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(54) REGENERATIVE ROTARY REFRIGERATOR/HEAT EXCHANGER WITH INTERMEDIARY FLUID AND PHASE CHANGE

(57) The invention relates to a refrigerator/heat exchanger device which uses the phase change capacity of the intermediary exchange fluid between the temperatures of the hot part and the cold part and the centrifugal force produced by the rotation in order to perform the function thereof continuously and efficiently. The inventive device can be used as a heat exchanger between two fluids, namely one cold fluid and one hot fluid, and as a refrigerator for any rotating hollow element which is immersed in a hot zone and another cold zone and which can be filled with a fluid that can change phase between the temperatures of the hot and cold zones.

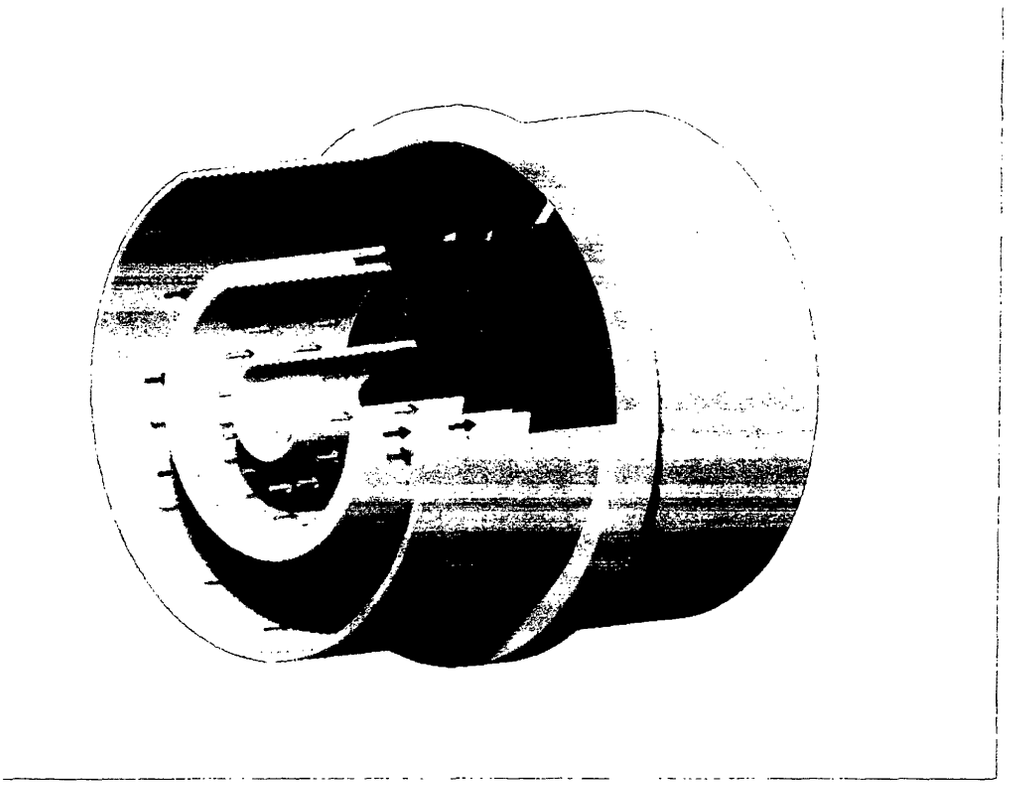


Figure 1

EP 1 555 501 A1

Description

Introduction

[0001] Due to the increasing need of cooling / heating fluids in a more efficient way and using less space, and so reducing the resources used, it appears the necessity of designing more efficient and compact heat exchangers that obtains a better energy efficiency in the heat exchange.

[0002] In most of applications where heat exchangers are used to cool - heat a fluid usually is also present the necessity of heat - cool another fluid for any other requirement, if this heating function is done using the same exchanger that is used to cool the other fluid the efficiency of the whole process will be increased notably (regeneration).

[0003] Next pages describe the basis of a rotating - regenerative heat exchanger that is able to do in an efficient way the functions described in previous paragraph.

[0004] The use of this device is also possible in the cooling of blades in the hot gas path areas, showing a clear application as cooler of materials located in hot gas areas, increasing this way the useful life of this components, as well as their substitution by others of lower heat resistant characteristics reducing costs.

