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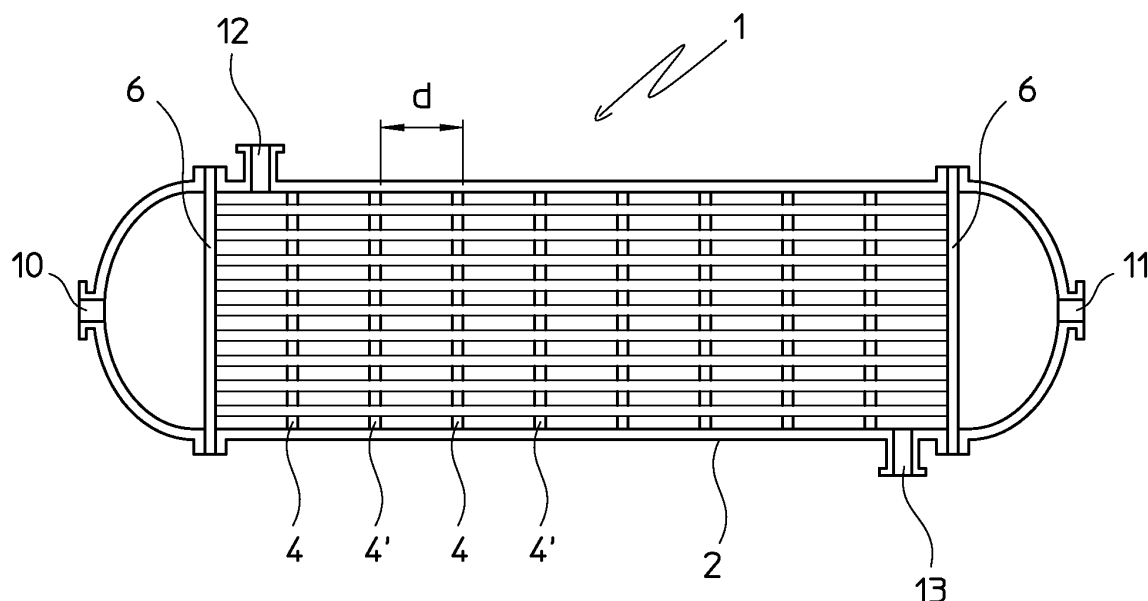
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(54) **A shell and tube equipment with a baffle structure for supporting the tubes**

(57) A shell-and-tube equipment (1) comprising: a vessel (2), a tube bundle (3) inside the vessel, a plurality of support baffles (4, 4a) for supporting the tubes of said bundle, said support baffles having spaced part slots (5, 5a) formed therein, said slots being sized to receive a

plurality of tubes therethrough, wherein said slots (5, 5a) are shaped as polygons with a number N of sides, and each slot receives at least a number N of tubes, which are located at the corner regions of the slot.



**Fig. 1**

## Description

### Field of the invention

**[0001]** The invention relates to the field of shell-and-tube equipment comprising a vessel and a tube bundle, for example shell-and-tube heat exchangers or shell-and-tube chemical reactors. The invention relates in particular to a baffle structure to support the tubes within the bundle.

### Background art

**[0002]** A known technique to support tubes of a tube bundle against vibrations is the rod-baffle cage which is disclosed inter alia in US 4,342,360.

**[0003]** The rod baffle design provides a precise guidance and support of tubes. A disadvantage, however, is the need to weld a large number of rod elements and related support rings. Another disadvantage is that the conventional rod-baffle design calls for tubes with a square pitch, being unsuitable for a triangular layout pattern of tubes. Another drawback of this prior art concerns the pressure drop of the shell side. In most cases, the shell side of the equipment is traversed by a heat exchange medium, such as condensing steam or a gas. It has been observed that the support means of the rod baffles induce a disturbance to the flow of said medium, affecting the overall coefficient of heat exchange.

