



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11) **EP 0 985 893 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:  
**21.08.2002 Bulletin 2002/34**

(51) Int Cl.7: **F27B 17/02, H05B 6/80**

(21) Application number: **99830546.0**

(22) Date of filing: **06.09.1999**

(54) **Microwave kiln for firing ceramic material under pressure**

Hochdruckmikrowellenofen zum Brennen von keramischem Material

Four à micro-ondes pour cuire sous pression des matériaux céramiques

(84) Designated Contracting States:  
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE**

(72) Inventor: **Borelli, Gaudenzio**  
**51100 Piazza, Pistola (IT)**

(30) Priority: **08.09.1998 IT F1980200 U**

(74) Representative: **Mannucci, Michele et al**  
**Ufficio Tecnico Ing.A. Mannucci,**  
**Via della Scala 4**  
**50123 Firenze (IT)**

(43) Date of publication of application:  
**15.03.2000 Bulletin 2000/11**

(73) Proprietor: **Colorobbia Italia S.p.a.**  
**50053 Sovigliana Vinci (Firenze) (IT)**

(56) References cited:  
**EP-A- 0 457 948** **DE-C- 19 648 366**  
**FR-A- 2 645 391** **GB-A- 2 262 333**  
**US-A- 4 835 354**

**EP 0 985 893 B1**

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

## Description

**[0001]** The present invention relates to a microwave kiln for firing ceramic material under pressure.

**[0002]** It is known that, for firing ceramic materials, kilns comprising a chamber for the combustion of a mixture of air/methane (or other) provided with a duct or flue for evacuation of the fumes are used. In kilns of this type the combustion chamber acts as a reaction chamber for the ceramic material being fired. It is also known that, in order to obtain particular ceramic materials, such as so-called "inclusion" pigments, an overpressure is generated inside the combustion/reaction chamber by partially throttling the duct for discharging the fumes.

**[0003]** In this way, however, the reaction conditions are difficult to reproduce and moreover the pressure which can be generated inside the chamber is limited to a few tenths of an atmosphere. Moreover, since the reaction occurs inside the combustion chamber, the combustion fumes contain considerable quantities of toxic reaction products with the consequent need to provide suitable means for elimination and filtration thereof.

**[0004]** The kilns of the type indicated above furthermore require considerable firing times and result in a significant amount of energy being wasted since most of the heat is lost in the flue emissions.

**[0005]** Microwave kilns used in laboratories for firing small quantities of ceramic material are also known.

**[0006]** The main object of the present invention is that of proposing a microwave kiln for firing under pressure ceramic material in an industrial quantity, which does not possess the drawbacks mentioned above.

**[0007]** Said object is achieved by means of a kiln which has the features indicated in the accompanying Claim 1. Particularly advantageous embodiments are defined in the dependent claims.

**[0008]** The advantages and features of the invention will become clear from the detailed description which follows, provided with reference to the accompanying drawings which illustrate a purely exemplary and non-limiting embodiment thereof and in which:

- Figure 1 shows, partially sectioned, a schematic front view of a kiln for firing ceramic material, constructed in accordance with the present invention;
- Figure 2 shows a schematic plan view of the kiln according to Figure 1;
- Figure 3 shows an enlarged detail of Figure 1.

**[0009]** In accordance with the accompanying figures, 1 denotes in its entirety a kiln for firing ceramic material.

**[0010]** This kiln 1 comprises a reactor consisting of a container 2 with a substantially cylindrical shape which extends along a substantially horizontal longitudinal axis 3 and which is made of non-magnetic metallic material, preferably stainless steel. The container 2 consists of a tubular element 4 which is closed at the ends and provided with one or two hatches 5 which are connected

to the tubular element 4 itself in a pressure-tight manner.

**[0011]** An upper-lateral and axially central portion of the container 2 has, formed in it, an opening 24 which has an elongated rectangular shape from the top downwards and is sealingly closed by means of a curved plate 25 made of material which is transparent to microwaves, preferably teflon. This plate has, arranged opposite it, the outlet mouth of a rectangular waveguide 27 which is connected, at the opposite end, to a magnetron 28.

