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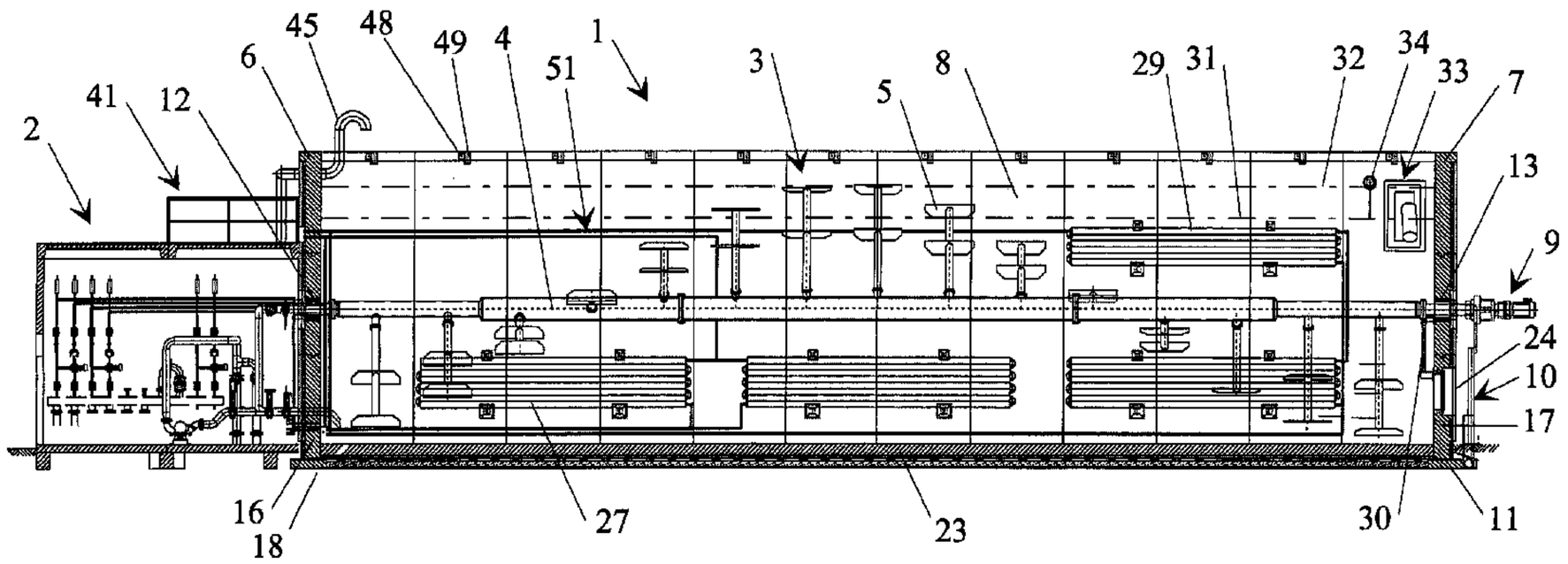
(54) Titre : BIOREACTEUR A FLUX PISTON EQUIPE D'UN AGITATEUR
(54) Title: PLUG FLOW BIOREACTOR WITH AGITATOR



(57) Abrégé/Abstract:
Disclosed is a bioreactor (1), especially a plug flow bioreactor, comprising an agitator (3) running along a longitudinal axis for thoroughly mixing a dry solid biomass that is to be outgassed in a fermentation chamber (8). In said bioreactor (1), an agitator (3) shaft (4) is mounted exclusively in two opposite end walls (6, 7) of the fermentation chamber (8) while at least one free end of the agitator (3) is connected to a drive unit (9) outside the fermentation chamber (8).

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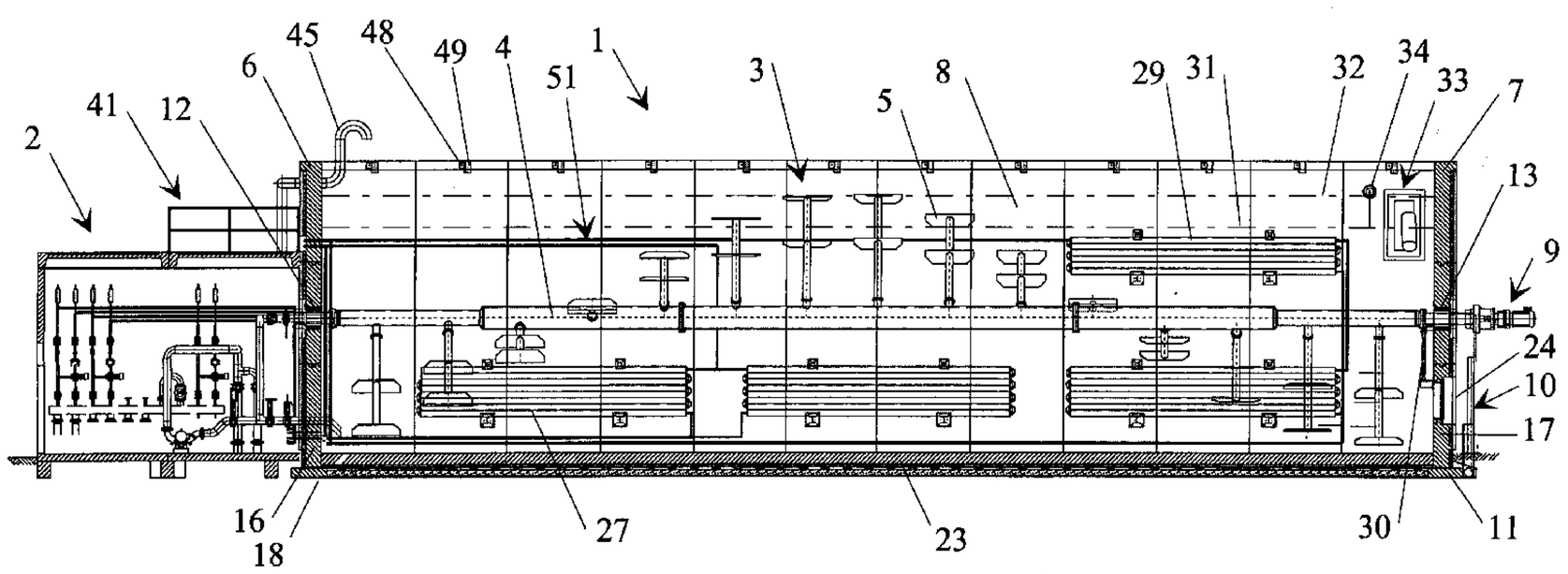

