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(54) Device for heat transfer by compression and expansion of gases

(57) A heat transfer device comprises two sub-systems, separated by a movable element, for instance a piston (P). The first sub-system is near the element (1) to be cooled and in thermal contact with said element (1) and comprises a first chamber (4) comprising a saturated gas, the second sub-system comprises a second chamber (18) in thermal contact with a cooled surface, the first and second chamber (4,18) being separated by the movable element (P). In the second chamber (18) a second gas is present which condenses on a cold surface when the second gas is pressurized by the movable element (P). Conduits lead the condensed liquid towards the element (1) to be cooled. The liquid evaporates in a third chamber (3) in thermal contact with the element (1) to be cooled and the first chamber (4). This preferred embodiment enables in a simple, yet efficient and reliable manner to provide a movable element (P) which separates the two gases, while also moving with little friction.

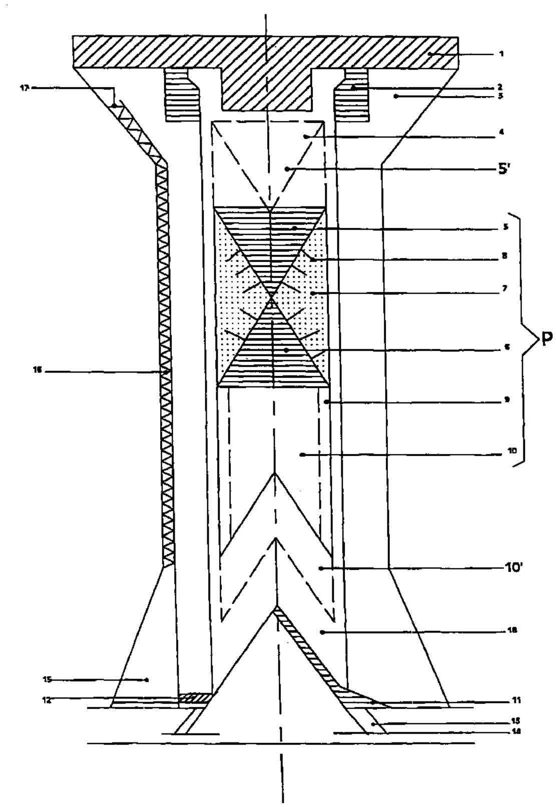

Figure 2

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Description

[0001] This invention relates to a device for heat transfer from an element to be cooled to a heat exchanger.

[0002] Devices for heat transfer called caloducts and more and more performing heat exchangers have been on the market since approximately 20 years. The known devices often use a cycle in which an element (such as a refrigerator or a pump or any device which needs to be cooled) is cooled by a compression-evaporation cycle or compression-expansion cycle. The known devices, however, are limited in the amount of heat (calories) they are able to transport in a given volume.

[0003] In addition to this, in many cases their efficiency is dependent on their position, i.e. whether they are vertically or horizontally oriented (or in an intermediary position).

[0004] Also the known devices for heat transfer rely on the use of pumps to drive the compression-expansion cycle which pumps take up space, require outside energy supply and may break down and furthermore form sources of heat.

[0005] The present invention has as an object increase the heat transport density, i.e. the amount of heat that can be transported in a given volume and without requiring external energy supply.

[0006] To this end the device in accordance with the invention comprises a first chamber in which a saturated gas is enclosed said chamber being in thermal contact with the element to be cooled, a second chamber in which a second gas is enclosed, the second chamber having a condensation surface and means for cooling the condensation surface, the two chambers being separated by a movable element, the device further comprising a means to transport condensed fluid of the second gas from the condensation surface to the element to be cooled in a third chamber, the first chamber being also in thermal contact with the third chamber and a means for returning second gas from the third to the second chamber in the gaseous phase.