**[0004]** A number of alternatives and improvements to said rod-baffle design have been proposed in the art.

**[0005]** US 2008/0245515 discloses a shell-and-tube device comprising slotted baffles having elongated parallel slots formed therein. The elongated slots are sized to receive a certain number of aligned tubes. Said slotted baffles can be made in a relatively cheap way, by cutting a metal sheet for example. However, this embodiment has a disadvantage in that the thin strips of metal formed between the slots are prone to vibration and instability, especially under the severe stress occurring during a transitory, for example during a startup when hot gases cause a relevant thermal stress. Indeed, the thickness of the baffle is generally smaller than the width of said strips, making them unstable under mechanical stress (especially a compression stress) and unable to provide a firm support to the tubes. To avoid this risk, the thickness of the metal sheet may be increased, which however increases also cost and weight and makes the cutting more difficult. Another partial solution to this problem is the provision of additional support means such as tie bars or reinforcing rings, which however require additional works inside the vessel, make the manufacturing process more difficult and more expensive and introduce a further source of disturbance for a gaseous medium traversing the shell side.

**[0006]** DE 10 2011 107 122 discloses a grid baffle layout where each one of the tubes passes through a respective four-sided window. Accordingly, the bundle is

supported and guided in an effective manner, however a very precise construction and alignment of the baffles is necessary since each single tube must meet a corresponding small window of the baffle. Hence, assembly may result difficult or impossible due to tolerances of the tube bundle, especially when tubes have a considerable length, e.g. of some meters. Furthermore, this design causes a relevant pressure drop of the shell side, since the design of the baffles leaves a small passage area for the medium flowing in the shell side.

### Summary of the invention

**[0007]** The problem underlying the invention is to provide a supporting structure for a bundle of tubes which overcomes the above drawbacks of the prior art, and in particular: provides a secure support against vibrations of tubes; allows using also a triangular layout of tubes; avoids an expensive realization, reduces to a minimum the negative influence on a gaseous medium flowing in the shell side of the equipment.

**[0008]** The problem is solved by a shell-and-tube equipment comprising:

- a vessel
- a tube bundle inside the vessel,
- a plurality of support baffles for supporting the tubes of said bundle, said support baffles having spaced apart slots formed therein, said slots being sized to receive a plurality of tubes therethrough,

### characterized in that:

said slots have the shape of polygons with a number N of sides, and

said slots are arranged in such a way that each slot receives at least a number N of tubes, which are located at corner regions of the polygonal slot.

**[0009]** Said corner regions are to be intended as sharp corners or rounded (beveled) corner regions. In some embodiments, the slots have beveled corners to avoid their overlapping, for example with triangular slots. In one embodiment of the invention, for example, slots designed to receive tubes with a triangular pitch have beveled corners, so that they actually have 6 sides, including three long sides and three short sides (chamfers) opposite to the long sides. Nevertheless, they are referred to as triangular slots, since they appear substantially as triangles.

**[0010]** Preferably, the baffles are arranged according to a repetition of a pattern along a longitudinal direction of the bundle. The slots of a generic baffle, according to said pattern, are staggered relative to the slots of the adjoining baffles. Said pattern hence comprises at least

a first baffle and a second baffle, and the slots of the second baffle are staggered relative to the slots of the first baffle.

**[0011]** The baffles arranged according to said pattern provide a complementary support for each tube of the bundle. For example, a tube is prevented against a lateral displacement in a given direction X by the first baffle of the pattern, and is prevented against a displacement in another direction Y by the second or another baffle of the pattern. More generally, a displacement of a tube in a certain direction is always prevented by at least one, or more, of the baffles forming the pattern.

**[0012]** Preferably, the slots of a baffle of the pattern are staggered relative to the slots of the previous or next baffle in the pattern by a distance which is equal to the pitch of the tubes in the tube bundle. The slots of adjoining baffles may be staggered relative to each other in one direction or in two directions.

**[0013]** An embodiment of the invention provides that the tubes are arranged according to a square pitch, and said baffles have square slots or, more generally, four-sided slots. Each slot receives four tubes located at the four corner regions of the slot, and said pattern of the baffles is formed by a first baffle and a second baffle, which means that first baffles and second baffles are alternated. The slots of the second baffles are staggered relative to the slots of the first baffle, by a distance equal to the pitch of the tubes, according to a first direction and a second direction in a plane perpendicular to the tubes.

**[0014]** In another embodiment, the tubes have a triangular pitch, and said baffles have triangular slots. Each slot receives three tubes at the corner regions. Preferably said slots are equilateral triangles.

**[0015]** In another embodiment, the tubes have a triangular pitch, and said baffles have hexagonal slots, each slot receiving six tubes at corner regions of the slot plus a seventh tube in the middle.

**[0016]** It must be noted that in all the above, a pattern of only two different baffles, with suitably spaced slots, can support the tubes in all directions in a plane perpendicular to the tubes themselves.

**[0017]** According to a preferred application of the invention, said equipment is a gas-gas heat exchanger. The exchanger may also contain a catalyst in the tubes or in the shell side, if required. A more preferred application of the invention relates to a reactor for the synthesis of ammonia.

**[0018]** An aspect of the invention is also a structure for supporting a tube bundle of a shell-and-tube equipment, according to the attached claims.

**[0019]** Thanks to the invention, the tubes are guided and supported against vibrations in a way similar to a rod-baffle cage, but avoiding the drawbacks of the conventional rod-baffle design, including the large number of welded joints. Indeed, the slotted baffles of the invention may be prepared from metal sheets and with a technique such as cutting, laser cutting, water cutting or equivalent, reducing the number of the welded junctions.

**[0020]** Another advantage of the invention is that a pattern of only two different baffles can support the tubes in all directions, thanks to the tubes being received at the corner regions of the slots. The rod-baffle design, on the contrary, needs the repetition of a pattern of four different baffles, in order to achieve the same effect, since each set of the conventional rods acts in one direction only.

**[0021]** A further and important advantage is that the invention allows using a triangular pitch, while the rod-baffle design requires a square pitch. Tubes in a triangular pitch are closer each other, thus providing a better use of the available volume compared to the square pitch layout. For example when tubes are filled with a catalyst the triangular pitch provides more room for said catalyst. Hence, the heat exchanger is more compact and less expensive for a given duty.

**[0022]** The invention does not use elongated slots which may suffer vibrations or instability under stress. There is no need to increase the thickness of the sheet in order to keep the baffles from the above problems, or provide expensive additional support means.

**[0023]** Additional advantages relate to the flow through the shell side. Firstly, the baffle structure according to the invention leaves a large passage area in the shell side, reducing the pressure drop. Furthermore, the applicant has noted the following advantage: the staggered slots avoid the formation of preferred "lanes" for the gaseous medium traversing the shell side. For example a gaseous flow line, after a passage through a slot of a generic baffle, impinges on the surface of the next baffle and is divided into a plurality of flow lines, passing through the slots of said next baffle. This effect provides for a certain mixing and, hence, a good heat exchange coefficient but, on the other hand, does not cause a high pressure drop. The applicant has found that the prior art solutions tend to generate helical flows or linear flows with contractions and expansions which are less preferable, since they increase the pressure drop and do not provide optimum heat exchange.

**[0024]** The above advantage is of particular importance for gas-gas heat exchangers, when the shell side is normally traversed by a gaseous flow having a considerable speed.

**[0025]** Another advantage of the invention is that the free space between the boundary of the bundle and the vessel is reduced to a minimum. This space does not contribute to the heat exchange; accordingly, the reduction of this free space means that the available internal volume of the equipment is best exploited.

**[0026]** Yet another advantage is that the structure of the invention is tolerant with respect to the unavoidable dimensional errors of the tubes. Each baffle provides a support for a tube according to two directions, leaving the tube free to flex to a certain extent in the other directions, to compensate for working tolerance.

**[0027]** In some embodiments, the shell-and-tube equipment may comprise a central duct, e.g. to collect a medium flowing in the shell side, or for another purpose.

The tube bundle is arranged in the annular space between the central duct and the outer vessel, and the baffles are ring-shaped as a consequence. In this case, the invention provides additional advantages. A conventional rod-baffle design would need an inner ring as a support means for the rods. The invention does not need this inner support ring, since the slotted baffle can be prepared, as above, by cutting a metal sheet of the desired shape, including a central aperture for the duct. Hence, the realization is simpler and less expensive.

**[0028]** These and other advantages will be more evident with the help of the following description of a preferred embodiment, with the help of the enclosed drawings.

#### Brief description of the figures

##### **[0029]**

Fig. 1 illustrates a shell-and-tube equipment according to an embodiment of the invention.

Fig. 2 is a scheme of tubes and baffles according to a square pitch.

Fig. 3 is a scheme of tubes and baffles according to a triangular pitch.

Fig. 4 is a cross section of an equipment according to an embodiment with a central duct.

#### Detailed description of a preferred embodiment

**[0030]** Fig. 1 illustrates a shell-and-tube equipment 1 comprising a vessel 2, a bundle of tubes 3, a plurality of support baffles 4, 4a for supporting said tubes 3. The tubes 3 are fixed to tubesheets 6. The baffles are spaced each other by a suitable distance d.

**[0031]** The equipment 1 processes a first fluid flowing in the tubes 3 and a second fluid flowing in the shell side, which means around the tube bundle. The first fluid (tube side) enters at 10 and leaves at 11, while the second fluid (shell side) enters for example at 12 and leaves at 13. In a preferred application, said first fluid and second fluid are gaseous, i.e. the equipment 1 is a gas-gas heat exchanger. In some applications the equipment 1 may carry out a chemical reaction and to this purpose, it may contain a suitable catalyst. In a preferred application, the equipment 1 is a reactor for the synthesis of ammonia, where synthesis of ammonia takes place in the tube side.

**[0032]** Said support baffles 4, 4a are made of a metal sheet of a suitable thickness. A number of slots are formed in the baffles, which are sized to receive a plurality of tubes 3 therethrough.

**[0033]** Fig. 2 shows an embodiment where tubes 3 are arranged according to a square pitch p, said pitch being the distance between centers of adjacent tubes (see Fig. 2) and the slots 5 are four-sided, e.g. square. Four tubes

3 are received at corner regions of each slot 5.

**[0034]** Fig. 2 also shows the slots 5' of a second baffle 4', next to said baffle 4 (see Fig. 1). Said slots 5' of the second baffle 4' are depicted with dotted lines and Fig. 2 shows they are staggered relative to the slots 5 of the first baffle 4. In a preferred embodiment, the baffles are staggered in both directions X and Y by a first distance s1 and a second distance s2. Preferably said first and second distances are equal ( $s1 = s2$ ) and more preferably they are equal to said tube pitch p, as shown in Fig. 2. Said directions X and Y are in a plane perpendicular to the tubes 3 and to the axis of the vessel 2.

**[0035]** The baffles are arranged according to a pattern where first baffles 4 and second baffles 4' alternate, as shown in Fig. 1. Hence, slots 5 and 5' of adjoining baffles are always staggered.

**[0036]** It can be seen that any generic tube, such as tube 3\* of Fig. 2, is embraced by an upper corner of a slot 5 and a lower corner of an adjoining slot 5', and so on according to the pattern of alternate baffles 4, 4'. Basically, a generic slot keeps the tube from displacement in two directions, e.g. left and down, while the next slot keeps the tube from displacement in the other two, e.g. right and up. Accordingly, the tube is secured against vibrations in all directions of plane X-Y.

**[0037]** A gaseous medium traversing the shell side of equipment 1, during operation, passes through the slots 5, 5' of the baffles, around the tubes 3, for example in the region 7 of Fig. 2. Due to the staggered arrangement of the slots, the flow passing through a baffle will impinge on the next baffle, providing a certain mixing of the flow and improvement of the heat exchange coefficient.

**[0038]** Said slots 5 or 5' can be obtained by cutting, laser cutting or another technique, starting from a metal sheet of a suitable thickness.

**[0039]** Fig. 3 relates to an embodiment where tubes are arranged according to a triangular pitch. In this embodiment, the baffles 4, 4' have substantially triangular slots 5, 5', each slot 5 or 5' receiving three tubes 3 at the corners. It may be noted that the slots 5, 5' in this embodiment appear to have six sides, namely three long sides 8 and three short sides 9; said short sides 9 however are formed by the beveled corners. Each long side 8 is opposite to a short side 9, so that the shape of the slot globally resembles to a triangle. Accordingly, the slot is considered three-sided.