(57) Abstract: Disclosed is a bioreactor (1), especially a plug flow bioreactor, comprising an agitator (3) running along a longitudinal axis for thoroughly mixing a dry solid biomass that is to be outgassed in a fermentation chamber (8). In said bioreactor (1), an agitator (3) shaft (4) is mounted exclusively in two opposite end walls (6, 7) of the fermentation chamber (8) while at least one free end of the agitator (3) is connected to a drive unit (9) outside the fermentation chamber (8).

(57) Zusammenfassung: Bei einem Fermenter (1), insbesondere Propfenstromfermenter, mit einem Langachsrührwerk (3) für ein Durchmischen einer auszugasenden Biomasse hoher Trockensubstanz in einem Gärraum (8) ist eine Welle (4) des Rührwerks (3) ausschließlich in zwei gegenüberliegenden, stirnseitigen Wänden (6, 7) des Gärraums (8) gelagert und ist wenigstens ein freies Ende des Rührwerks (3) außerhalb des Gärraums (8) an einen Antrieb (9) angeschlossen.

WO 2008/067800 A3

PLUG FLOW BIOREACTOR WITH AGITATOR

The invention concerns a bioreactor, especially a plug flow bioreactor, which has a long-shaft agitator for thoroughly mixing a biomass with a high solids content that is to be degassed in a fermentation chamber.

The use of bioreactors of this type in biogas plants is well known and has proven effective. In this connection, the aforementioned bioreactors are used for the fermentation of biowaste, green waste, food waste or the like, which has a high solids content, for example, more than 40%, without the addition of liquid manure. The resulting fermentation is dry mesophilic or thermophilic fermentation at moderate temperatures, for example, 37-41°C or 50-60°C.

In addition, a plug flow bioreactor can be continuously charged, which is equivalent to a large input of biomass to be fermented, which in turn results in a high gas yield. In this regard, the agitator ensures optimal degassing and a uniform temperature distribution, and the plug flow that develops ensures a well-defined residence time of the substrate in the bioreactor.

Plug flow bioreactors of the type under discussion are comparatively complicated type in their design and normally require a large number of additional buildings, for example, operations buildings, gas accumulators, etc.

The capital expenses of biogas plants operated in this way are correspondingly high.

Against this technical background, the objective of the invention is to develop a bioreactor which can be built simply and thus inexpensively in a short construction time and

which has a high gas output and yet is very easy to maintain.

In one aspect, there is provided a plug flow bioreactor, comprising: a fermentation chamber having a first end wall and a second end wall opposite the first end wall; a long-shaft agitator comprising a central shaft having a plurality of axial sections and configured to mix a biomass with a high solids content to degas the biomass in the fermentation chamber, the long-shaft agitator being supported exclusively in the two opposite end walls of the fermentation chamber; a plurality of blades that extend radially from the long-shaft agitator, wherein at least one blade is affixed to each of the plurality of axial sections of the long-shaft agitator; a drive outside the fermentation chamber coupled to at least one free end of the long-shaft agitator, the drive being positioned along a longitudinal axis of the agitator; a foundation supporting the fermentation chamber; and a support separate from the drive, the support being coupled to the drive and to the foundation to support the drive outside of the fermentation chamber and to introduce torque of the drive into the foundation, wherein axial ends of the long-shaft agitator arranged at the opposite end walls of the fermentation chamber have a smaller diameter than a section of the long-shaft agitator arranged between the axial ends of the long-shaft agitator.

In another aspect, there is provided a bioreactor, especially a plug flow bioreactor, which has a long-shaft agitator for thoroughly mixing a biomass with a high solids content that is to be degassed in a fermentation chamber, by the measures that a shaft of the agitator is supported exclusively in two opposite end walls of the fermentation chamber and that at least one free end of the agitator is connected to a drive outside the fermentation chamber.

Due to the exclusive mounting of the long-shaft agitator in the end walls, undisturbed plug flow develops, which ensures uniform material throughput and uniform temperature distribution in the substrate to be degassed. Dead water at an additional center bearing of the agitator shaft is avoided, since a center bearing of this type that rotates completely in the

fermentation substrate and is therefore susceptible is dispensed with in accordance with the invention.

