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Description

The invention relates to irregular states in cooling circuits, in which a working fluid acting as a coolant 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 laevorotary 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,
- 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.

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 in air recirculation mode cleans the air in the housing. 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.

US 2005/0126264 A1 describes a manually operated device for detecting leakages which has a sensor head with sensors. These sensors can also send and receive light impulses, for example in the UV range. The sensors serve mainly to detect chemical properties of the substances which escape in the case of leakages.

US 2011/0146801 A1 describes a device for injecting additives into a closed system by means of a service connection in the high-pressure section of a thermal pump, an air conditioning system or a freezer. The additives can serve to make escape points visible in the case of leakages.

Furthermore, DE 195 25 064 C1 discloses a device according to the preamble of claim 1 for the secure implementation of a laevorotatory thermodynamic Clausius-Rankine cyclic process by means of an inflammable working fluid.

The known systems are however not capable of detecting and reporting the precise location of the leakage, neither are they capable of repairing the leakage automatically. The task of the invention is thus to make available a device which is suitable to detect the precise location of the leakage. Said device is supposed to report said location and ideally automatically repair the leakage.

The invention solves the task with a device according to claim 1. It is a device for the secure implementation of a laevorotatory thermodynamic Clausius-Rankine cyclic process by means of an inflammable working fluid, which in gaseous state under atmospheric conditions is heavier than air and is guided in a closed, hermetically sealed working fluid circulation, having

- at least one compressor for working fluid,
- at least one relaxation unit for working fluid,
- at least two heat exchangers for working fluid having respectively at least two connections for heat exchange fluids,
- a sealed housing which includes all devices connected to the close working fluid circulation and can include further devices,
- wherein to the working fluid is added a liquid which fluoresces under UV light or a fine-particle salt which fluoresces under UV light,
- in the interior of the housing are mounted a plurality of light sources which emit UV light,
- in the interior of the housing is mounted at least one CCD chip which detects fluorescing light and has a UV filter,
- the CCD chip outputs a signal when it detects fluorescing light and specifies the direction from which this signal comes, and

- in the interior of the housing is arranged a plurality of mirrors such that fluorescing light, which becomes visible in the case of leakages, is mirrored onto the CCD chip.

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 addition of the liquid which fluoresces under UV light, or to the fine-particle salt which fluoresces under UV light can be undertaken continuously or once at the filling.

This achieves that at a small leak position moreover the working fluid also a liquid which fluoresces under UV light or a fine-particle salt which fluoresces under UV light emerges from this leak position. While the working fluid is gaseous under the interior conditions of the housing, the fluorescing fluid or the fluorescing salt remains at the leak position. This is excited to luminesce by the light sources, which are as a rule LEDs. This luminescing is detected by the CCD chip, as a result of which a leakage is inferred.

Here, care must be taken that the radiated UV light has no proportions of visible light which could result in a false signal in the CCD chip. Where appropriate, the CCD chip is to be equipped with appropriate colour filters which filter out light which is transmitted from the UV light sources and does not correspond to the frequency spectrum of the desired fluorescence.

Means which can serve as fluorescing liquids or salts are generally known in the prior art and can be obtained commercially for inflammable working fluids such as for example propane or R290. For example, fluorescein or its disodium salt uranine, which luminesce is bright green when excited by UV, can be used.

Embodiments of the invention concern the CCD chip. By reason of the prices which are nowadays low, also several CCD chips of this sort can be used. Differently from in commercial digital cameras, however, these should not generate any sharp images, but rather determine the source of the fluorescent light. What is important here is that every corner, every pipe, every pipe connection and every component which conducts working fluid is observed from all sides and that leakages are unable to occur at any invisible, hidden places.

For this reason, the CCD chip has either a wide-angle lens without aperture, which facilitates a panoramic view, preferably this is a wide-angle lens or so-called fisheye. Or the chip is in the form of a compound eye, such as is commercially obtainable in the case of micro-lenses. In this manner, it is possible for one specific pixel of the CCD chip to be assigned in each case to each solid angle, one thus experiences in this manner from where the light signal comes which indicates a leakage. In the first instance only traces of light can be detected which reach the CCD chip directly.

Further embodiments of the inventions concern the means of making it possible to detect also the remaining traces of light. In order also to detect leakages which are hidden from other apparatus devices or which are located on rear sides or undersides, a multiplicity of mirrors is arranged in the interior, which divert such traces of light onto the CCD chip. In many cases, it is sensible to use for this purpose mirrors which are curved in a defined manner such as concave mirrors or parabolic mirrors. Conclusions can then be reached indirectly regarding the appropriate leakage positions, using the calculation of the rays' process.

