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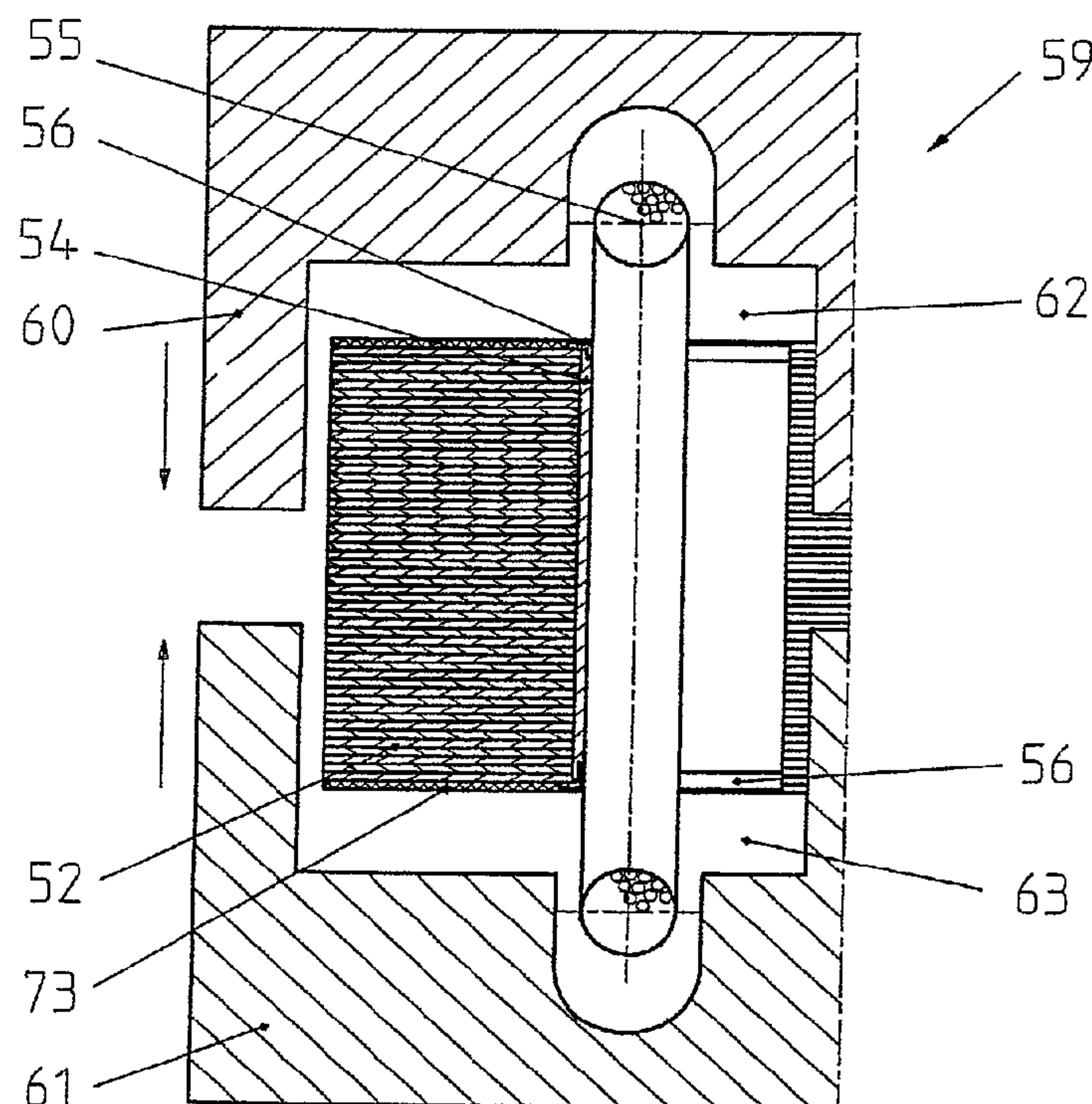
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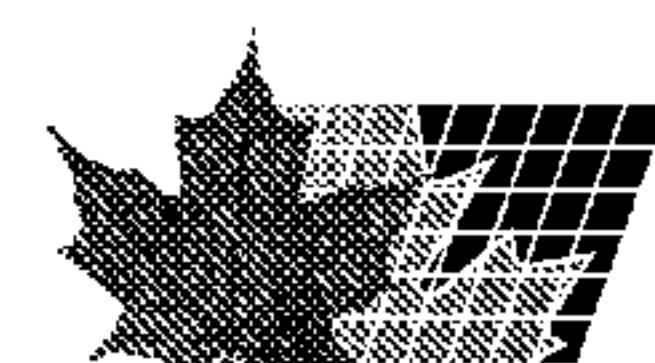
(54) Titre : PROCEDE POUR LA PRODUCTION DE NOYAUX FEUILLETES ET MODULES ELECTROMAGNETIQUES
AINSI OBTENUS

(54) Title: PROCESS FOR THE PRODUCTION OF LAMINATED CORES AND ELECTROMAGNETIC UNITS
PRODUCED THEREFROM



(57) Abrégé/Abstract:

The invention relates to a process for producing a laminated core consisting of ferromagnetic material and/or a unit containing said laminated core and at least one other component. According to the invention, the laminated core comprises unfinished magnetic steel sheets and is positioned in a shaping tool. The sheets are subsequently encased with a mixture by pouring said mixture into the tool and hardening of the mixture in one working stage, and connected to each other to form a finished laminated core. To produce the unit, the laminated core can be connected to the component during the same working stage, and the whole unit can be provided with its final, electrical, magnetic, mechanical and/or geometric properties.



ABSTRACT OF THE DISCLOSURE

The invention relates to a process for producing a laminated core consisting of ferromagnetic material and/or a unit containing said laminated core and at least one other component. According to the invention, the laminated core comprises unfinished magnetic steel sheets and is positioned in a shaping tool. The sheets are subsequently encased with a mixture by pouring said mixture into the tool and hardening of the mixture in one working stage, and connected to each other to form a finished laminated core. To produce the unit, the laminated core can be connected to the component during the same working stage, and the whole unit can be provided with its final, electrical, magnetic, mechanical and/or geometric properties.

Method of Manufacturing Sheet Stacks and Electromagnetic
Components produced therefrom

5 The invention relates to a method of manufacturing sheet stacks according to the preamble to claim 1, and for the manufacture of electromagnetic assemblies provided with such sheet stacks according to the preamble to claim 2. The invention also relates to sheet stacks and components manufactured according to these methods.

10 Electromagnetic assemblies which operate with alternating fields, frequently have iron cores of ferromagnetic material, which serve the purpose of guiding magnetic fields at every point where no air gaps are provided or desired. In order to
15 avoid eddy current and eddy current losses, these iron cores are predominantly assembled from a plurality of sheet metal blanks, which are obtained by stamping from sheet metal panels or strips, which consist for example of steel or iron plates e.g.
20 0.35 to 1.00 mm thick, and which are insulated from one another by a lacquer coating, an oxide layer or other means. The insulation can be applied to the bands, strips or panels either already in the rolling mill to the sheet metal band or strip, or subsequently in a special coating plant, and nowadays usually consists of an extremely thin silica phosphate layer, which is
25 applied as the sheets are rolled out.

In addition it is frequently desired to connect the individual stamped blanks together to form a solid sheet stack. This is
30 achieved e.g. by the application of mechanical means becoming effective by form fit or positive locking, or simply in that the finished sheet stacks or cores are surrounded by a winding, in which case it is however also necessary electrically to insulate the windings from the core.