The arrangement of the drive outside the fermentation chamber allows simple inspection of the chamber without the need for personnel to make a dangerous entrance into the chamber on a regular basis. In accordance with the invention, entrance of personnel into the fermentation chamber of a bioreactor thus becomes a rare occurrence.

In a design modification of the bioreactor of the invention, it is provided that the torque of the drive, decoupled from a rising end wall of the fermentation chamber, is introduced into a foundation. This end wall can then also be correspondingly weakly dimensioned.

Alternatively, it can be provided that the torque of the drive, set down from the bearing by means of a torque support, is introduced into a rising end wall of the fermentation chamber.

Both alternatives allow safe absorption of the high drive power of about 30 kW at a

torque of about 100,000 Nm without any weakening of the wall in the immediate vicinity of the opening for the bearing or the shaft due to a large number of fastening bolts, heavy-duty dowels or the like.

Furthermore, it is normally provided that both bearings of the agitator are accessible and replaceable from outside the fermentation chamber, so that for an inspection as well as in the event of damage, naturally, after the substrate level in the fermentation chamber has been lowered sufficiently, entrance into the fermentation chamber is not necessary.

It can also be provided that a central shaft of the agitator composed of several axial sections has a section of reduced diameter at each end wall. Accordingly, the bearings in the end walls also can have a small diameter, so that the end walls are weakened only slightly by the corresponding openings for the bearings.

In a bioreactor of the invention, it is further preferred that walls composed of segmented precast concrete units rest on continuous footings. First of all, the construction of the bioreactor with segmented precast concrete units does not require an expensive foundation but rather only the construction of cost-effective continuous footings. The capital expenses can be further reduced in this way. The short construction time and a large degree of independence from weather contribute further to reduced capital expenses. Beyond that, especially a very high, constant concrete quality, which withstands even aggressive substrates and gases at all times, is guaranteed.

In a further design modification of the bioreactor of the invention, it is provided that the undersides of the walls have a foot with an L-shaped bend and that the foot rests on a continuous footing. Without any anchoring, a segmented precast concrete unit of this type can first simply be set onto the continuous footing and aligned. If all of the precast concrete units

are then correctly positioned and possibly braced, a bioreactor bottom plate, which may consist of multiple layers, can be constructed by simply casting into the space between the walls.

Furthermore, the use of precast concrete units provides a simple means for forming the longitudinal walls to taper towards the top. This takes the decreasing pressure by the substrate into account, and material can thus be saved.

Moreover, with the use of segmented precast concrete units, it can be effective for a wall to have at least longitudinal bracing, for example, in the form of tension rods. A mechanically stable structure is guaranteed in this way.

The mechanical stability of the bioreactor is further enhanced if opposite segments of the precast concrete units of the longitudinal walls are joined on the upper side by a tension rod that can be placed especially under a tensile load and by a beam that can be placed under a compressive load. Due to this distribution to a tension rod that can be placed under a tensile load and a beam that can be placed under a compressive load, the tension rod and the beam can be designed optimally and with the appropriate material. In particular, it is provided that a tension rod is made of a metal, especially a high-grade steel, and that the beam is a wooden beam that is merely inserted in pockets in the walls. This further reduces capital expenses.

Moreover, the high mechanical stability of the bioreactor of the invention allows the fermentation chamber to be covered by a roof that serves as a gas accumulator and is designed with a semicircular cross section. This makes it possible to avoid an external gas accumulator. Furthermore, there is no need for a heavy and expensive concrete roof that seals the fermentation chamber at the top. In accordance with the invention, it is possible, rather, for the roof to be constructed in the manner of an inflatable hall, in particular, for it to be formed by a sheet, and for it to be removed during operation. Inspection work is thus greatly

simplified, and, for example, when necessary, the long-shaft agitator can be removed and restored without any trouble when the roof has been removed. In particular, these measures also make it possible largely to avoid dangerous work inside a closed fermentation chamber.

Finally, the fermentation chamber is covered by a net.

A net of this type serves effectively for the colonization of sulfur bacteria, which are useful in the fermentation processes in a bioreactor of the aforementioned type. In addition, the net, which is supported on the tension rods and/or stays, can support a membranous sheet on the underside of the gas accumulator and thus prevent the sheet from sagging into the fermentation chamber.

The invention is explained in greater detail below with reference to the figures, which show schematic representations of a specific embodiment of the invention.

Figure 1 shows a bioreactor.

Figure 2 shows a partial section of the bioreactor of Figure 1 in a top view.

Figure 3 shows a section along line III in Figure 2.

Figure 4 shows a section along line IV in Figure 2.

Figure 5 shows a section along line V in Figure 1.

Figure 1 shows an off-center longitudinal section through a bioreactor 1 of the invention with an operations building 2, which is connected to the end face of the bioreactor 1. The bioreactor illustrated in the drawing is designed as a plug flow bioreactor with a long-shaft agitator 3, which has a central shaft 4 with a plurality of blades 5 that rotate spirally in the axial direction. The shaft 3 of the agitator 3 is supported on bearings exclusively in the two opposite end walls 6, 7. A center bearing is deliberately dispensed with.

The shaft 4 passes through the wall 7 on the end opposite the operations building 2 and

is connected to an electric motor drive 9 outside the fermentation chamber 8. Decoupled from the end wall 7 of the fermentation chamber 8, the torque produced by the drive 9 is introduced into a foundation 11 via a triangular support structure 10 (see also Figure 3).

