(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 746 864 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
24.01.2007 Bulletin 2007/04

(51) Int Cl.:
H05B 3/00 *(2006.01)* ***H05B 6/00*** *(2006.01)*
F24D 13/04 *(2006.01)*

(21) Application number: **04077354.1**

(22) Date of filing: **18.08.2004**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL HR LT LV MK

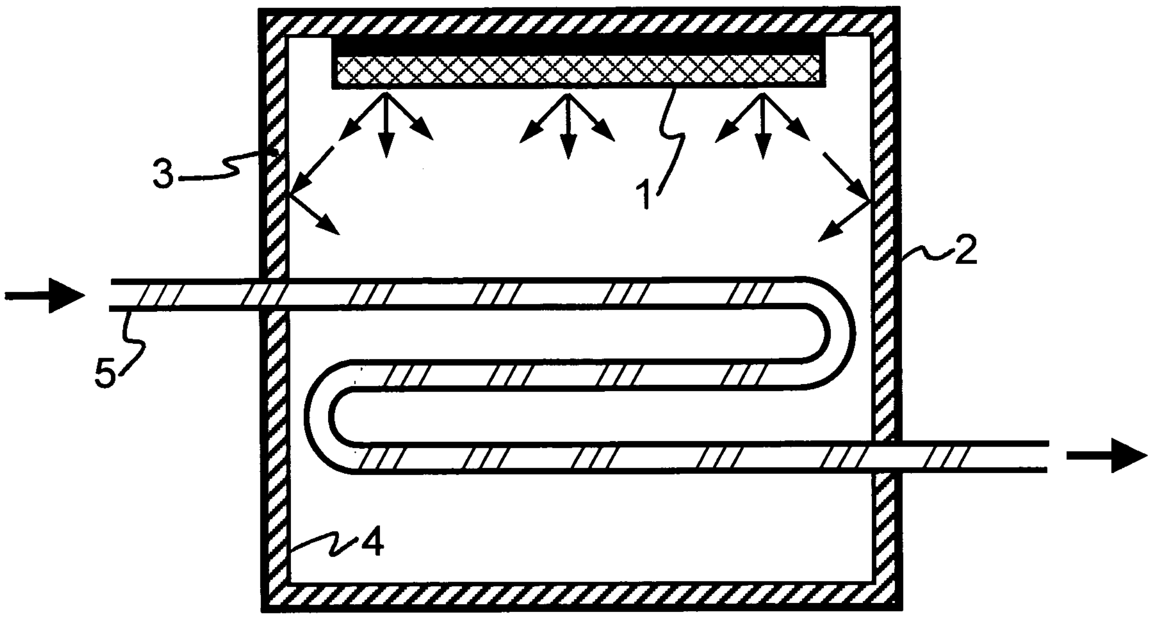
(71) Applicant: **De Ruiter, Remco**
4761 HM Zevenbergen (NL)

(72) Inventor: **De Ruiter , Adrianus Gerardus**
4761 ZV Zevenbergen (NL)

(54) **System with high energy efficiency for indirectly heating a target medium using electromagnetic radiation**

(57) The present invention generally relates to a system for indirectly heating a target medium, characterised by the fact that said system comprises an energy converter to convert electrical energy into electromagnetic radiation which is then absorbed by a suitable medium wherein said electromagnetic radiation is converted into heat, whereby the overall energy efficiency of the system is higher than 80 percent.

Figure 1



EP 1 746 864 A1

Description

[0001] The present invention generally relates to a system for indirectly heating a target medium, characterised by the fact that said system comprises an energy converter to convert electrical energy into electromagnetic radiation which is then absorbed by a suitable medium wherein said electromagnetic radiation is converted into heat, whereby the overall energy efficiency of the system is higher than 80 percent.