35 In order to avoid such connection methods, which are in fact comparatively cost-effective, but cannot always be used, it is already known (DE 31 10 339 C2) firstly to provide strips

manufactured from silicated magnetic steel sheet preferably on both sides with additional adhesive layers, which consist for example of a pre-hardened duroplastic adhesive, and if necessary are applied in the rolling mill in a complex, expensive working step. The sheet stacks are then produced in that sheet metal blanks or lamellae are stamped out from such sheet metal strips drawn off from coils (drums), and these are then combined into stacks and thereafter securely fastened together by heating with simultaneous pressure, in order to form a mechanically secure sheet stack. Then the finished sheet stacks are additionally provided with a coating of an epoxy resin or the like, in order to provide the cut edges of the sheets revealed during cutting subsequently with an anti-corrosion layer. This method is therefore in fact suitable for manufacturing compact, high-quality sheet stacks, but due to the high technical outlay and the necessarily high manufacturing costs for coating the sheets with adhesive, is only infrequently used. A further disadvantage is that the off-cuts occurring during stamping of the sheet metal blanks are provided with an adhesive layer, which prevents properly categorised recycling of the sheet metal off-cuts, and therefore should be avoided for reasons of environmental protection.

A method of the type already identified is also known (DE-A-30 12 320), in which magnetic steel sheets kept spaced apart and having no adhesive layers, are connected together in that they are inserted in the stacked condition into a tool, and the interspaces between them are filled with a hardenable adhesive. The spaces between the magnetic steel sheets are in this case obtained by spacers which consist for example of the granules of a metal oxide powder applied by sintering, said granules being equal to or smaller than 2µm. Due to the fact that the magnetic steel sheets must be provided with an additional metal oxide layer, the outlay on work and cost is not less in comparison to the application of conventional adhesive layers. In addition, the finished sheets stacks must be provided with an external anti-corrosion layer, should protection against corrosion be desired or necessary. Finally, it is necessary when using this

- 2A -

known method to maintain a fine or high vacuum of about $1.3 \cdot 10^{-3}$ and less, which is undesirable for reasons of process technology, and increases the overall necessary outlay on work and cost.

5

Finally, it is known (DE-A-15 38 991), to insulate the individual sheets of a sheet stack for electrical motors from one another in that an insulating material is compressed radially by compressed air into the interspaces between the individual sheets from a central bore in the stacked sheet stack. The fact that complete insulation is obtained is said to be indicated by the fact that the insulating material emerges at the outer wall of the stack. Apart from the fact that such a method is unsuitable for mass manufacture of sheets stacks to be produced in large numbers, like the other methods it demands a further step as required in order to apply an anti-corrosion layer.

Sheet stacks of the type described are in addition frequently connected together with other components in order to form finished assemblies. In this respect it is for example known (DE 40 21 591 C2) to surround the individual parts of the stator of an electric motor, particularly a sheet stack and the associated windings, with a casting resin in a shaping tool, so that on the one hand the windings are electrically insulated and on the other hand a cohesive composite member is obtained. Correspondingly, it is known in manufacturing the rotors of electric motors (DE 43 38 913 A1) firstly to assemble the associated shafts, sheet stacks, windings and commutators loosely together, and then to provide them with a plastic covering in a shaping tool by injection moulding, injection pressure or the like. This does in fact give rise to the advantage that the sheet stack is subsequently provided with an insulation or an anti-corrosion layer on the cut edges revealed during stamping of the

40

plates. In all these methods however a condition is the presence of finished sheet stacks produced in the way explained above.

5 The object underlying the invention is to propose a method for manufacturing sheet stacks and electromagnetic assemblies provided with sheet stacks, which enables the use of simple, cost-effective plates, whose off-cuts can be disposed of in an environmentally acceptable manner, and which further requires
10 fewer individual steps than previously and therefore in particular leads to simplifications in manufacture of the assemblies. Moreover, a high degree of mechanical strength and a high degree of resistance to external or internal weathering influences is to be achieved.

15

The characterising features of claims 1,2,10 and 11 serve to fulfil this purpose.

Further advantageous features of the invention will become
20 apparent from the sub-claims.

The invention may with advantage be used at every point where sheet stacks made of ferromagnetic material are required. The term "electromagnetic assemblies" therefore in particular
25 comprises electrical motors on a basis of three-phase, synchronous and asynchronous current and parts thereof such for example as stators and runners as well as choke coils with iron cores, transformers and magnets, particularly load-raising or lifting magnets and parts thereof.

30

The invention will be explained in more detail in the following with reference to two embodiments given by way of example, which are shown in the accompanying drawing on slightly varying scales. Shown are:

35

Figure 1: a perspective, exploded view of some plates of a sheet stack for a magnet core according to the invention;

- Figure 2: a perspective view of the components used to produce a complete magnet core, with the sheet stack in the stacked condition;
- 5
- Figure 3: a perspective view of the magnet core according to Figure 2 in the combined condition of all the components;
- 10
- Figure 4: a perspective view of the winding of a winding member of the magnet core according to Figure 3;
- Figure 5: a perspective view of a magnet pole produced with the magnet core according to Figures 1 to 4,
- 15
- after arrangement in one half of a tool, serving to impregnate the sheet stack, for wetting through the sheet stack and the winding, for connecting the sheet stack with the other components and for surrounding the entire magnet pole with a hardenable mixture;
- 20
- Figure 6: a cross-section through the tool along the line VI-VI of Figure 5 with the magnet pole inserted;
- 25
- Figure 7: a schematic view of the insertion of a hardenable mixture into the tool according to Figures 5 and 6;
- Figure 8: a perspective view of the completed magnet pole;
- 30
- Figure 9: a partly exploded view of a longitudinal section through a sheet stack for the stator of an electric motor;
- Figure 10: a plan view of a section of an assembly, which comprises the sheet stack according to Figure 9 and windings shown schematically;
- 35
- Figure 11: a cross-section along the line XI-XI of Figure 10;

Figure 12: a cross-section similar to Figure 11 through the assembly, but after insertion into a tool, which serves to impregnate the sheet stack and the winding, to connect the sheet stack with the windings of the stator, and to surround the entire stator with a hardenable mixture;

Figure 13: a schematic view of the introduction of a hardenable mixture into the tool according to Figure 12; and

Figure 14: a cross-section similar to Figure 11 through the finished stator.

The invention will be explained in more detail in the following with reference to the examples of a magnet pole, which is suitable for example for a magnetic levitation train (DE 33 03 961 C2 and DE 34 10 119 A1), and of a stator for an electric motor, whose construction, function and geometry are well known to the person skilled in the art and therefore need no further detailed explanation.

In a known way, a magnet pole includes an iron core consisting of a sheet stack, and a winding applied thereto. According to Figures 1 to 8 the iron core consists of a plurality of individual sheets or lamellae 1, arranged in parallel and aligned flush on one another, which have been obtained for example by stamping out from a ferromagnetic magnetic sheet strip, which has been unwound from a drum (coil), and passed to a stamping tool. According to the invention, a raw magnetic steel sheet strip is involved. In this respect the term "raw" is understood to mean that the magnetic steel sheet strip, contrary for example to DE 31 10 339 C2, has no adhesive layer applied in a separate working procedure. On the contrary, the sheet strip, as is conventional with magnetic steel sheets, can be provided with an electrically insulating layer by means of a lacquer coating, an oxide layer or other means which may be applied in a cost-effective manner on both sides. This layer can already be applied in the rolling mill to the sheet strip, and

in the case of magnetic steel sheets conventional today usually consists of an extremely thin silica phosphate layer, which is produced as the magnetic steel sheets are rolled out. For the purposes of the invention this layer is comparatively

5 irrelevant, as under certain circumstances it can also be totally omitted.

The individual sheets 1, of which only a few are shown in Figure 1, in the embodiment have a thickness of for example 0.35 to 1.00 mm, and have identical dimensions, and each have a forward
10 or rear wide side 2, and in the respective circumferential directions, a narrow upper side 3, a lower side 4 and two side edges 5 and 6. In addition, they are each provided during the stamping procedure at identical points with at least one hole 7 and in order to form the iron core after the stamping procedure
15 into packets 8 (Figure 2), are stacked, being laid on one another with their forward or rear wide sides 2 flush and parallel with one another. The number of sheets 1 per packet 8 depends on the size and thickness of the magnetic pole to be produced. The mutual alignment of the sheets 1 is carried out
20 appropriately with the aid of slide blocks or rods 9, upon which the sheets 1 are threaded with their holes 7. In the stacked sheet packet 8, for example, the upper sides 3 of the individual sheets 1 form a magnet pole surface 10, while the undersides 4 form an assembly surface 11.