[0005] Also, taking in account its rotative concept and the amount of energy that in the way of pressure and kinetic energy the fluids to cool - heat usually have, with an adequate blade design a turbine type device can be obtained simultaneously extracting power from both fluids.

Description and working concept

[0006] First of all fluids to heat - cool have to be conducted to the heat exchanger using concentrical conduction, being the cooling fluid in the inner pipe and the fluid to cool down in the exterior one. Both fluids can circulate in the same direction or in opposite directions, being more effective the second one to also increase the heat exchange across the concentrical pipes.

[0007] Using the concentrical pipes both fluids are conducted to the hollow rotating blades that are the heat exchange pieces, both fluids get across the blades without mixing, because there is a sealing system between both fluids, and at the exit of the blades the fluids are conducted using the concentrical scheme to the areas where they are required.

[0008] Concentrical conduction are only required at the inlet and outlet of the heat exchanger, being any other disposition possible before or after the exchanger.

[0009] All the heat exchanger is shown in schematics in figure 1.

[0010] Refrigeration takes place in the hollow blades as follows. In the inner hollow part of the blades there is a liquid that is able to have a phase change to gas between the temperatures of the cooling and cooled fluids (i.e. at cooling fluid temperature the inner fluid of the blades is liquid and at the cooled fluid temperature is gas).

[0011] When the inner fluid circulates in the external area of the blades that is in contact with the hot external fluid this was will make the phase change of the inner liquid to gas. Being the heat exchange with phase change of the inner fluid the heat exchange efficiency is highly increased.

[0012] The fluid inside the blades gasified in the external area of the blade is rotating as well as the blade, and as long as the fluid located in the inner area of the blade is still liquid it will push down the gas to the inner part of the blade (this happens due to the rotation force on the liquid part of the fluid that is more dense that the gas phase and it is pushed to the external area of the blade), in this area the gas will be liquefied again because of the temperature of the external fluid circulating into the inner pipe that will be heated by the heat exchange phase of the inner blade fluid.

[0013] This working cycle is continuos , providing the centre of rotation of the blades is coincident with the centre of both concentrical conductions.

[0014] Figure 2 shows an scheme of the described process.

[0015] External and internal walls of the blades will be designed in a way that increases as much as possible the HTC, using ribs, turbulators, or whaterever improved design.

[0016] The rotation of the blades can be achieved using an external motor or, in order to get a better efficiency, using the energy available in the fluids to cool - heat designing the blades in an adequate mode. It can be seen a scheme of design of the blades powered by fluids in figure 3.

[0017] The transition of the fluids from the static zone (concentrical pipes) to the rotating one (blades) will be designed using adequate sealing systems depending on the fluids (i.e. labyrinth seals, gas seals, mechanical seals..).

[0018] As it has been commented previously the same device is also useful to cool down the material of the blades located in the hot fluid path, because as long as in the inner hollow are is all the time circulating a mixture of the inner gas liquid fluid, the temperature of this mixing is always lower than the one of the fluid located in the external area of the blade, so the blade material temperature is sensibly reduced.

[0019] To use the device in whatever of its applications is not required to use any other device or external cooling fluid, this reduces the cost of auxiliary pumping cooling device (cooling towers) for the external cooling fluid.

Application fields

[0020] The design in its heat exchanger version is ap-

plicable to whatever industrial field requiring an efficient heat exchange. Clear immediate application examples can be found in gas or steam turbines for the cooling of different stages, secondary airflow preconditioning or preheating of heavy fuels. In petrochemical or industrial plants to heat or cool several process fluids. In terrestrial vehicles, ships or planes to cool down engines and heating the air-conditioned for passengers. In air conditioning systems to reduce their size and achieve better efficiencies, ...

[0021] The design in its material cooling version it can be applied immediately in all type of turbo machinery that deals with hot fluids to refrigerate turbo machinery components located in the hot fluid path.

Figure description

[0022] Figures shown are only schemes not showing any dimension as long as these values will change depending on the application. The only point for showing this figure is to help on the description and location of the main components of the system.

[0023] Figure 4 shows cooling and cooling fluids circulating in the same direction to simplify the figure, not existing in the design any obstacle to make both fluids to circulate in different directions as we have told before.

[0024] Surfaces have also been represented without any HTC increasing device to ease the drawings.

[0025] In side view of figure 5 external cases has been turn transparent to facilitate the view of internal components.