**[0012]** According to the invention, the magnetron 28 is supported, in a manner not shown, on suitable guides so as to be able to perform translatory movements in both directions, over an arc of a circle of about 90° with its center on the axis 3, as a result of the action of an actuator device consisting, for example, of a hydrodynamic piston 29 or other device suitable for the movement described. During the course of these translatory movements, the waveguide 27 moves integrally with the magnetron so that the outlet mouth remains constantly in contact with the plate 25.

**[0013]** In order to prevent microwaves reflected inside the container 2 from passing out through the teflon window 25, the waveguide 27 is connected, on the two sides which face the directions of translation, to metal sheets 26 of flexible non-magnetic material. Each of said sheets 26 is connected at the opposite end to a rolling-up device 31 which is known per se and fixed to the container 2 at the top (or bottom) end of the window 25. In this way, whatever the position of the magnetron 28 with the waveguide 27 during its translatory movements, the part of the teflon window 25 which is not occupied by the outlet mouth of the waveguide 27, is constantly screened by the portions of each sheet 26 which extend from the rolling-up devices 31 to the two sides of the waveguide mouth (see in particular Fig. 3).

**[0014]** The container 2 is provided internally with a box-shaped body 13 which is made of - preferably 98% pure - low-density alumina (bubble alumina) bricks. The internal cavity 14 of said box-shaped body 13 forms the firing chamber for the ceramic material. Since the bricks are made of material with a low microwave absorption capacity, the firing chamber 14 is thermally insulated inside the container 2.

**[0015]** Microwave-absorbing elements 15, for example in the form of small bars, are located adjacent to the walls of the cavity 14 (at the bottom and on the sides in the example shown in Fig. 1). Said elements are, basically, made of material with a high dielectric loss factor and have the characteristic feature that they heat up considerably if subjected to the action of microwaves.

**[0016]** Advantageously means are provided for causing rotation of the ceramic material about a vertical axis. In particular, in the preferred embodiment illustrated in Figs. 1 and 2, an axially central bottom portion of the container 2 has, formed in it, a vertical hole 6 coaxially seating in a sealed manner a shaft 7 having a bottom end 8 arranged underneath the container 2 itself and connected coaxially to the output spindle of an electric

motor 9. Said shaft 7 also has a top end 10 extending inside the container 2 and having its free end arranged underneath the axis 3 of the container 2 itself. A central portion of a horizontal surface 11, on which the group of bricks 13 enclosing the firing chamber 14 rests, is rigidly connected to the top end 10 of the shaft 7. An edge portion of the surface 11 at the bottom runs along an annular stainless-steel element 12 which is welded to given portions of the internal surface of the container 2 and has the function of a screen for the shaft 7. During use, the motor 9 causes rotation of the surface 11 about the axis of the shaft 7 in a single direction or alternately in both directions. Loading and unloading of the kiln are performed, via hatches 5, by means of extraction of the box-shaped body 13 from the container 2.

**[0017]** Following the translatory movements of the magnetron 28 and rotation of the surface 11, the microwave electromagnetic field strikes, in a uniform manner, through the teflon plate 25, the absorbent elements 15 and the ceramic material located inside the firing chamber 14, usually contained inside a crucible. Owing to these arrangements, the temperature of the material is substantially homogeneous, without the creation of hot points or cold points, and may reach values even greater than 1300°C.

**[0018]** According to that shown in Figure 2 by way of example, the container 2 is provided with two inlet holes 16 (and, where necessary, outlet holes) for gas flows at a pressure greater than atmospheric pressure (for example four bars and more) and is provided with two holes 17 for connection to special valves (not shown) which can be used to keep the pressure inside the container 2 itself under control. The container 2 also has a hole 18 communicating with a safety valve (not shown) and has a hole 19 through which an Ni/Cr thermocouple 20 extends inside the container 2 itself, said thermocouple being provided with a steel sheath and being designed to keep the temperature of the external shell of the container 2 itself under control. A further hole 21 formed in the container 2 allows the introduction, inside the container 2 itself, of a Pt/Rh thermocouple 22 which is provided with a platinum sheath and extends through the lining 13 as far as the inside of the firing chamber 14, so as to measure the internal temperature of the box-shaped body 14 itself, without being subject to the effect of interference arising from the microwave electromagnetic field.

