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54	TITLE OF INVENTION

Method for producing directly reduced metal in a multi-tiered furnace

57	ABSTRACT (NOT MORE THAN 150 WORDS)

NUMBER OF SHEETS ~~18~~	19

The sheet(s) containing the abstract is/are attached.

If no classification is furnished, Form P.9 should accompany this form.
The figure of the drawing to which the abstract refers is attached.

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PCT

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Mit internationalem Recherchenbericht.

(54) Title: METHOD FOR PRODUCING DIRECTLY REDUCED METAL IN A MULTI-TIERED FURNACE

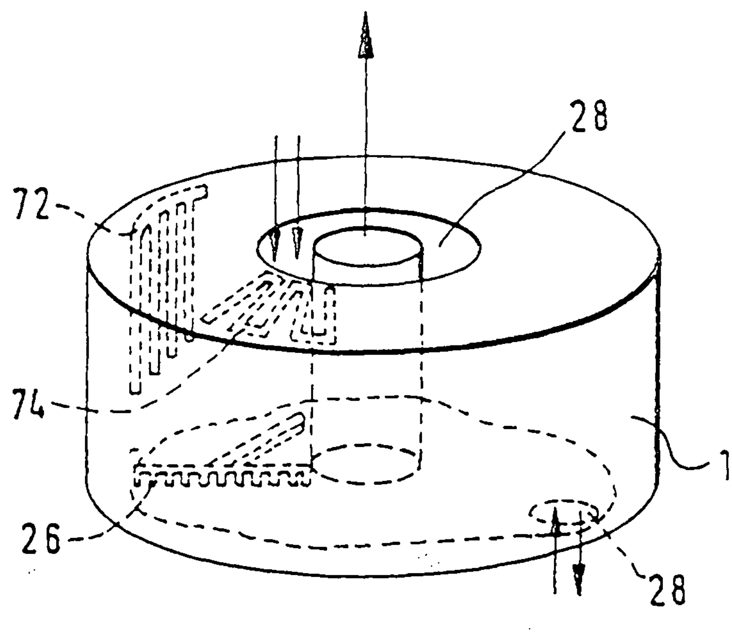
(54) Bezeichnung: VERFAHREN ZUM HERSTELLEN VON DIREKT REDUZIERTEM METALL IN EINEM ETAGENOFEN

(57) Abstract

The invention relates to a method for producing directly reduced metal in a multi-tiered furnace, whereby metal oxides and a reducing agent are inserted into the furnace and the process heat required for the reduction of the metal oxides is generated by indirect heating of the individual tiers of said furnace.

(57) Zusammenfassung

Verfahren zum Herstellen von direkt reduziertem Metall in einem Etagenofen, wobei Metalloxide und Reduktionsmittel in den Etagenofen eingeführt werden und die benötigte Prozesswärme zum Reduzieren der Metalloxide durch indirektes Beheizen einzelner Etagen des Etagenofens erzeugt wird.



PROCESS FOR PRODUCTION OF DIRECTLY REDUCED METAL IN A MULTIPLE-HEARTH FURNACE

The invention relates to a process for production of directly reduced metal in a multiple-hearth furnace.

Multiple-hearth furnaces are used for production of metals from the corresponding metallic oxides, a metallic oxide and a reducing agent being introduced into the multiple-hearth furnace and reacting with each other at high temperature.

The metallic oxides and the reducing agents are introduced into the multiple-hearth furnace, circulated by rakes extending over the individual hearths and conveyed to the edge of the hearth, from where they fall through several openings provided for the purpose on to a lower hearth. From there the metallic oxides mixed with reducing agents are conveyed to the centre of the hearth and then fall on to the underlying hearth. During transport from the top downwards through the multiple-hearth furnace the metallic oxides and the reducing agents are heated gradually.

As the reduction of metallic oxides is endothermal, a relatively large amount of energy must be expended to initiate and maintain the reactions. To achieve this the multiple-hearth furnace is heated by gas burners or the like and some of the reducing agent - generally the volatile part of a carbon carrier such as coal - is burnt by injection of a gas containing oxygen in the multiple-hearth furnace. The required process heat is produced by combustion of the coal and by the gas burners and carbon dioxide is formed. Above a specific temperature the carbon dioxide present in the hot gases reacts with the carbon in the multiple-hearth furnace in order to form carbon monoxide according to the Boudouard equilibrium. The carbon monoxide formed in this way reduces the metallic oxides to metal. The carbon monoxide content of the gases in the multiple-hearth furnace essentially determines the reduction potential.

