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(54) Title: ELECTRICALLY CONDUCTIVE BUILDING MATERIAL AND PROCESS FOR PRODUCING IT

(57) Abstract: The invention relates to an electrically conductive plaster material comprising a mixture of graphite and amorphous carbon and gypsum, for shielding against electromagnetic radiation, and heating. It has been shown that this mixture has excellent shielding properties in the 1MHz to 18GHz ranges, and can be made to include X-rays and Gamma rays and Maser amplified radiation beams. It is easy to apply and can be used as a render, or made into plasterboard, partition panels or tiles, and is flame retardant and resistant to shock. It can also be used as a low cost heating material which is safe, easy to install and can be used in houses, offices and for de-icing and preventing settlement of snow.



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ELECTRICALLY CONDUCTIVE BUILDING MATERIAL
AND PROCESS FOR PRODUCING IT

The present invention concerns an electrically
5 conductive building material comprising graphite
particles and amorphous carbon, in particular plaster
and a process for producing it.

The use of carbons to make cementitious building
10 materials electrically conductive is known. US patent
5,908,584 to Bennett discloses electrically conductive
concrete comprising a mixture of graphite, amorphous
carbon and sand with a cement binder for making a
coating or mortar, a sandwich shaped construction
15 panel, and building blocks.

WO00/69789 to MANTLE & LLAY LTD et al, provides a
concrete or cementitious product having one or more
forms of carbon dispersed therethrough so as to reduce
20 thermal conductance across the product. The one or more
forms of carbon are preferably dispersed therethrough
in small clusters and/or agglomerates that are wholly
or substantially isolated from each other.

25 The chemical reactions involved in the manufacture and
setting of cement are extremely complex, and together
with the polymorphic nature of the particles demand
close monitoring of the mixing to ensure uniform
covering of the sand by the carbon. To reduce the
30 effect of uneven conductivity in cementitious mortar
caused by incomplete mixing, the product can be applied
more thickly, but this increases the weight per area

covered, introducing weight-bearing problems in the construction.

A high percentage of carbon in a cement mix reduces the strength of the product making it brittle, fragile and subject to fracture, which can interrupt the conductivity, and make the shielding unreliable. This effect can be overcome to an extent by subjecting the mixture to pressure during the setting process, or by the addition of additives, both of which add to the cost.

Cementitious products take many years to dry out completely. Whether as mortar, building blocks or poured concrete, cement retains some free water radicals even when it is set and apparently dry. Many substances, and in particular steel and other metals, in contact with the material are subjected to chemical and electrolytic action, causing long term corrosion or chemical change.

Cement and cementitious products have long setting times, which make the mortar and plaster difficult to apply without additives, which add to the cost, and can cause long delays on external surfaces in icy cold weather.

The complex chemical reaction and the crystalline formation involved in making cement and concrete yield a rigid product. Cement mortars and plasters are subject to minute fracturing, and the products have to be made thick to achieve their strength.

The aim of the present invention is:

1. to propose an electrically conductive building
5 material, in particular plaster, which is easy to use,
long lasting and economic to apply, to make reliable
EMI shielding accessible to those using computers and
electronic data storage installations who cannot afford
the protection currently available,
 - 10 2. to propose an electrically conductive plaster with
consistent and reliable attenuation properties over a
wide spectrum of electromagnetic wavelengths,
 3. to propose an electrically conductive plaster
capable of resisting Maser beams in the microwave
15 frequencies, (amplified radiation which in the visible
light frequencies is known as Laser),
 4. to propose an electrically conductive plaster that
can be used in the construction of pre-fabricated rooms
and buildings,
 - 20 5. to propose an electrically conductive plaster that
does not shatter with shock and is retardant to flames,
 6. to propose an electrically conductive plaster that
will heat up when a current is passed through it.
- 25 The electrically conductive material according to the
present invention comprises graphite particles having a
particle size not greater than about 12 microns and
amorphous carbon, bound in a gypsum/carbon matrix.
- 30 According to a preferred embodiment the matrix
comprises a crystalline lattice of gypsum integrated
with amorphous carbon.