[0002] Most of the direct heating processes used in domestic and industrial applications are either based on the direct burning of fossil fuels like coal, natural gas or oil to convert de caloric contents of such fuels directly into thermal energy ('heat'), or use electrically resistive elements to convert electrical energy directly into heat. This heat is then directly transferred to the matter to be heated or to a transport medium for thermal energy. These methods of direct heating have, although very widely used, a very low energy efficiency since, in general, no more than 35 percent of the energy input is converted into useful output energy. Despite their low energy efficiency and the fact that the use of fossil fuels presents obvious dangers to the environment, for instance by the 'greenhouse effect', direct heating processes can be found everywhere in our daily lives: to generate electricity, to power our cars, to cook our food, to heat our house and our water. As an alternative to direct heating processes, indirect heating processes have been presented. In many indirect heating processes electrical energy is converted into some form of electromagnetic radiation or a nuclear reaction generates electromagnetic radiation that is absorbed by the matter that is to be heated, where it makes the matter's molecules vibrate faster causing the temperature of the matter to rise. Forms of such indirect heating processes are used in for instance nuclear power plants, the common microwave oven for domestic use or the infrared lamps used by physiotherapists. Most of these indirect heating processes are only efficient for very specific applications and kinds of matter, are hazardous to the human health or have other specific disadvantages. The energy efficiency of the indirect heating processes in nuclear power plants, for instance, is not much higher than the abovementioned energy efficiency of direct heating processes using fossil fuels, and the disposal of the resulting nuclear waste products presents serious dangers to the human health and the environment. The indirect heating process used in kitchen microwave ovens has an energy efficiency of about 60 percent, but this process only works with matters containing water, sugar or fat molecules. A serious drawback of many indirect heating processes is the fact that the energy efficiency of the processes increases when radiation with a higher intensity is used, which in turn presents more dangers to the human health and the environment, thus requires more expensive safety precautions.

[0003] Systems and methods for indirect heating that are presently known from prior art generally do not provide adequate solutions to the abovementioned drawbacks causing such indirect heating processes to be unsuitable for widespread use in common industrial and domestic heating applications.

[0004] The present invention aims to remedy the aforementioned disadvantages associated with the prior art. To achieve this a system for indirectly heating a target medium is proposed, which system is characterised by the fact that it comprises an energy converter to convert electrical energy into electromagnetic radiation which is then absorbed by a suitable medium wherein said electromagnetic radiation is converted into heat, whereby the overall energy efficiency of the system is higher than 80 percent.

[0005] Indirect heating processes can achieve an energy efficiency higher than 80 percent when the energy conversion characteristics of the source of the electromagnetic radiation approximate the characteristics of a so-called 'black body'. A black body converts all of it's input energy into electromagnetic radiation and constitutes in this respect a perfect radiator. Presently there are energy converters readily available on the market that convert electrical energy into electromagnetic radiation and have energy conversion characteristics that approximate those of a black body·® For instance the energy converters produced by the LEXIN Group in The Netherlands reach a very high energy efficiency in the far infrared wavelength range (3,000 nm. - 10,000 nm.). For the sake of clarity of the remainder of this description it is assumed that said energy converter in the system for indirectly heating a target medium according to the present invention, has conversion characteristics that approximate those of a black body.

[0006] In an advantageous embodiment of the system for indirectly heating a target medium according to the present invention, the system is characterised by the fact that said suitable medium which absorbs said electromagnetic radiation and wherein said electromagnetic radiation is converted into heat, is also the target medium that is to be heated. The target medium could for instance be water flowing through a plastic spiral, whereby the water is heated by absorbing the electromagnetic radiation generated by said energy converter, thus constituting for instance a heater for tap water using indirect heating.

[0007] In a second advantageous embodiment of the system for indirectly heating a target medium according to the present invention, the system is characterised by the fact that said electromagnetic radiation is first absorbed by an accumulation medium wherein it is converted into heat, which heat is then transferred to a target medium by means of thermal conduction. The said accumulation medium could for instance be soapstone (steatite), a material with very good heat retaining characteristics. When air would be the target medium, for instance to heat a room, the heat accumulated in the soapstone could be transferred to the air by blowing it over or through said soapstone thus in effect constituting a soapstone ventilator heater using indirect heating.

[0008] In a third advantageous embodiment of the system for indirectly heating a target medium according to the present invention, the system is characterised by the fact that said electromagnetic radiation is first absorbed by a transport medium wherein it is converted into heat, whereby said transport medium transports the heat to the location of a target medium where the heat is transferred to said target medium by means of thermal conduction. When water would be the transport medium and air would be the target medium, this embodiment of the system for indirectly heating a target medium according to the present invention could constitute a central heating system using indirect heating.

[0009] In a fourth advantageous embodiment of the system for indirectly heating a target medium according to the present invention, the system is characterised by the fact that the electromagnetic radiation is first absorbed by an accumulation medium wherein it is converted into heat, which heat is then transferred to said transport medium by thermal conduction. In analogy to the abovementioned third advantageous embodiment of the system for indirectly heating a target medium according to the present invention, this fourth embodiment could also constitute a central heating system using indirect heating, but equipped with for instance a soapstone accumulation medium for faster and better absorption of the electromagnetic radiation produced by said energy converter.