The shaft 3, which is supported in the bearings 12, 13 in the walls 6, 7, is divided into five axial sections. The two end sections 14, 15 of the shaft 4 have a reduced diameter relative to the three middle sections. The bearings 12, 13 of the shaft 4, as well as the drive 9, are accessible and replaceable from outside the fermentation chamber 8.

Figure 1 also shows that the end walls 6, 7, which have essentially constant material thickness over their height, are each formed by at least three horizontally subdivided precast concrete units. The lowermost precast concrete units 16, 17 preferably have L-shaped feet by which they are supported on continuous footings 11, 18.

Similarly to the end walls 6, 7, the longitudinal walls 19, 20 are formed by precast concrete units, which likewise are horizontally and vertically segmented. The lowermost rows of the precast concrete units are likewise supported on continuous footings 21, 22. When at least the lowermost rows of the precast concrete units have been placed so that they are positioned on the continuous footings 11, 18, 21, 22, a multilayer floor 23 that joins the walls 6, 7; 19, 20 can be cast.

The end walls 6, 7 have an essentially constant cross section over their height. Like the end walls 6, 7, the longitudinal walls 19, 20 are also made comparatively massive to seal the fermentation chamber 8 and have an insulating layer that faces outward and is covered by a plate.

Besides an opening for holding the bearing 13, the end wall 7 has only one other opening 24 for a manhole, but the wall 6 is provided with a number of other openings, through

which a variety of different conduction systems can be passed into the operations room 2. For example, openings 25, 26, which are preferably lined with fiber-cement sheaths, are used to carry out the feed and return of a plurality of heaters 27 to 30, which are installed on the longitudinal walls 19, 20 and the end wall 7 and which can be vented via pipelines 51 that pass through the wall 6 to the outside.

Even heaters 29 installed at a high level lie below a minimum level 31 of the substrate introduced into the fermentation chamber 8. This minimum level 31 is indicated by a dot-dash line. The upper level 32, which is also indicated by a dot-dash line, lies above the upwardly directed blades 5 of the agitator 3.

The biomass is introduced through a supply line 33 in the longitudinal wall 19. In the immediate vicinity of this supply line 33, liquid substrate is introduced through another supply line 34. Accordingly, at the other end of the bioreactor 1, a lower substrate outlet 35 and an upper substrate outlet 36 are provided in the wall 6.

Other openings 37, 38 in the wall 6 allow measurements of the level of filling and/or the temperature. Openings 39, 40 enclosed by transparent glass make it possible to look into the fermentation chamber 8 from a work platform 41 on the roof of the operations building 2, which can be reached by stairs 42.

Another opening 43 serves the purpose of negative and positive pressure safety, and still another opening 44 formed above the upper level 32 serves for the passage of a pipe system 45 for the removal of gas.

The longitudinal walls 19, 20 have a cross section that tapers towards the top (see Figures 3 and 4). To obtain good mechanical bracing of the precast concrete units, the two longitudinal walls 19, 20 have a plurality of longitudinal stays 46, 47, which are designed, for

example, as tension rods, for longitudinally bracing the lateral walls 19, 20.

In addition, opposite segments of precast concrete units of the two longitudinal walls 19, 20 are joined on the upper side by a tension rod 48 that is made of metal, especially high-grade steel, that can be placed especially under a tensile load and by a wooden beam 49 that can be placed under a compressive load and is merely inserted in pockets of the segments of the longitudinal walls 19, 20. This ensures that the walls 6, 7, 19, 20 have sufficient stability to allow a roof 50 to be placed on them. The roof 50 (see Figure 5) is designed with a semicircular cross section and is provided as a gas accumulator, from which the gas formed in the fermentation chamber 8 can be removed through the pipe system 45, which opens above the upper level 32 of the substrate.

The roof 50 is formed in the manner of an inflatable hall, whose gas-tight sheet can also be removed during operation, so that the fermentation chamber 8 is practically freely accessible from above, for example, for inspection work.

A net that serves as a growth surface for sulfur bacteria and thus allows effective internal desulfurization is preferably also provided between the roof 50 and the fermentation chamber 8. In addition, the net, supported on the tension rods 48 and/or the beam 49, prevents a membranous sheet on the underside of the gas accumulator from sagging into the fermentation chamber 8.

CLAIMS

1. A plug flow bioreactor, comprising:

a fermentation chamber having a first end wall and a second end wall opposite the first end wall;

a long-shaft agitator comprising a central shaft having a plurality of axial sections including end sections and configured to mix a biomass with a high solids content to degas the biomass in the fermentation chamber, the long-shaft agitator being supported exclusively in the two opposite end walls of the fermentation chamber;

a plurality of blades that extend radially from the long-shaft agitator, wherein at least one blade is affixed to each of the plurality of axial sections of the long-shaft agitator;

a drive outside the fermentation chamber coupled to at least one free end of the long-shaft agitator, the drive being positioned along a longitudinal axis of the agitator;

a foundation supporting the fermentation chamber; and

a support separate from the drive, the support being coupled to the drive and to the foundation to support the drive outside of the fermentation chamber and to introduce torque of the drive into the foundation,

wherein the end sections of the long-shaft agitator arranged at the opposite end walls of the fermentation chamber have a smaller diameter than one of the axial sections of the long-shaft agitator arranged between the end sections of the long-shaft agitator.

2. The plug flow bioreactor according to claim 1, further comprising a bearing in each of the two opposite end walls of the fermentation chamber, the bearings configured to support the long-shaft agitator.

3. The plug flow bioreactor according to claim 2, wherein the bearings of the long-shaft agitator are configured to be accessible and replaceable from the outside of the fermentation chamber.

