned air.

The presented systems have had until now little success on the market. This can be attributed to the following reasons:

- Ease of installation: in the case of modernisations of old heating systems, the devices which are to be newly installed need to be dismountable and able to be transported. For example, they need to be carried down cellar stairs and brought into winding and low cellar rooms. Construction, start-up and maintenance must be possible on location without great effort. This excludes to the most extent large and heavy pressurised containers, furthermore systems which can no longer be deinstalled after an accident.
- Ease of diagnosis: the operating states should be easily discernible from the outside, this concerns the safety and ability to check with regards to possible leakages and includes the filling level of the working fluid as well as the filling degree of any introduced adsorbents.
- Ease of maintenance: system diagnoses should be able to take place without great additional effort. Safety-relevant systems should be able to be regularly tested or examined for reliability. Inasmuch as system diagnoses are not able to be carried out easily, possibly contaminated parts should be able to be exchanged easily for new parts.
- Fail safety: the system should on the one hand the secured against faults, should at the same time however be able to run reliably, at least in emergency mode. In the case of a temporary external fault, the systems should either be able to start again automatically or be able to be restarted without great effort.
- Energy efficiency: the systems should be able to be operated in a low-energy manner: this is countered by a high use of energy for safety measures.
- Robustness: in the case of more serious faults, whether they are external or system-internal in character, the controllability must be guaranteed, this concerns e.g. ventilation systems which could block or pressurised containers which are under pressure or become hot for example in the case of a fire.

– Costs: the safety measures should be insignificant both in the case of purchase price and with regard to running costs and should exceed the savings in energy costs in comparison with conventional systems. They should be economical.

The task of the invention is therefore the provision of an improved lining device, which better solves the outlined problems and no longer has the disadvantages.

The invention solves this task with the device according to claim 1. The device is for safely carrying out a left-turning thermodynamic Clausius-Rankine cycle by means of an inflammable working fluid which in the gaseous state under atmospheric conditions is heavier than air and is guided in a closed, hermetically sealed working fluid circuit, having

– at least one compressor for working fluid,
– at least one pressure relief apparatus for working fluid,
– at least two heat exchangers for working fluid, each with at least two connections for heat transfer fluids,
– a closed housing which comprises all apparatuses connected to the closed working fluid circuit, can comprise further apparatuses, and is lined with an adsorbent which is able to adsorb working fluid,
– wherein an adsorbent is used which can adsorb the working fluid and an inert gas,
– wherein the working fluid has a stronger absorptive bond to the adsorbent than the inert gas,
– and wherein the adsorbent with which the housing is lined is preloaded saturated with the inert gas.

As heat exchanger fluid are to be understood here all gaseous or fluid media with which heat is transferred, that is for example air, water, brine, heat transfer oils or similar.

The advantage is here that in the case of a leakage with the release of the working fluid there takes place a displacement of the inert gas out of the adsorbent with the simultaneous adsorption of the working fluid. The displaced inert gas inertises the interior of the container and thereby reduces at the same time the danger of explosion. Moreover, the desorption of the displaced inert gas has the effect that the adsorptive heating of the adsorbent at the adsorption is significantly lower since it is no longer the entire adsorption heat which is free, but rather only the difference between the adsorption heat of the working fluid and the desorption heat of the inert gas. Thereby it is also prevented that already adsorbent working fluid is expelled again by heat generation.

In a particular embodiment of the invention, propane is used as a working fluid, active carbon as an adsorbent and carbon dioxide as an inert gas. The active carbon can here be doped in a known manner such that an optimal loading with propane occurs; admittedly, a chemisorption is here to be avoided, since then the simultaneous desorption of carbon dioxide does not take place.

In terms of apparatus, a lining of this sort is undertaken preferably by means of dimensionally stable mats or moulded bodies which contain the adsorbent and which can be removed and taken away in a simple manner after the housing is opened. Typically, they are permeable for gas and liquid on the side facing the container interior, while the form stability is guaranteed by a stable rear-side-structure.

In an embodiment of the invention, it is provided that these mats or moulded bodies have on the side facing the housing interior a flat surface and possess on their upper side film-like blinds which can be drawn down, which in the case of a dismantling are drawn over the surface like a bag and keep it closed thereafter for the dismantling and for the removal. In a further embodiment of the invention, this device is also used for the assembly, in order to prevent the inert gas diffusing away prematurely from the lining.