[0010] The system for indirectly heating a target medium according of the present invention could furthermore advantageously be characterised by the fact that said electromagnetic radiation produced by said energy converter has a wavelength that is within the infra red wavelength range 400 nm. - 10,000 nm. An important advantage of the use of this wavelength range is that in the electromagnetic spectrum infra red radiation, especially in the far infra red wavelength range (3,000 nm. - 10,000 nm.), is easily absorbed by most matter and presents the least risks for the human health, even at higher radiation intensities. The aforementioned LEXIN Group produces energy converters for the far infra red wavelength range that have a high energy efficiency, approximate the radiation characteristics of a black body, and are economically feasible to use in a wide range of industrial and domestic heating processes.

[0011] In yet another advantageous embodiment of the system for indirectly heating a target medium according to the present invention, the system is characterised by the fact that said energy converter producing said electromagnetic radiation is thermally insulated from the rest of the system and from the outside environment. This is important for reaching a high energy efficiency of the system. From Stefan's Law applied to a black body

$$E_{total} = \sigma T^4 \text{ with } \sigma = 5.67 * 10^{-8} Wm^{-2} K^{-4} \qquad (1)$$

we can see that the total energy that is radiated by a black body increases with temperature to the fourth power. So optimal efficiency of the said energy converter that approximates black body radiation characteristics, is achieved when all the input energy is indeed used to increase the temperature of the radiating surface of the energy converter. As much of the thermal energy as possible should therefore be confined to the part of the system where the energy converter is located and which is thermally insulated from the rest of the system and from the outside environment.

[0012] The system for indirectly heating a target medium according to the present invention can further be advantageously characterised by the fact that said energy converter producing said electromagnetic radiation is located within a housing that is reflective to the electromagnetic radiation produced and is constructed in such a way that as much of the electromagnetic radiation as possible is finally absorbed by the target medium, the accumulation medium or the transport medium. In an optimal situation all the electromagnetic radiation that is produced by said energy converter is absorbed by either the target medium, the accumulation medium or the transport medium. The walls of the housing of the energy converter should therefore be constructed from such material and in such a way that radiation photons that are not immediately absorbed by said media, are reflected by said walls to increase the probability that they are finally absorbed by either the target medium, the accumulation medium, the transport medium or by the energy converter itself where these reflected photons stimulate emission of new radiation photons.

[0013] Another embodiment of the system for indirectly heating a target medium according to the present invention is advantageously characterised by the fact that, in case a transport medium is used, this consists of a thermal oil or a mixture of thermal oils. Thermal oils have better heat retaining characteristics than water.

[0014] In case thermal oil or a mixture of thermal oils is/are used as transport medium in the system for indirectly heating a target medium according to the present invention, said system may be advantageously characterised by the fact that graphite is added to said thermal oil or said mixture of thermal oils to increase the heat retaining characteristics of the oil or mixture of oils even further.

[0015] In case an accumulation medium is present in the system for indirectly heating a target medium according to the present invention, said system may be advantageously characterised by the fact that said accumulation medium consists of soapstone (steatite). This material is a magnesium silicate and is known for its excellent heat retaining properties. Soapstone furthermore is a very good absorber and radiator for infra red radiation.

[0016] In an advantageous embodiment of the system for indirectly heating a target medium according to the present invention, the system is characterised by the fact that said energy converter producing electromagnetic radiation is located in a pressurised housing and the target medium is water that is also present in said pressurised housing where it is converted into superheated steam by the radiation produced by said energy converter. This superheated steam could then for instance be used to drive a turbine, after which the condensed steam is reinjected in the pressurised housing of the energy converter to be reheated.

[0017] In the following a number of preferred embodiments of the system for indirectly heating a target medium according to the present invention will be described. The following description and the attached drawings will show to the reader in more detail how the invention remedies the aforementioned disadvantages associated with the prior art. However, the reader should observe that description and drawings are merely meant to illustrate application of the invention and should in no way be regarded as limiting the scope of the present invention.

[0018] Figures 1 - 4 show partly cross-sectional schematic views of four specific embodiments of the system for indirectly heating a target medium according to the present invention. Identical items in the figures are denoted by identical references.