4. The plug flow bioreactor according to any one of claims 1 to 3, further comprising:

a pair of longitudinal walls connecting the first and second end walls,

wherein the first end wall, the second end wall, and the pair of longitudinal walls each comprise a plurality of segmented precast concrete units configured to rest on continuous footings.

5. The plug flow bioreactor according to claim 4, wherein the walls have a foot with an L-shaped bend configured to rest on the continuous footing.

6. The plug flow bioreactor according to claim 4 or 5, wherein the walls taper towards a top opposite the continuous footing.

7. The plug flow bioreactor according to any one of claims 4 to 6, wherein the longitudinal walls further comprise longitudinal stays.

8. The plug flow bioreactor according to any one of claims 4 to 7, further comprising:

a tension rod configured to join opposite segments of the precast concrete units of the longitudinal walls; and

a beam configured to join the opposite segments of the precast concrete units of the longitudinal walls,

wherein the beam can bear a compressive load.

9. The plug flow bioreactor according to claim 8, wherein the tension rod comprises metal.

10. The plug flow bioreactor according to claim 8 or 9, wherein the beam comprises wood.

11. The plug flow bioreactor according to any one of claims 1 to 10, further comprising a roof to cover the fermentation chamber, the roof being configured to serve as a gas accumulator, the roof having a semicircular cross section.

12. The plug flow bioreactor according to claim 11, wherein the roof is constructed in the manner of an inflatable hall.

13. The plug flow bioreactor according to claim 11 or 12, wherein the roof comprises a removable sheet configured to be removed from the fermentation chamber during operation.

14. The plug flow bioreactor according to any one of claims 1 to 10, further comprising a net configured to cover the fermentation chamber and extending between a roof and the fermentation chamber.

15. The plug flow bioreactor according to claim 14, further comprising:

a membranous sheet on the underside of a gas accumulator; and

tension rods to support the net, the net positioned to prevent the membranous sheet from sagging into the fermentation chamber.

16. The plug flow bioreactor according to any one of claims 1 to 15, wherein a support structure is triangular.

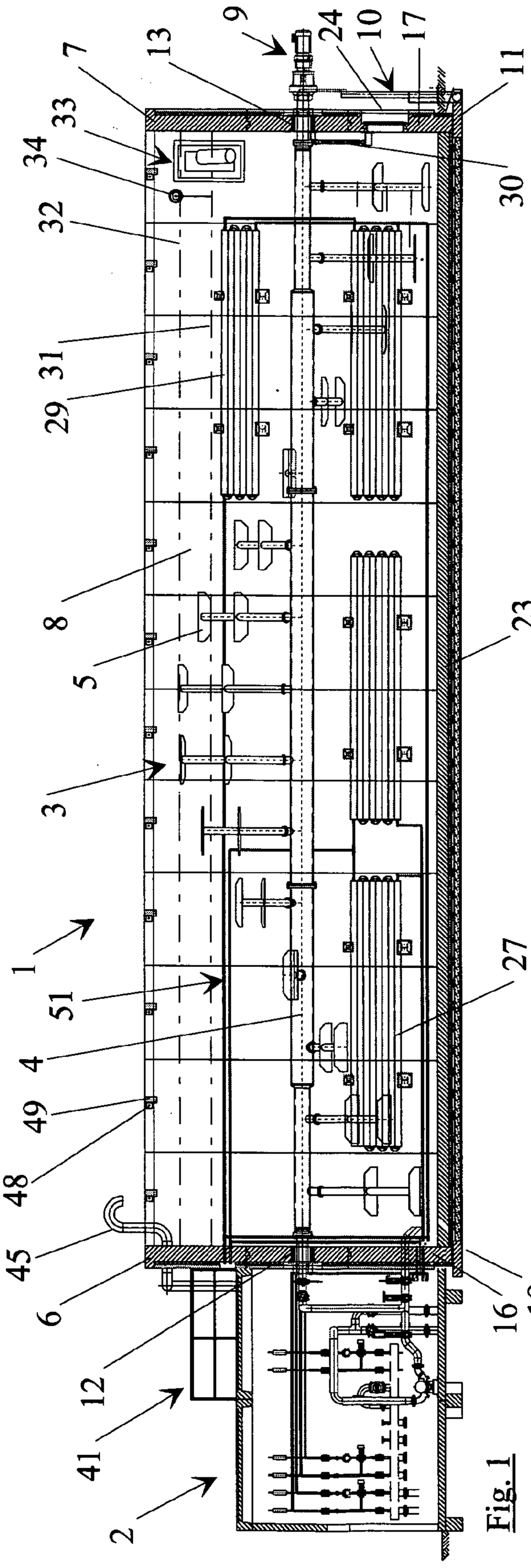
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Fig. 1

