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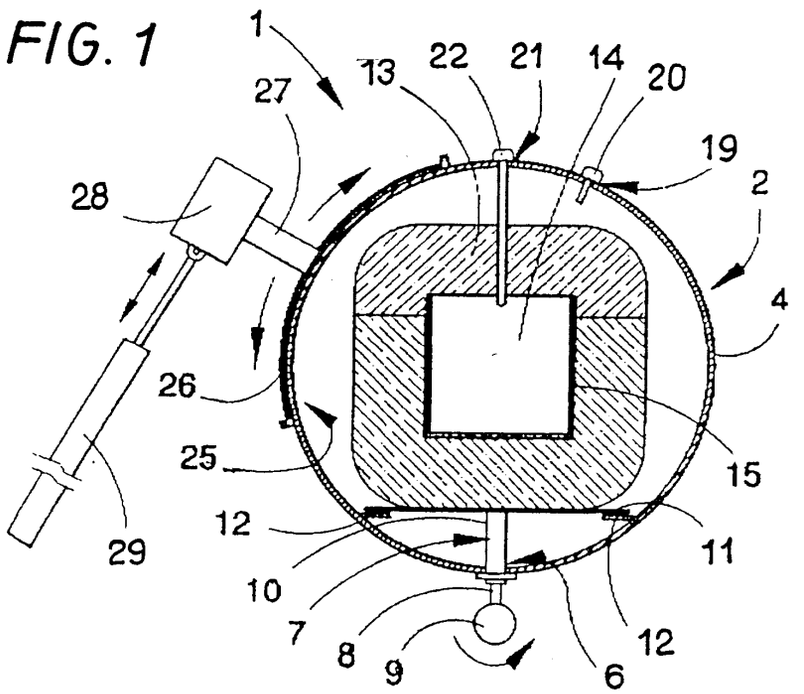
(54) Microwave kiln for firing ceramic material under pressure

(57) A microwave kiln for firing ceramic material under pressure comprises a container (2), a box-shaped body (13) made of low-density alumina and rotatable inside the container (2) about a vertical axis, a firing chamber for the ceramic material, consisting of the internal cavity (14) of the box-shaped body (13), a magnetron (28) for generating microwaves and a waveguide (27) for introducing said waves inside the container (2) through an opening (24), means designed to generate a pressure greater than atmospheric pressure inside the container (2); the magnetron (28) and the waveguide (27) being movable along the opening (24) in order to produce a substantially uniform electromagnetic field inside the container (2); elements (15) made of material with a high dielectric loss factor being provided adjacent to the walls of the internal cavity (14) of the box-shaped body (13).

FIG. 1



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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 electromagnetic 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 inventive idea. Moreover, all the details described may be replaced by technically equivalent elements.

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.

FIG. 1

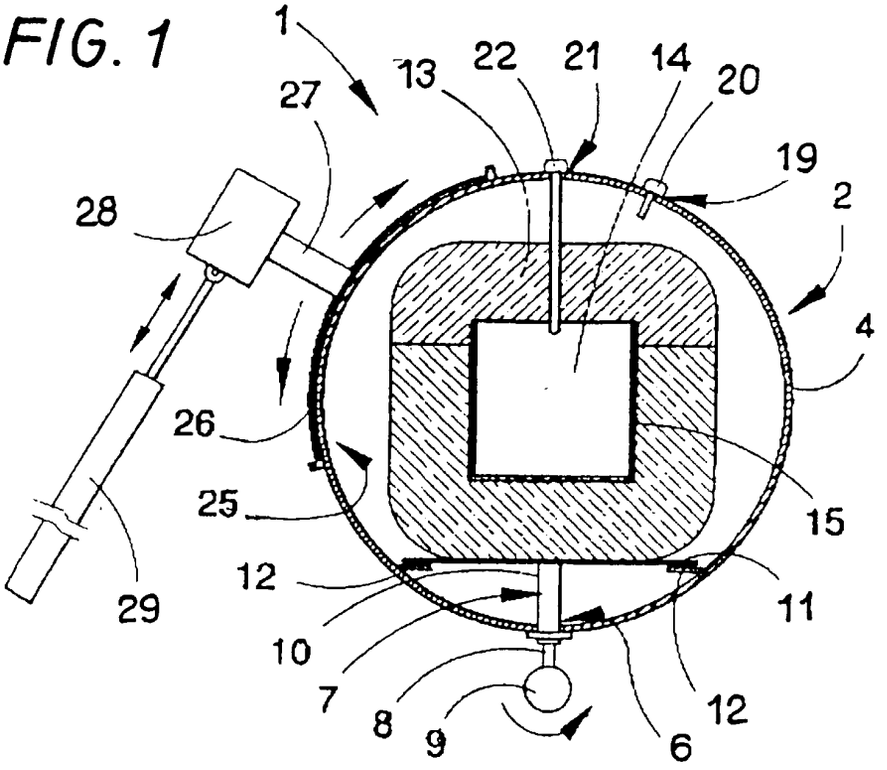
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FIG. 2