[0019] Figure 1 shows a particular embodiment of the system for indirectly heating a target medium according to the present invention, whereby this embodiment constitutes a highly energy-efficient water heater, for instance to heat tap water in a domestic environment. In figure 1 an energy converter (1) is located in a housing (2). The energy converter (1), which is in this case screen-shaped (in the figures the plane of the screen is oriented perpendicular to the drawing plane), converts electrical energy into electromagnetic radiation that is emitted into the inner part of the housing (2). The housing (2) is equipped with a layer (3) of thermally insulating material to keep as much of the thermal energy as possible inside. A spiral-shaped tube (5) of a suitable plastic material penetrates the walls of the housing (2) on the left and right side. When water flows through the tube (5) and enters the housing (2) it is subjected to the electromagnetic radiation produced by energy converter (1). The water absorbs part of the electromagnetic radiation and is heated up when it flows through the spiral inside the housing (2). The final temperature of the water when it leaves the housing depends on several parameters, like for instance the kind of radiation used, the radiation intensity, the original temperature of the water, the velocity of flow of the water, the length of the part of the tube (5) that is inside the housing (2), the material of the tube etc. To increase the chance that radiation photons are absorbed by the water, the inside of the housing (2) is covered with a coating (4) that is reflective for the radiation used. Tests have shown that with the use® of screen-shaped energy converters produced by the LEXIN Group situated in The Netherlands, it is possible to continuously produce 10 litres of water per minute with a temperature of 60 °C. and thereby reach an energy efficiency of over 80 percent with the system for indirectly heating a target medium according to the present invention. The measures of the housing for the tested system were 40 cm. x 40 cm. x 10 cm. The LEXIN energy converter that was used in the tests, produces radiation in the far infra red wavelength range (3,000 nm. - 10,000 nm.). Due to the radiation characteristics of the LEXIN® energy converter, which approximate those of a black body, in combination with the thermal insulation (3) and the reflective coating (4), an energy efficiency of over 80 percent was achieved. Comparable tap water heaters for domestic use have energy efficiencies that are generally below 35 percent.

[0020] Figure 2 shows another particular embodiment of the system for indirectly heating a target medium according to the present invention, whereby this embodiment constitutes an accumulation ventilator heater, for instance to be used for heating a room in a house. In figure 2 an energy converter (1) is located in a housing (2). The energy converter (1), which is in this case screen-shaped, converts electrical energy into electromagnetic radiation that is emitted into the inner part of the housing (2). The housing (2) is equipped with a layer (3) of thermally insulating material to keep as much of the thermal energy as possible inside. Located in the inner part of the housing (2) is an accumulation medium (6) that is continuously subjected to the electromagnetic radiation produced by energy converter (1). Within the accumulation medium (6) the absorbed radiation is converted into heat. For reaching an energy efficiency of over 80 percent with this embodiment of the system for indirectly heating a target medium according to the present invention, the accumulation medium must have good absorption and heat accumulation properties for the kind of radiation used. In this case soapstone (steatite) was used, which has excellent absorption and accumulation properties for radiation in the far infra red wavelength range that is produced by the screen-shaped energy converters produced by the LEXIN® Group situated in The Netherlands that were used for testing. Within the soapstone accumulation medium (6) there is a network (7) of air channels between an inlet at the left side of the housing (2) and an outlet at the right side of the housing (2). A ventilator (8) situated at the outlet side of the network of air channels draws a flow of air through the channels in the soapstone. This air is heated by the heat accumulated in the soapstone through thermal conduction and the heated air is then dispersed into the environment. Accumulation ventilator heaters known from prior art are generally heated by resistive electrical heating elements and have a very low energy efficiency. With this embodiment of the system for indirectly heating a target medium according to the present invention however, an energy efficiency of over 80 percent can be achieved.

[0021] Figure 3 shows a further embodiment of the system for indirectly heating a target medium according to the present invention, whereby this embodiment constitutes a central heating system, for instance to be used in conventional domestic heating. The construction and functioning of the system is very similar to that of the embodiment of the system according to the present invention shown in figure 1 and described above. In this case however, the fluid that flows through the spiral (9) which is inside the housing (2), is not the target medium that is to be heated, as was the case for the tap water heater. In this embodiment such fluid constitutes a transport medium for transporting the heat that was generated by the electromagnetic radiation produced by energy converter (1), to one or more radiators (10), that transfer the transported heat to the ambient air by way of thermal conduction. Although with the use of water as transport medium high energy efficiencies can be achieved, the system performance can be increased by using a thermal oil or a mixture of thermal oils as transport medium instead. Adding graphite to the thermal oil or mixture of thermal oils increases the radiation absorption and heat retaining properties of the transport medium even further. Also in this case tests have shown that with the use of LEXIN® energy converters producing radiation in the far infra red wavelength range, in combination with thermal insulation (3) and a reflective coating (4), energy efficiencies of over 80 percent can be achieved.