[0007] The principle mode of operation of the device is as follows:

[0008] The saturated gas is heated by the element to be cooled. This will greatly increase the pressure in the first chamber, causing the movable element to move and compress the second gas in the second chamber. This will cause the second gas will liquefy at the condensation surface, and because of the increased pressure in the second chamber the liquid will be transported by the one-way transport means to the element to be cooled. The liquid will evaporate in the third chamber, cooling the element to be cooled, but also the first chamber. This evaporation increases the pressure in the third chamber, causing the second gas to be forced into the second chamber, at the same time decreasing (because the first gas is cooled) the pressure in the first chamber. The movable element will move back, the saturated gas wilt be heated again, so that the pressure in the first chamber is increased which will start the cycle again. The result is that a evaporation-cooling cycle is started which is in fact driven by the heat supply. A very efficient cooling results. There are no external sources of energy, such as pumps necessary. The movable element separates the two chambers and thus separates the two gases preventing mixing of the two gases. Such mixing may have a negative effect on the cooling efficiency of the device. Preferably the device comprises a piston having a high magnetic coercivity and a magnetisable liquid is used for sealing. This preferred embodiment enables in a simple, yet efficient and reliable manner to provide a movable element which separates the two gases, while also moving with little friction.

[0009] The present innovation permits an increased amount of heat to be transported in a very small volume and the possibility of precise adjustment and work, regulated by the feedback of liquid from the condensation side. Preferably the means to transport and/or the means for returning comprise one-way systems for instance one-way valves.

[0010] Such systems ensure that the flow of material is and cannot but be in the desired direction. This increases the efficiency of the device.

[0011] Preferably a part of the first chamber being close to the element to be cooled, and removed from the second chamber, is thermally isolated from the third chamber.

[0012] This has the advantage that, when the volume of the first chamber is small (i.e. during the part of the cycle in which the saturated gas is to be heated to move the movable element back towards the second chamber), the first chamber is not cooled by the second gas in the third chamber. The saturated gas will be rapidly heated, which increases the speed of expansion in the first chamber.

[0013] These and further aspects of the invention will be further explained and illustrated by means of the figures in which a preferred embodiment of the device is schematically shown.

Figure 1 shows schematically a device according to the invention
Figure 2 illustrates the operation of a device according to the invention.

[0014] For ease of understanding in the further discussion the first chamber will be described as 'expansion chamber', the second chamber as 'condensation chamber' and the third chamber as 'evaporation chamber'. The first gas will be described as 'saturated gas', the second gas as 'refrigerant gas'.

[0015] Figure 1 shows schematically a device according to the invention. In the figure 1:

1. is the element to be cooled
2. is an element made of thermally isolating material surrounding the upper (i.e. near the element 1) part of the expansion chamber;
3. is the third chamber (evaporation chamber) in which the refrigerant gas evaporates;
4. is the first chamber (expansion chamber) for the saturated gas expansion;

P. is the movable element, in this exemplary and preferred embodiment formed a part by a piston, which piston comprises two sub-pistons, a sub-piston comprising parts 5, 6 and 7 for transmission of forces, and a sub-piston comprising part **10** for compression of gas in the second chamber 18.

5. A part of the piston for transmission of forces. This piston has a given magnetic polarity;
6. is the opposed part of the same piston with the inverse magnetic polarity;
7. is the volume reserved to a magnetisable liquid for sealing.
8. schematically indicates caverns and magnetic forces that keep the magnetisable liquid in place;
9. anti-frictional surface of the compression part (10) providing boundary lubrication
10. is a part of the piston to compress the refrigerant gas;
11. is a one-way (diode) valve for the letting gas in from chamber 3 into chamber 18 (the second chamber) when the movable element P moves towards element 1 (expansion in the second chamber 18);
12. is a one-way (diode) valve for letting condensed gas out of chamber 18 during the compression stage of the second chamber 18 (when movable element P moves towards part 14;
13. are cooling conductors of the heat exchanger with the external part;
14. is the inlet and outlet conduct of the cold source;
15. is a volume reserved to the condensed liquid;
16. is a spongy part which, due to capillary action transports the liquid to part 17;
17. is the inlet of the liquid in the evaporation chamber 3;
18. is the second (condensation) chamber.