A disadvantage of this process is that oxidised gases and oxygen are introduced into the multiple-hearth furnace, where reduction is to take place. Furthermore, a large quantity of waste gases, which must be treated, is produced.

In this type of multiple-hearth furnace, which is heated by a hot flame on a natural gas basis, it is difficult to produce and maintain a uniform temperature profile. As the different zones or hearths are connected to each other, it is difficult to control the conditions in the individual zones independently of each other. The gases leaving one hearth influence the conditions on the next upper hearth.

Consequently, the task of the present invention is to propose a process for the production of directly reduced metal which manages with smaller gas quantities.

According to the invention this problem is solved by a process for the production of directly reduced metal in a multiple-hearth furnace, characterised in that metallic oxides and reducing agents are introduced into the multiple-hearth furnace and the required process heat for reduction of the metallic oxides is produced by indirect heating of individual hearths in the multiple-hearth furnace.

In the process according to the invention the process heat is fed to the multiple-hearth furnace by radiation energy and not by combustion of the reducing agent in situ or by gas burners as in the already known processes.

An important advantage of the invention is that no oxygen or other oxidised gases need be injected into the multiple-hearth furnace in order to produce the required process heat. The quantity of gases circulating in the multiple-hearth furnace is thus substantially reduced. Only significantly smaller quantities of waste gas need be after-treated, with the result that the process is less expensive.

Furthermore, the gas flow rates on the individual hearths are smaller due to the lower gas quantities. Less dust is whirled up and discharged from the multiple-hearth furnace.As no oxygen or other oxidised gases are injected into the multiple-hearth furnace, the reduction potential of the gases inside the multiple-hearth furnace is higher than in already known multiple-hearth furnaces.

According to a first preferred embodiment the individual hearths are heated indirectly independently of each other.

Furthermore, this process permits more uniform heating of the multiple-hearth furnace and its contents.

The process can take place under a pressure of 1 to 5 bar, with the result that the multiple-hearth furnace can be of more compact design.

Electrical heating resistors are advantageously used for indirect heating of individual hearths.

In addition to the solid reducing agents, gaseous reducing agents are used in an advantageous embodiment.

The metallic oxides are, for example, iron ore, zinc ores, waste containing oil and iron oxide and various forms of problematical waste such as dusts containing iron oxide contaminated by zinc oxides and/or other heavy metal oxides.

The invention also relates to a multiple-hearth furnace comprising several hearths one above the other for the production of directly reduced metal. The multiple-hearth furnace according to the invention is characterised by means for indirect heating of individual hearths, which produce the required process heat for reduction of the metallic oxides.

The multiple-hearth furnace can, for example, be brought to the required temperature and maintained at this temperature by electrical heating resistors installed inside the multiple-hearth furnace.

It is accordingly possible to adjust the temperature on each hearth selectively without thereby significantly affecting the conditions in the adjacent hearths. In contrast to the traditional multiple-hearth furnaces, the conditions on the different hearths can be controlled independently of each other.With the same capacity and gas flow rates on the hearths the multiple-hearth furnace for production of directly reduced metal by the process according to the invention may be smaller than a conventional multiple-hearth furnace.

The indirect heating elements can be installed on the surface and/or below the individual hearths. However, they can also be mounted on the side wall.

This process is particularly advantageous in the direct reduction of iron ore.

Further advantageous embodiments are listed in the sub-claims.

An embodiment of the invention is described below with the aid of the enclosed figure.

Fig. 1 is a section through a multiple-hearth furnace for production of directly reduced metal,

Fig. 2 the schematic arrangement of the electrical heating resistors in the multiple-hearth furnace.

Fig. 1 shows a section through a multiple-hearth furnace 10, which has several - in this case twelve - hearths 12 one above the other. These unsupported hearths 12 as well as the shell 14, cover 16 and bottom 18 of the multiple-hearth furnace 10 are made from refractory material.

An outlet 20, through which the gases can be evacuated from the multiple-hearth furnace 10, and an opening 22, through which metallic oxides and reducing agents can be charged to the top hearth, are provided in the cover 16 of the multiple-hearth furnace 10. However, the metallic oxides can also be introduced separately from the reducing agents further below into the multiple-hearth furnace 10.

A shaft 24, on which rakes 26 extending over the respective hearths 12 are mounted, is installed in the centre of the multiple-hearth furnace. The shaft 24 and the rakes 26 are air- or water-cooled.

The rakes 26 are designed in such a way that they circulate the material on a hearth from the outside inwards and then from the inside outwards on the underlying hearth in order to transport the material from the top downwards through the multiple-hearth furnace 10.