[0022] Figure 4 shows an embodiment of the system for indirectly heating a target medium according to the present invention, that is largely identical to the embodiment that is shown in figure 3 and described above, also constituting a central heating system, suitable for use in for instance conventional domestic heating. In this embodiment however, the spiral (9) is embedded in an accumulation medium (6) to achieve even better radiation absorption and heat accumulation. As mentioned earlier, soapstone is the preferred material for such an accumulation medium in combination with the use of LEXIN® energy converters producing radiation in the far infra red wavelength range, thermal insulation (3) and a reflective coating (4). Also in this embodiment the use of thermal oil or a mixture of thermal oils with added graphite can increase the energy efficiency of the system even further.

[0023] The system for indirectly heating a target medium according to the present invention enables the economically feasible, safe and highly energy-efficient use of indirect heating using electromagnetic radiation in a wide range of industrial and domestic heating processes. As such it overcomes numerous drawbacks of systems and methods known from prior art.

[0024] All parts of the described embodiments of the system for indirectly heating a target medium according to the present invention are commonly available and can be manufactured by using commonly available materials and commonly known production methods.

Claims

1. System for indirectly heating a target medium, **characterised by** the fact that said system comprises an energy converter to convert electrical energy into electromagnetic radiation which is then absorbed by a suitable medium wherein said electromagnetic radiation is converted into heat, whereby the overall energy efficiency of the system is higher than 80 percent.

2. System according to claim 1 for indirectly heating a target medium, **characterised by** the fact that said suitable medium which absorbs said electromagnetic radiation and wherein said electromagnetic radiation is converted into heat, is also the target medium that is to be heated.

3. System according to claim 1 for indirectly heating a target medium, **characterised by** the fact that said electromagnetic radiation is first absorbed by an accumulation medium wherein it is converted into heat, which heat is then transferred to a target medium by means of thermal conduction.

4. System according to claim 1 for indirectly heating a target medium, **characterised by** the fact that said electromagnetic radiation is first absorbed by a transport medium wherein it is converted into heat, whereby said transport medium transports the heat to the location of a target medium where the heat is transferred to said target medium by means of thermal conduction.

5. System according to claim 4 for indirectly heating a target medium, **characterised by** the fact that the electromagnetic radiation is first absorbed by an accumulation medium wherein it is converted into heat, which heat is then transferred to said transport medium by thermal conduction.

6. System according to one of the preceding claims for indirectly heating a target medium, **characterised by** the fact that said electromagnetic radiation produced by said energy converter has a wavelength that is within the infra red wavelength range 400 nm. - 10,000 nm.

7. System according to one of the preceding claims for indirectly heating a target medium, **characterised by** the fact that said energy converter producing said electromagnetic radiation is thermally insulated from the rest of the system and from the outside environment.

8. System according to one of the preceding claims for indirectly heating a target medium, **characterised by** the fact that said energy converter producing said electromagnetic radiation is located within a housing that is reflective to the electromagnetic radiation produced and is constructed in such a way that as much of the electromagnetic radiation as possible is finally absorbed by the target medium, the accumulation medium or the transport medium.

9. System according to one of the claims 4 - 8 for indirectly heating a target medium, **characterised by** the fact that said transport medium consists of a thermal oil or a mixture of thermal oils.

10. System according to claim 9 for indirectly heating a target medium, **characterised by** the fact that graphite is added to said thermal oil or said mixture of thermal oils to increase the heat retaining characteristics of the oil or mixture of oils.

11. System according to one of the claims 3 - 10 for indirectly heating a target medium, **characterised by** the fact that said accumulation medium consists of soapstone (steatite).

12. System according to claim 2, **characterised by** the fact that said target medium is water that is heated by said energy converter producing electromagnetic radiation, to superheated steam, whereby said energy converter is located in a pressurised housing.