25 After formation of the stack, the two end faces of the sheet stack 8 are respectively connected to an additional component in the form of pole jaws 12,13, which ensure the necessary stability of the magnetic core and serve as carriers for a
30 further component in the form of a winding body 14 (Figures 2 and 3). The relative alignment of the pole jaws 12,13 to the sheet stack 8 is appropriately carried out in that the pole jaws 12,13 are provided with holes 15, and are thrust with these on the ends of the rods 9 projecting out of the sheet stack 8, and
35 then accommodate these ends in themselves. Although the pole jaws can also consist of iron, they are preferably made from aluminium in order to reduce weight.

The winding body 14 substantially consists of a frame made from insulating material, e.g. plastic, which in the embodiment surrounds a substantially cuboid cavity 16, whose dimensions of height, length and width substantially correspond to the external dimensions of the sheet stack 8 inclusive of the pole jaws 12 and 13. Moreover the winding body 14 is provided on its upper and lower end with a respective outwardly projecting surrounding assembly flange 17, so that a surrounding accommodation space 18 results for a winding 19 (Figure 4) between the two assembly flanges 17.

For correct positioning of the winding body 14 relative to the sheet stack 8, the pole jaws 12,13 are provided on their outer end faces with guide grooves 20, which are disposed vertically to the rods 9 and to the magnet pole surface 10. Correspondingly, the winding body 14 has on two opposite sides inwardly projecting guide ribs 21, which, when the winding body 14 is set on the sheet stack 8 from above or below, enter the guide grooves 20 and then enable a displacement of the winding body 14 relative to the magnet pole surface 10 into a desired position (Figure 3), which is appropriately established by a stop means not shown in further detail.

As is in particular seen from Figure 4, the winding body 14, after its positioning on the sheet stack 8, is provided with the winding 19, which is formed from alternatively succeeding layers of a conductor 23 and of an insulator 24, and comes to lie between the assembly flanges 17. The conductor 23 consists for example of an endless aluminium strip unwound from a supply coil 25, while the insulator 24 for example is a strip of a conventional insulating film unwound from a supply coil 26. Unwinding of the conductor 23 and of the insulator 24 from the supply coils 25,26, or their winding onto the winding body 14, is effected in a known way in the direction of the arrows entered in Figure 4. Naturally it would also be alternatively possible to apply the winding 22 onto the winding body 14 before the latter is mounted on the sheet stack 8, or the winding, here shown as a layer winding, can be subdivided into a plurality of panels to be connected together.

In the assembly described in Figures 1 to 3 of a magnet core, the individual plates 1 loosely threaded onto the rods 9, are held in position only by the rods 9 and the winding body 14, the winding body 14 abutting on the lateral edges 5,6 of the sheets 1 and on the forward or rear sides of the pole jaws 12,13. In contrast, the winding 19 is held in position on the magnet core by the assembly flange 17. Thus the sheets 1 are simultaneously pressed against one another via the pole jaws 12,13 with a pre-selected pressure, so that they abut closely on one another. In order to connect all these parts securely, the assembly substantially visible from Figure 4 is inserted into a mould or a shaping tool 28 (Figures 5 to 7); in the embodiment what is involved is a tool 28 with two tool halves 29 and 30, which are provided similarly to an injection moulding tool on opposite sides with apertures 31,32, which in the closed condition of the tool 28 (Figure 7) form a cavity or hollow mould space, whose dimensions are only slightly larger than the outer dimensions of the finished wound magnet pole.

For correct positioning of the magnet pole in the cavity, there serve on the one hand for example the lower assembly flanges 17, and on the other hand if required additional positioning means 33. In the embodiment these consist of rods, which project into holes 34 (Figure 2), which are formed in the pole jaws 12,13 additionally to the holes 16 and at points which remain accessible beneath the winding body 14 in the assembled condition, as in particular Figure 6 shows. The positioning means 33 are for example mounted in the side jaws of the tool half 30 and upon closing of the tool 28 are moved automatically into the holes 34. Further positioning means not shown may be disposed in the base of the tool half 30. In this way it is possible to align the sheet stack 8 and the winding body 14 relative to one another in the tool.

One of the tool halves 29,30 is provided according to Figure 7 with an inlet opening extending as far as the cavity, to which is connected the outlet of a line 37 provided with a control valve 6, and which in addition has two inlets 40 and 41 each connected to a metering pump 38 and 39. Preceding the metering

pumps 38,39 in each case is a respective mixing container 42,43 and following them is a mixer 44 incorporated in the line 37. These devices serve the purpose of preparing a hardenable mixture, in particular a casting resin mixture, and after
5 closing the tool 28, of introducing it into the cavity. In this way, in one single working step, a plurality of objects are achieved. On the one hand the loosely stacked sheets 1 of the sheet stack 8, by means of insertion of the mixture, are provided with the adhesive layers necessary between them, and
10 simultaneously with the use of an adhesive, they are connected together to form a solid packet. On the other hand this packet is connected with the assembly 45 forming with the other components the finished magnet pole (Figure 8), to form a solid constructive unit, which simultaneously is covered as an entire
15 unit and in particular at the cut edge of the sheets 1, with an anti-corrosion layer, which is indicated schematically in Figure 6 by a line 46. The pre-selectable thickness of this layer substantially depends on the spacing between the various components of the assembly after insertion into the tool from
20 one another, and from the wall portions defining the cavity, and can for example come to up to 10 mm, preferably 2 to 3 mm. Moreover, the assembly 45, due to the complete coverage with the hardenable mixture, receives its final mechanical electromagnetic and geometric properties, the special design of
25 the tool 28 depending on the individual case, and the apertures 31,32 forming the mould hollow, contributing to this.

The mixture to be used is preferably a hardenable (durpolastic) casting resin mix on a basis of epoxy or polycycloolefine and
30 consists for example of two components, namely for example a casting resin prepared in the mixing container 42 and if necessary provided with an additive, e.g. an epoxy resin or an epoxy resin mixture, and a hardener prepared in the mixing container 43, e.g. an epoxy hardener. The two components are
35 metered in a preselected ratio by means of the metering pumps 38,39, introduced into the mixer 44, intimately mixed together therein and then from that point introduced via the line 37 and the control valve 36 into the cavity. Thus supply of the casting resin mixture is effected at a pressure of e.g. 1-3 bar,

in order in particular to wet through or impregnate the sheet stack 8 in such a way that all the plates are covered on all sides by a thin casting resin layer.

- 5 After the cavity is filled, the casting resin mixture, preferably with heating of the entire tool 28, is left to harden, until removal from the mould can take place and the finished assembly 45 can be removed from the tool 28. Alternatively, the tool 28 may also be heated before
10 introduction of the casting resin mass. Moreover, it is best only to harden the casting resin mass in the tool 28 and then to subject the finished assemblies 45 to a heat treatment, in order for example to terminate the hardening procedure and/or to expel slowly-evaporating components. In addition, a cleaning stage
15 could be added.

In an embodiment of the invention felt to be best until now, the casting resin mixture is introduced after the pressure-gelating procedure into the cavities between the plates 1 and the other
20 components of the assembly 45, or between these and the walls of the mould hollow. The pressure-gelating process is particularly advantageous, as the shrinkage occurring during hardening is compensated for in this way. In this method, which is also termed a reaction resin injection moulding (e.g. Kunststoff-Lexikon, Hrg. Dr.-Ing. K. Stoeckhart and Prof. Dr.-Ing. W.
25 Woebcken, Carl Hanser Verlag, München, BRD, 8th edition, 1992), both reaction resin masses with a long pot time and also highly-reactive resin masses can be used, which are automatically mixed and metered with the aid of the mix container 42,43 only briefly
30 before injection into the tool 28, in an automatic manner. Thus the two inlets 40,41 shown in Figure 7 can also open into a pressure container, from which the prepared reaction resin mixture is then expressed into the line 37 by means of compressed air.