**[0040]** In both embodiments of Fig. 2 or Fig. 3, a pattern of only two different baffles 4, 4' can effectively support the tubes 3 in all directions, thanks to the fact that the tubes are received at the corner regions of the slots 5, 5'. The conventional rod-baffle design, on the contrary, needs the repetition of a pattern of four different baffles, in order to achieve the same effect, since each set of the conventional rods acts in one direction only.

**[0041]** Fig. 4 relates to an embodiment where the shell-and-tube equipment comprises a central duct 10 coaxial to the shell 2. The tubes 3 are arranged in the annular region between the duct 10 and the outer shell 2, and

the baffles 4, 4' are ring-shaped as a consequence. Fig. 4 shows tubes with a square pitch but the same embodiment with central duct 10 may use triangular pitch as in Fig. 3.

**[0042]** In this case, the invention is advantageous in that it does not need an inner ring for supporting the baffles. Provided that the baffles have a sufficient thickness, also an outer ring may not be necessary.

## Claims

1. A shell-and-tube equipment (1) comprising:

- a vessel (2),
- a bundle of tubes (3) inside the vessel,
- a plurality of support baffles (4, 4') for supporting the tubes of said bundle, said support baffles having spaced apart slots (5, 5') formed therein, said slots being sized to receive a plurality of tubes therethrough,

### characterized in that:

said slots (5, 5') have the shape of polygons with a number N of sides, and  
said slots (5, 5') are arranged in such a way that each slot receives at least a number N of tubes, which are located at corner regions of the polygonal slot.

2. An equipment according to claim 1, **characterized in that** said plurality of baffles are arranged according to a repetition of a pattern along a longitudinal direction of the bundle, where the pattern is formed by at least a first slotted baffle (4) and a second slotted baffle (4'), and where the slots (5') of the second baffle (4') are staggered relative to the slots (5) of the first baffle (4).

3. An equipment according to claim 2, wherein the slots of the second baffle are staggered relative to the slots of the first baffle in one direction or in two directions, by a distance (s1, s2) which is equal to the pitch (p) of the tubes (3) of said tube bundle.

4. An equipment according to claim 3, wherein said tubes are arranged according to a square pitch, and:

- said baffles have four-sided slots, each slot receiving four tubes located at the four corner regions of the slot,
- said pattern of the baffles is formed by first baffles (4) alternated to second baffles (4'), wherein the slots (5') of the second baffles are staggered relative to the slots (5) of the first baffle, by a distance equal to the pitch of the tubes, according to a first direction (X) and a second

direction (Y) in a plane perpendicular to said tubes (3).

5. An equipment according to claim 4, the slots (5, 5') being square.

6. An equipment according to claim 2 or 3, wherein the tubes (3) have a triangular pitch, and said baffles (4, 4') have slots with a substantially triangular shape, each slot receiving three tubes at said corner regions of the slot.

7. An equipment according to claim 2 or 3, wherein the tubes (3) have a triangular pitch, and said baffles have hexagonal slots, each slot receiving six tubes at corner regions of the slot plus a seventh tube in the middle.

8. An equipment according to any of the previous claims, said slots (5, 5') being formed with any of cutting, laser cutting, water cutting.

9. An equipment according to any of the previous claims, comprising a central duct (10) and the tubes (3) being arranged in the annular space between said central duct and the vessel, and the baffles (4, 4') being ring-shaped.

10. An equipment according to any of the previous claims, for use as a gas-gas heat exchanger or for use as a reactor for the synthesis of ammonia.

11. A structure for supporting a tube bundle of a shell-and-tube equipment, comprising a plurality of support baffles (4, 4') for supporting the tubes of said bundle, said support baffles having spaced apart slots (5, 5') formed therein, said slots being sized to receive a plurality of tubes therethrough, **characterized in that:**

said slots (5, 5') have the shape of polygons with a number N of sides, and  
said slots (5, 5') are arranged in such a way that each slot receives at least a number N of tubes, which are located at corner regions of the polygonal slot.