**[0019]** Said gas flows have the function of washing and saturating the reaction environment inside the container 2 and their pressure is fixed and equal to values which, during use, have proved to be ideal for achieving the desired results.

**[0020]** In accordance with that shown in Figure 2, two portions of the container 2 arranged in the vicinity of the axial ends of the container 2 itself are transversely delimited by respective grilles 23 which are preferably made of stainless-steel sheet metal and which have the function of delimiting the zone of action of the said elec-

tromagnetic field.

**[0021]** It should be noted that, according to a preferred embodiment of the present invention and in accordance with that shown schematically in Figure 2, computer means of type known per se are provided, said means typically consisting of a PLC and being schematically indicated in the form of a block 30, for regulating the said valves associated with the holes 16 and the generator 28 in such a way as to control in accordance with a predefined program the pressure inside the container 2 and define temperature/time firing curves using a system of feedback from the thermocouple 22 to the generator 28 itself.

**[0022]** The tests carried out using a kiln in accordance with that described and illustrated have shown that the kiln itself, in accordance with the predefined objects, can be used to produce on an industrial scale innovative ceramic products, for example of the type mentioned in the introduction of the present description, having an economic effect of major importance on the market.

**[0023]** Moreover, the kiln described is able to avoid the presence of combustion fumes containing gases which are harmful for the environment, as well as dust, thus avoiding high purification costs.

**[0024]** It has also been established that the kiln 1 is able to operate in a mode which saves a great deal of energy since substantially all the energy supplied remains confined inside the container 2: in conventional kilns, on the other hand, at least 40% of the energy supplied is lost in the flue emissions.

**[0025]** Moreover, the kiln 1 is able to achieve a significant reduction in the time required for firing the ceramic material, in particular if the latter absorbs microwaves.

**[0026]** In an industrial kiln according to the invention, for example, one or more 2.45 GHz magnetrons with an overall power output of 100-150 kWatt and with a production capacity of 500-800 kg per firing cycle may be used.

**[0027]** The invention thus conceived may be subject to numerous modifications and variations, all of which falling within the scope of the invention.

## Claims

1. A microwave kiln for firing ceramic material under pressure, comprising a container (2), a firing chamber located inside said container (2), means for generating microwaves located outside said container (2) and designed to convey the microwaves inside said container (2) through an opening (24) provided in the wall thereof, means designed to rotate the ceramic material about a vertical axis, and means designed to generate a pressure greater than atmospheric pressure inside said container (2), **characterized in that** it comprises means designed to move said microwave generators with respect to said opening (24) so as to produce a substantially

uniform electromagnetic field inside said container (2).

2. The kiln as claimed in claim 1, **characterized in that** said microwave generator means comprise at least one magnetron (28) connected by means of a waveguide (27) to said opening (24) and movable along it together with the waveguide, a plate (25) made of material transparent to microwaves being provided for a sealing closure of the opening.
3. The kiln as claimed in claim 2, **characterized in that** said container (2) has a cylindrical shape, said opening (24) occupies a portion of the side wall of the container (2) and the magnetron (28) moves in both directions, together with the waveguide (27), over an arc of a circle substantially centered on the axis (3) of the container.
4. The kiln as claimed in claims 1 to 3, **characterized in that** it comprises means designed to screen the portions of the opening (24) which are not affected by passing of the microwaves generated by the magnetron.
5. The kiln as claimed in claim 4, **characterized in that** said screening means consist of metal sheets (26) of flexible non-magnetic material of variable length.
6. The kiln as claimed in one of claims 1 to 5, **characterized in that** it comprises, inside said container (2), a box-shaped body (13) which is made of a material which has a low microwave absorption capacity, preferably low-density alumina, the internal cavity (14) of said box-shaped body (13) forming the firing chamber for the ceramic material.
7. The kiln as claimed in claim 6, **characterized in that** it comprises microwave-absorbing elements (15) which are made of material with a high dielectric loss factor and located adjacent to the walls of said cavity (14).
8. The kiln as claimed in claim 6 or 7, **characterized in that** said box-shaped body (13) rests on a rotating surface (11).
9. The kiln as claimed in one of claims 3 to 8, **characterized in that** two portions of the said container (2) arranged in the vicinity of the axial ends of the container (2) itself are transversely delimited by respective metal grilles (23) which perform the function, during use, of delimiting the zone of action of the said electromagnetic field.
10. The kiln as claimed in any one of the preceding claims, **characterized in that** it comprises means

for controlling the pressure and the temperature inside the container (2) and computer means (30) for managing the firing time of the ceramic material.