The precision can be increased when always in each case two traces of light from the same light source meet on the CCD chip from different mirrors and in this manner an adjustment or correction of errors can take place. The same effect can be also achieved by using several CCD chips, although these are more expensive than mirrors.

In a further embodiment of the invention it is provided that an evaluation unit is connected downstream from the CCD chip which determines from the light signals of the individual pixels the locations at which fluorescence emerges and forwards these locations to a control unit which where appropriate triggers an alarm or security measures.

One of these security measures is the addition of a sealant to the working fluid, in order to close small leakages. To this end, it is provided that the sealant is stored in a separate container which is connected via a controllable connection to the working fluid circulation and can be channelled into the working fluid circulation in an automatically controlled manner. The device can be built according to EP 2 918 987 A1, wherein the piston 40 shown there is to be replaced by a controllable hydraulic cylinder. The patent proprietor of EP 2 918 987 A1 Errecom offers also a sealant licensed for R290 under the commercial name "Extreme White", which can be used here.

In the case that a small leakage is detected, the signal is then given that sealant is to be supplied automatically and thereafter it should be checked whether the leakage still exists.

The invention will now be described in more detail in outline with reference to figure 1.

shows a schematic diagram of a cooling circuit 1 having a compressor 2, a condenser 3, a relaxation unit 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 flammable working fluid propane, which is also known under the name R290, to which is added a liquid which fluoresces under UV light such as fluoreszein or a fine-particle salt which fluoresces under UV light such as uranine.

The UV-LEDs 11 illuminate the interior of the housing with UV light. This illumination can take place continuously or over predefined timeslots. If working fluid emerges at a leak position 12, the fluorescing agent, which in contrast to the evaporating propane remains, effects a light signal 13 as a result of the UV excitation. This light signal 13 is diverted by means of the mirrors 14 onto the CCD chip 15, the illuminated pixels of which specify the two room corners from which the light signal originates. From this, the evaluation unit 16, which has the coordinates and the alignment of the mirrors, calculates the location of the leakage as well as the probable size.

In the case that it is a small leakage, sealant is supplied to the working fluid by means of the sealant feed 17 and after a short time it is checked whether the leakage has been successfully sealed.

List of reference signs

1 cooling circuit
2 compressor
3 condenser
4 relaxation unit
5 evaporator
6 housing
7 heat source connection
8 heat source flow pipe
9 heatsink flow pipe
10 heatsink connection
11 UV LEDs
12 leak position
13 light signal
14 mirror
15 CCD chip
16 evaluation unit
17 sealant feed

Patentkrav

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

- mindst en kompressor (2) til arbejdsfluidet,
- mindst en afspændingsanordning (4) til arbejdsfluidet, og
- mindst to varmevekslere (3, 5) til arbejdsfluidet, hver med mindst to forbindelser (7, 8, 9, 10) til varmevekslerfluider, og med
- et tætnet hus (6), som omfatter alle anordninger forbundet til det lukkede arbejdsfluidomløb og kan omfatte yderligere anordninger,

kendetegnet ved, at

- der til arbejdsfluidet tilsættes en under UV-lys fluorescerende væske eller et under UV-lys fluorescerende fint spredt salt,
- i husets indre er der anbragt en flerhed af lyskilder (11), som udsender UV-lys,
- i husets indre er der anbragt mindst en CCD-chip (15), som detekterer fluorescerende lys, og som har et UV-filter,
- CCD-chippen udlæser et signal, når den detekterer fluorescerende lys og angiver retningen, hvorfra dette signal kommer, og
- i husets (6) indre er der indrettet en flerhed af spejle (14), således at fluorescerende lys, hvilket bliver synligt ved lækager, spejles på CCD-chippen (15), idet indretningen har en flerhed af lyskilder (11), som udsender UV-lys, den mindst ene CCD-chip (15) og flerheden af spejle (14).

2. Indretning ifølge krav 1, **kendetegnet ved, at** CCD-chippen (15) har et vidvinkelobjektiv uden blænde, som muliggør en panoramaudsigt.

3. Indretning ifølge krav 1, **kendetegnet ved, at** CCD-chippen (15) har et facetøje, som muliggør en panoramaudsigt.

4. Indretning ifølge et af kravene 2 eller 3, **kendetegnet ved, at** til hver pixel af CCD-chippen (15) tildeles i hvert tilfælde en rumvinkel.

5. Indretning ifølge krav 1, **kendetegnet ved, at** som en flerhed af spejle (14) anvendes buede spejle, hvis brændpunkt er rettet mod CCD-chippen (15).

