Abstract: A regenerative heater for heating the working fluid of a system, the heater comprising at least one volume of material arranged to be heated to at or above the melting temperature of the material, the heater also comprising passages through the at least one volume of material for the flow therethrough of the working fluid.
A REGENERATIVE HEATER

Field of the Invention
The present invention also relates to a regenerative heater for heating the working fluid of a system.

Background of the Invention
Many processes require a source of a large amount of heat to drive the process, such as for example, power generation, metals processing and glass working. Various heat sources have been employed in these processes such as electrical heating and high temperature steam generated by nuclear power, coal or another combustible fuel.

Summary of the Invention
According to an aspect of the present invention, there is provided a regenerative heater for heating the working fluid of a system, the heater comprising at least one volume of material arranged to be heated to at or above the melting temperature of the material, the heater also comprising passages through the at least one volume of material for the flow therethrough of the working fluid.

In an embodiment, the heater comprises at least two volumes of material, preferably three. The heater may comprise more than three volumes of material.

In an embodiment, when the heater comprises at least two volumes of material, the passages are arranged for the working fluid to flow through the volumes of material in series.

In other embodiments, however, the passages may be arranged for the working fluid to flow through the volumes of material in parallel.

In an embodiment, the volume(s) of material is heated using a heating fluid flowing through spaces through the volume(s) of material.
The heating fluid may be steam or any other heated medium generated by nuclear power, coal or other combustible fuel or hot exhaust gases from a gas turbine for example.

In an embodiment, the passages through which the working fluid flow are separate from the spaces through which the heating fluid flow.

In other embodiments, the volume(s) of material may be heated using any other suitable means, such as waste heat from another process, direct heating from a furnace, electrical source or solar thermal heat.

In an embodiment, when the heater comprises at least two volumes of material, the materials in the volumes are different. The different materials preferably have different melting temperatures.

In one embodiment, the materials are of progressively decreasing melting temperatures from the first volume to the last volume, the passages being arranged for the flow of the working fluid through the last volume first and the first volume last.

In an embodiment, working fluid flows counter-currently to the heating fluid. Thus, the spaces are arranged for the flow of the heating fluid through the first volume first and the last volume last.

In an embodiment, at least one of the volumes of material contains a mixture of two or more different materials.

In an embodiment, one of the materials in the mixture of materials of the or each volume is for improving the heat transfer of the or each volume of material. Such a material may be graphite.

In an embodiment, one of the materials in the mixture of materials of the or each volume is for affecting the melting temperature of the or each volume of material.

In one such embodiment, aluminium is mixed with silicon to reduce the melting temperature of the volume of
material.

In an embodiment, when the regenerative heater comprises at least two volumes of material, the material in the volumes are each mixtures of the same materials but at different ratios.

The different ratios preferably have different melting temperatures.

The materials in the volumes may be referred to as "phase change materials" or "PCMs". Any suitable phase change materials may be employed.

In an embodiment of the invention, when the heater comprises three volumes of material the first volume contains silicon, which has a melting temperature of about 1410°C, the second volume contains lithium fluoride, which has a melting temperature of about 870°C and the third volume contains magnesium oxide or calcite, which have a melting temperature of about 560°C.

In an embodiment, the volume (s) of material is held in a container (s) which is able to withstand the temperatures of the molten material (s) held therein.

In an embodiment, the container (s) is manufactured from a ceramic, preferably silicon carbide.

In an embodiment, the heater also comprises a recuperator for recovering energy in the heating fluid which exits the volume (s) of material.

In an embodiment, the heater also comprises a number of valves on the inlets and outlets to the heater which can be used to control the flow rate of the working fluid and the heating fluid through the heater to maintain the temperature of the material (s) in the volume (s) so as to keep them in a molten phase.

The heater is suitable for use in any process heating application including power generation, light metal processing, steel making, silicon refining, glass making, and any other process requiring high levels of energy at high volumes.
Brief Description of the Drawings

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawing, in which:

Figure 1 is a schematic view of a regenerative heater for heating the working fluid of a system according to an embodiment of the present invention.

Detailed Description of Embodiments

Referring to Figure 1, a regenerative heater 13 for heating the working fluid of a system is shown. The heater 13 comprises first, second and third volumes 40, 41, and 42 respectively, of material. It is readily understood that the heater 13 may comprise less or more volumes of material to that shown in Figure 1. The volumes 40, 41, 42 are arranged to be heated to at or above the melting temperature of the material. The heater 13 also comprises passages through the volumes 40, 41, 42 of material for the flow therethrough of the working fluid. The working fluid, is thus heated by the volumes 40, 41, 42 of material. In the embodiment shown in Figure 1, the passages are arranged for the working fluid to flow through the volumes 40, 41, 42 of material in series. However, in other embodiments the passages may be arranged for the working fluid to flow through the volumes 40, 41, 42 of material in parallel.