Figure 1

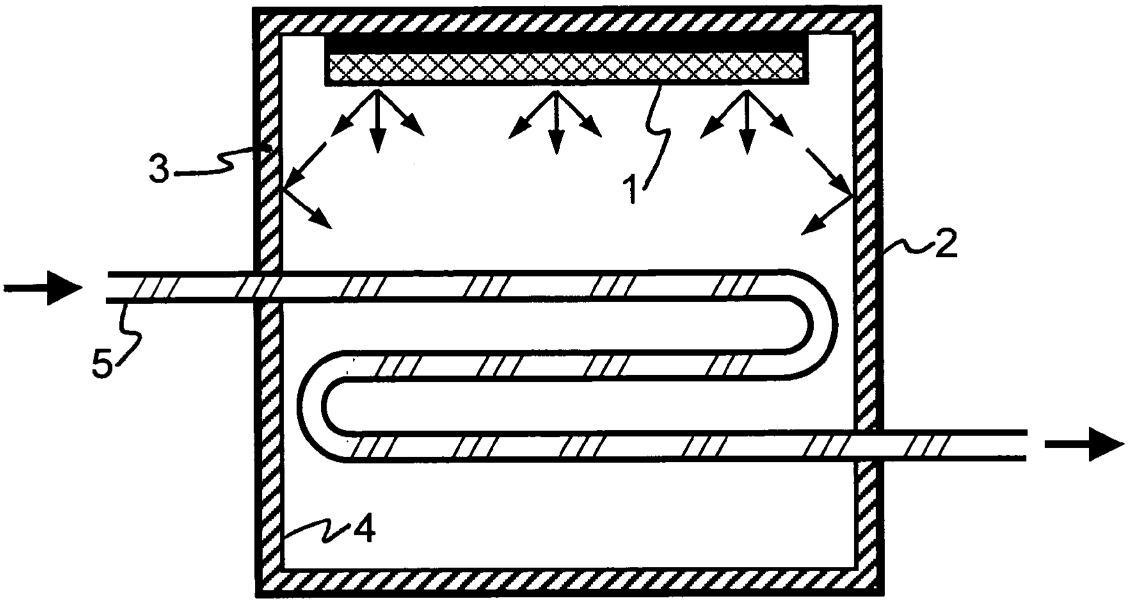


Figure 2

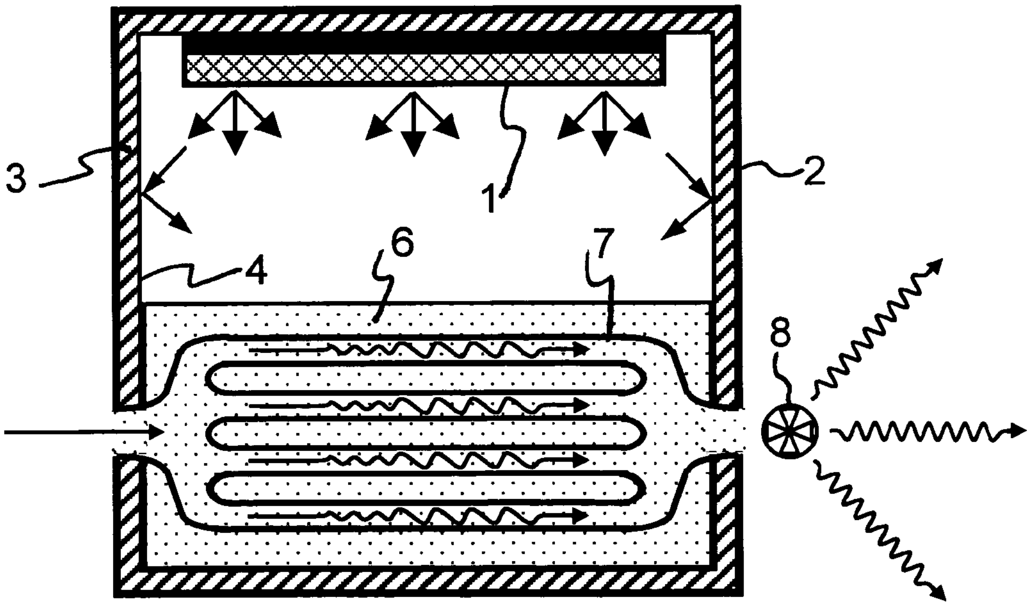