Various embodiments are claimed in claims 3 to 22.

The invention relates also to a process for producing
5 the electrically conductive material wherein a portion
of amorphous carbon is mixed dry with the gypsum, water
is then added to start the hydration process, producing
a supersaturated solution in which crystals start to
10 form and as the crystals coalesce, minute particles of
amorphous carbon become incorporated into the lattice
causing it to become electrically conductive, the rest
of amorphous carbon is mixed with the graphite
separately, coating it, and the mixture is added to the
hydrating solution as the crystallisation accelerates,
15 trapping the coated electrically conductive graphite
particles between the interlocking crystals which form
a binding matrix

The gypsum matrix has properties not present in
20 cementitious or other products, which give the material
according to the present invention unique electrical,
chemical and physical characteristics.

When water is added to the hemihydrate or anhydrite
25 (calcined) forms of gypsum, ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$ or CaSO_4), the
calcined gypsum hydrates to the dihydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$).
If just enough water is added to produce a homogeneous,
fluid, stable, non-sedimenting slurry, the hydration is
uniform throughout the mixture. The uniformity of the
30 hydration ensures uniformity in the distribution of the
carbons throughout the mixture, so the electrical
conductivity is not jeopardised by incomplete mixing.

In the mechanism of hydration of gypsum hemihydrate mentioned above, mixing and wetting of the hemihydrate powder, which causes disintegration of the hemihydrate particles, is followed by a short induction period, after which nuclei begin to form from the supersaturated solution. The hemihydrate is converted directly into dihydrate. The anhydrite also converts directly into the dihydrate without converting to hemihydrate, and so may not form the same supersaturated solution. As the hydration proceeds and the slurry sets, dihydrate crystals grow, intergrow and interlock. (U.Ludwig, J.K. Kuhlmann, Tonind, Ztg. Keram. Rundsch. 98 (1974) 1- 4).

15

Mixing of the carbons is done in two stages; (I) before hydration, a portion of amorphous carbon is mixed with the gypsum. Water is then added to start the hydration process. Minute particles in this amorphous carbon, especially nano particles sized between 1 to 10 nanometers, will enter the lattice as the crystals start to form. This will make the matrix itself electrically conductive (ii) The rest of the amorphous carbon is mixed with the graphite. The particles of amorphous carbon are so fine that it displays some of the properties of a liquid, and will coat the graphite sticking to it as if by surface tension. This mixture is added as the hydration proceeds and formation of the crystals accelerates. This carbon combination will not be absorbed into the lattice, but will be trapped with residual particles of amorphous carbon larger the minute ones (nano particles) from the first mix, in the

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25
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matrix by the interlocking of the forming crystals, forming a consistent highly conductive material.

However, even with the most stringent quality control
5 incomplete mixing with non-conductive binders can result in gaps or 'windows' in conductivity. The smallest defect in one spot can cause the attenuation in a whole room to fail. In the material according to the present invention the graphite becomes locked into
10 a matrix, which is itself electrically conductive. This provides a consistent and reliable shielding with no gaps or 'windows' caused by mixing failure in the product.

15 Another advantage of the material according to the present invention is the fact that the graphite becomes locked into the matrix, making the plaster strong and not subject to fracture. A higher percentage of carbons can be included in the mixture without weakening the
20 material or making it brittle or fragile, so reliable shielding is provided with thin plaster coatings.

Another advantage of the material according to the present invention is the fact that part of the
25 conductive amorphous carbon becomes integrated into the crystalline gypsum lattice. This carbon is evenly and closely dispersed and, together with the graphite bound by the matrix, provides a material capable of withstanding bombardment from Maser amplified
30 radiation.