In the embodiment shown in Figure 1 the volumes of material 40, 41, 42 are heated using a heating fluid flowing through spaces through the volumes of material 40, 41, 42. The heating fluid may be steam or any other heated medium generated by nuclear power, coal or other combustible fuel or hot exhaust gasses from a gas turbine. The volumes 40, 41, 42 of material may be heated using any other suitable means, such as waste heat from another process, direct heating from a furnace, electrical or solar thermal heat. The passages through which the working fluid flow are separate from the spaces through
which the heating fluid flow. This enables continuous operation of the heater 13 as well as preventing any mixing of the two fluids, which avoids problems such as contamination, particularly dust contamination, oxygenation and carbonation of the working fluid.

The materials in the volumes 40, 41, 42 may be different and in one embodiment are of progressively decreasing melting temperatures from the first volume 40 to the third volume 42. The materials used may be referred to as "phase change materials" or "PCMs". Any suitable phase change materials may be employed. In an embodiment of the invention, however, the first volume 40 contains silicon, which has a melting temperature of about 1410°C, the second volume 41 contains lithium fluoride, which has a melting temperature of about 870°C and the third volume 42 contains magnesium oxide or calcite, which have a melting temperature of about 560°C. The volumes of material 40, 41, 42 are all held in containers, which are of a material which is able to withstand the temperatures of the molten materials held therein. A particularly suitable material in this regard is a ceramic material, preferably silicon carbide.

In another arrangement, the volumes of material 40, 41, 42 may contain a mixture of two or more different materials. In one form, each volume of material 40, 41, 42 comprises the mixture of the same materials but at different ratios. The different ratios preferably have different melting temperatures, thus providing the graduated heating of the working fluid flowing through the volumes of material 40, 41, 42. In this respect, at least one of the materials in the mixture of materials of each volume is for affecting the melting temperature of the volumes of material. For example, aluminium may be mixed with silicon to reduce the melting temperature of the silicon. Alternatively, or in addition to this, one of the materials in the mixture of materials may be for improving the heat transfer of the volume of material. Such a
material for example is graphite, which may be added to salts for example such as lithium fluoride, magnesium oxide, calcite or sodium chloride to improve the heat transfer of these materials. This, advantageously, enables the volumes of material 40, 41, 42 to reach their melting temperatures more rapidly as well as improving the heat transfer from the volumes of material 40, 41, 42 to the working fluid. This in turn enables faster start-up and shut down of the system 10.

The working fluid flows counter-currently to the heating fluid, entering the heater 13 through the inlet 26 to be heated firstly by the lowest temperature volume of material, in this case the third volume 42, and finally by the highest temperature volume of material, in this case the first volume 40 before exiting through the outlet 27. The heating fluid heats the volumes 40, 41, 42 in reverse order, that is, it enters the heater 13 through inlet 43 to heat the first volume 40, which is required to be at the highest temperature, first and heats the third volume 42 last.

In another embodiment, the material in each or two of the volumes 40, 41, 42 is the same. In this embodiment, the volumes may not be as readily heated to at or above the melting temperature of the material using the heating fluid in series because as the heating fluid flows through the heater 13, it loses energy and heat as it flows through the volumes 40, 41, 42. Thus, the volumes 40, 41, 42 in this embodiment may need to be heated in parallel or alternatively by a different source of heat.

The heater 13 also comprises a recuperator 44 for recovering energy in the heating fluid which exits the third volume of material 42.

The heater 13 also comprises a number of valves 45 on the inlets and outlets to the heater 13 which can be used to control the flow rate of the working fluid and the heating fluid through the heater 13 to maintain the temperature of the phase change materials in the volumes.
40, 41, 42 so as to keep them in a molten phase.

The flowrate of the working fluid is also controlled with respect to its temperature at the outlet 27 of the heater 13. For some applications of the heater 13, the temperature of the working fluid required at the outlet 27 of the heater 13 is much less than the melting temperature of silicon (and hence the temperature of the first volume 40). The reason for this, for example, may to not damage the turbine in a power generation system.

Because of this large temperature difference, the heater 13 advantageously enables quick start-up of the system with which the heater is being applied.