Figure 3

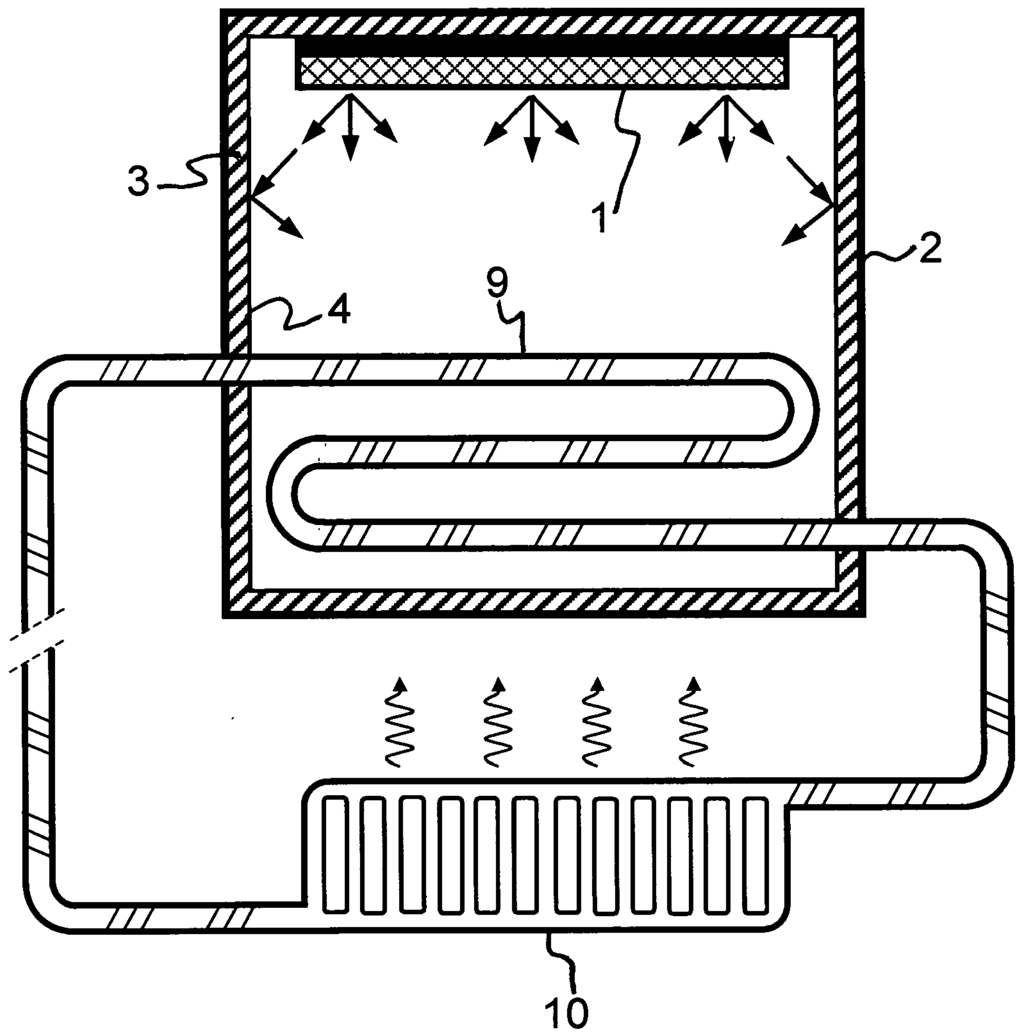
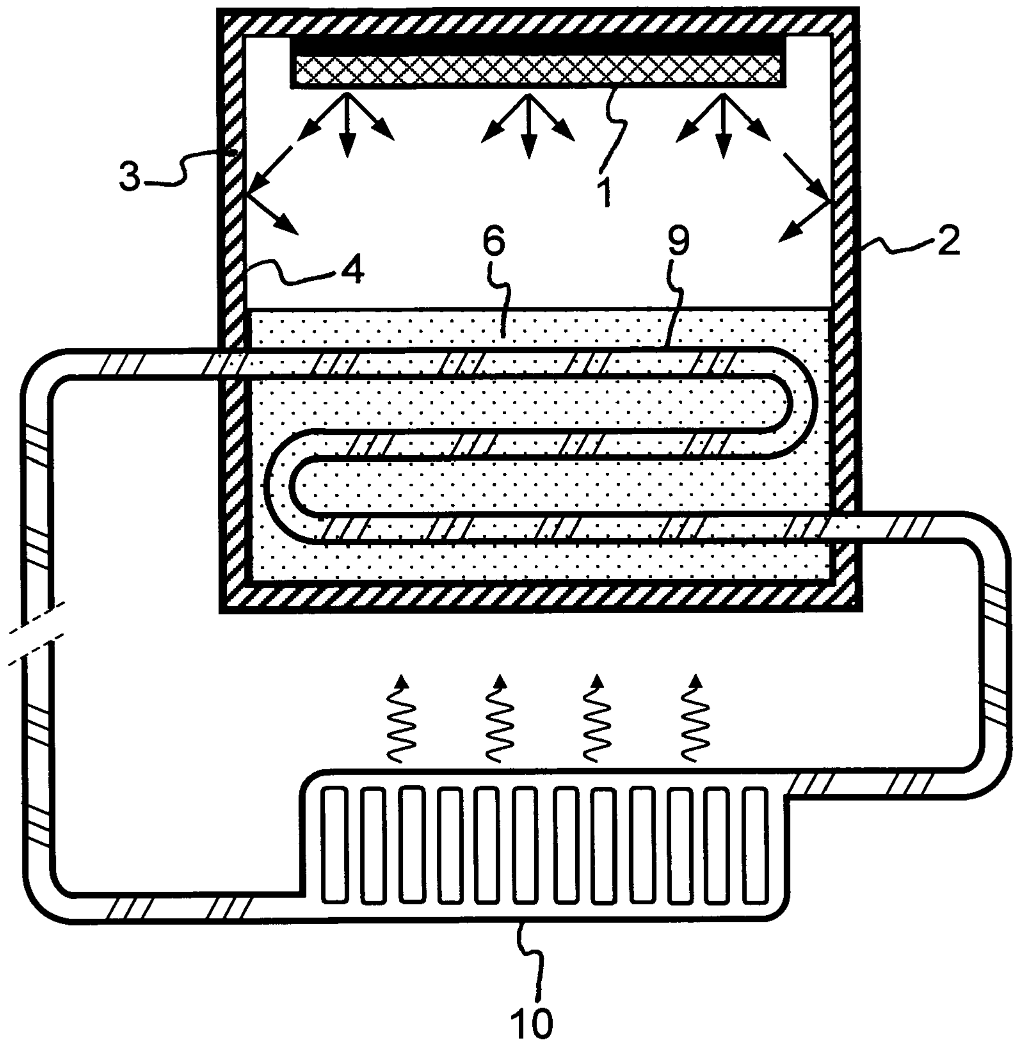