[0026] Relationship between L1, L2, L3, D1, D2 & D3 will be fixed depending on the fluids to use, the flow to cool, the materials to use,... The number of cooling stages (discs) of blades will be also fixed taking in account the specific application.

[0027] Some of the major required data to dimension the system are next ones (and of course there can be others that can also play a role in the design):

- Mass flows of the cooling and cooled fluids.
- Adaptation capacity of the fluid from the normal piping on the system to the required concentrical disposition of the exchanger.
- Rotating speed of the blade and number of blades per stage.
- Pressure of the fluids in the system.
- Temperature reduction (on increase) that will be achieved using the exchanger.

[0028] Figure 6 shows a front view showing inlet of both fluids to the device.

[0029] Figure 7 shows the blades transparent to allow the viewing of the concentrical disposition of the concentrical conducts.

Claims

1. Heat exchanger - cooler regenerative with intermediate fluid and phase change, where the intermediate fluid is used to do the heat exchange between the hot and cold sides improving the exchange efficiency because the intermediate fluids is subjected to phase change during the exchange periods as it is described in the description annexed to this patent claim.

2. Equipment according to claims 1 to be used in whatever the industry as heat exchanger as well as in turbo machinery or rotating machinery as coolant for materials of the machinery itself.

3. Equipment according to previous claims, not depending on its dimensions, shape, finishing, number of blades, number of stages of blades, combined use with other devices or being part of those ones, materials for manufacturing the device, sealing systems to be used between rotating and static parts.

Amended claims under Art. 19.1 PCT

1. Heat exchanger - cooler regenerative with intermediate fluid and phase change, where the intermediate fluid is used to do the heat exchange between the hot and cold sides improving the exchange efficiency because the intermediate fluids is subjected to phase change during the exchange periods as it is described in the description annexed to this patent claim. The heat exchange is being done continuously between the intermediate interchange fluid and the hot fluid cooling the last one, and betweent the intermediate interchange fluid and the cold one heating this one. The hot and cold fluids circulate through concentrical conducts in the heat exchanger being the cold fluid in the inner area and the hot one in the external area. The intermediate cooling fluid is gasified when is in the area of the hot fluid and get condensed back when is in the cold fluid area. Due to the rotational movements of the hollow blades where the intermediate fluid is located, the liquid part of the fluid that is located in the inner area is pushed to the external area of the blade due to the rotational forces (because the density of the liquid is bigger than the one of the gasified part) making this way the gasified part to be sent back to the inner part of the blade. This process is repetitive being always condensation and vaporisation in the inner and outer areas of the hollow blades.

2. Equipment according to claims 1 to be used in whatever the industry as heat exchanger as well as

in turbo machinery or rotating machinery as coolant for materials of the machinery itself. Beyond its function as heat exchanger described in first claim the proposed system is also useful as internal cooling of components located in hot fluid areas. As long as the intermediate fluid is continuously changing from liquid to gas and from this back to liquid, this fluid is able to get a lot of hot from the hot areas that is going to be released in the cold one when condensation takes place. In this way the temperature inside the hollow blade is going to be more or less constant and of course lower that the one in the hot area getting this way an effective cooling of the blade material.

3. Equipment according to previous claims, not depending on its dimensions, shape, finishing, number of blades, number of stages of blades, combined use with other devices or being part of those ones, materials for manufacturing the device, sealing systems to be used between rotating and static parts.