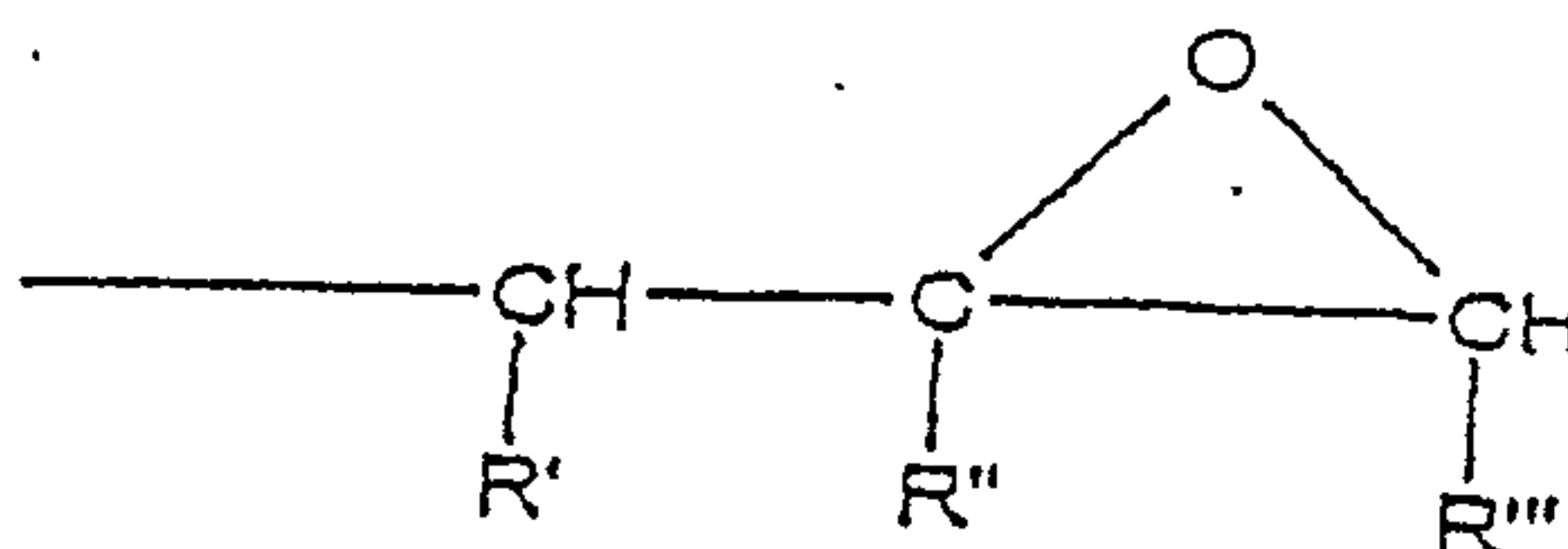
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Numerous mixtures, particularly those which are thermally hardenable, are suitable for producing the assembly 45.

Preferred hardenable mixtures are epoxy resin/hardener mixtures and mixtures of a tensioned cycloolefine and a catalyst for the ring-opening metathesis polymerisation.

- 5 Suitable as epoxy resins, which can be used according to the invention are all types of epoxy resins, such for example as those which contain groups of the formula

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- directly bonded to oxygen, nitrogen or sulphur atoms, in which either R' and R'' each contain one hydrogen atom, in which case R'' means a hydrogen atom or a methyl group, or R' and R'' together represent -CH₂CH₂ of -CH₂CH₂CH₂-, in which case R'' means a hydrogen atom. As examples of such resins there should be mentioned polyglycidylesters and poly(β-methylglycidyl)esters, which can be obtained by conversion of a compound
- 25 containing two or more carboxylic acid groups per molecule with epichlorhydrin, glycerine dichlorhydrin or β-methylepichlorhydrin in the presence of alkali. Such polyglycidyl esters can be derived from aliphatic polycarboxylic acids, e.g. oxalic acid, succinic acid,
- 30 glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid or dimerised or trimerised linolaic acid, from a cycloaliphatic polycarboxylic acids such as tetrahydrophthalic acid, 4-methyltetrahydrophthalic acid, hexahydrophthalic acid
- 35 and 4-methylhexahydrophthalic acid, and from aromatic polycarboxylic acids, such as phthalic acid, isophthalic acid and terephthalic acid.

Further examples are polyglycidyl ethers and poly(β -methylglycidyl) ethers, which are obtainable by conversion of a compound containing at least two free alcoholic and/or phenolic hydroxyl groups per molecule with the corresponding
5 epichlorhydrin under alkaline conditions, or also in the presence of an acidic catalyst with subsequent alkali treatment.

These ethers can be produced with poly-
(epichlorhydrin) from acyclic alcohols, such as
10 ethylene glycol, diethylene glycol and higher poly-
(oxyethylene)-glycols, propane-1,2-diol und poly-
(oxypropylene)-glycols, propane-1,3-diol, butane-1,4-
diol, poly-(oxytetramethylene)-glycols, pentane-1,5-
diol, hexane-1,6-diol, hexane-2,4,6-triol, glycerine,
15 1,1,1-trimethylolpropane, pentaerythrite und sorbite,
from cycloaliphatic alcohols, such as resorcite,
chinite, bis-(4-hydroxycyclohexyl)-methane, 2,2-bis-
(4-hydroxycyclohexyl)propane and 1, 1 -bis-
(hydroxymethyl)-cyclohexene-3, and from alcohols with
20 aromatic cores, such as N,N-bis-(2-hydroxyethyl)-
aniline and p,p'-bis-(2-hydroxyethylamino)-
diphenylmethane. They can also be produced from
single-core phenols, such as resorcin und
hydroquinone, and multicore phenols such as bis-(4-
25 hydroxyphenyl)- methane, 4,4dihydroxydiphenyl, bis-(4
hydroxyphenyl)- sulfone, 1,1,2,2-tetrakis-(4
hydroxyphenyl)ethane, 2,2-bis-(4-hydroxyphenyl)
propane (bisphenol A) and 2,2-bis-(3,5-dibromo-4
hydroxyphenyl)-propane.

30 Further suitable hydroxy compounds for producing polyglycidyl
ethers and poly(β -methylglycidyl) ethers, are the novolacks
obtainable by condensation of aldehydes, such as formaldehyde,
acetaldehyde, chloral and furfural and phenoline, such for
35 example as phenol, o-cresol, m-cresol, p-cresol, 3,5-
dimethylphenol, 4-chlorophenol and 4-tert.-butylphenol.