[0016] The expansion chamber 4 comprises a saturated gas, able to exert a big pressure under the action of an increase of temperature. This gas will be rapidly cooled in its expansion phase by thermal contact with the third chamber. This heat exchange forces the gas in the first chamber to re-contract to its initial position. A movable element, preferably a special piston as shown in figure 1, transmits the expansion force towards the second condensation chamber. The device according to the invention therefor forms a kind of caloduct (heat conduction duct) in which two gases are used, one expanded by temperature in the expansion chamber 3, the other compressed by the first in the condensation chamber 18. Additionally, the two gases interact in compression - expansion, via a movable element P, acting as a force transmitter that forms a part this device. The movable element separates the two chambers and thus separates the two gases preventing mixing of the two gases. Such mixing may have a negative effect on the cooling efficiency of the device.

[0017] The element P is preferably a piston having two elements, preferably double inverse cones 5 and 6 that are bound to each other, preferably by means of magnetic forces. For that end the cones preferably have a very high magnetic coercivity. The elements 5 and 6 are preferably made of a material having a high magnetic coercitivity and contains a magnetisable liquid, around its middle, facilitating in this way the translation of the piston forming at the same time hermetic seals. This preferred embodiment enables in a simple, yet efficient and reliable manner to provide a movable element which separates the two gases, while also moving with little friction.

[0018] Losses of magnetisable liquid on the walls of this piston can be reduced or minimized or even eliminated using one or more of three effects:

- The cones have poles formed by permanent magnets and reciprocally attracted, the magnetisable liquid being placed between these poles.
- The walls of the part in which the piston is moving have a high degree of the polishing. This reduces the ruggedness of the walls. The magnetisable fluid preferably has a very strong superficial tension to counteract the counter-forces of the gases acting in a synergetic way within small tolerances. This combined with the high degree of polishing ensures a smooth operation of the piston (thus little losses due to friction) while still maintaining a good sealing action between the first and second chamber.
- The internal walls of the cones are rough and are provided with caverns. Said caverns increase the attraction, more in particular by increasing superficial tension and magnetic forces due to magnetic effects, providing thus a capacity for retaining the magnetisable liquid. This ensures that the magnetisable liquid remains attached to the cones and does not stick to the walls or is lost in any other way. A loss of magnetisable liquid could jeopardize the sealing action of it. Mercury is preferred as a liquid metal because it remains liquid even at low temperatures.

[0019] The condensation chamber 18 interacts with the piston 10 for transmission of forces in the following way:

1. The compression piston 10 is attached to a part

of the transmission piston (parts 5, 6, 7) to which it is bound on the side of the condensation chamber 18.

2. This piston 10 is preferably internally so formed that the bottom of its cylinder offers a maximum surface for cooling and that its diameter is the same as the diameter of the expansion chamber 4 of the saturated gas. Using other internal shapes, compression in two stages is also possible.

3. The cylinder and the piston are preferably made of special materials which do not appreciably expand in the limits of temperature and under the given pressures. The sides of the compressing piston, preferably as an added precautionary measure, form an anti-frictional surface by boundary lubrication or solid lubrication, which is obtained by adding e.g. an additive on the basis of MoS_2 (Molybdene Bisulphite) to the ceramic material.