Figures

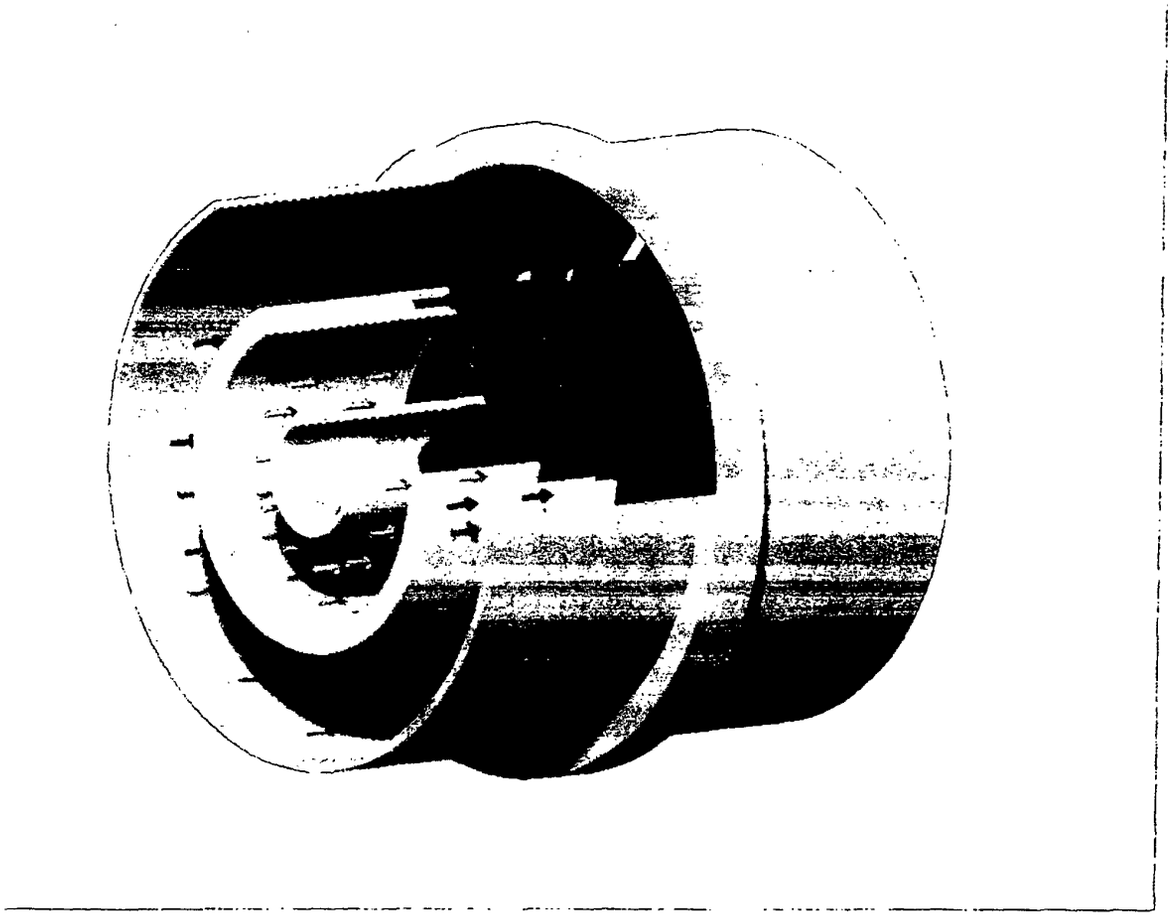
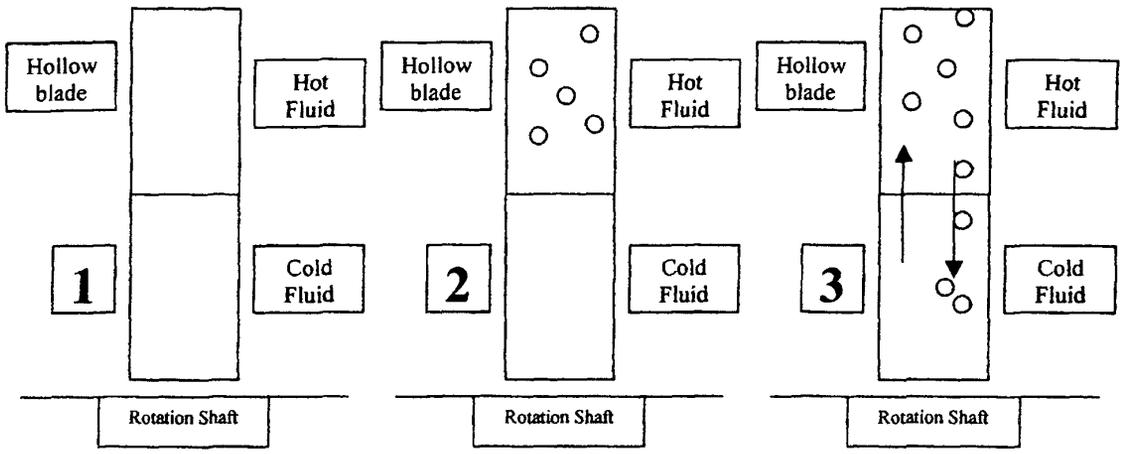