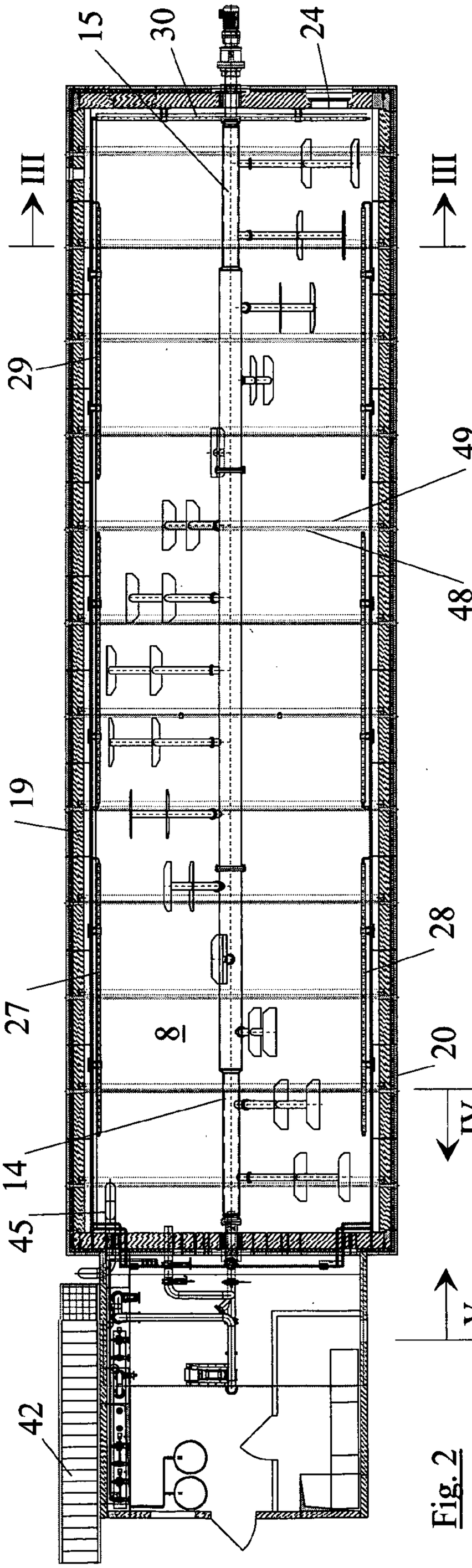
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Fig. 2

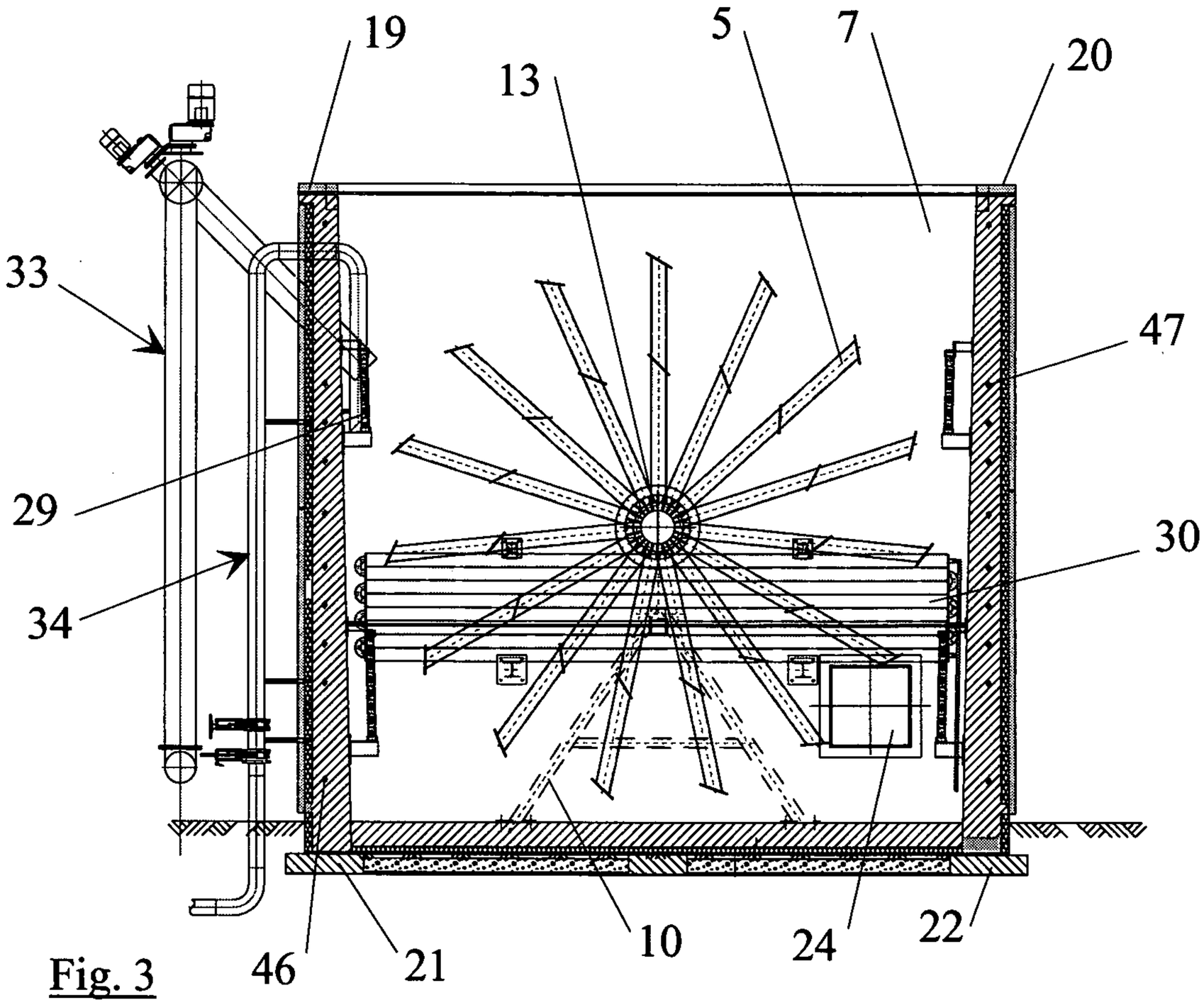
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Fig. 3