The heater is suitable for use in any process heating application including power generation, light metal processing, steel making, silicon refining, glass making, and any other process requiring high levels of energy at high volumes.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, ie. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.
CLAIMS

1. A regenerative heater for heating the working fluid of a system, the heater comprising at least one volume of material arranged to be heated to at or above the melting temperature of the material, the heater also comprising passages through the at least one volume of material for the flow therethrough of the working fluid.

2. A regenerative heater as claimed in claim 1, wherein the heater comprises at least two volumes of material.

3. A regenerative heater as claimed in claim 2, wherein the passages are arranged for the working fluid to flow through the at least two volumes of material in series.

4. A regenerative heater as claimed in either claim 2 or 3, wherein the materials in the volumes are different.

5. A regenerative heater as claimed in claim 4, wherein the different materials have different melting temperatures.

6. A regenerative heater as claimed in claim 4 or claim 5, wherein the materials are of progressively decreasing melting temperatures from the first volume to the last volume, the passages being arranged for the flow of the working fluid through the last volume first and the first volume last.

7. A regenerative heater as claimed in either claim 2 or 3, wherein at least one of the volumes of material contains a mixture of two or more different materials.
8. A regenerative heater as claimed in claim 7, wherein one of the materials in the mixture of materials of the or each volume is for improving the heat transfer of the or each volume of material.

9. A regenerative heater as claimed in claim 8, wherein the material for improving the heat transfer is graphite.

10. A regenerative heater as claimed in any one of claims 7 to 9, wherein the material in the volumes are each mixtures of the same materials but at different ratios.

11. A regenerative heater as claimed in claim 10, wherein the different ratios have different melting temperatures.

12. A regenerative heater as claimed in any one of the preceding claims, wherein the volume(s) of material is heated using a heating fluid flowing through spaces through the volume(s) of material.

13. A regenerative heater as claimed in claim 12, wherein the heating fluid is steam.

14. A regenerative heater as claimed in either claim 12 or 13, wherein the passages through which the working fluid flow are separate from the spaces through which the heating fluid flow.

15. A regenerative heater as claimed in any one of claims 12 to 13, wherein the heating fluid is arranged to flow counter-currently to the working fluid.

16. A regenerative heater as claimed in any one of claims 1 to 11, wherein the volume(s) of material is
heated using direct heating from a furnace, electrical source or solar thermal heat.

17. A regenerative heater as claimed in any one of the preceding claims, wherein the volume(s) of material is held in a container(s) which is able to withstand the temperatures of the molten material(s) held therein.

18. A regenerative heater as claimed in claim 17, wherein the container(s) is manufactured from a ceramic.

19. A regenerative heater as claimed in either claim 17 or 18, wherein the container(s) is manufacture from silicon carbide.

20. A regenerative heater as claimed in any one of the preceding claims, wherein the heater also comprises a recuperator for recovering energy in the heating fluid which exits the volume(s) of material.

21. A regenerative heater as claimed in any one of the preceding claims, wherein the heater also comprises a number of valves on the inlets and outlets to the heater which can be used to control the flow rate of the working fluid and the heating fluid through the heater to maintain the temperature of the material(s) in the volume(s) so as to keep them in a molten phase.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.  
F28D 17/00 (2006.01)  F28D 15/00 (2006.01)  F28D 20/02 (2006.01)  F28D 7/00 (2006.01)  F28D 19/00 (2006.01)

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)

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)

DWPI; ESAPCE; GOOGLE PATENTS: melting, molten, regenerative, phase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>WO 1997/002408 A1 (LEWIS, Ralph) 23 January 1997 Abstract, Fig. 1, page 6, line 17-page 9, line 30</td>
<td>1.12-18, 20.21</td>
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<td>X</td>
<td>U.S 4727930 A (BRUCKNER et al) 01 March 1988 Abstract, Fig. 1, column 4, lines 35-36; column 7, lines 43-44; column 10, lines 1-8</td>
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<td>X</td>
<td>U.S 4512388 A (CLAAR et al) 23 April 1985 Whole document</td>
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<td>X</td>
<td>Derwent abstract Accession No. 84-305052/49, Class Q78, J8 4045916 B (AGENCY OF INDUSTRIAL SCIENCE TECHNOLOGY) 09 November 1984 Abstract</td>
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Further documents are listed in the continuation of Box C

See patent family annex

* Special categories of cited documents:
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Date of the actual completion of the international search 25 September 2007

Date of mailing of the international search report 17 SEP 2007

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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX