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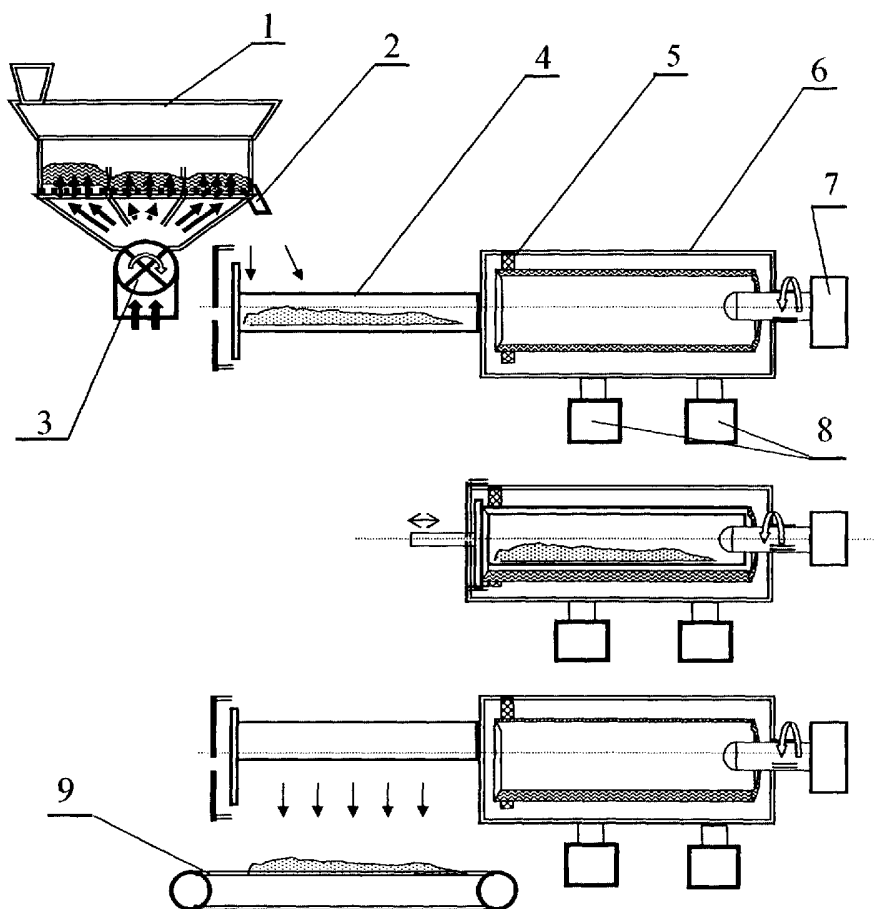
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(54) Title: METHOD TO DRY DIELECTRIC MATERIALS AND AN EQUIPMENT TO DRY DIELECTRIC MATERIALS



(57) Abstract: The method of drying dielectric materials is based on at least 2 phases. In Phase I the reduced in size dielectric material is dried in the initial process starting from the initial moisture of the dielectric material in the range from 80% to 90% to the level of 20% to 45%. After that in Phase II the initially dried dielectric material is dried with the use of microwave energy, that is carried out in a rotating cylindrically shaped chamber with the use of pressure level from 1kPa to 6kPa and frequency of microwave energy in the range of 600 MHz to 6 GHz and with the delivered microwave power of 2W to 40 W per gram of the dried material leading to obtain the moisture level of 8% to 30%. In this phase the material is heated up to the temperature not greater than 80 degrees Celsius. Subsequently the final drying process is carried out to obtain moisture level from 6 to 10%. The method to dry

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dielectric materials equipped with product preparation segment, initial drying, microwave chamber and final drying segment. The microwave chamber has a cylindrically shaped chamber of the form of a dielectric cylinder 5 inside its metal cavity 6. Additionally, metal cavity 6 is connected to the vacuum pump 7 and is equipped with microwave generators 8 characterised by low ripples of microwave power $T < 20\%$.

Method to dry dielectric materials and en equipment to dry dielectric materials

The subject of the patent in question is a way of drying dielectric materials
5 and equipment for drying dielectric materials with particular focus on drying
vegetables, fruits or meat, in cubed, sliced or seed-form with the aim to achieve
dried material characterized by high level of porosity and ability to rehydrate.

Already known methods of drying biological materials are based on an
input of dielectric materials in the forms of cubes, slices or seeds to dryers.
10 In conveyer belt dryers, the material is placed on a movable belt, that is in motion,
surrounded by a stream of warm air, in chamber dryers, the material is placed on
trays or sieves located inside the chamber filled with circulating hot air. In barrel
type of dryers the material that is subject to the drying process is placed inside the
rotating barrel, with hot air coming through it.

15 We are familiar with the Polish patent application No P338303 where we
can find the method and equipment for drying biological materials with vegetables,
fruit and meat in particular. With the use of this method the material is placed
inside the dielectric cylinder positioned inside a metal chamber that acts as an uni-
or multi-mode microwave resonator. Subsequently, the air from the inside of the
20 tube is pumped out in order to reduce pressure in the range of 1kPa to 40 kPa and
with microwave energy being introduced to the chamber with the use of one or
several microwave generators with frequencies ranging from 400 MHz to
6000 MHz within the time span from several minutes to several hours. Within the
time of microwave heat treatment the dielectric cylinder with the dried dielectric
25 material is rotating or is transitioned inside the metal chamber in such a way so as
forces the dried material to change its position inside the chamber. The drying
equipment has a dielectric cylinder placed inside the metal chamber that forms
a uni- or multi-mode microwave resonator and is settled on a rotary bush (sleeve)
connected to the power unit. The interior side of the chamber is connected to the
30 vacuum pump. The metal chamber is connected to one or several microwave
generators with frequency ranging from 400 MHz to 6 GHz with the use of

1 intervals of wave-guide and intervals of concentric lines.

Another known method of drying fruit and vegetables and equipment for drying vegetables, fruit and meat in particular is recorded in PCT application No WO0124648. This application describes a portable conveyer belt dryer. This dryer consists of 4 segments: product preparation with cutting, cleaning and dripping
5 instruments. The second segment serves as an initial dryer consisting of 2 conveyer belt dryers, with one of them being equipped with a heat exchanger with a forced current of hot air. The next segment is a microwave chamber and the last segment is final drying with the use of chamber dryer. The material being subject to a drying process both inside the subsequent segments and in between them is carried
10 on conveyer belts. The method of drying fruits and vegetables embraces the crumbling, cleaning, dripping of the material which is then placed on a conveyer belts that carry the material through the subsequent dryer's segments subject to heat treatment. Next the material is initially dried in warm air, with microwaves in a metal microwave chamber and finally dried in a chamber dryer.

15 The subject of the present invention is a method to dry dielectric material where dielectric material in the form of vegetables, fruits, herbs and meat in particular is initially crumbled (reduced in size) and then cleaned, dripped and dried. The initial drying is with the use of warm air, then inside the microwave metal chamber and the final drying takes place in chamber dryer.

20 Also, the subject to the invention is equipment for drying dielectric materials divided into 3 parts: product preparation segment, initial drying segment, microwave chamber segment and final drying segment.

The essence of the invention is that the drying process is carried out in at least two phases. Phase I embraces the initial drying of crumbled dielectric material
25 starting with moisture level in the range of 80% to 90% to the final moisture level in this phase of 20% to 45%. Phase II embraces the dielectric material after treatment in Phase I which is now dried with the use of microwave energy being directed to a cylindrical rotating chamber with the pressure in the range of 1kPa to 6kPa, with microwave energy frequency ranging from 600 MHz to 6 GHz and with
30 supplied microwave power of 2W to 40 W per 1 gram of the dried material in order to obtain the moisture level of the dielectric material ranging from 8% to 30%. In

- 1 Phase II the material is heated up to the temperature not higher than 80 degrees Celsius. Final drying process takes place in what we called Phase III, with moisture level at 6 – 10%.

The drying process of the dielectric material takes advantage of a pulse-fluid bed or vibro-fluid bed dryer and the final drying process takes place in
5 a chamber or membrane dryer.

The essence of this equipment is that the initial drying segment consists of a pulse-fluid bed or vibro-fluid bed dryer and the interior part of the metal microwave chamber is a cylindrical chamber in the form of rotary settled dielectric cylinder, and the metal cavity is connected to the vacuum pump.

- 10 The metal cavity takes advantage of microwave generators characterized by low ripples of microwave power $\tau < 20\%$.

An additional advantage is that there is a movable container inside the dielectric cylinder.

- Advantageously, the microwave chamber with the metal cavity is settled in
15 a rotary way.

The hereby discussed equipment has as its variation a front batch container on the inlet of the metal cavity and a back batch container on the outlet with both containers having a vacuum seal.

- Advantageously, the equipment has a metal cavity with at least two
20 generators. Each generator is equipped with a tube antenna, whilst these tube antennas are connected in such a way that the polarization (direction) of electromagnetic waves transmitted by the first generator is perpendicular to the polarization (direction) of electromagnetic waves transmitted by the second generator. The intersection of the tube antenna has a rectangular shape with the
25 shorter side of the external rim rectangle of the tube antenna being shorter than the length of the transmitted electromagnetic wave, however the lines of the electromagnetic field that are transmitted from the generator are parallel to the longer side of the rectangle.

- It is also advantageous when the tube antennas transmitting the
30 electromagnetic waves with polarization (direction) that is perpendicular to the symmetric axis of the cylindrical metal cavity are settled under the cavity whilst

- 1 the tube antennas transmitting electromagnetic waves with polarization (direction)
parallel to the symmetry axis of the cylindrical metal cavity are shifted in the same
direction as the direction in which the dielectric cylinder is rotating.

The new method introduces a multi phase process, where the crumbled
dielectric material in the form of cubes, stripes, slices, or seeds of particularly
5 fruits, vegetables and herbs are initially dried in fluid, fountain or pulse-fluid bed
dryers, and the drying process is carried out with pulse or continuous convection of
the dried material in a hot air stream. Phase I drying is carried out to obtain a lower
level of moisture and to dry out the surface of the material. Phase II of drying takes
place in a rotating dielectric cylinder inside the metal chamber equipped with at
10 least one microwave generator. As a result of the microwave energy a rapid
evaporation of water from the dried cubes, stripes, slices or seeds takes place which
additionally causes aeration of the material and a quick reduction of moisture. The
drying process may be finished in this phase, however, it can be continued in order
to obtain a further reduction of water content with the use of known, conventional
15 drying machines such as conveyer belt or chamber or membrane drying machines
in particular. In the present method dielectric cylinder is rotating which causes
continuous relocation of the material resulting in a better uniformity of drying
effect.

The dried material obtained in the present method is characterised with
20 lightly aerial structure and thus an increased ability to a quick re-hydration, which
enables it to be used widely in all instant dishes. Fruits and vegetables dried with
the use of the new method in the temperature below 60°C preserve full aroma,
colour and flavour and they do not contain any additives especially sugar or fat
which makes them a real dietetic product.

25 The subject of the invention is explained in a closer way in the following
figures: Figure 1 - that presents a block diagram of the device equipped with a
movable dielectric container, Figure 2 - presents a block diagram of the device
equipped with input and output containers, Figure 3 presents a block diagram of
the device for drying dielectric materials with a rotary settled microwave chamber,
30 Figure 4 - presents a metal cavity (bottom view) with depicted fields from a tube
antenna, Figure 5 - presents a cross-section A-A through a metal cavity with

- 1 a shifted tube antenna in the direction of the cavity rotation, Figure 6 – presents a view on a tube antenna taken from the metal cavity with electromagnetic lines marked.

Example 1

The presently discussed method of drying dielectric material starts with
5 cleaning and cutting of vegetables in the form of cubes with the use of known methods. Wet vegetable cubes with moisture level equal to 80% are poured into chamber 1 of pulse-fluid bed dryer. Hot air is introduced to chamber 1 via the air divider 3. Hot air stream is introduced in a pulse manner and is used for drying vegetable cubes in the initial process till the vegetable cubes reach 20% moisture
10 level. In the second phase, initially dried material are poured into dryer 1 through an outlet whole 2 to a dielectric container 4 which is introduced to the inner part of the dielectric cylinder 5 settled inside the metal cavity 6. Metal cavity is connected to the vacuum pump 7. Having closed the dielectric cylinder the air is pumped out and the pressure is reduced to 1 kPa. Metal cavity 6 is equipped in 2 microwave
15 generators 8 characterised by a low ripples of microwave power $\tau < 20\%$. Having pumped out the air from the inside of the dielectric cylinder 5 the microwave generators generate energy in the amount of 2 W per 1 gram of the dried material where the frequency of the microwave energy of 600 MHz. The generated microwave energy causes the material to be heated up to the temperature of 80°C
20 and vegetables are dried to achieve 15% moisture level. The dielectric cylinder 5 is rotating during the microwave drying process. After the microwave drying process, the inner part of the dielectric cylinder 5 is filled with air anew, next the container 4 is shifted and turned and then the already dried vegetables are poured on a conveyer belt 9 of the widely known conveyer belt dryer where the final drying
25 process takes place to achieve 10% final moisture level for vegetables. Vegetables having been dried with the use of this method are characterised by maintaining their natural colours, aroma components and vitamins and the dried matter is a little airy and presents very good re-hydration characteristics.

Example 2

- 30 The dielectric material drying method is conducted in the same way for fruits with this distinction that the initial fruit moisture is 90%. The first phase is

1 carried out till the material reaches 45% moisture. In the second phase, the initially
dried fruit is dried inside the dielectric cylinder 5 with the reduced air pressure to
60 kPa, with microwave power density of 20 W/g and with the microwave energy
frequency of 6 GHz till the material reaches 30% moisture level. The generated
microwave energy causes the material to be heated up to 60°C. Subsequently, the
5 final drying process takes place in the chamber dryer to achieve the fruit moisture
level equal to 10%. The fruits dried with the use of this method are characterised
by the fact that the natural colour, aroma components and vitamins are preserved
and the dried matter is little airy (fluffy) and presents very good re-hydration
characteristics.

10 Example 3

The presently discussed method of drying dielectric materials is conducted
as in Example 1 with the exception that this time the initially dried herbs are
poured from chamber 1 of the dryer through the output whole 2 to the inside of
input container 10 equipped with the vacuum seal. The material is input to the
15 dielectric cylinder 5 which is settled inside the metal cavity 6. The metal cavity 6 is
connected to the vacuum pump 7 that after the closing of the dielectric cylinder 5,
pumps out the air reducing the air pressure to 6kPa. The metal cavity 6 is equipped
with four microwave generators 8 while the drying process is carried out under
reduced pressure conditions to 4 kPa, with microwave power density of 10W/g and
20 frequency of the microwave energy of 2450 MHz, to achieve the moisture level of
the dielectric material of 25%. The already dried herbs are poured out from the
output container 11 which is also equipped with vacuum seal and is carried to the
first conveyer belt 12.

Example 4

25 The drying process is carried out just like in example 1 but this time the
metal cavity 6 is settled in a rotary manner. The initially dried vegetables are
poured from chamber 1 of the pulso-fluid dryer through the outlet whole 2 into the
conveyer belt 12 and then from this conveyer belt to the inside of the dielectric
cylinder 5 settled inside the metal chamber 6 positioned vertically (see the
30 simplified chart). Metal cavity 6 is closed up and shifted to the horizontal position
where microwaves are used in dielectric cylinder. After the drying process the

- 1 metal cavity is shifted to the vertical position and the dried material is poured onto the conveyer belt 14.

Example 5

The device for drying of dielectric materials is equipped with a segment for product preparation, initial drying segment, microwave chamber and final drying
5 segment. The initial drying segment consists of pulse-fluid bed dryer equipped with chamber 1. Hot air is introduced to the chamber 1 via an air divider 3. The initially dried material is poured from chamber 1 through the outlet whole 2 to the dielectric container 4, which is introduced to the inner part of the dielectric cylinder 5 that is settled inside the metal cavity 6. The metal cavity is connected to
10 the vacuum pump 7 and is equipped with two microwave power generators 8 characterised by low microwave power ripples $\tau < 20\%$. The dried material is poured to the conveyer belt 9 of the widely known conveyer belt dryer.

Example 6

The difference here is that the metal cavity 6 is settled in a rotary manner
15 and the initially dried vegetables are poured from chamber 1 through outlet whole 2 to the second conveyer belt 12. The vegetables find their way to the inside of the dielectric cylinder 5 settled inside the metal cavity 6 set in a perpendicular direction to the ground then the metal cavity 6 is closed and turned to the horizontal position. After the vegetables have been treated with microwave energy
20 the metal cavity 6 is opened and the dried matter is poured to the third conveyer 14 belt leading the material to the chamber dryer.

Example 7

This example presents the way to dry dielectric materials in a continuous mode similar to example 5. The initial drying takes the form of a vibro-fluid bed
25 dryer and on the front part of the metal cavity 6 there is a input container 10 and on the back there is an output container 11. The input container 10 and output container 11 are equipped with vacuum seal. Inside the dielectric cylinder 5 there is a conveyer worm that eases out the movement of the dielectric material. Metal cavity 6 is equipped with 8 microwave generators 8.

30 Example 8

The device for drying dielectric materials just like in example five with this

1 distinction that the device has a metal cavity 6 equipped with five generators 8 of
1,5 kW power each and tube antennas 15. The tube antennas 15 of the generators 8
are connected to metal cavity 6 in such a way that the polarisation (direction) of the
electromagnetic wave transmitted by the tube antenna 15 of the first generator 8 is
perpendicular to the polarisation (direction) of the electromagnetic wave
5 transmitted by the tube antenna of the second generator 8. The tube antennas 15 of
the third and fifth generator 8 are connected in the same way as the tube antenna 15
of the first generator 8, and tube antenna 15 of the fourth generator are connected
such as the tube antenna 15 of the second generator. Every tube antenna 15 has its
intersection in the shape of a rectangle and the shorter side of the external rim
10 rectangle of the tube antenna 15 is shorter than the length of transmitted
electromagnetic wave, and the lines of the electromagnetic field transmitted by the
generator 8 are parallel to the longer side of the rectangle.

Example 9

The dielectric material dryer as in example seven is used in this example
15 with the difference that this time the tube antennas 15 transmitting the
electromagnetic wave of the direction perpendicular to the intersection of the
cavity 6 are settled under cavity 6. However, antenna 15 transmitting
electromagnetic waves with polarisation directed in a parallel way to the
intersection of the cavity 6 are shifted into the direction of rotation of the dielectric
20 cylinder 5 by the angle 20 degrees. The shorter side of the rectangle of the external
rim of the tube antenna 15 is shorter from the length of the electromagnetic wave.
(It is illustrated by Fig 5 and Fig 4 – view from the under of the metal cavity 6).

Patent Claims

- 5 1. Method of drying dielectric materials based on reducing in size, cleaning, dripping and drying vegetables, fruit, meat, herbs next they are dried in warm air and then in metal microwave chamber and subsequently finally dried in chamber dryers, the process is unique as the drying takes place in at least two Phases; in Phase I the dielectric material is reduced in size and then dried in
10 the initial drying process starting from the initial moisture level of the dielectric material ranging from 80% to 90% to moisture level ranging from 20% to 45% whereas in Phase II the initially dried material is subject to microwave energy freed in rotating cylindrical cavity under pressure conditions of 1kPa to 6kPa with the frequency of microwave energy ranging
15 from 600 MHz to 6GHz and with microwave power supply from 2W to 40W per 1 gram of the dried material in order to obtain the moisture level of the dielectric material in the range from 8% to 30%, in Phase II the material is heated to the temperature not exceeding 80 degrees Celsius and subsequently the final drying process takes place to obtain moisture level from 6% to 10%.
- 20 2. Method according to Claim 1 is unique as the initial drying process of the reduced in size dielectric material is carried out in the pulso-fluid dryer.
3. Method according to Claim 1 is unique as the initial drying process of the reduced in size dielectric material is carried out in the vibro-fluid dryer.
4. Method according to Claim 1 is unique as the final drying process is
25 carried out in the chamber dryer to obtain moisture level from 6% to 10%.
5. The machinery for drying the dielectric materials is equipped with the preparation segment, the initial drying segment, microwave chamber and final drying segment unique as the initial drying takes place in pulso-fluid dryer, and the microwave chamber has a rotary settled cylindrical chamber in
30 the form of dielectric cylinder (5) inside the metal cavity (6) and in addition metal cavity (6) is connected to the vacuum pump (7).