Recent research in nanotechnology has shown that minute particles of less than 10 nanometers display unusual properties, which enables them to interact with molecules within crystals. The sophisticated equipment
5 needed to produce such particles normally makes them very expensive to produce and their derivatives highly expensive. An advantage of the material according to the present invention is that it uses carbon. This is the only substance, which produces nano particles
10 naturally. The gasses produced from the incomplete combustion of organic material produce a deposit of amorphous carbon part of whose particles are of nano size. This requires no sophisticated equipment, and is often produced as a by-product of other processes, so
15 enabling the present invention to benefit from nanotechnology without incurring any high cost.

Cementitious products have limitations, as previous mentioned, which make them impractical in many
20 applications. The material according to the present invention produces inexpensive easy-to-apply electrically conductive plaster, which overcomes these limitations. It makes protective shielding available for vast numbers of computer and other electronic data
25 storage installations which, due to the high cost of existing technology, are currently vulnerable to interference from intentional or unintentional electromagnetic radiation.

30 Because of the way the carbons in the present invention are incorporated into the gypsum, its physical and chemical properties remain virtually unchanged and

become the properties of the material according to the present invention. gypsum, $(\text{CaSO}_4 \cdot 2\text{H}_2\text{O})$, is chemically stable.

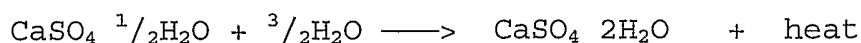
5 When the hydration reaction described above is complete, any spare water evaporates off. The plaster being completely dry and chemically inert, there is no metallic corrosion or chemical reaction with other substances. This simplifies connection between the
10 plaster and other electrically conductive components such as doors, vents and windows in a shielded enclosure.

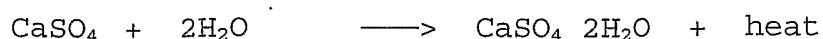
Gypsum adheres to gypsum. Since the material according
15 to the invention has the same physical properties gypsum plaster without carbons will adhere to that material. The colour of the material according to the present invention is also grey, but a layer of pure gypsum plaster, which is white and opaque, will adhere
20 to the material and provide a smooth white surface, which can be painted or papered to give an aesthetically pleasing finish.

Gypsum is an insulator. A layer of pure gypsum plaster
25 will adhere to the material according to the invention and can be used to an insulate it electrically.

The gypsum hydration process gives out heat, and the reaction time is short.

30





Another advantage of the material according to the present invention is the fact that the heat given out during hydration prevents delays caused by water freezing during setting in cold weather, and the reaction time, which keeps setting time short, makes the plaster easy to apply.

<u>Setting Times (min)</u>	<u>Initial setting</u>	<u>Final setting</u>
Projection plaster	60 - 120	170 - 220
Bonding plaster	50 - 90	80 - 200
Lightweight plaster	50 - 90	100 - 170

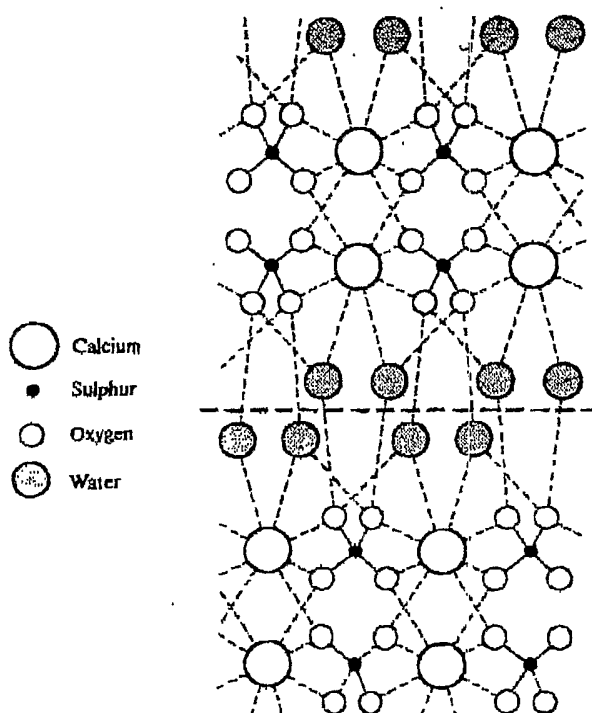
Gypsum is a flame retardant, so the material according to the present invention also acts as a flame retardant. When exposed to heat, gypsum dihydrate changes to hemihydrate or anhydrite, releasing water.