## Patentansprüche

1. Mikrowellenofen zum Brennen von Keramikmaterial unter Druck, mit einem Behälter (2), einer in dem Behälter (2) angeordneten Kammer, einer Einrichtung zum Erzeugen von Mikrowellen, die außerhalb des Behälters (2) angeordnet ist und die Mikrowellen in den Behälter (2) durch eine in dessen Wand vorgesehene Öffnung (34) einleitet, Mittel zum Drehen des Keramikmaterials um eine vertikale Achse, und Mittel zum Erzeugen eines Drucks über Atmosphärendruck innerhalb des Behälters (2), **dadurch gekennzeichnet, daß** er Mittel aufweist, die ausgebildet sind, um die Mikrowellengeneratoren relativ zu der Öffnung (24) zu bewegen, um ein im wesentlichen gleichförmiges elektromagnetisches Feld innerhalb des Behälters (2) zu erzeugen.
2. Ofen nach Anspruch 1, **dadurch gekennzeichnet, daß** die Mikrowellengeneratoreinrichtung mindestens ein Magnetron (28) aufweist, das über einen Wellenleiter (27) mit der Öffnung (24) verbunden und längs dieser zusammen mit dem Wellenleiter bewegbar ist, wobei eine Platte (25) aus für Mikrowellen durchlässigem Material als abdichtender Verschluss für die Öffnung vorgesehen ist.
3. Ofen nach Anspruch 2, **dadurch gekennzeichnet, daß** Behälter (2) zylindrische Form hat, daß die Öffnung (24) einen Teil der Seitenwand des Behälters (2) einnimmt und daß das Magnetron (28) zusammen mit dem Wellenleiter (27) in beiden Richtungen bewegbar ist über einen Kreisbogen, der im wesentlichen auf die Achse (3) des Behälters zentriert ist.
4. Ofen nach den Ansprüchen 1 bis 3, **dadurch gekennzeichnet, daß** er Mittel aufweist zum Abschirmen der Bereiche der Öffnung (24), die von dem Durchtritt der von dem Magnetron erzeugten Mikrowellen nicht betroffen sind.
5. Ofen nach Anspruch 4, **dadurch gekennzeichnet, daß** die Abschirmmittel aus Metallblechen (26) aus flexiblem, nicht magnetischem Material mit veränderlicher Länge bestehen.
6. Ofen nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, daß** er innerhalb des Behälters (2) einen kastenförmigen Körper (13) aufweist, der aus einem Material mit niedrigem Absorptionsvermögen für Mikrowellen besteht, vorzugsweise aus Aluminiumoxid geringer Dichte, wobei der innere

Hohlraum (14) des kastenförmigen Körpers (13) die Brennkammer für das Keramikmaterial bildet.

7. Ofen nach Anspruch 6, **dadurch gekennzeichnet, daß** er Mikrowellen absorbierende Elemente (15) aufweist, die aus einem Material mit hohem dielektrischen Verlustfaktor bestehen und angrenzend an die Wände des Hohlraums (14) angeordnet sind. 5
8. Ofen nach Anspruch 6 oder 7, **dadurch gekennzeichnet, daß** der kastenförmige Körper (13) auf einer rotierenden Oberfläche (11) ruht. 10
9. Ofen nach einem der Ansprüche 3 bis 8, **dadurch gekennzeichnet, daß** zwei Bereiche des Behälters (2), die nahe den axialen Enden des Behälters (2) angeordnet sind, in Querrichtung durch jeweilige Metallgitter (23) begrenzt sind, die im Betrieb die Funktion einer Begrenzung der Wirkungszone des elektromagnetischen Feldes ausüben. 15
10. Ofen nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, daß** er Mittel zum Steuern des Druckes und der Temperatur innerhalb des Behälters (2) sowie Computermittel (30) zum Steuern der Brennzeit des Keramikmaterials aufweist. 25