On the rear side, the mats or moulded bodies are fixed in a known manner with hooks or click fasteners.

The invention will be described hereinafter in more detail with reference to two schematic diagrams. Here:

figure 1 shows a cooling circuit with a lining,

figure 2 shows an embodiment example for an adsorbent moulded body with a blind device.

Figure 1 shows a schematic diagram of a cooling circuit 1 having a compressor 2, a condenser 3, a pressure relief apparatus 4 and an evaporator 5 in a closed housing 6. The housing 6 has a heat source connection 7, a heat source flow pipe 8, a heat sink flow pipe 9 and a heat sink connection 10. The cooling circuit 1 is operated in this example with the inflammable working fluid propane, which is known also by the description R290. Propane is heavier than air, therefore in the case of a leakage in the cooling circuit 1 it tends to sink downwards in the housing 6. By reason of temperature differences in the housing and corresponding convection, propane from leakages is located also in the rest of the housing interior. This housing 6 is for this reason completely lined with the adsorbent lining 11.

Figure 2 shows an adsorbent moulded body of the type of which several can or should be present in the housing, wherein the housing interior can also completely enclose these moulded bodies, especially on the lower side, since propane emerging as a result of a leak sinks in air. Such moulded bodies contribute incidentally also to the reduction of noise emissions.

The exemplary adsorbent moulded body 12 has in its interior an active carbon mat 13 which consists either of active carbon fibres or of active carbon pellets which are fixed in a permeable matrix. Also honeycomb bodies are possible. On the rear side is located a bearing structure with click fastenings 14 with which the adsorbent moulded body 12 is fixed on the interior of the housing 6. On the opposite side is located a permeable holding grid 15.

For the mounting and dismantling, the adsorbent moulded body has a blind device 16 which consists of rollers on which prior to use films can be simultaneously drawn on and rolled up on the front side and the rear side, and after use can be drawn down and closed at the bottom. The films on the front side and rear side can here also form a bag which has a pull lock and which closes the adsorbent moulded bodies in a gas tight-manner prior to and after use.

List of reference signs

1 cooling circuit
2 compressor
3 condenser
4 pressure relief apparatus
5 evaporator
6 housing
7 heat source connection
8 heat source flow pipe
9 heatsink flow pipe
10 heatsink connection
11 adsorbent lining
12 adsorbent moulded body
13 active carbon mat
14 rear side with click fastening
15 holding grid
16 blind device
17 film

Patentkrav

1. Indretning til sikker udførelse af en venstredrejende termodynamisk Clausius-Rankine-cyklus (1) ved hjælp af et antændeligt arbejdsfluid, med et arbejdsfluid som i gasformig tilstand under atmosfæriske betingelser er tungere end luft, og med et lukket, hermetisk tætnet arbejdsfluidkredsløb, som har

- mindst en kompressor (2) til arbejdsfluid,
- mindst et afspændingsapparat (4) til arbejdsfluid,
- mindst to varmevekslere (3, 5) til arbejdsfluid, hver med mindst to forbindelser (7, 8, 9, 10) til varmeoverførselsfluider, og med
- et lukket hus (6),
- som omfatter alle apparater forbundet til det lukkede arbejdsfluidkredsløb,
- kan omfatte yderligere apparater,
- og er foret med et adsorptionsmiddel (11), som er i stand til at adsorbere arbejdsfluid,

kendetegnet ved, at

- det anvendte adsorptionsmiddel kan adsorbere en inert gas, og adsorptionsmidlet er forbelastet mættet med den inerte gas,
- idet arbejdsfluidet har en større adsorptiv binding til adsorptionsmidlet end den inerte gas.

2. Indretning ifølge krav 1, **kendetegnet ved, at** adsorptionsmidlet er aktivkul, arbejdsfluidet er propan, og den inaktive gas er kuldioxid.

3. Indretning ifølge et af kravene 1 eller 2, **kendetegnet ved, at** foringen (11) med adsorptionsmiddel udføres ved hjælp af formstabile måtter eller formstøbte legemer (12).

4. Indretning ifølge et af kravene 1 til 3, **kendetegnet ved, at** de formstabile måtter eller formstøbte legemer (12) har et for gas og væske gennemtrængeligt holdegitter (15) og en formstabil bagsidestruktur (14) med en fastgørelses-indretning.