Figure 1



1. Blade rotating without being any change in the intermediate fluid. The intermediate fluid is liquid as long as hot and cold external fluids are not yet in the exchanger.
2. Both external fluids hot and cold are actually inside the heat exchanger. The external blade area located inside the hot fluid starts getting hot and in the intermediate cooling fluid inside the blade nucleation of small gas bubbles start to get vaporised as long as the phase change temperature has been overcome. The inner area of the intermediate cooling flow keeps on being liquid.
3. As long as the blade is rotating and the relative density of the liquid part of the intermediate fluid is bigger that the one of the vapour area, the liquid phase pushed by the rotational force goes to the external area of the blade, forcing the gas phase on that area to be push down to the inner part of the blade. As long as the inner part temperature of the blade is below the phase change temperature the vapour change to liquid. Mean while the liquid that did go to the external area has overcome its phase change temperature and is now gas and the cycle keeps on going.

Figure 2

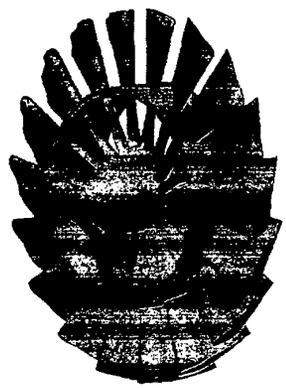


Figure 3

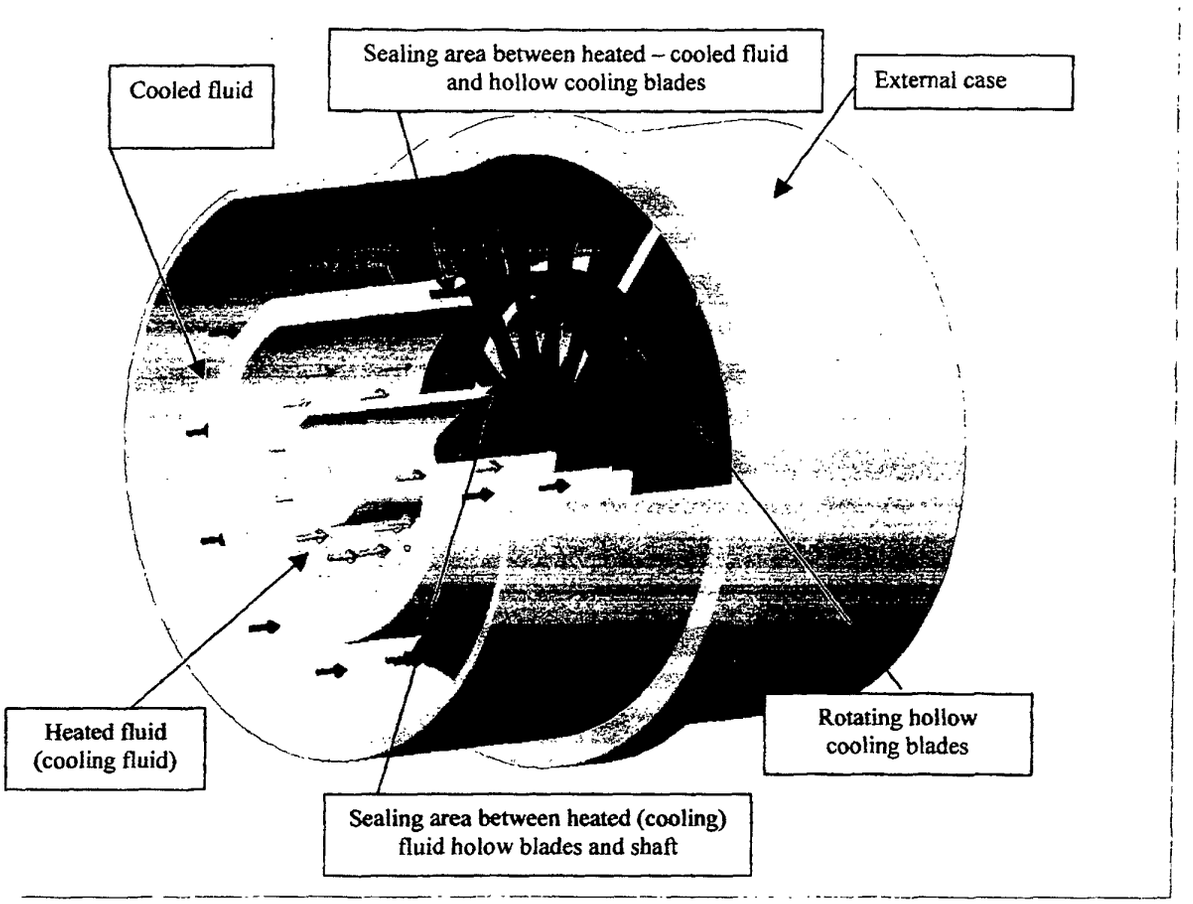

Cooled fluid
Sealing area between heated – cooled fluid and hollow cooling blades
External case
Heated fluid (cooling fluid)
Rotating hollow cooling blades
Sealing area between heated (cooling) fluid holow blades and shaft