- 1 6. The machinery according to claim 5 is unique as the metal cavity (6) is designed in the form of a cylindrical metal cavity (6).
7. Machinery according to claim 5 is unique as the metal cavity (6) is equipped with microwave generators (8) that are characterised by low ripples of microwave power $\tau < 20\%$.
- 5 8. Machinery according to claim 5 is unique as the initial drying takes place in the vibro-fluid dryer.
9. Machinery according to claim 5 is unique as the inner part of the dielectric cylinder (5) is filled with the movable rotary settled container (4).
10. Machinery according to claim 5 is unique as the microwave chamber with the metal cavity (6) and generators are settled in a swinging manner.
- 10 11. Machinery according to claim 5 is unique as there is a input container (10) at the front part of the metal cavity (6) and there is an output container (11) at the end of the metal cavity (6) whereas the input container (10) and output container (11) are equipped with the vacuum seal.
- 15 12. Machinery according to claim 5 is unique as the metal cavity (6) is equipped with at least two generators (8) and each one of them is equipped with tube antenna (15), and these tube antenna (15) of the generators (8) are connected in such a manner that the direction of polarisation of the electromagnetic wave transmitted by the tube antenna (15) of the first generator (8) is perpendicular to the direction of polarisation of the electromagnetic wave transmitted by the tube antenna (15) of the second generator (8).
- 20 13. Machinery according to claim 12 is unique as the tube antenna's (15) intersection is rectangular where the shorter side of the rectangle laying near the external rim of the tube antenna (15) is shorter from the length of the transmitted electromagnetic wave whereas the lines of force of the electromagnetic field transmitted by generator (8) are parallel to the longer side of the rectangle.
- 25 14. Machinery according to the claim 12 is unique as the tube antenna (15) transmitting the electromagnetic wave with the direction of polarisation perpendicular to the symmetry axis of the cylindrically shaped metal cavity
- 30

11

- 1 (6) are settled under the cavity (6), whereas the tube antenna (15) transmitting electromagnetic wave with the direction of polarisation parallel to the symmetry axis of the cylindrically shaped metal cavity (6) are shifted in the direction of the twist direction of the dielectric cylinder.

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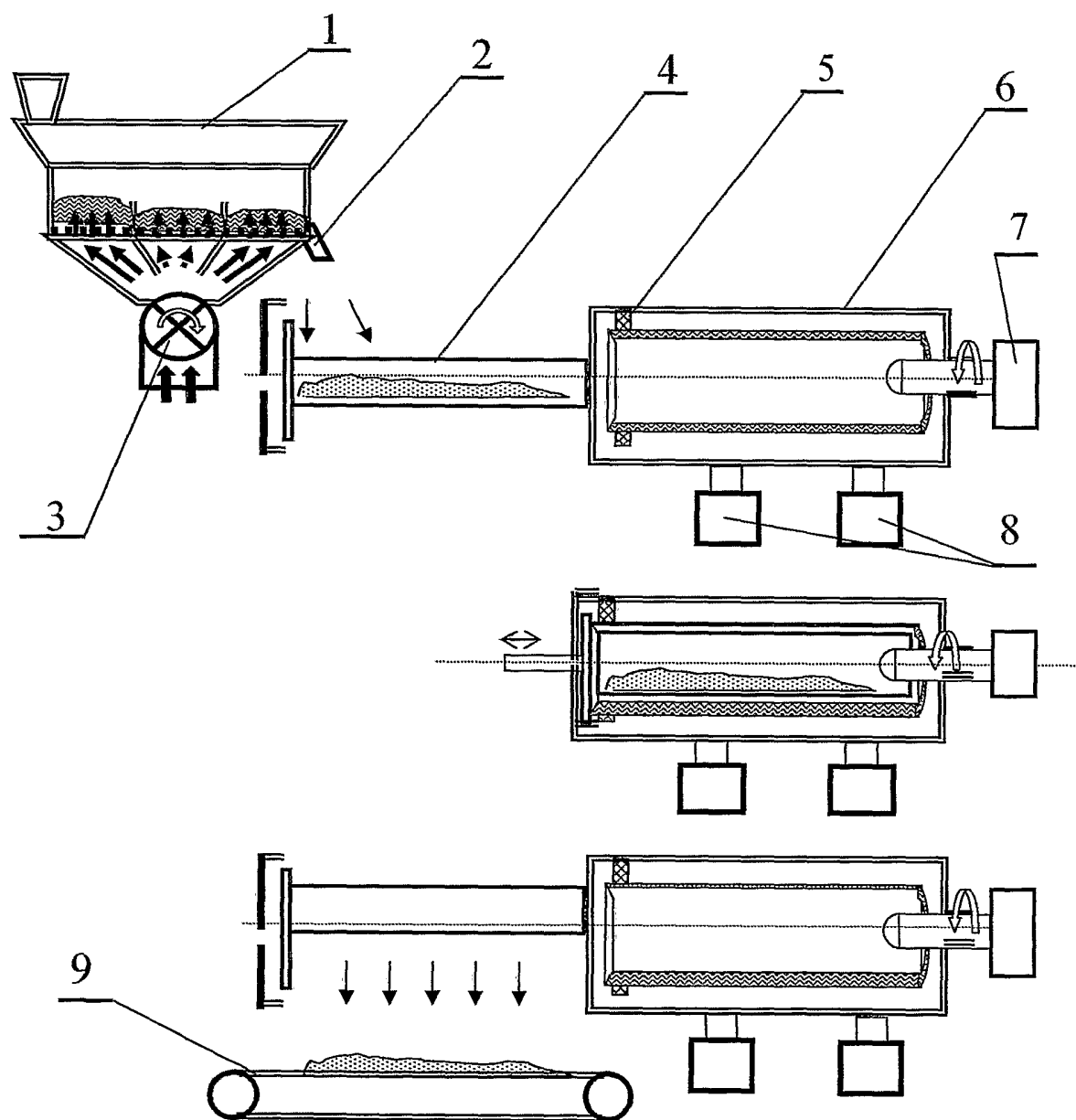


Fig. 1

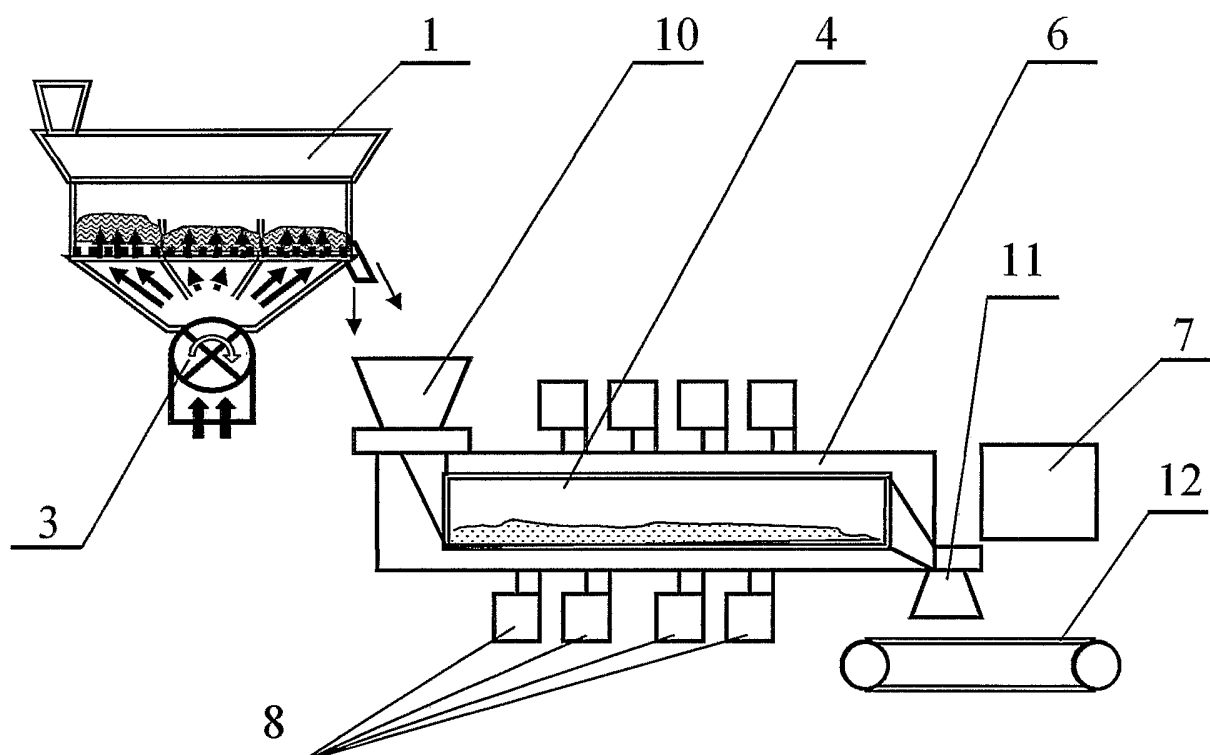


Fig. 2

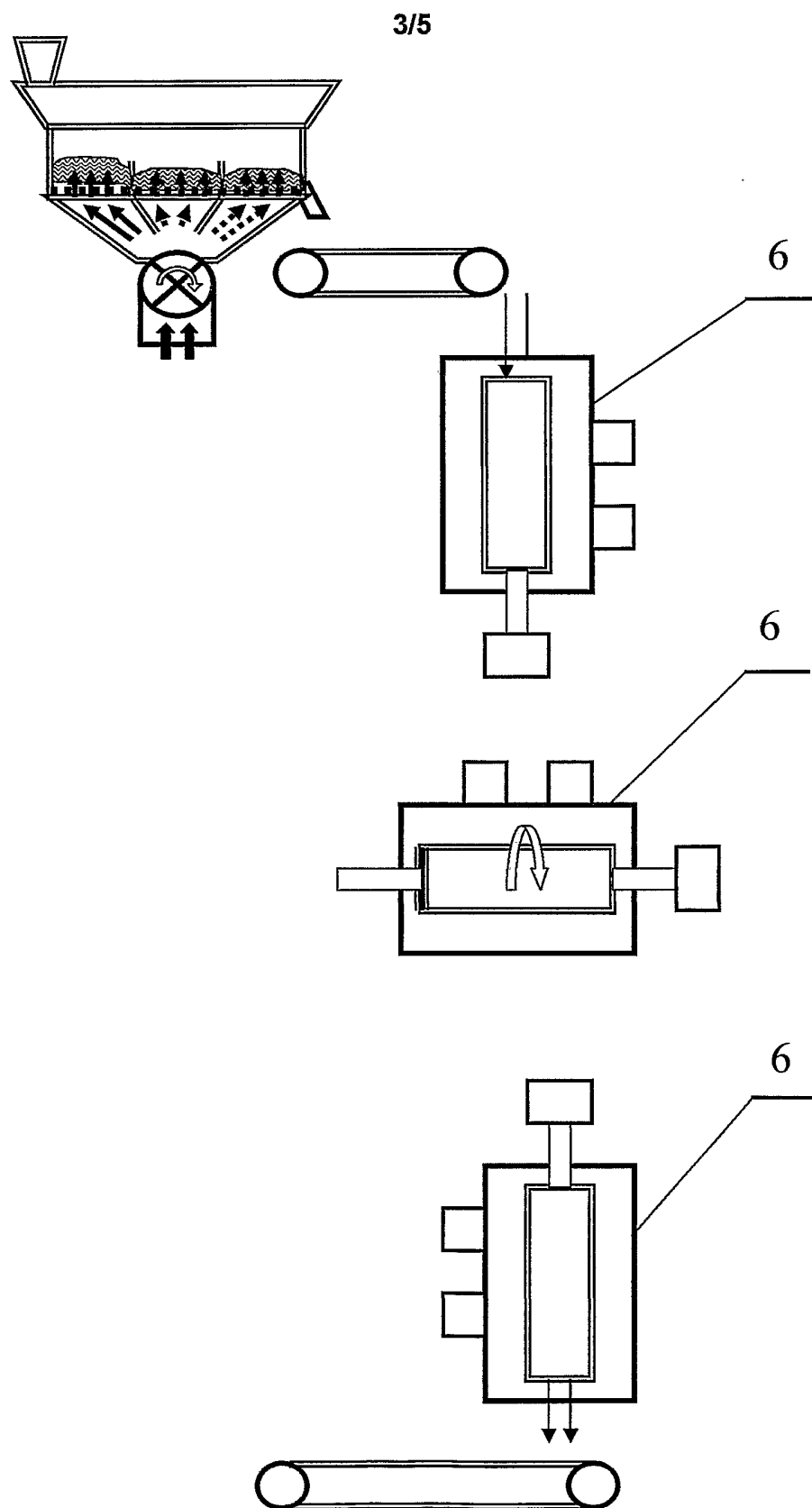


Fig. 3

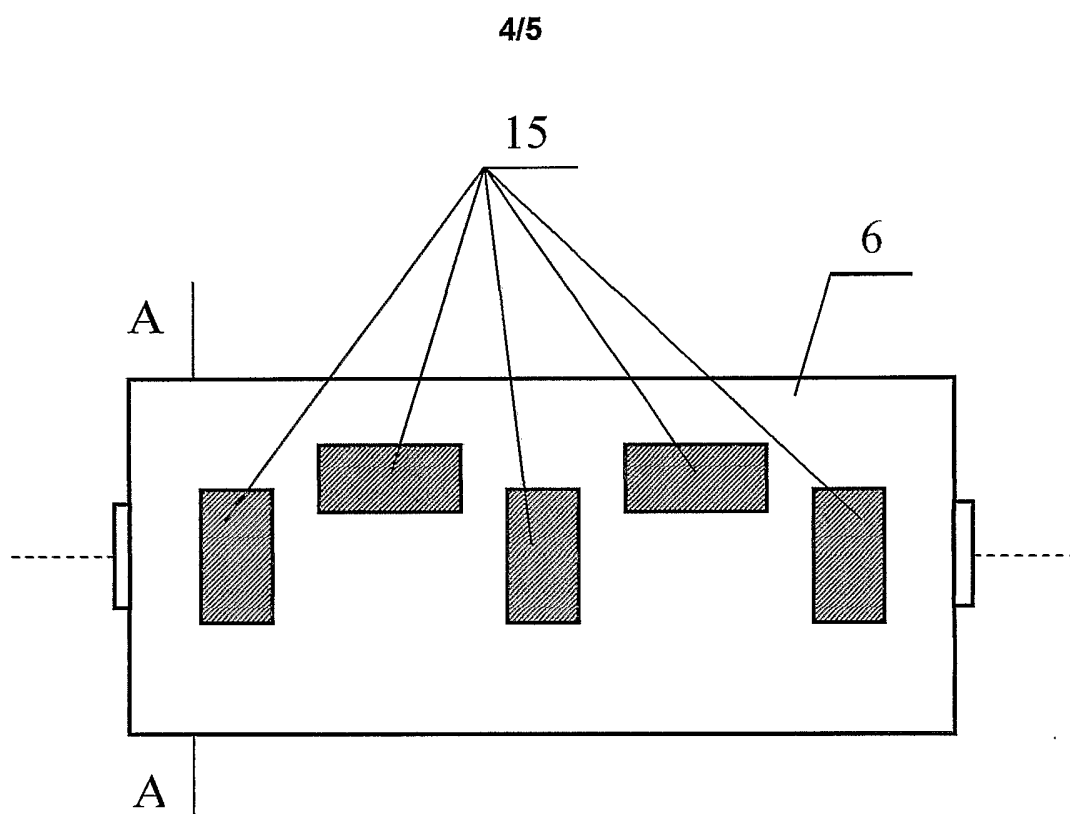


Fig. 4

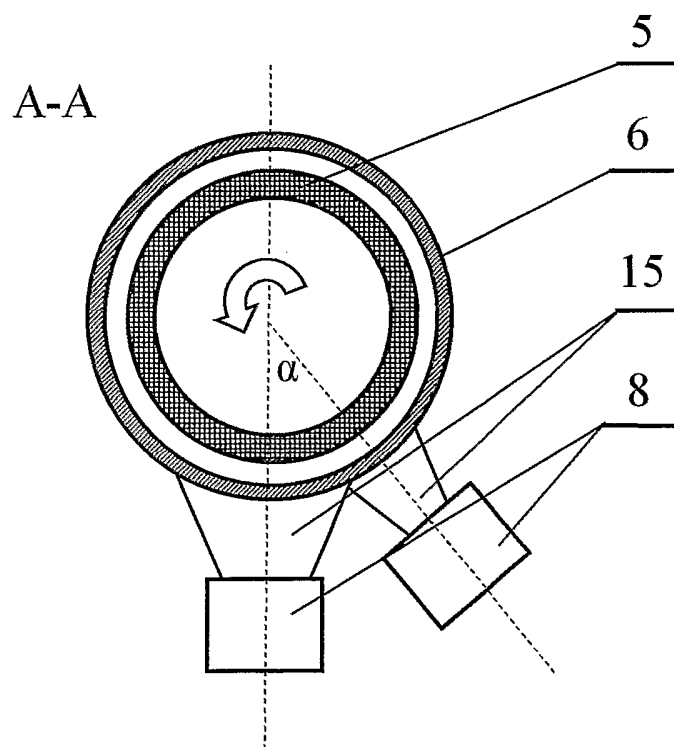


Fig. 5