#### Revendications

1. Four à micro-ondes pour la cuisson d'un matériau céramique sous pression comprenant une enceinte (2), une chambre de cuisson située à l'intérieur de ladite enceinte (2), des moyens pour produire des micro-ondes et situés à l'extérieur de ladite enceinte (2) et conçus de manière à véhiculer les micro-ondes à l'intérieur de ladite enceinte (2) par une ouverture (24) prévue dans la paroi de l'enceinte, les moyens conçus pour faire tourner le matériau céramique autour d'un axe vertical et des moyens conçus pour produire une pression supérieure à la pression atmosphérique à l'intérieur de ladite enceinte (2), **caractérisé en ce qu'il** comporte des moyens constitués pour déplacer lesdits moyen de production de micro-ondes par rapport à ladite ouverture (24) de manière à produire un champ électromagnétique essentiellement uniforme à l'intérieur dudit conteneur (2). 30
2. Four selon la revendication 1, **caractérisé en ce que** lesdits moyens de production de micro-ondes comprennent au moins un magnétron (28) connecté au moyen d'un guide d'ondes (27) à ladite ouverture (24) et déplaçable le long de cette ouverture conjointement avec le guide d'ondes, une plaque (25) formée d'un matériau transparent pour les micro-ondes, qui est prévu pour réaliser une fermeture étanche de l'ouverture. 40
3. Four selon la revendication 1, **caractérisé en ce que** ladite enceinte (2) possède une forme cylindrique, ladite ouverture (24) occupe une partie de la paroi latérale de l'enceinte (2) et le magnétron (28) se déplace dans les deux directions, conjointement avec le guide d'ondes (27) sur un arc de cercle essentiellement centré sur l'axe (3) du conteneur. 45
4. Four selon les revendications 1 à 3, **caractérisé en ce qu'il** comprend les moyens conçus pour protéger les parties de l'ouverture (24) qui ne sont pas affectées par le passage des micro-ondes produites par le magnétron. 50
5. Four selon la revendication 4, **caractérisé en ce que** lesdits moyens formant écran sont constitués par des feuilles métalliques (26) formées d'un matériau amagnétique flexible de longueur variable; 55
6. Four selon l'une des revendications 1 à 5, **caractérisé en ce qu'il** comprend, à l'intérieur de ladite enceinte (2) un corps en forme de boîte (13), qui est formé d'un matériau qui possède une faible capacité d'absorption des micro-ondes, de préférence de l'alumine basse densité, la cavité interne (14) dudit corps en forme de boîte (13) formant la chambre de combustion sur le matériau céramique. 60
7. Four selon la revendication 6, **caractérisé en ce qu'il** comprend les éléments (15) d'absorption du micro-ondes, qui sont formés d'un matériau possédant un facteur de perte diélectrique élevé et situés au voisinage des parois de ladite cavité (14). 65
8. Four selon la revendication 6 ou 7, **caractérisé en ce que** ledit corps en forme de boîte (13) est en appui sur une surface rotative (11). 70
9. Four selon l'une quelconque des revendications 3 à 8, **caractérisé en ce que** deux parties de ladite enceinte (2) disposées au voisinage des extrémités axiales de l'enceinte (2) elle-même sont délimitées transversalement par des grilles métalliques respectives (23) qui assument, pendant l'utilisation, la fonction de délimitation de la zone d'action dudit champ électromagnétique. 75
10. Four selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'il** comprend des moyens pour commander la pression et la température à l'intérieur de l'enceinte (2) et des moyens informatiques (30) pour gérer la durée de cuisson du matériau céramique. 80