<u>Gypsum Dehydration</u>	<u>Temperature required</u>
$\text{CaSO}_4 \cdot 2\text{H}_2\text{O} \xrightarrow{\text{heat}} \text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O} + \frac{3}{2}\text{H}_2\text{O}$	> 130° C
$\text{CaSO}_4 \cdot 2\text{H}_2\text{O} \xrightarrow{\text{heat}} \text{CaSO}_4 + 2\text{H}_2\text{O}$	> 600° C
$\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O} \xrightarrow{\text{heat}} \text{CaSO}_4 + \frac{1}{2}\text{H}_2\text{O}$	> 600° C

The water released at the surface inhibits the transfer of heat to the lower plaster layers, delaying destruction of the electromagnetic shield. In an outbreak of fire or attack by an incendiary device, this retardation gives occupants of a shielded room or building extra time to download or remove sensitive data before making their escape.

A further advantage of the material according to the present invention is the fact that gypsum has a more simple chemistry and crystalline structure than that of cement. The chemical reactions consist of dehydration and hydration of the gypsum ingredients, as described above, and the crystals are uniformly monoclinic with three axes, one pair not at right angles, and one direction of perfect cleavage. This allows for some slip along the line of cleavage where the ions are linked by water, when the material is subjected to stress or percussion. The basic structure is held firm by the intergrowth and interlocking of the crystals described above.

15



In the structure of gypsum CaSO₄ shown above, the heavy broken line indicates the cleavage, which breaks only hydrogen bonds.

The material according to the present invention has excellent workability, and can be made into plasterboard, partitions, ceiling and floor tiles, fibre-reinforced boards and pre-cast panels. Due to the plasticity described above these components are shock resistant and will not shatter under attack. Using β -hemihydrate as the starting gypsum ingredient, the material can be made into a mortar which adheres to any masonry surface, including gypsum surfaces, does not crack, expands slightly on setting, and sets fast. This mortar can be used to connect the electrically conductive components for use in the rapid construction of prefabricated or portable Faraday Cages for military or civilian installations.

According to an embodiment the weight of amorphous carbon mixed with the gypsum represents at least 1%, preferably between 1% and 5%, of the weight of gypsum.

20

According to another embodiment the weight of the amorphous carbon mixed with the graphite represents at least 2%, preferably between 2% and 10%, of the total weight of the graphite.

25

According to another embodiment the total weight of the graphite represents between 15% and 75% of the total weight of the material.

According to another embodiment the material comprises glass fibres and or magnetic or magnetisable metallic molecules.

30

According to a preferred embodiment the amorphous carbon comprises nano particles of 1 to 10 nanometres. The proportion of nano particles in the portion of amorphous carbon mixed with the gypsum represents at
5 least 1%, preferably 1% to 50% of the amorphous carbon weight.

The material according to the invention can be used principally in the following ways:

10

1. as a plaster or mortar
2. as a plasterboard.
3. as tiles, particularly for ceilings and floors
4. as fibre-reinforced light weight plasterboard
- 15 5. as partition panels
6. as structural panels

One or other of these six forms of material according to the invention can be used to provide an electrically
20 conductive lining to a room or building, which will attenuate radiation and shield the contents from electromagnetic interference.

According to an embodiment of the invention including
25 Barium Sulphate in the mixture the material can be used to provide attenuation in the surface of a room or building to protect it from X-rays or Gamma rays, so providing shielding for hospitals, laboratories and other sensitive installations vulnerable to intentional
30 or unintentional bombardment from such radiation.

According to another embodiment the material can be used in military command posts and other sensitive installations to shield them from bombardment by Maser amplified microwave radiation beams.