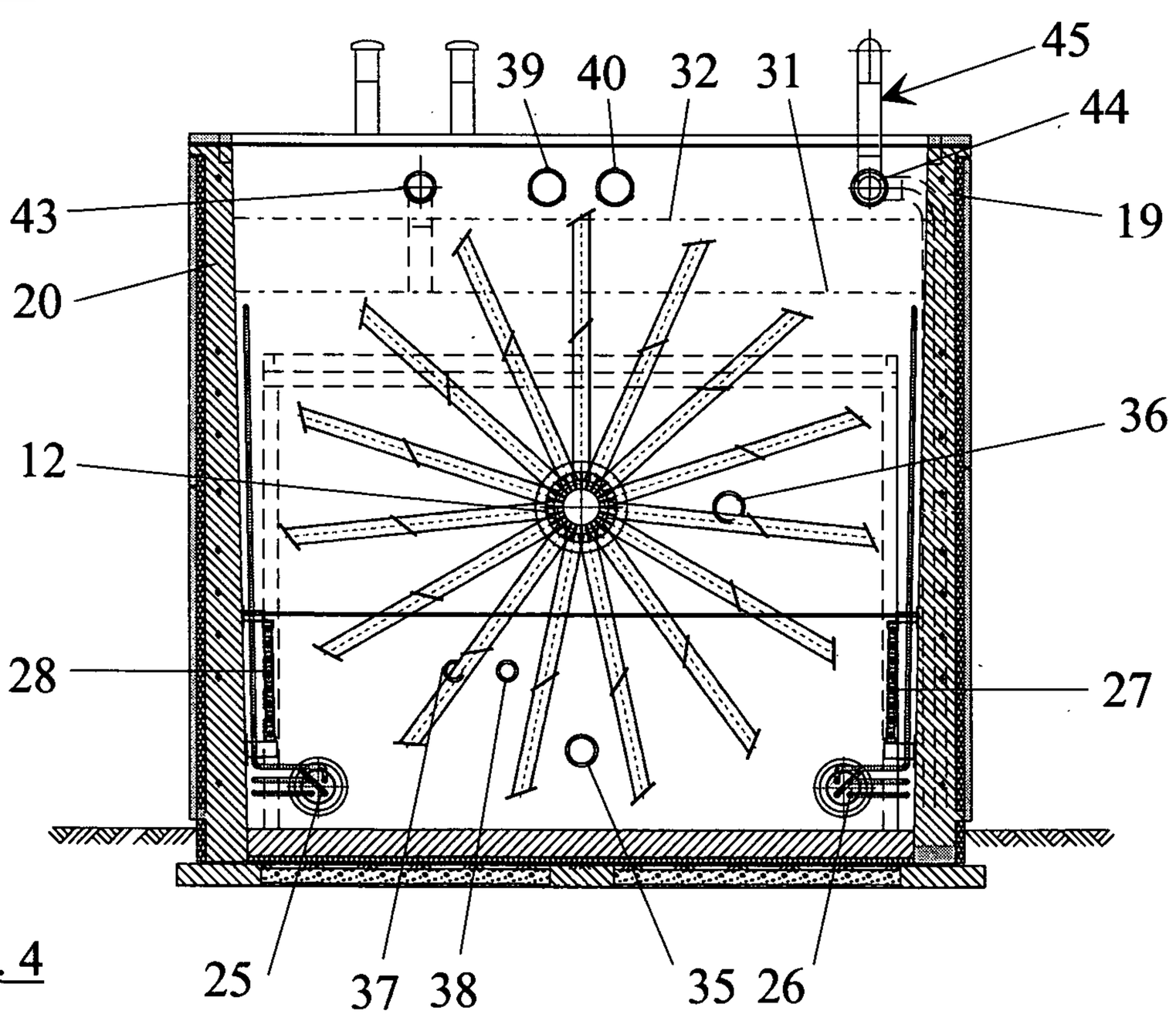
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Fig. 4