5. Indretning ifølge et af kravene 1 til 4, **kendetegnet ved, at** de formstabile måtter eller formstøbte legemer (12) har en jalousiindretning (16), med hvilken mindst en folie (17) kan trækkes på en gastæt måde over de formstabile måtter eller formstøbte legemer.

Fig. 1

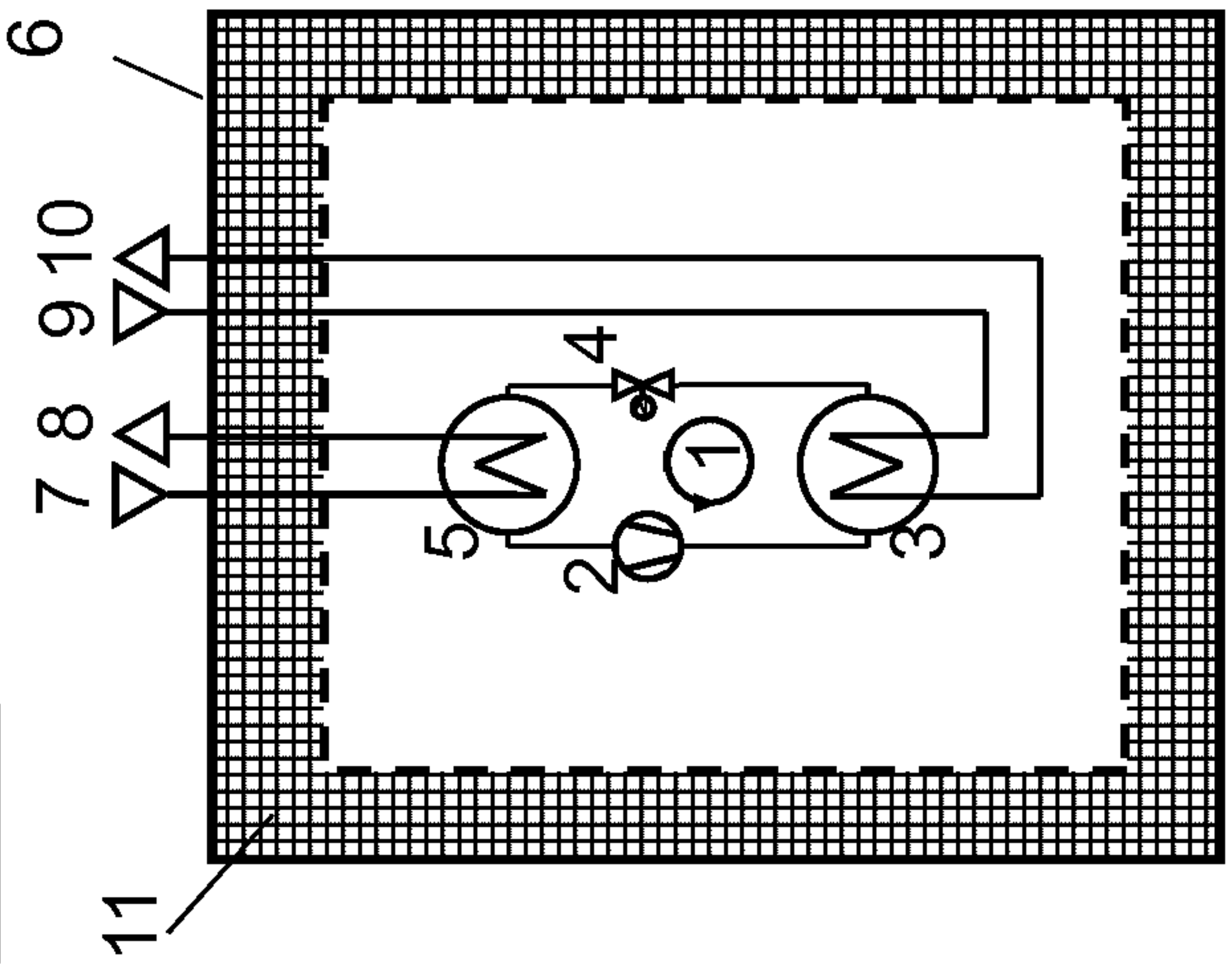

Fig. 2