Poly-(N-glycidyl)-compounds can be obtained for example

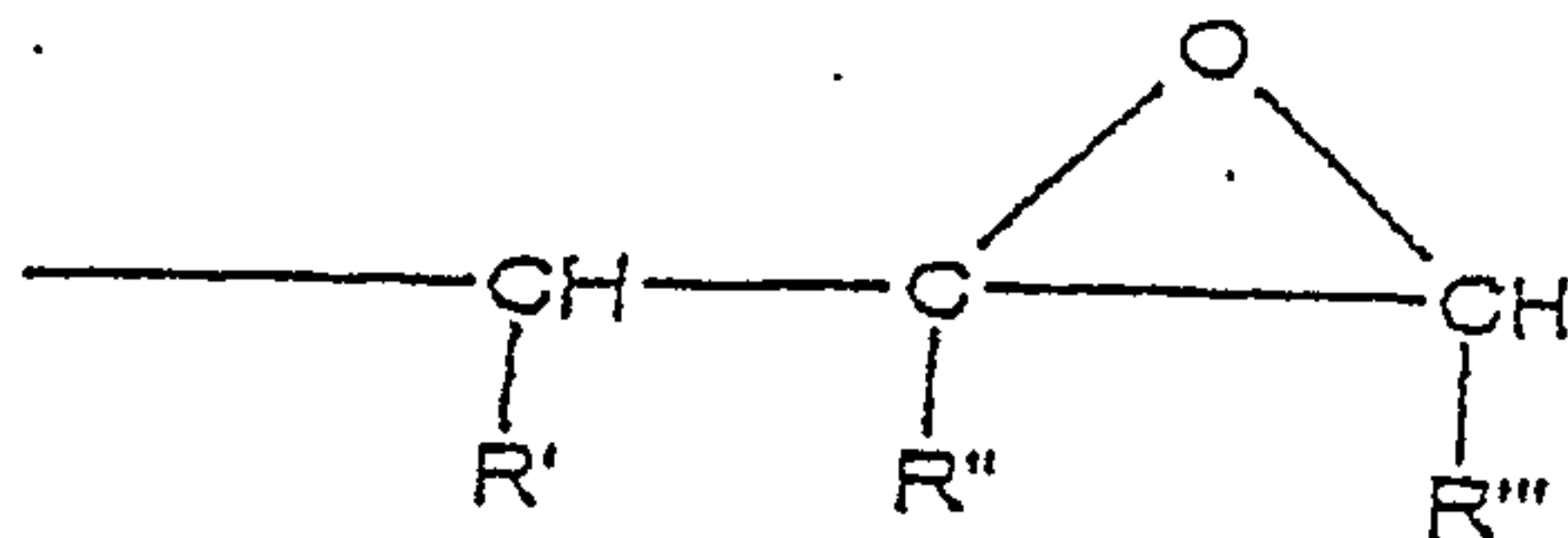
by dehydrochlorination of the conversion products of
epichlorohydrin with at least two amines containing amino
hydrogen atoms, such as such as aniline, n-butylamine,
bis-(4-aminophenyl

methane, and bis-(4-methylaminophenyl)-methane.

Further suitable poly-(n-glycidyl) compounds are
triglycidylisocyanurate and n,n'-diglycidyl derivatives
of cyclic alkylene ureas, such as ethylene-urea and
1,3-propylene-urea, and hydantoines, such for example
as 5,5-dimethylhydantoine.

Poly-(S-glycidyl)-compounds are for example the Di-S-glycidyl
derivates of dithiolene, such as ethane-1,2-dithiol and Bis-(4-
mercaptomethylphenyl)-ether.

Examples for epoxy resins with groups of the formula



wherein R' and R'' together mean a -CH₂CH₂- or
a -CH₂-CH₂-CH₂-CH₂-group, are bis-(2,3-epoxycyclopentyl)-
ether, 2,3-epoxycyclopentylglycidylether, 1,2-bis-(2,3-
epoxycyclopentylloxy)-ethane and 3',4'-
epoxycyclohexylmethenyl-3',4'-epoxycyclohexane-
carboxylate.

Also considered are epoxy resins, in which the glycidyl
groups or β-methylglycidyl groups are bonded to
heteroatoms of various types, e.g. the N,N,O-triglycidyl
derivate of 4-aminophenol, the
glycidylether/glycidylester of salicylic acid or p-

hydroxybenzoic acid, N-glycidyl-N'-(2-glycidyloxypropyl)-
5,5dimethylhydantoine and
2-glycidyloxy-1,3-bis-(5,5-dimethyl-1-glycidylhydantoinyl-
3)-propane.

5

If required, epoxy resin mixtures can be used.

Preferably, diglycidylethers of bisphenols are used. Examples
of this are bisphenol A-diglycidyl ether, bisphenol F-diglycidyl
10 ether and bisphenol S-diglycidyl ether. Bisphenol A-diglycidyl
ether is particularly preferred.

Quite particularly preferred are liquid and low-viscosity epoxy
resins. Appropriately the viscosity at 25°C does not exceed a
15 value of 20'000 mPas.

In a method according to the invention, all the known epoxy
resin hardeners can in theory be used.

20 Preferably a carboxylic acid or a carboxylic acid anhydride is
used as an epoxy hardener.

aliphatic dicarboxylic acids, such as oxalic acid, malic
acid, succinic acid, glutaric acid, adipic acid, pimelic
25 acid, suberic acid, azelaic acid, sebacic acid, 3,6,9-
trioxaundecandic acid, or dimerised or trimerised linoleic
acid;

cycloaliphatic polycarboxylic acids, such for example
as tetrahydrophthalic acid, 4-methyltetrahydrophthalic
30 acid, hexahydrophthalic acid and 4-

methylhexahydrophthalic acid; aromatic dicarboxylic
acids, such as phthalic acid, isophthalic acid,
terephthalic acid or naphthalic acid;
or diester-dicarboxylic acids, which are obtainable for
35 example by conversion of glycols, e.g. polypropylene glycol
with two equivalents dicarboxylic acid anhydride, such e.g.
as tetrahy-
drophthalic acid anhydride.

There can be considered in theory as anhydride hardeners all anhydrides of di- and higher-functional carboxylic acids, such as linear aliphatic polymeric anhydrides and cyclic carboxylic acid anhydrides.

5

- polysebacic acid polyanhydride, polyazelaic acid polyanhydride, succinic acid anhydride, citraconic acid anhydride, itaconic acid anhydride, alkenyl-substituted succinic acid anhydride, dodecenylsuccinic acid anhydride, maleic acid anhydride, tricarballic acid anhydride, nadican hydride, methylnadican hydride, linoleic acid adduct on maleic acid anhydride, alkylised endoalkylene tetrahydrophthalic acid anhydride, methyltetrahydrophthalic acid anhydride, tetrahydrophthalic acid anhydride, hexahydrophthalic acid anhydride, pyromellitic acid dianhydride, trimellitic acid anhydride, phthalic acid anhydride, tetrachlorophthalic acid anhydride, tetrabromophthalic acid anhydride, dichloromaleic acid anhydride, chloronadic anhydride and chloredicanhydride.
- 20 Preferably liquid or easily-melting dicarboxylic acid anhydrides are used as epoxy resin hardeners.

- Particularly preferred anhydride hardeners are methylnadicanhydride, tetrahydrophthalic acid anhydride and methyltetrahydrophthalic acid anhydride, methylnadicanhydride and methyltetrahydrophthalic acid anhydride being preferably used as an isomer mixture.
- 25

- If required the anhydride hardener can be used in combination with a reaction accelerator conventional for anhydride hardeners. There are suitable for example as reaction accelerators tertiary amines, carboxylic acid salts, metal chelates or organophosphenes. Preferred accelerators are the tertiary amines, such for example as N, N-dimethylbenzylamine, or substituted imidazoles.
- 30
- 35

- In a further preferred embodiment of the invention, there is used as a hardenable mixture a mixture of a tensioned cycloolefine and a catalyst for the ring-opening metathesis polymerisation.
- 40

Within the framework of the present invention, by cycloolefines is to be understood all cycloolefines with the exception of cyclohexene and its derivatives, which cannot be polymerised with the ring-opening metathesis. Suitable cycloolefines for example
 5 are described in WO 96/16100 and WO 96/202235.

Preferably, a Diels-Alder adduct of cyclopentadiene is used in the method according to the invention.

10 Particularly preferred are tetracyclododecene, methyltetracyclododecene and in particular dicyclopentadiene.

A large number of compounds of the transition metals titanium, vanadium, molybdenum, tungsten, rhenium, iridium, ruthenium and
 15 osmium is known to the person skilled in the art as catalysts for the ring-opening metathesis polymerisation (ROMP-catalysts). In this case for example what is involved are complex metal halogenides, metallo-carbenes or co-ordination catalysts of the Ziegler-Natta type. All these known ROMP-catalysts can in theory
 20 be used as component (b) in the compositions according to the invention.