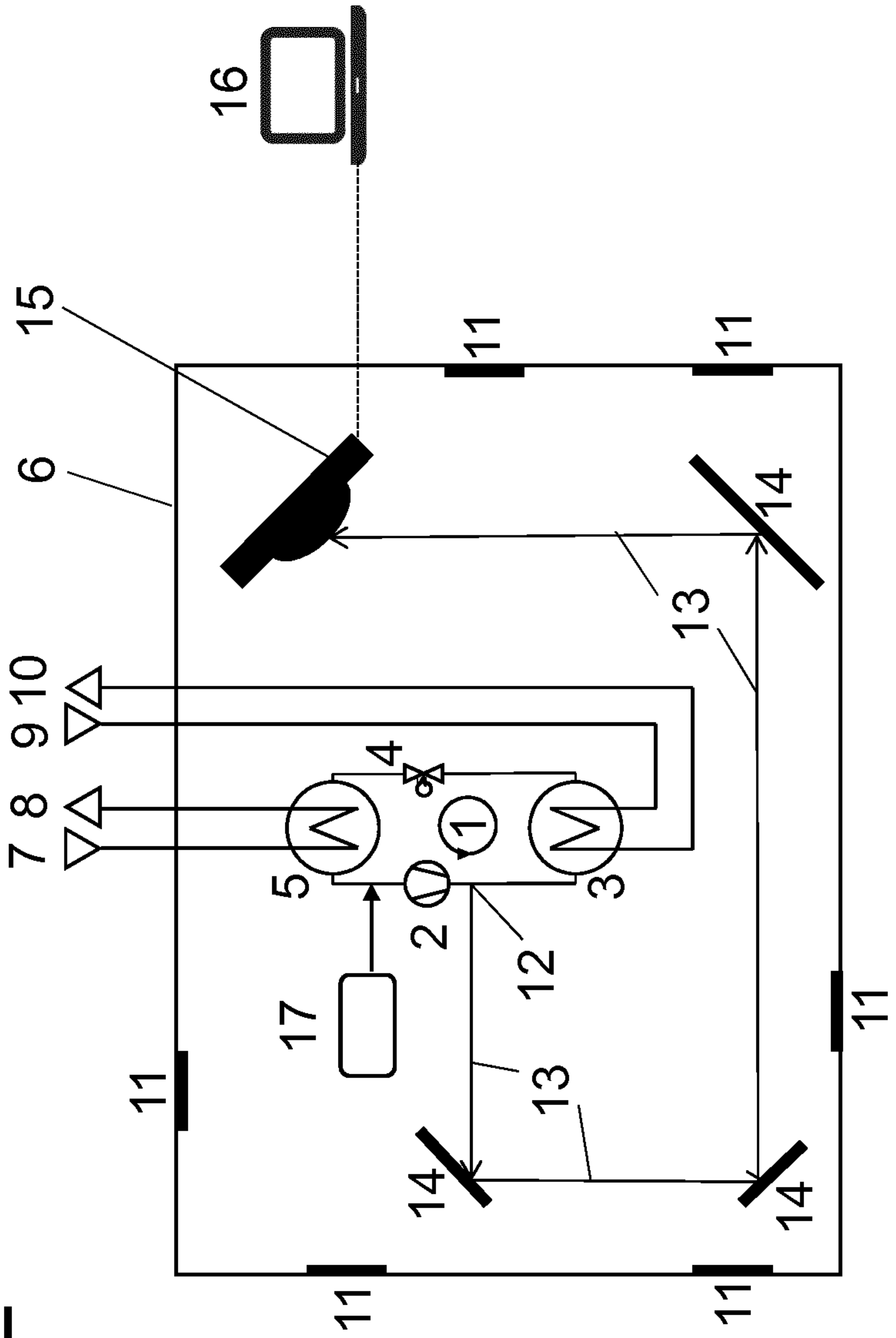
6. Indretning ifølge et af kravene 1 eller 5, **kendetegnet ved, at** hver placering, ved hvilken en lækage kan forekomme, overføres til CCD-chippen (15) gennem respektivt mindst to spejle (14).

7. Indretning ifølge et af kravene 1 til 6, **kendetegnet ved, at** CCD-chippen (15) efterfølges af en evalueringsenhed (16), som fra lyssignalerne af de individuelle pixels bestemmer placeringerne, ved hvilke fluorescens optræder, og videresender disse placeringer til en styreenhed, som eventuelt udløser en alarm eller sikkerhedsforanstaltninger.

8. Indretning ifølge et af kravene 1 til 7, **kendetegnet ved, at** et tætningsmiddel tilsættes arbejdsfluidet, for at lukke små lækager.

9. Indretning ifølge krav 8, **kendetegnet ved, at** tætningsmidlet opbevares i en separat beholder, som er forbundet via en styrbar forbindelse til arbejdsfluidkredsløbet, og som kan føres ind i arbejdsfluidkredsløbet på en automatisk styret måde.

Fig. 1



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