Figure 4

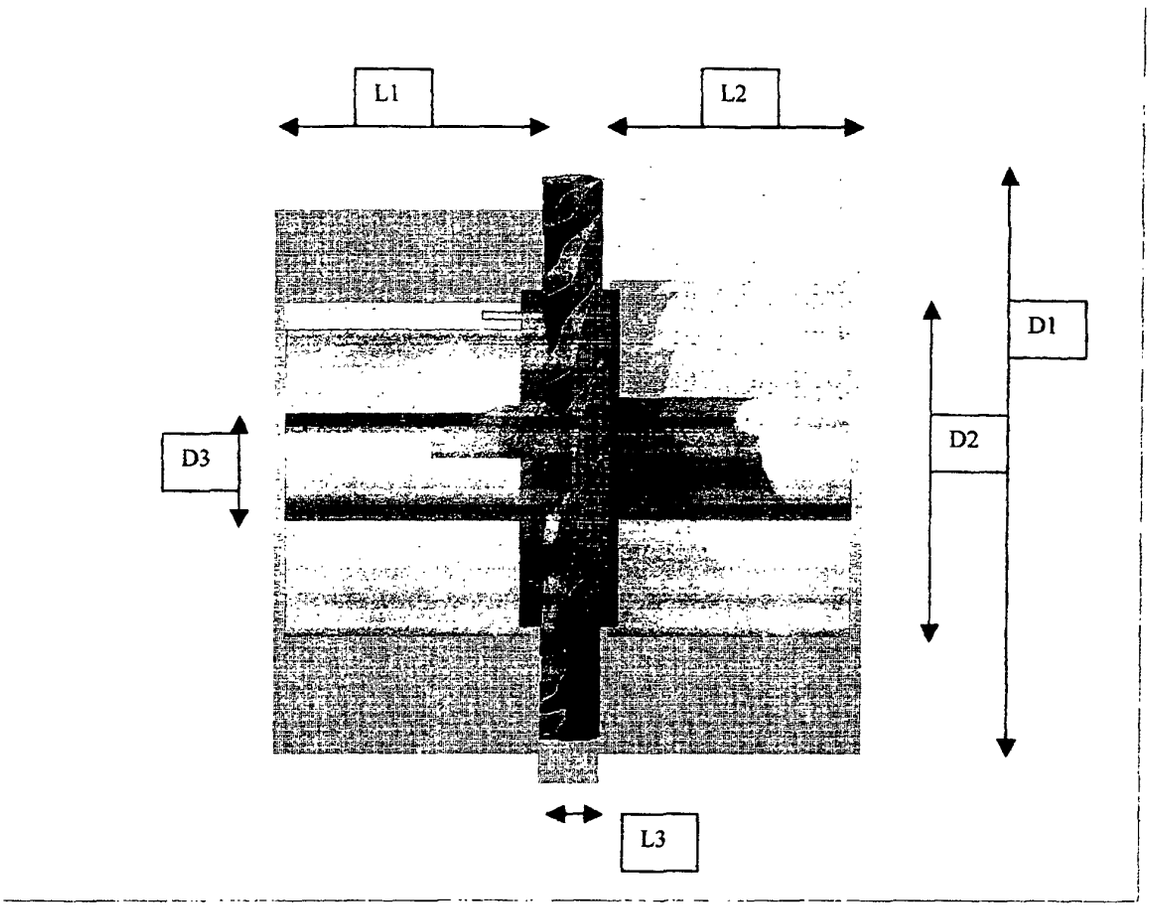


Figure 5

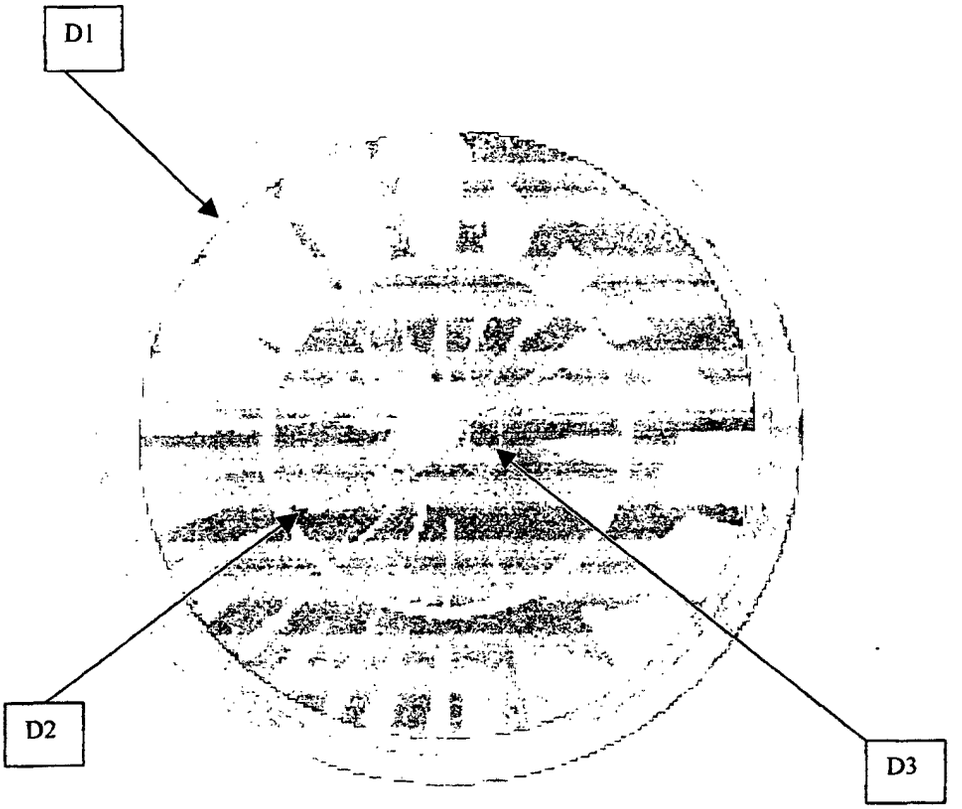


Figure 6

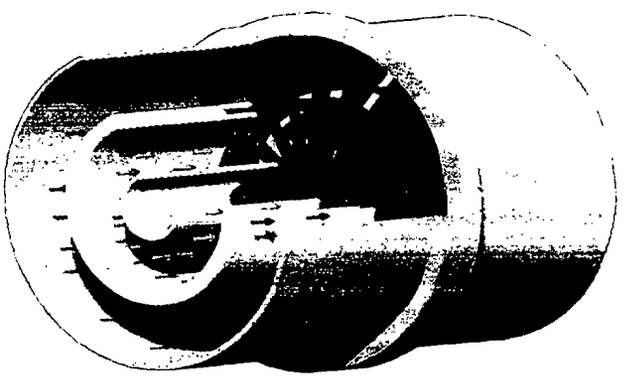


Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/ ES 02/00379

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7: F28D 11/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7: F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, OEPMPAT, PAJ, WPI.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 582 128 A (JARREBY) 15 April 1986 (15.04.86), column 2, line 66 - column 3, line 68; claim 1; figures 1, 2.	1-3
X	US 3 563 710 A (DEW et al.) 16 Febrero 1971 (16.02.71), column 2, line 50 - column 5, line 14; figures .	1-3
X	DE 34 31 713 A1 (JOSEF VAN BAAL GmbH) 18 July 1985 (18.07.85), abstract ; figures.	1-3

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 October 2002(31.10.02)	06 November 2002 (06.11.02)
Name and mailing address of the ISA/ S.P.T.O	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/ ES 02/00379

Patent document cited in search report	Publication date	Patent familiy member(s)	Publication date
US 4582128 A	15-04-1986	SE 8207251 A	21-06-1984
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Form PCT/ISA/210 (patent family annex) (July 1992)