The metallic oxides are either mixed with solid reducing agents such as lignite coke, petroleum coke or coal outside the multiple-hearth furnace 10 and the mixture of metallic oxides and reducing agents is subsequently charged to the top hearth.

However, the metallic oxides can also be charged separately to the top hearth and the solid reducing agents introduced into the multiple-hearth furnace 10 further below through an inlet opening 30 in the shell 14.

The metallic oxides can possibly be predried outside the multiple-hearth furnace 10 before or after they are mixed with the solid reducing agents.

After the mixture of metallic oxides and reducing agents has been charged to the first hearth of the multiple-hearth furnace 10, it is circulated by the rakes 26 and conveyed to the edge of the hearth, from where it falls through several openings 28 provided for the purpose on to the underlying hearth. From there the metallic oxides mixed with reducing agents are conveyed towards the centre of the hearth and then fall on to the underlying hearth. During transport the metallic oxides and reducing agents are gradually heated.

During this time moisture is removed from the metallic oxides mixed with reducing agents by contact with the hearth 12 and the rising hot gases. The top hearths in the multiple-hearth furnace 10 thus belong to the drying and preheating zone.

At least one inlet opening 30, through which the reducing agents are introduced, if they have not already been introduced into the multiple-hearth furnace 10 together with the metallic oxides, is provided in the side walls of the multiple-hearth furnace 10 - normally in the upper third. Either all or additional reducing agents can be introduced into the multiple-hearth furnace 10 through this inlet opening 30. These reducing agents may be present both in gaseous as well as in liquid or solid form. These reducing agents are, for example, carbon monoxide, hydrogen, natural gas, petroleum and petroleum derivatives or solid carbon carriers such as lignite coke, petroleum coke, blast furnace dust, coal or the like.

The reducing agent, in this case coal, which is introduced to a hearth further below in the multiple-hearth furnace 10, is mixed there with the heated metallic oxides by the rakes 26. The metallic oxides are gradually reduced to metal by the high temperature and the presence of reducing agents during transport through the multiple-hearth furnace 10.

The reduction of the metallic oxides can be controlled accurately and the process carried out under optimum conditions by the controlled feed of solid, liquid and gaseous reducing agents at various points of the multiple-hearth furnace 10 and by the possibility of exhausting excess gases at critical points.

Nozzles 30 for injection of hot (250°C to 500°C) gases containing oxygen, through which air or another gas containing oxygen can be fed into the multiple-hearth furnace 10, are provided in the side wall. As a result of the high temperatures and the presence of oxygen the combustible gases can be burnt in the upper hearths 12 of the multiple-hearth furnace 10 and the resulting energy used for drying the metallic oxides and reducing agents.

In the last or last two hearths provision is made for feeding a gaseous reducing agent, e.g. carbon monoxide or hydrogen, through special nozzles 44. In this atmosphere with increased reduction potential reduction of the metallic oxides can be completed.

The metal produced is subsequently discharged together with the ash through the outlet 46 in the bottom 18 of the multiple-hearth furnace 10.

The metal discharged at the outlet 46 is cooled in a cooler 48 with the ash and reducing agents, which can in certain circumstances be re-used. The reduced metal is subsequently separated from the ash of the reducing agents and any reducing agents 52 which can be re-used, via a separator 50.

The gas mixture from the multiple-hearth furnace 10 passes through the outlet 20 into an after-burner 54, where the combustible gases of the gas mixture are burnt. The gas mixture is subsequently fed into a cooler 56 supplied with a cooling medium and cooled. The cooled gas mixture is subsequently cleaned with the aid of a cyclone filter 58 before it is discharged into the atmosphere.

If the multiple-hearth furnace 10 is operated under overpressure, pressure locks must, of course, be provided at the openings 22, 30 for feed of the metallic oxides and reducing agents and at the outlet 20. The bearings of shaft 24 must also be sealed and the outlet 46 provided with a lock for discharge of hot material.

The waste gases of the multiple-hearth furnace 10 can, however, also be used to drive a turbine which generates electricity. In this case post-combustion inside the multiple-hearth furnace 10 should be dispensed with and no gas containing oxygen introduced through the nozzles 32 into the multiple-hearth furnace 10.

This multiple-hearth furnace 10 permits the use of iron ore, zinc ores, waste containing oil and iron oxide and various problematical wastes such as dusts containing iron oxide contaminated by zinc oxides and/or other heavy metal oxides.

Dusts or sludges containing iron oxide from electric or converter steel mills, which contain hardly any carbon, or dust from the waste gas cleaning of blast furnaces can thus be introduced into the multiple-hearth furnace 10 through a special opening 30. The reduction of the residual materials can be accurately controlled and the process carried out under optimum conditions by the controlled feed of solid, liquid and gaseous reducing agents at various points of the multiple-hearth furnace 10 and the possibility of exhausting excess gases at critical points.