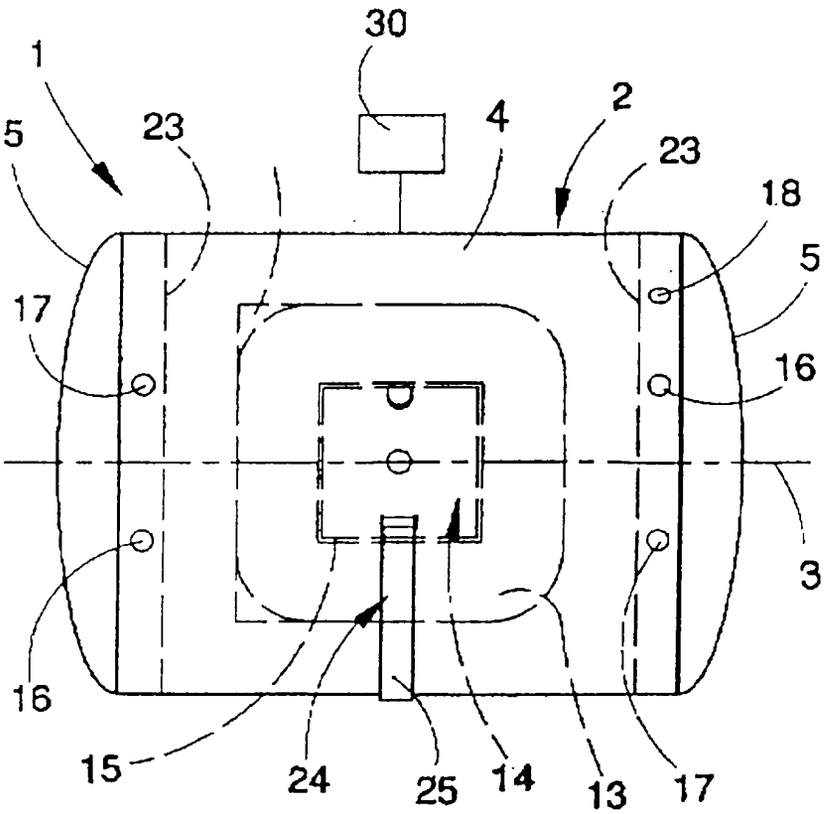
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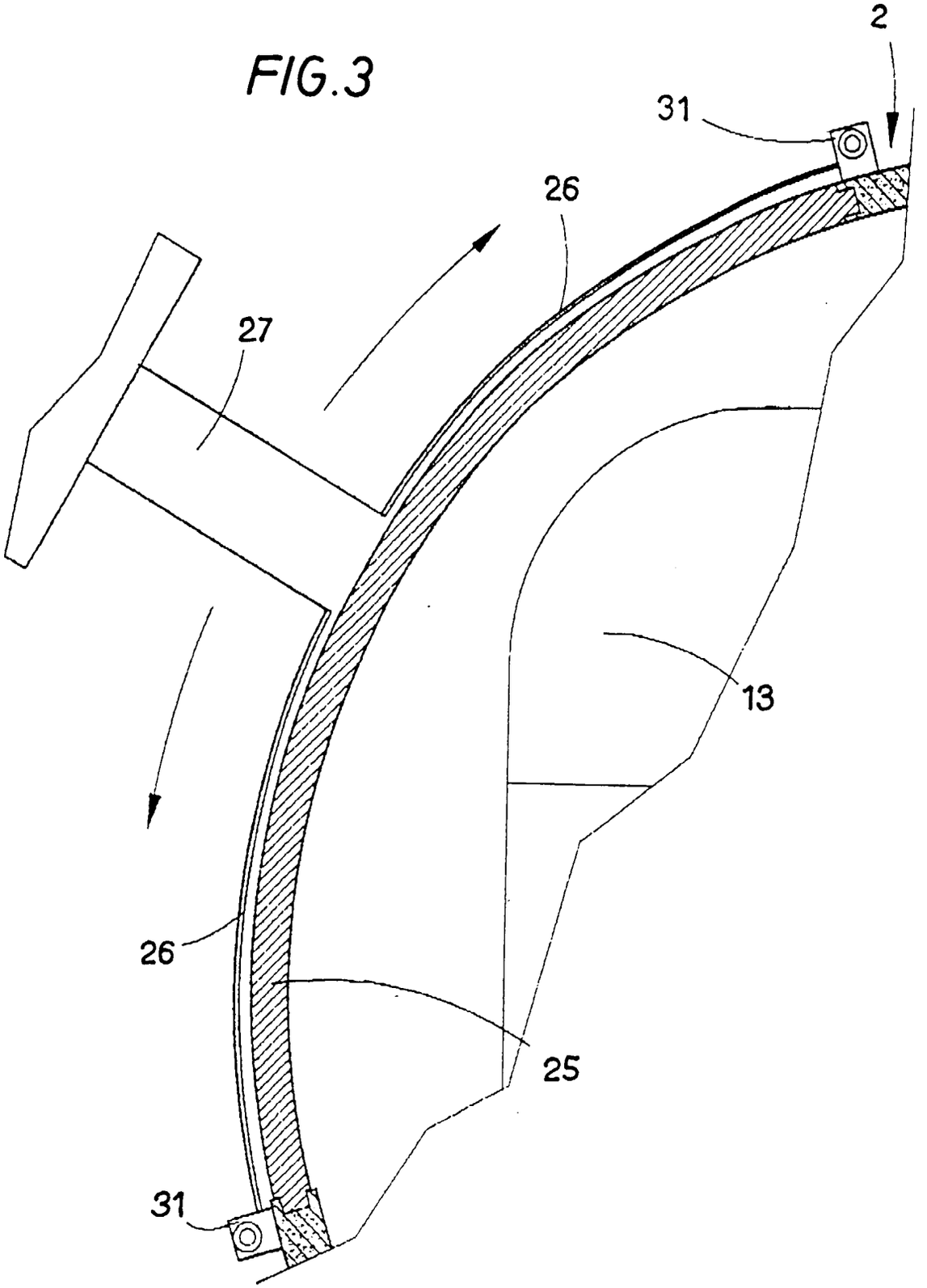
FIG.3



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EUROPEAN SEARCH REPORT

Application Number
EP 99 83 0546

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

F27B
H05B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 December 1999	Coulomb, J

CATEGORY OF CITED DOCUMENTS

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10-12-1999

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