[0020] At the moment of the compression phase (when piston 10 is at position 10' indicated in figure 2), the cooling of an exterior source via part 14 ensures the condensation of the refrigerant gas in second chamber 18 because the bottom is overcooled. The liquid is transported, via the valve 12, the chamber 15 and the ducts 16 in the third chamber 3, also called gazificator, which is situated around at least a part of the expansion chamber 4 of the saturated gases. This cools the saturated gas in chamber 4, leading to a contraction of the gas in chamber 4 so that the piston moves upwards towards element 1 (to or near to extreme position 5' in figure 2). This movement of the piston also causes gas to return from chamber 3, via valve 11 to chamber 18. At the extreme position 5' the gases in the chamber 4 are no longer or at least to a much smaller degree cooled by the evaporating gases in chamber 3. In particular, in this preferred embodiment, the part 2 made of thermally isolating material ensures that the gas in chamber 4 is hardly cooled, but instead, due to element 1 heated. This leads to a rapid expansion of the saturated gas in chamber 4, pushing movable element P away from element 1. This causes cooling of the saturated gas in chamber 4, condensation of gas in chamber 18, which condensed liquid then leaves chamber 18 via valve 12 as explained above, after which the cycle recommences.

[0021] The device therefor is a self-contained device in which a refrigerant gas is cycled not needing any outside energy supply, because the energy for the cycle is in fact supplied by heat from element 1. This enables very compact designs enabling higher refrigerating power per volume, no electrical leads to the outside world and less break-down. Cooling of the condensor 14 can be done by circulation of cooling liquid.

[0022] It will be clear that, within the framework of the invention many variations are possible. So is, in the shown preferred exemplary embodiments, the movable element formed by a special preferred piston. This is, however, for the invention in its broadest sense not to be regarded as a restriction.

<u>Summarized the invention can be described as follows.</u>

[0023] A heat transfer device comprises two sub-systems, separated by a movable element P, for instance a piston. The first sub-system is near the element to be cooled and in thermal contact with said element and comprises a first chamber comprising a saturated gas, the second sub-system comprises a second chamber in thermal contact with a cooled surface, the first and second chamber being separated by the movable element. In the second chamber a second gas is present which condenses on the cooled surface when the second gas is pressurized by the movable element. Conduits lead the condensed liquid from the second chamber towards the element to be cooled. The liquid evaporates in a third chamber in thermal contact with the element to be cooled and the first chamber. Preferably the device comprises a piston having a high magnetic coercivity (thus generating a strong magnetic field) and a magnetisable liquid is used for sealing. This preferred embodiment enables in a simple, yet efficient and reliable manner to provide a movable element which separates the two gases, while also moving with little friction.

Claims

1. A device for heat transfer from an element to be cooled to a heat exchanger, characterized in that the device comprises a first chamber in which a saturated gas is enclosed said chamber being in thermal contact with the element to be cooled, a second chamber in which a second gas is enclosed, the second chamber having a condensation surface and means for cooling the condensation surface, the two chambers being separated by a movable element, the device further comprising a means to transport condensed fluid of the second gas from the condensation surface to the element to be cooled in a third chamber, the first chamber being also in thermal contact with the third chamber and a means for returning second gas from the third to the second chamber in the gaseous phase.

2. Device as claimed in claim 1, characterized in that the means to transport and/or the means for returning comprise one-way valves.

3. Device as claimed in claim 1 or 2, characterized in that a part of the first chamber being close to the element to be cooled, and removed from the second chamber, is thermally isolated from the third chamber.

4. Device as claimed in claims 1, 2 or 3, characterized in that the movable element comprises a piston with a strong magnetic coercivity and having a magnetisable liquid.

5. Device as claimed in claim 4, characterized in that the piston comprises two permanent magnets and a liquid metal to form a movable seal between the first and second chamber.