As these dusts or sludges containing iron oxide are often contaminated by heavy metal oxides, a large proportion of the gases flowing upwards in the multiple-hearth furnace can be exhausted from the multiple-hearth furnace 10 below the hearth to which the dusts or sludges containing heavy metal oxides are charged, through an exhaust connection piece 60 in the side wall and re-injected into the multiple-hearth furnace 10 through an inlet 62 above this hearth. Consequently the quantity of gas present on the hearths to which the dusts or sludges containing heavy metal oxides are introduced is small. The heavy metal oxides present in the dusts or sludges are reduced after introduction into the multiple-hearth furnace, and the metals formed evaporate. They can then be exhausted from the multiple-hearth furnace 10 in a relatively small gas quantity on this hearth through an outlet 64 in the side wall.

The small volume of gas with a relatively high heavy metal content can then be cleaned separately. As a result of the small waste gas quantities the gas flow rates on the corresponding hearths are low, and only small amounts of dust are thus discharged with this waste gas. Consequently an extremely high heavy metal concentration in the waste gas results.

The combustible gases in the gas mixture removed are burnt in an after-burner 66. The remainder of the gas mixture is cooled in a cooler 68 and subsequently cleaned by a cyclone filter 70 before it is discharged into the atmosphere.

The iron oxide present in the dusts is reduced to iron with the waste containing oil and iron oxide.

All rising gases, including the volatile constituents of the reducing agents, can be fully burnt in the drying plant for the residual materials containing heavy metal and iron oxide and possibly for the reducing agents outside the multiple-hearth furnace and the residual heat of the waste gases of the multiple-hearth furnace thus used in an optimum manner.

Fig. 2 shows a schematic representation of a hearth in the multiple-hearth furnace 10, in which heating resistors 72, 74 are mounted on the side wall or shell 14 and below a hearth 12.

P-PWU-401/WO-AMENDED

PATENT CLAIMS

1. Process for production of directly reduced metal in a multiple-hearth furnace, characterised in that metallic oxides and reducing agents are introduced into the multiple-hearth furnace and the required process heat for reduction of the metallic oxides is produced by indirect heating of the metallic oxides only by means of the hearths or the shell of the multiple-hearth furnace by electrical heating resistors installed underneath individual hearths or on the shell of the multiple-hearth furnace, and the individual hearths are indirectly heated, independently of each other.

2. Process according to claim 1, characterised in that the process is carried out under a pressure of 1 to 5 bar.

3. Process according to one of the preceding claims, characterised in that gaseous reducing agents are used.

4. Process according to one of the preceding claims, characterised in that the metallic oxides are iron ore, zinc ores, waste containing oil and iron oxide, and various problematical wastes such as e.g. dusts containing iron oxide contaminated by zinc oxides and/or other heavy metal oxides.

5. Multiple-hearth furnace comprising several hearths one above the other for production of directly reduced metal from metallic oxides, characterised by electrical heating resistors which are installed under the individual hearths or on the shell of the multiple-hearth furnace, wherein the process heat required to reduce the metallic oxides is produced by

indirect heating of the metallic oxides only by the electrical heating resistors, wherein the heating resistors are independent of each other.

6. Multiple-hearth furnace according to claim 5, characterised in that the electrical heating resistors have a protective sheath.