A ruthenium (+II)-complex salt or an osmium(+II)-complex salt is preferably used, particularly preferably a ruthenium (+II)-complex salt, as component (b).

25

As the use of absolutely water-free substances and apparatus requires an additional outlay, it is recommended that moisture-insensitive ROMP-catalysts be used, such for example as the ruthenium (+II) and osmium (+II) complex salts described in WO
 30 96/16100 and WO 96/20235.

Particularly preferred ROMP-catalysts are

Particularly preferred ROMP-catalysts are

35 $[(\text{Cyclohexyl})_3\text{P}]_2\text{RuCl}_2$, $[(\text{C}_6\text{H}_5)_3\text{P}]_3\text{RuCl}_2$, $[(\text{C}_6\text{H}_5)_3\text{P}]_3(\text{CO})\text{RuH}_2$,
 $[(\text{C}_6\text{H}_5)_3\text{P}]_3\text{RuCl}(\text{cyclopentadienyl})$,
 $[(\text{Cyclohexyl})_3\text{P}]_2(\text{CH}_3\text{OH})\text{Ru}(\text{tosylate})_2$, $[(\text{o-tolyl})_3\text{P}]_3\text{RuCl}_2$,

$[(CH_3)_2CH]_3P(p\text{-cymol})RuCl_2$ and in particular
 $(Cyclohexyl)_3P(p\text{-cymol})RuCl_2$.

5 The desired viscosity of the hardenable mixture can be adjusted
by the addition of thermoplastic materials. Examples of suitable
thermoplastics are polystyrol, polynorbornene (e.g. Norsorex NS
of the Company Nippon Zeon), hydrated polynorbornene derivates
(e.g. Zeonox of the Company Nippon Zeon) polycylooctene, (e.g.
Vesternamer of the Company Hüls) and polybutadiene.

10

A particular advantage of the method described for manufacturing
the assembly 45 resides in the fact that the process steps of
impregnation of the loosely layered sheet stack 8, surrounding of
the other components and of the entire assembly 45 with an anti-
15 corrosion layer 46 (Figure 6) and the secure connection of all
parts together can be effected in one single working step,
without the necessity for additional mechanical connecting means.
Thus the procedures of loading and unloading the tool 28, opening
and closing the tool 28 and filling of the remaining cavities
20 within the hollow mould may be to a large extent automated.

If in addition hardenable mixtures with electrically insulating
properties are used, which applies to the abovenamed materials,
then there results the further advantage that the sheets 1 are
25 surrounded in the single named working step with an electrically
insulating layer, so that in theory also entirely untreated
magnetic steel sheets having no insulating layers, can be used as
initial materials.

A further outstanding advantage of the invention in this case
30 resides in the fact that the individual sheets 1 of the sheet
stack 8 can be inserted in an in fact totally untreated but
however stacked and densely packed condition into the tool 28.
Due to the natural surface roughness in the area of their wide
sides 7, there remain between the sheets 1, even in the stacked,
35 densely packed condition a sufficiently large number and size of
cavities, which fill with this mixture upon its penetration into

the tool 28, which then, in the hardened condition, provides the necessary insulation between the individual sheets 1 without the formation of disruptive bubbles of the like. This effect can be further improved and optimised in that, before or during
5 injection of the mixture, the cavity is at least partly evacuated, in order to produce a slight reduction in pressure of e.g. 2 to 10 millibars, if necessary to be determined by tests, and thus to suction the mixture additionally into the cavity, so that simultaneously the necessity is removed of expelling the
10 air still located in the cavity with the aid of the mixture.

Finally a further advantage is that the external shape of the assembly 45 can be selected substantially independently of the shape of the individual sheets 1 produced by stamping, and of
15 the winding 19 laid around it. In particular, by means of corresponding formation of the mould hollow, it can be assured that the external anti-corrosion layer is sufficiently thick and environmentally resistant, whilst simultaneously by means of the stacking of the sheets 1 and the pressure used to clamp them,
20 the required thin adhesive and if necessary insulating layers can be produced between the individual sheets 1.

The embodiment according to Figures 1 to 8 may be modified and/or supplemented in many ways.

5 Particularly, the undersides 4 (Figure 1) of the sheets 1 of the
entire sheet stack and/or the undersides of the pole jaws 12,13
can be kept free of mixture. For this purpose for example the
cavity of the tool 28 is so designed that the said undersides,
after location of the various components in the tool 28, abut
10 directly on corresponding wall portions. As the undersides of
the sheet stacks and/or of the pole jaws 12,13 in a complete
magnet, usually consisting of a plurality of such magnet poles,
are magnetically connected together by means of ferromagnetic
pole backs located beneath the windings 19, it is ensured in
15 this way that in the boundary surfaces between the magnet poles
and the magnet back no magnetically disruptive slots formed by
included mixture arise.

Figures 9 to 14 show the manufacture of a sheet stack 51 for the
stator of an electrical alternating current motor. Similarly to
20 Figures 1 to 8, the sheet stack 51 includes a plurality of
plates or lamellae 52, which are shown in the upper portion of
Figure 9 in the exploded condition and in the lower portion of
Figure 9 in the ready stacked condition abutting parallel and
flush on one another. The sheets 52 are obtained by stamping
25 out from a raw ferromagnetic sheet metal strip or the like which
has no adhesive layer. The sheets 52 in the embodiment have
identical dimensions and, as can be seen from the plan view in
Figure 10, have a circular form. On their inner circumference,
the sheets 52 are provided with U-shaped cut-outs 53, which in
30 the stacked condition are aligned towards one another and form
continuous grooves. In a known way, groove sleeves 54 are
pressed into these grooves, said groove sleeves according to
Figure 9 extending over the entire height of the sheet stack 51
and enabling the formation of the stack in a simple way.

35

The groove sleeves 54 serve to accommodate windings 55 (Figure
9) the centre lines of which have a substantially flat-oval
configuration, as can be seen from the front view or plan view
according to Figures 9 and 10, for a winding 55 which is not yet

mounted. These correspondingly prepared windings 55, in dependence on the type of winding provided for an individual case, are pressed with their long sides into groove sleeves 54 (Figure 10), which are spaced apart by two or a multiple of times, in Figure 10 by three times the groove division from one another, while their short sides form the winding heads. Therefore, in the assembled condition, the winding 55 adopts the position indicated by the broken line 55a (see also Figure 11). The groove sleeves 54 appropriately consist of paper, cardboard or an insulating plastic, so that the windings 55 are sufficiently insulated from the plates 52, even if these latter have no insulating layer or have lost it due to the stamping procedure. In order axially to secure the groove sleeves 54 in the sheet stack 51, respective groove sleeve collars 56 (Figure 11) can be used, which are clipped onto the upper or lower ends of the groove sleeves 54, or may also be integrated in the groove sleeves 54 as a fold.

After all the windings 55 have been inserted into the associated groove sleeves 54 and have been electrically interconnected in the necessary way (Figure 11), the loosely pre-mounted assembly is introduced, similarly to the assembly according to Figure 4, into a tool 59 (Figures 12,13) which in the embodiment has two tool halves 60,61, which are provided on sides facing one another with apertures 62,63, which in the closed condition of the tool 59 form a mould hollow or cavity, the dimensions of which are slightly greater than the external dimensions of the inserted assembly. The assembly may be positioned in the tool similarly to Figure 6 with the aid of spacers or other positioning aids not shown, which preferably engage on the assembly at points where no surrounding with a hardenable mixture is necessary.

After the tool 59 is closed in the direction of the arrows appearing in Figure 12, a hardenable mixture is introduced into the cavity, for which purpose the tool 59, similarly to Figure 7, is provided with an inlet opening extending as far as the cavity, and which is connected by means of a line 64 (Figure 14) to a control valve 65 and via metering pumps 66,67 to mixing

containers 68,69, which contain a reaction resin or a hardener or the like, in order to prepare the mixture therefrom. The reaction resin and hardener ingredients metered by the metering pumps 66,67 are mixed in a mixer 70. The method steps of
5 introduction of the mixture into the cavity, of hardening or hardening out of the mixture, of heat treatment and if necessary cleaning are similar to the embodiment according to Figures 1 to 8 and therefore need not be described again. The same applies to the usable mixtures, particularly casting resin mixtures,
10 whose preparation, the preferred injection of the mixture at a pressure of e.g. 1 to 3 bar, the preferable additional evacuation of the cavity and the preferred use of the pressure-gelating method.

15 After removal from the mould, the finished assembly 71 visible in Figure 14 is obtained in the form of a stator. This assembly 71 is provided all round with an anti-corrosion and if necessary insulating layer 72, the thickness of which corresponds to the spacing between the various components and the walls of the
20 associated tool halves 60,61 in the closed condition of the tool 59, and can be correspondingly pre-selected.

The advantages attained in manufacturing the assembly 71 according to the method described are similar to those explained
25 in conjunction with the assembly 45. Thus the external shape of the finished assembly 71 can be selected to a large extent independently on the stamped shape of the individual sheets 52, so that as required the final electrical, magnetic, mechanical and/or geometric properties of the sheet stacks or of the
30 assembly 71 are at least partly obtained only by the treatment of all components with the hardenable mixture in a tool. This applies particularly with respect to the application of the layers between the individual sheets, the external anti-corrosion layer, the permanent interconnection of the various
35 parts and the final external shape of the surrounded sheet stacks, assemblies or parts thereof. A particular advantage in addition is that additional connecting means such for example as screws, rivets, adhesives or the like are required neither for positioning nor for connecting the individual parts, and the

mechanical strength and environmental resistance can be established by the thickness of the external covering with the hardenable mixture.

5

As shown in particular by Figure 11, it may also be appropriate to cover the sheet stacks or assemblies inserted into the tool at specific points, e.g. on their outer sides, with a spacer member 73 produced from a porous material, consisting e.g. of a woven mat produced from plastic fibres or the like, which holds the sheet stack 51 or the like at a desired spacing from the walls of the mould hollow. Such elements or mats are fully impregnated with the mixture during the injection procedure, so that during hardening a stable, strong plastic resin layer results, which forms a mechanically strong external wall on the finished assembly 71 and increases its mechanical strength.

In order to improve the electrical properties (dielectric constant, loss factor) there may be added to the hardenable mixtures silanes, e.g. the compounds offered by the Company Osi Specialties under the title Silquest Silane. Suitable silanes are for example octyltriethoxysilane, methyltriethoxysilane and vinyltriethoxysilane.

In addition, the hardenable mixtures can contain fillers such for example as metal powder, wood powder, glass powder, glass pearls or semi-metal and metal oxides. Preferred fillers are Wollastonite, Al_2O_3 and SiO_2 , quartz powder of the various SiO_2 modifications being particularly preferred.

30

In addition to the additives mentioned, further additives such for example as anti-oxidising agents, light-protective agents, plasticisers, pigments, dye stuffs, thixotropic agents, viscosity improvers, de-foamers, anti-static agents, lubricants and mould release agents can be contained in the hardenable mixtures.

35

Moreover, the hardenable mixtures may be produced according to known methods, conventionally with the aid of known mixing units

(stirrers, kneaders, rollers, mills, dry mixers or thin-layer de-gassing mixers). The various methods for producing mixtures are known to the person skilled in the art and are for example described in Becker/Braun: "Kunststoff-Handbuch, vol. 10, Duroplaste", Carl Hanser Verlag 1988, pages 515 ff and 825 ff.

It if is desired to stack the individual sheets 1,61 in a way other than that explained above, they can be fixed with appropriate auxiliary means, e.g. spacers, on the ends in such a way that the spacings between the individual sheets are approximately equal. In this case it is irrelevant that the spaces between all the plates are exactly identical. There need only be sufficient room for entry of the insulating resin compound into the inter-spaces between the individual plates 1,61. The spacing between the plates 1 in this way can be adjusted for example from 1 μm to 100 μm , preferably to 2 μm to 5 μm .

The metal plates usable in the method according to the invention are preferably steel plates, although other ferrömagnetic materials can also be used.

The invention is not restricted to the embodiments described by way of example, which may be varied in many ways. This applies in particular with respect to the assemblies having ferromagnetic sheet stacks and which can be manufactured according to the method described. According to the method described, sheet stacks of all types for all types of apparatus may be manufactured, which have a magnetic circuit, which for electromagnetic purposes require a sheet stack assembled from individual plates. Independently thereof, the sheet stacks may be individually manufactured according to the method described, and may be subsequently combined in a conventional method of construction with other components in order to form assemblies. Thus it is self-evident that the sheet stacks and/or assemblies described can be provided also with other components not described in more detail, e.g. with externally-leading electrical or mechanical connections, which are likewise fixed and/or formed by the surrounding hardenable mixture. Finally the invention comprises also the sheet stacks and assemblies

manufactured according to the described method, the individual features being also applicable in combinations other than those described and illustrated in the drawing.

-26- 25

Claims

1. Method of manufacturing a sheet stack (8,51) for
electromagnetic assemblies, consisting of ferromagnetic
5 material, in which the sheet stack (8,51) is assembled from raw
magnetic steel sheets (1,52) and is positioned, if necessary
with the use of positioning aids, in a shaping tool (28,59), and
the sheets (1,52) by means of introduction of a hardenable
mixture into the tool (28,59) and hardening or hardening out of
10 the casting compound, are connected together to form the
finished sheet stack (8,51) in one single working step,
characterised in that it is carried out as a pressure-gelating
method, and the sheet stack (8,51), formed without the use of
spacers, is simultaneously totally surrounded with the mixture
15 in the tool (28,59), in order to form an anti-corrosion layer.

2. Method of manufacturing an electromagnetic assembly
(45,71) including at least one sheet stack (8,51) consisting of
ferromagnetic material and one further component (12-14,53-56),
20 characterised in that the sheet stack (8,51) is assembled from
raw magnetic steel sheets (1,52), and is positioned together
with the further components (12-14,53-56), if necessary with the
use of positioning aids, in a tool (28,59), and in that then, by
introduction of a hardenable mixture into the tool (28,59) and
25 hardening or hardening out of the mixture according to the
pressure-gelating method, in one single step the sheets (1,52)
are connected together to form the finished sheet stack (8,51),
the sheet stack (8,51) is connected to the component (12-14,53-
56), and the assembly (45,71) is surrounded with the mixture in
30 order to form an anti-corrosion layer.

3. Method according to claim 1 or 2, characterised in that a
pressure of 2-10 mbar is maintained in the tool.

35 4. Method according to claim 2 or 3, characterised in that
the assembly (45,71) as a whole is only provided with its final
electrical, mechanical and/or geometric properties by the
mixture.

-27-26

5. Method according to one of claims 1 to 4, characterised in that at least one section of the sheet stack (8,51) and/or of the component (12-14,53-56) is used for mounting a positioning member upon introduction into the tool (28,59).

5

6. Method according to claim 5, characterised in that a spacer member (73) produced from a porous material is used as a positioning member.

10 7. Method according to one of claims 1 to 6, characterised in that a thermally hardenable mixture is used as a hardenable mixture.

15 8. Method according to one of claims 1 to 7, characterised in that raw non-pre-treated sheets (1,52) are used to produce the sheet stack (8,51), and the mutual electrical insulation between the sheets (1,52) is produced by application of a hardenable mixture with electrically insulating properties.

20 9. Method according to one of claims 1 to 8, characterised in that selected areas of the sheets (1) or of the sheet stack (8) remain free of mixture.

25 10. Sheet stack, characterised in that it is manufactured by the method according to one of claims 1 to 9.