5

According to another embodiment, panels of the material can be used as reflectors to shield schools and other buildings from radiation from Cellular Telephone Base Station transmission, which is feared to be damaging to health.

10

According to another embodiment, the render made from the material of the invention may be plastered over damaged masonry surfaces.

15

According to another embodiment, Roof, Ceiling and Wall covering from the material of the invention may be used to protect the occupants of rooms or buildings from bombardment from mentally destabilising EMR weapons.

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According to another embodiment, the material of the invention may be used to provide a flame-retardant electrically conductive EMI shield for rooms and buildings to give the occupants more time in case of fire or attack.

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According to another embodiment, the material of the invention may be used to provide a shock-resistant electrically conductive EMI shield for rooms and buildings to protect the occupants and contents from damage caused by shattering or cracking of walls or

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wall surfaces in the event of an earthquake or bomb attack.

The attenuation attained by the material according to the invention can be > 40dB over a range of frequencies of 1MHz to 18 GHz. Attenuation varies according to the ratio of carbons to gypsum in the mixture. With the high proportion of carbons tolerated by gypsum before it weakens, attenuation up to 60dBs can be achieved across most frequencies in this band. With the inclusion of Barium Sulphate in the mixture, the frequency range of attenuation can be extended to include X-rays and Gamma rays.

When a current is passed through the material according to the invention, it heats up. If the current flows through two single terminals attached each side of a tile or panel of the material it will not heat evenly and develop 'hotspots'. To use the material for heating purposes the current must flow evenly through it. To achieve this a metal strip or bar must be attached to either side of the product, which in turn is attached to terminals. The active chemical nature and water retention of water of cement and cementitious products makes this very difficult. The current sets up electrolytic cells with the metals causing them to erode. This makes it difficult to terminate the component effectively, and wires connecting product units cannot run through cement without protection.

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The heating properties of the material according to the present invention are characterised by the fact that it

acts as a semi-conductor with the resistivity increasing with temperature. This makes it more efficient at lower temperatures(< 40° C), and there is only one heat exchange, such as heating water, so
5 reducing the power consumption.

Another embodiment of the invention sets the wires or busbars connecting the products or components made from the material according to the invention in non-carbon
10 gypsum to insulate them electrically.

Another embodiment of the invention uses a layer of material according to the invention in plasterboard to provide low temperature invisible wall heating.
15

Hot air rises, so the lower the source of the heating, the more energy efficient it will be.

Another embodiment of the invention uses wainscoting made from the material according to the invention to provide low level, invisible wall heating.
20

Another embodiment of the invention uses floor tiles made from the material according to the invention to provide floor heating.
25

Another embodiment of the invention uses thick tiles for use in storage heaters, to take advantage of electricity off-peak tariff incentives.
30

Another embodiment of the invention uses thick floor tiles to provide storage floor heating.

Another embodiment of the invention uses ceiling or roof tiles made from material according to the invention to prevent settling or ice forming on roofs
5 in cold regions, in particular ski resorts and areas with heavy snowfalls, where heavy accumulation of snow on roofs constitutes a danger.

Floor and wall heating, and snow or ice prevention
10 normally involve temperatures $< 40^{\circ} \text{C}$, which can be generated using low voltage current controlled by transformers reducing the danger of electrocution and the running costs.

Claims

1. Electrically conductive building material, in particular plaster, comprising graphite particles
5 having a particle size not greater than about 12 microns and amorphous carbon, bound in a gypsum/carbon matrix.
2. Electrically conductive building material according
10 to claim 1, wherein the matrix comprises a crystalline lattice of gypsum integrated with amorphous carbon.
3. Electrically conductive building material according to one of the claims 1 to 2, wherein the amorphous
15 carbon comprises nano particles sized 1 to 10 nanometres.
4. Electrically conductive building material according to one of the claims 1 to 3 , wherein the material
20 comprises just enough water to produce a homogeneous, fluid, stable, non-sedimenting slurry.
5. Electrically conductive building material according to one of the claims 1 to 4 in which before hydration a
25 portion of amorphous carbon is mixed with the gypsum the weight of which represents at least 1% of the weight of the gypsum.
6. Electrically conductive building material according
30 to claim to 5, wherein the weight of amorphous carbon mixed with the gypsum represents between 1 and 5% of the weight of the gypsum.