7. A process as claimed in claim 1, substantially as herein described and illustrated.

8. A furnace as claimed in claim 5, substantially as herein described and illustrated.

9. A new process for producing directly reduced metal, or a new furnace, substantially as herein described.

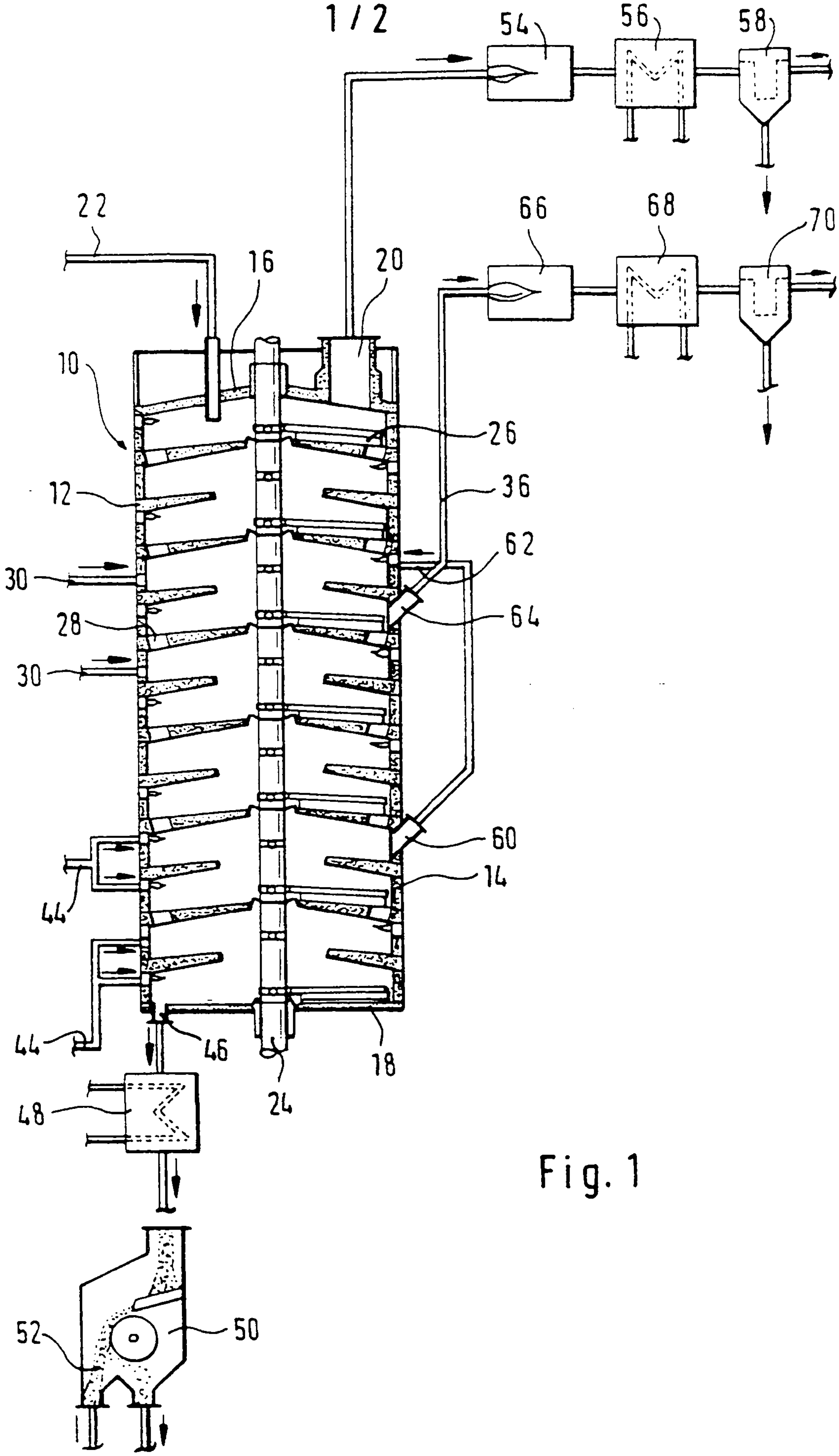

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Fig. 1

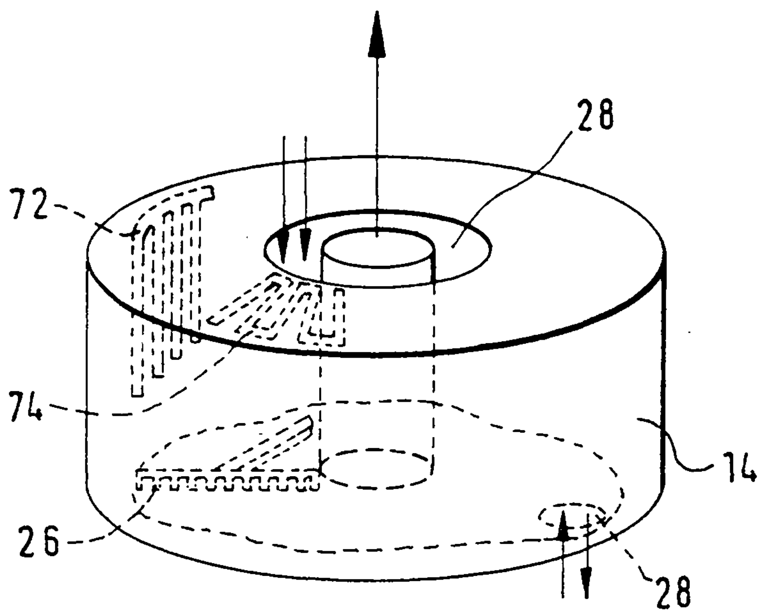

Fig. 2