6. Device as claimed in claim 5, characterized in that the permanent magnets are cone-shaped.

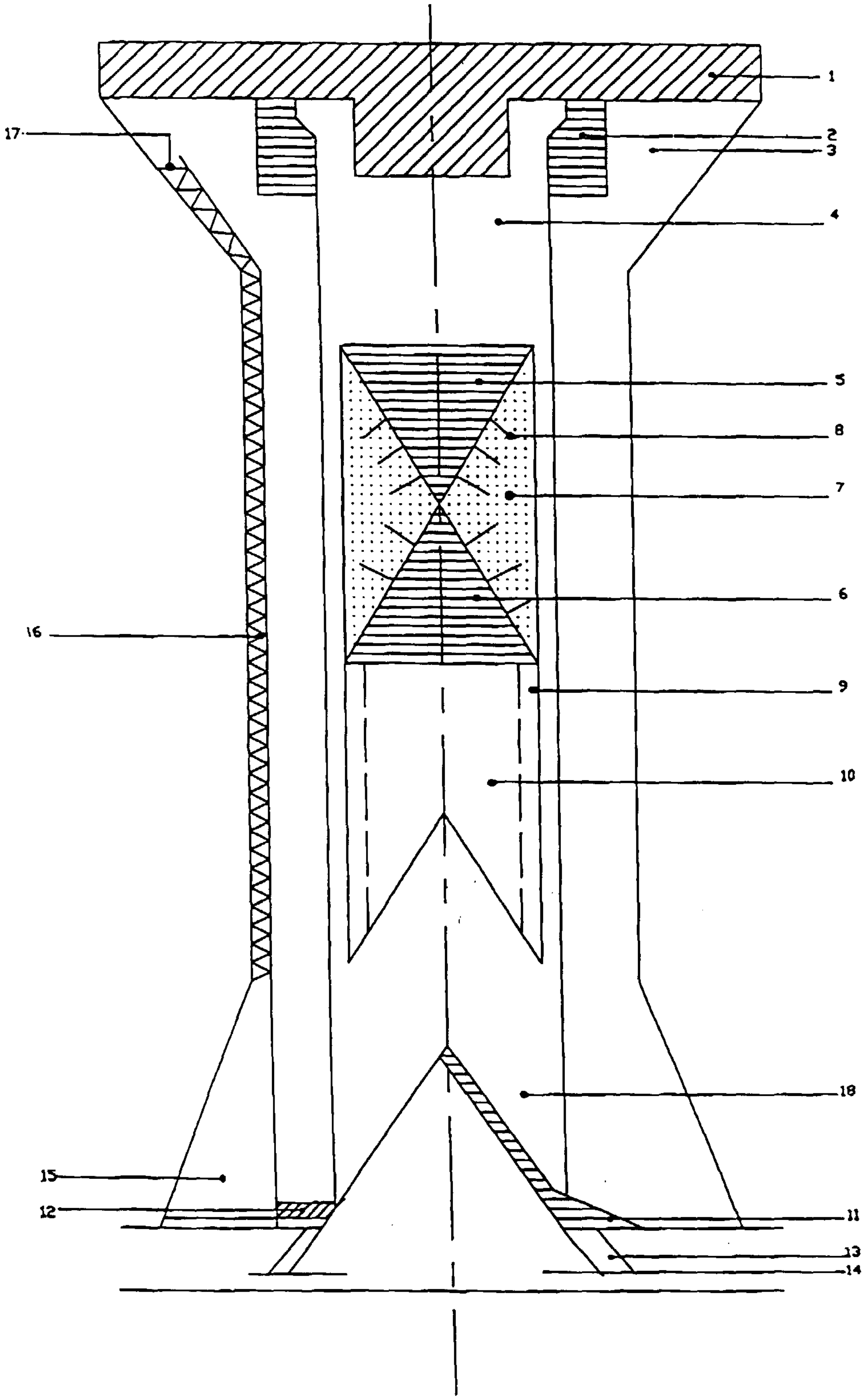

Figure 1

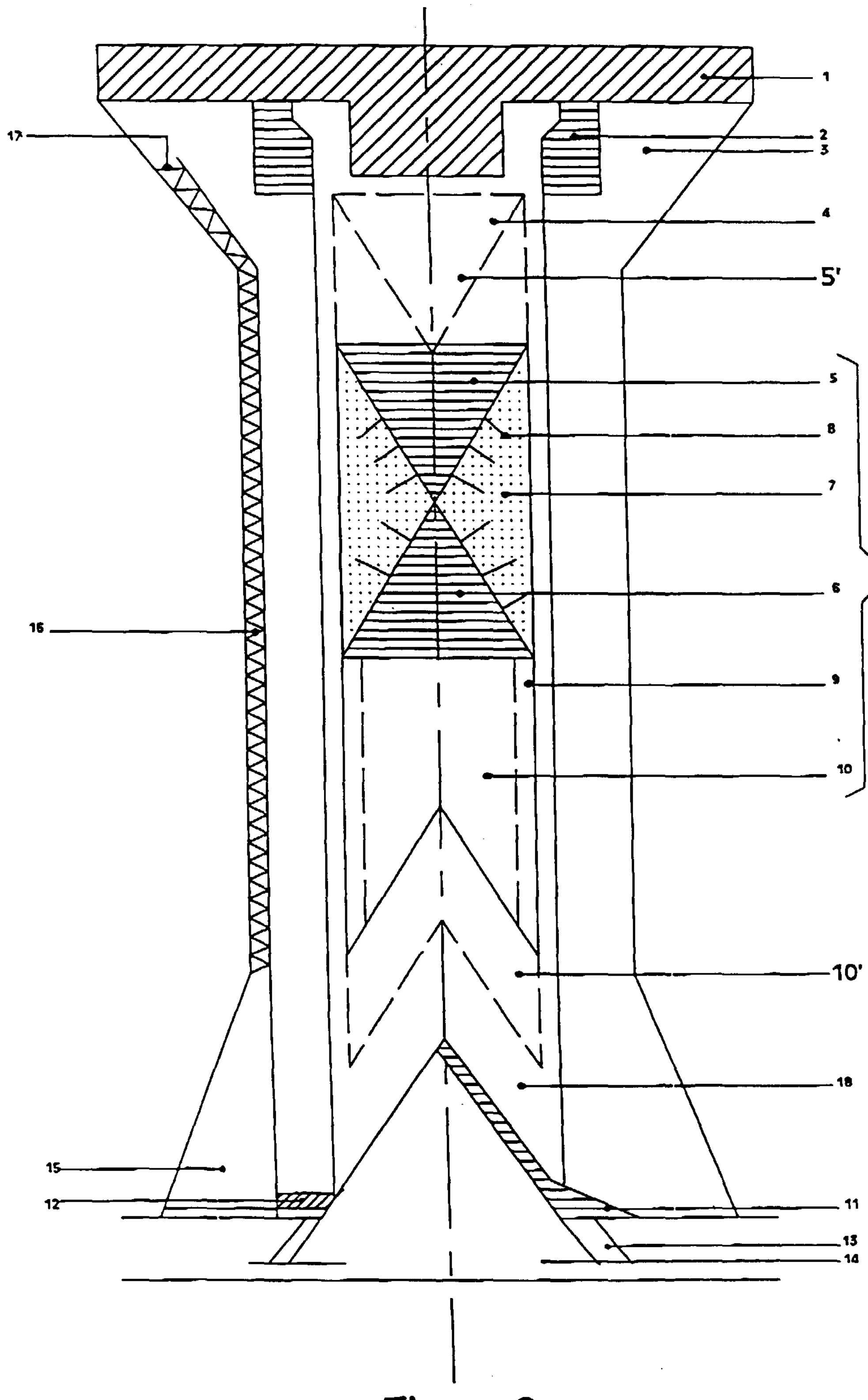

Figure 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 87 0269

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 720 177 A (KIRBY JAMES R ET AL) 24 February 1998 * column 4, line 5 - column 8, line 53; figures 1-13 *	1,2,4	F25B25/00
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 June 1999	Boets, A

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 87 0269

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