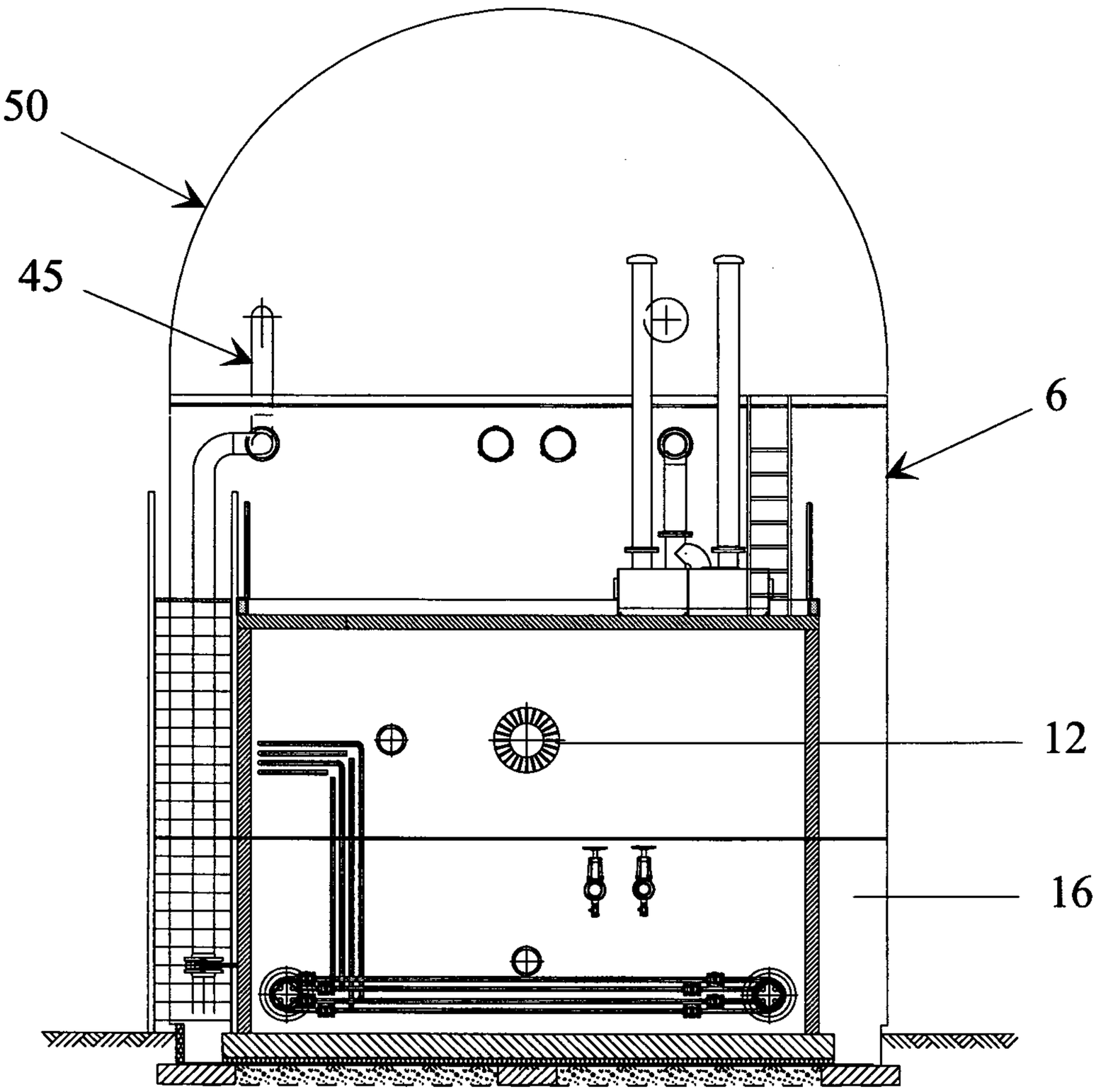
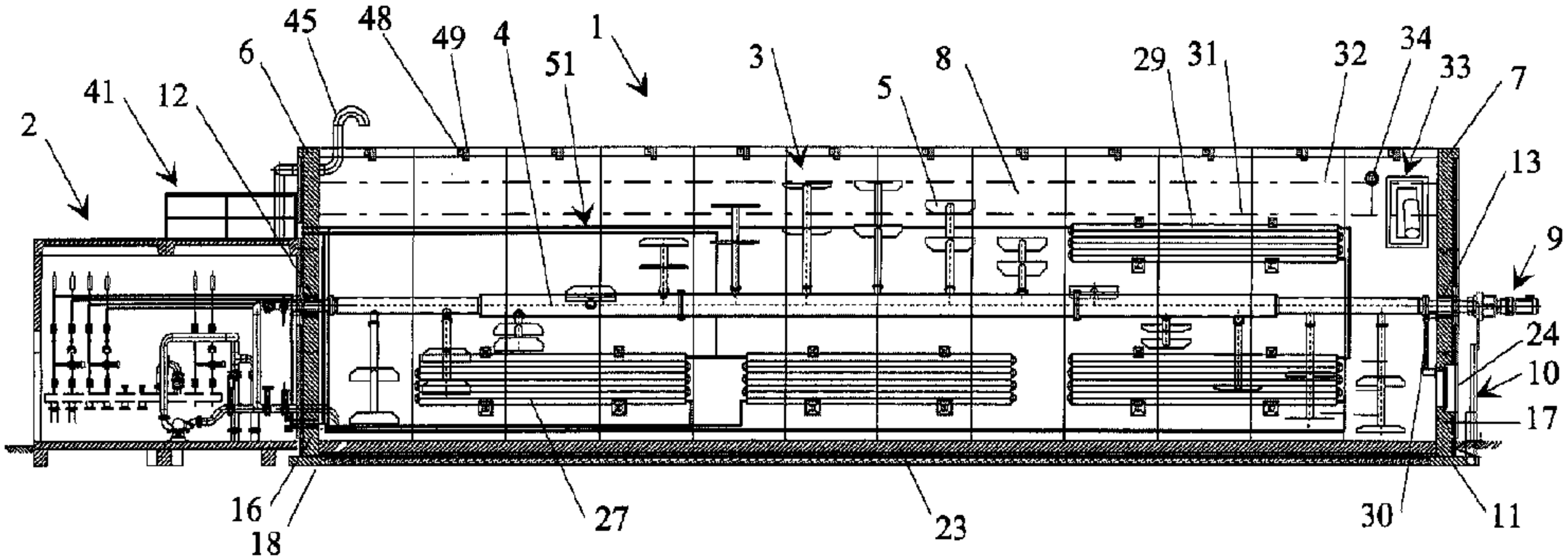


Fig. 5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