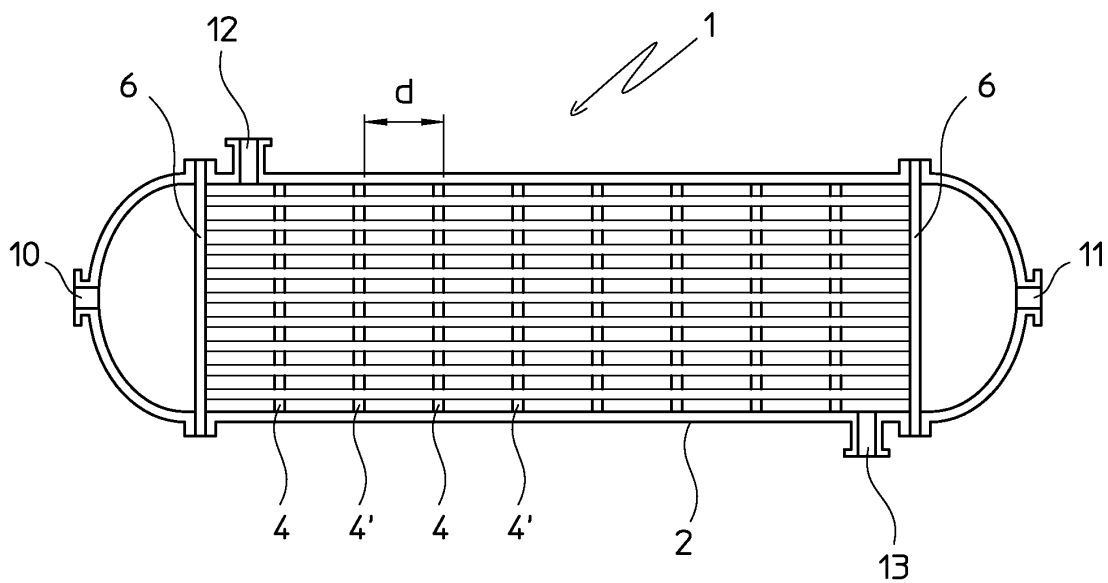


Fig. 1

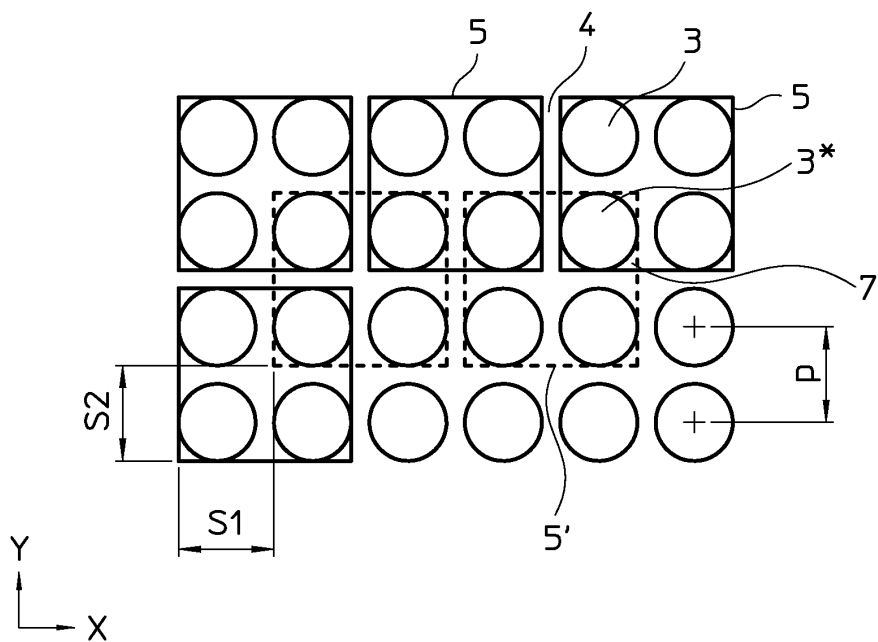


Fig. 2

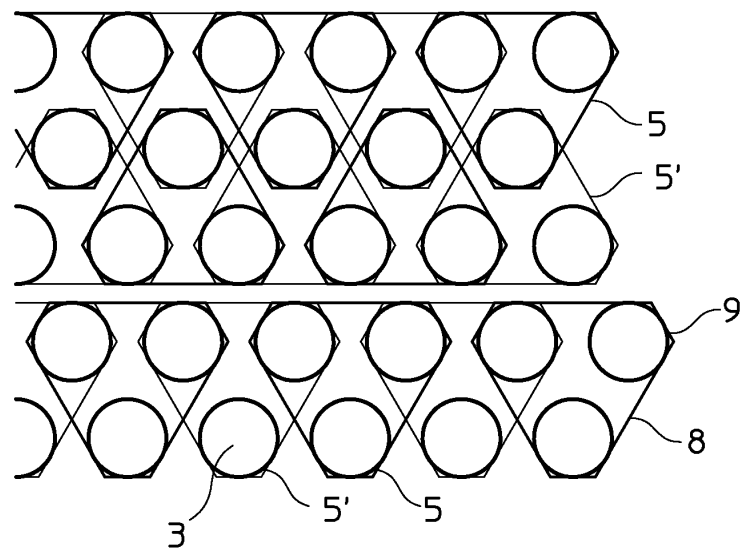


Fig. 3

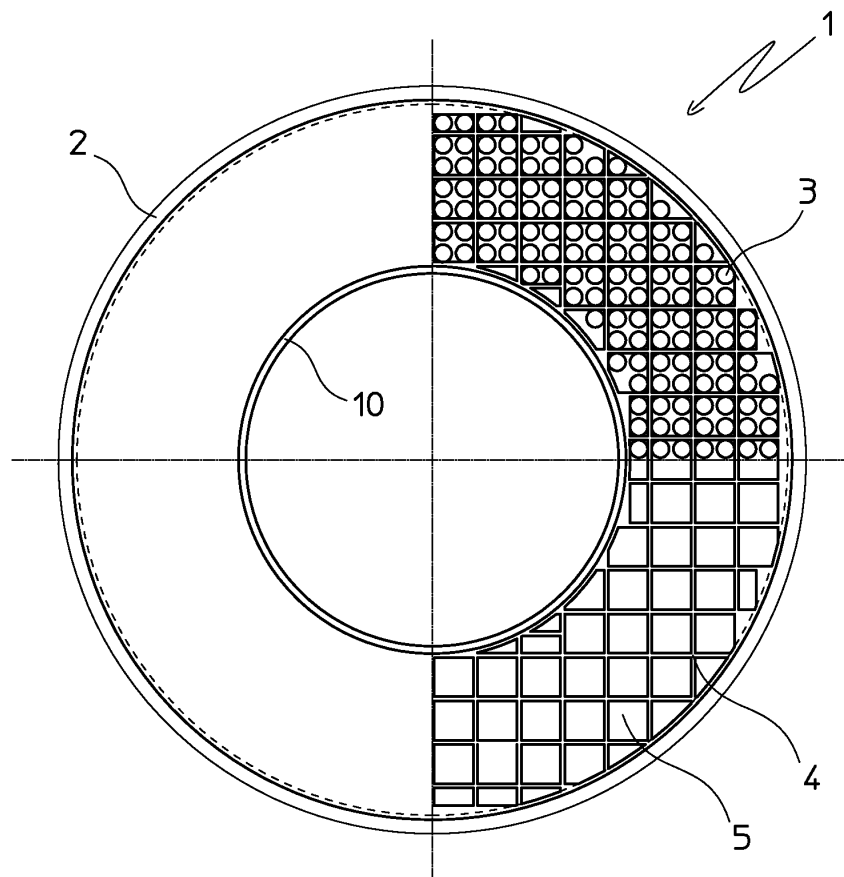


Fig. 4



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**REFERENCES CITED IN THE DESCRIPTION**

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