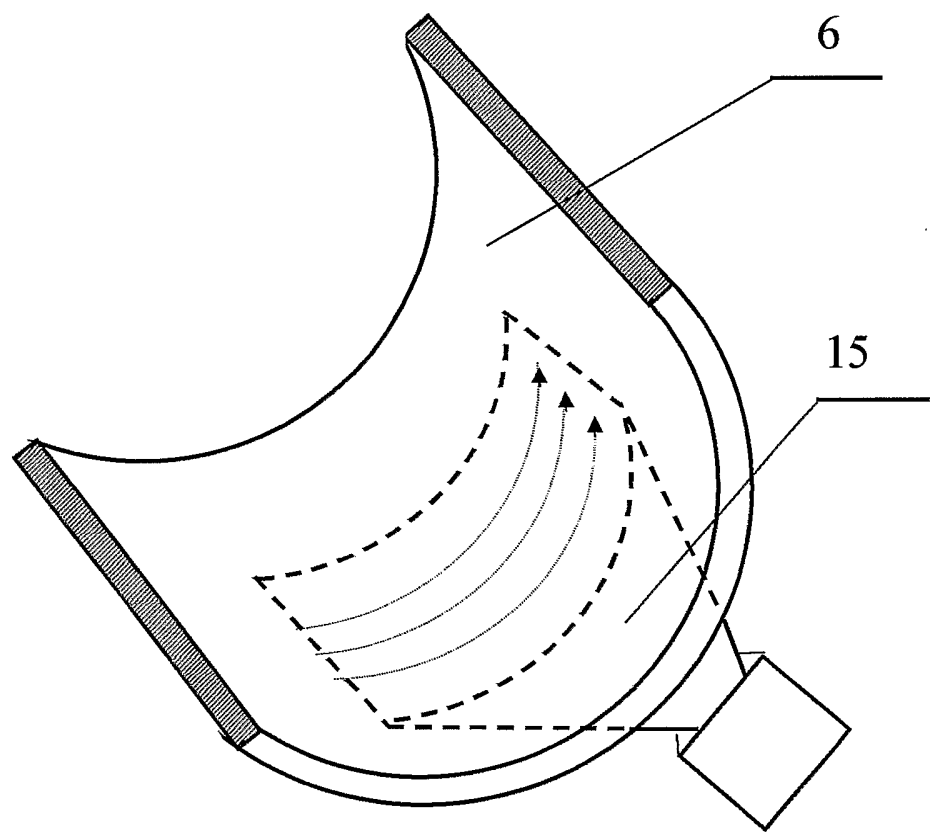


Fig. 6

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A23B7/01 A23B7/02 A23B4/01 A23B4/03 A23L3/50
A23L3/54 F26B11/04 F26B3/092

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 A23B A23L F26B

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, WPI Data, PAJ, FSTA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International Application No

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