Figure 4



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 07 7354

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 6 268 596 B1 (LAUF ROBERT J ET AL) 31 July 2001 (2001-07-31) * column 6, line 14 - line 30; figure 2 * -----	1-4,7	H05B3/00 H05B6/00 F24D13/04
X	US 2 607 877 A (FENTON STEVENS EDWIN) 19 August 1952 (1952-08-19) * column 2, line 53 - column 3, line 8; figure 2 * -----	1-4,6-8	
X	WO 03/039194 A (SMITH KEVIN ; MICRO HEAT LTD (GB)) 8 May 2003 (2003-05-08) * page 11; figure 1 * -----	1-4,7,8	
X	US 4 114 011 A (STUBBS ELMER L) 12 September 1978 (1978-09-12) * column 2, line 50 - column 3, line 39; figure 2 * -----	1-4,7,8	
X	US 4 420 677 A (PARTINGTON EVERETT J) 13 December 1983 (1983-12-13) * column 2, line 63 - column 3, line 27; figures 1,2 * -----	1-4,7,8	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H05B F24D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	24 January 2005	Gea Haupt, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

2

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 07 7354

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-01-2005

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 6268596	B1	31-07-2001	NONE			
US 2607877	A	19-08-1952	NONE			
WO 03039194	A	08-05-2003	CA	2464753	A1	08-05-2003
			EP	1438876	A2	21-07-2004
			WO	03039194	A2	08-05-2003
			NO	20032943	A	26-08-2003
US 4114011	A	12-09-1978	CA	1089023	A1	04-11-1980
			DE	2731513	A1	19-01-1978
			GB	1585356	A	04-03-1981
			JP	53008850	A	26-01-1978
US 4420677	A	13-12-1983	CA	1152549	A1	23-08-1983
			EP	0033338	A1	12-08-1981
			WO	8100500	A1	19-02-1981

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82