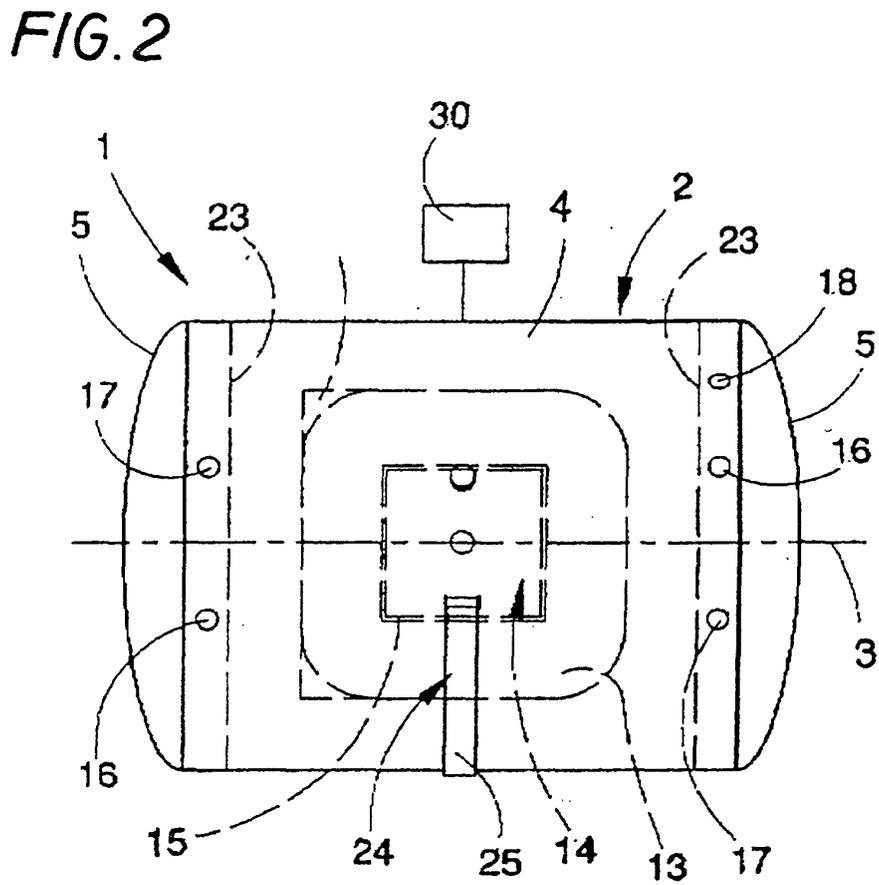
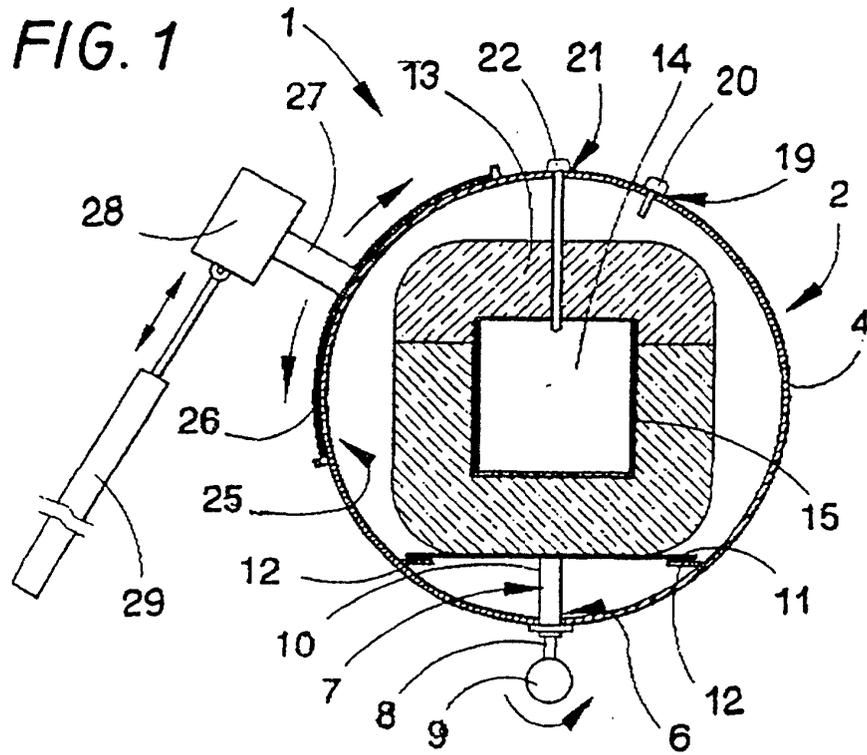


FIG. 3