7. Electrically conductive building material according to one of the claims 1 to 6, wherein the weight of the amorphous carbon mixed with the graphite represents at least 2% of the total weight of the graphite.

5

8. Electrically conductive building material according to one of the claims 1 to 7, wherein the amorphous carbon comprises nano particles and the quantity of nano particles in the portion of the amorphous carbon mixed with the gypsum represents at least 1% of amorphous carbon weight.

9. Electrically conductive building material according to one of the claims 5 to 7, wherein the amorphous carbon comprises nano particles and the quantity of nano particles in the portion of the amorphous carbon mixed with the gypsum represents 1% to 50% of amorphous carbon weight.

10. Electrically conductive building material according to claims 5 to 9 wherein the weight of the amorphous carbon mixed with the graphite represents between 2% and 10 % of the total weight of the graphite.

11. Electrically conductive building material according to claims 1 to 10, wherein the total weight of graphite represents between 15% to 75% of the total weight of the material.

12. Electrically conductive building material according to one of the claims 1 to 11 wherein the material comprises one or more forms of gypsum.

13. Electrically conductive building material according to one of the claims 1 to 11 wherein the gypsum is Calcium Sulphate dihydrate, or hemihydrate α - and β -
5 forms.

14. Electrically conductive building material according to one of claims 1 to 13, wherein the said material when the gypsum is in its β -hemihydrate form comprises
10 small amounts of glass fibre to produce gypsum ceiling tiles.

15. Electrically conductive building material according to one of the claims 1 to 14 wherein the said material
15 comprises one or more forms of Calcium Sulphate, (dihydrate, hemihydrate α - or β - or anhydrite II or III) to make multiphase plasters.

16. Electrically conductive building material according to one of the claims 1 to 15, wherein the material
20 further comprises magnetic or magnetisable metallic molecules.

17. Electrically conductive building material according to claim 16, wherein the said molecules are magnetic
25 salts.

18. Electrically conductive building material according to one of the claims 16 or 17, wherein the said
30 molecules are ferrites.

19. Electrically conductive building material according to claim 12, wherein the said material when the gypsum is in its β - hemihydrate form comprises additives to produce retarded hemihydrate gypsum plaster and
5 premixed lightweight gypsum plaster.

20. Electrically conductive building material according to one of the claims 1 to 15, wherein it is sandwiched between two layers of paper or other sheets to make a
10 plasterboard.

21. Electrically conductive building material according to one of the claims 1 to 15, wherein it is sandwiched between two support sheets to make a construction
15 panel.

22. Electrically conductive building material according to one of the claims 1 to 15, wherein the material is mixed with 10% to 50% of Barium Sulphate to obtain
20 attenuation of X-rays and Gamma rays.

23. A process for producing the electrically conductive building material according to one of the claims 1 to 22 wherein a portion of amorphous carbon is mixed dry
25 with the gypsum, water is then added to start the hydration process, producing a supersaturated solution in which crystals start to form and as the crystals coalesce, minute particles of amorphous carbon become incorporated into the lattice causing it to become
30 electrically conductive, the rest of amorphous carbon is mixed with the graphite separately, coating it, and the mixture is added to the hydrating solution as the

crystallisation accelerates, trapping the coated electrically conductive graphite particles between the interlocking crystals which form a binding matrix.

- 5 24. A process according to claim 23 for producing the material according to one of the claims 1 to 22, wherein the material is mixed with water-retaining hydrophilic colloid additives to make it suitable for continuous machine application.

INTERNATIONAL SEARCH REPORT

Inte al Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C04B28/14 C04B14/02 C04B40/00

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)
IPC 7 C04B

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

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Name and mailing address of the ISA

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Gattinger, I

INTERNATIONAL SEARCH REPORT

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