11. Assembly, characterised in that it is manufactured by the method according to one of claims 2 to 9.

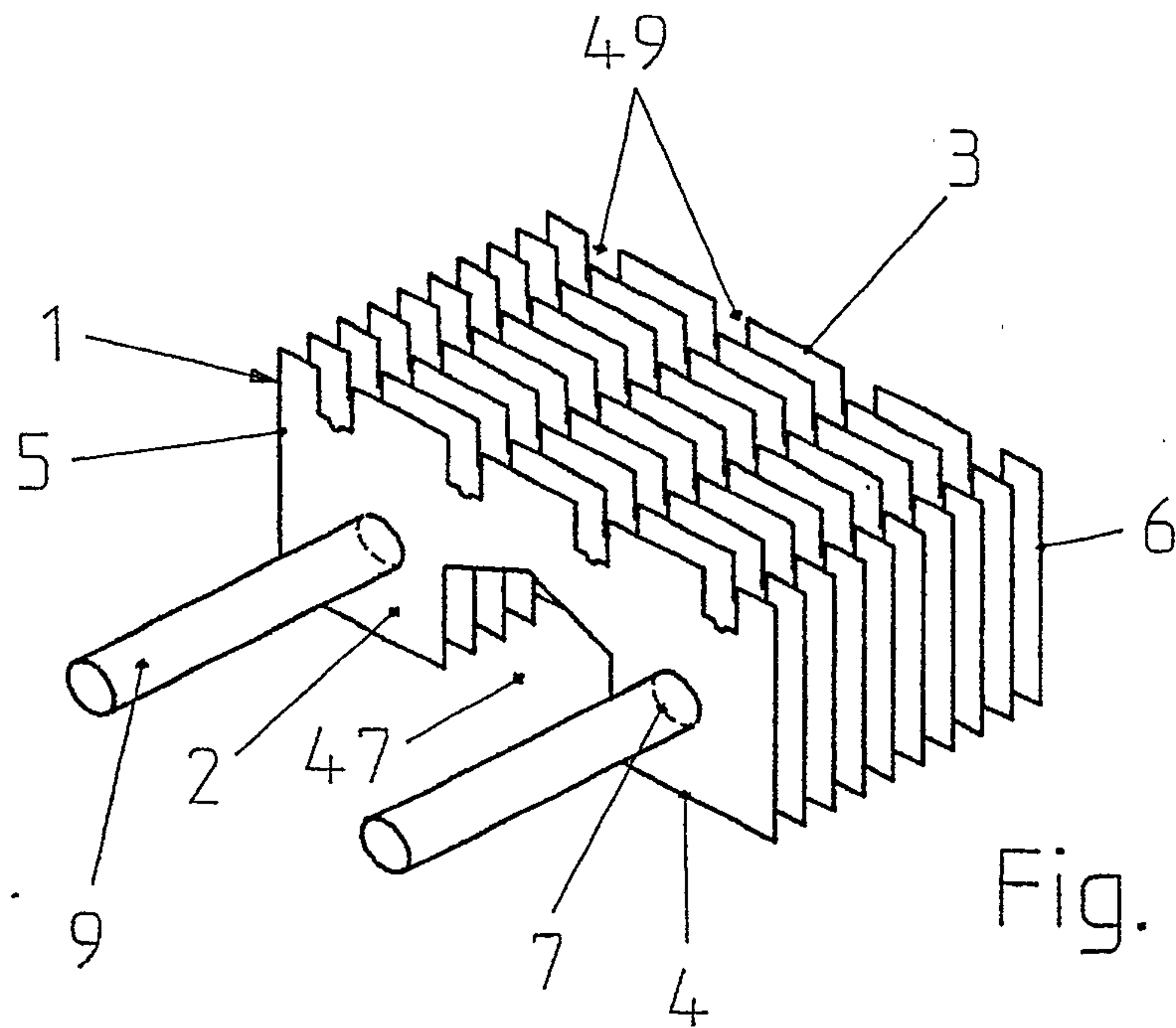


Fig. 1

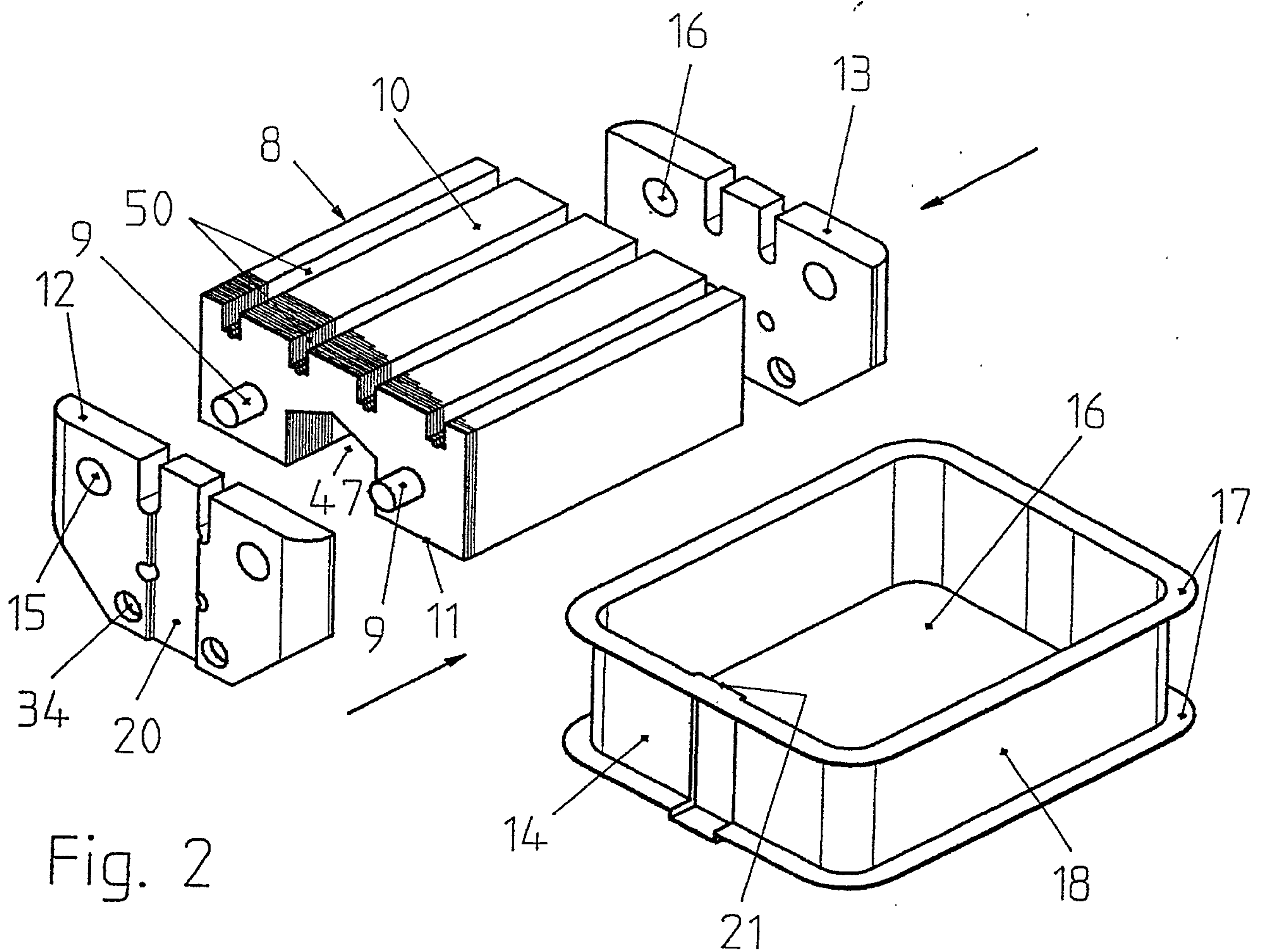
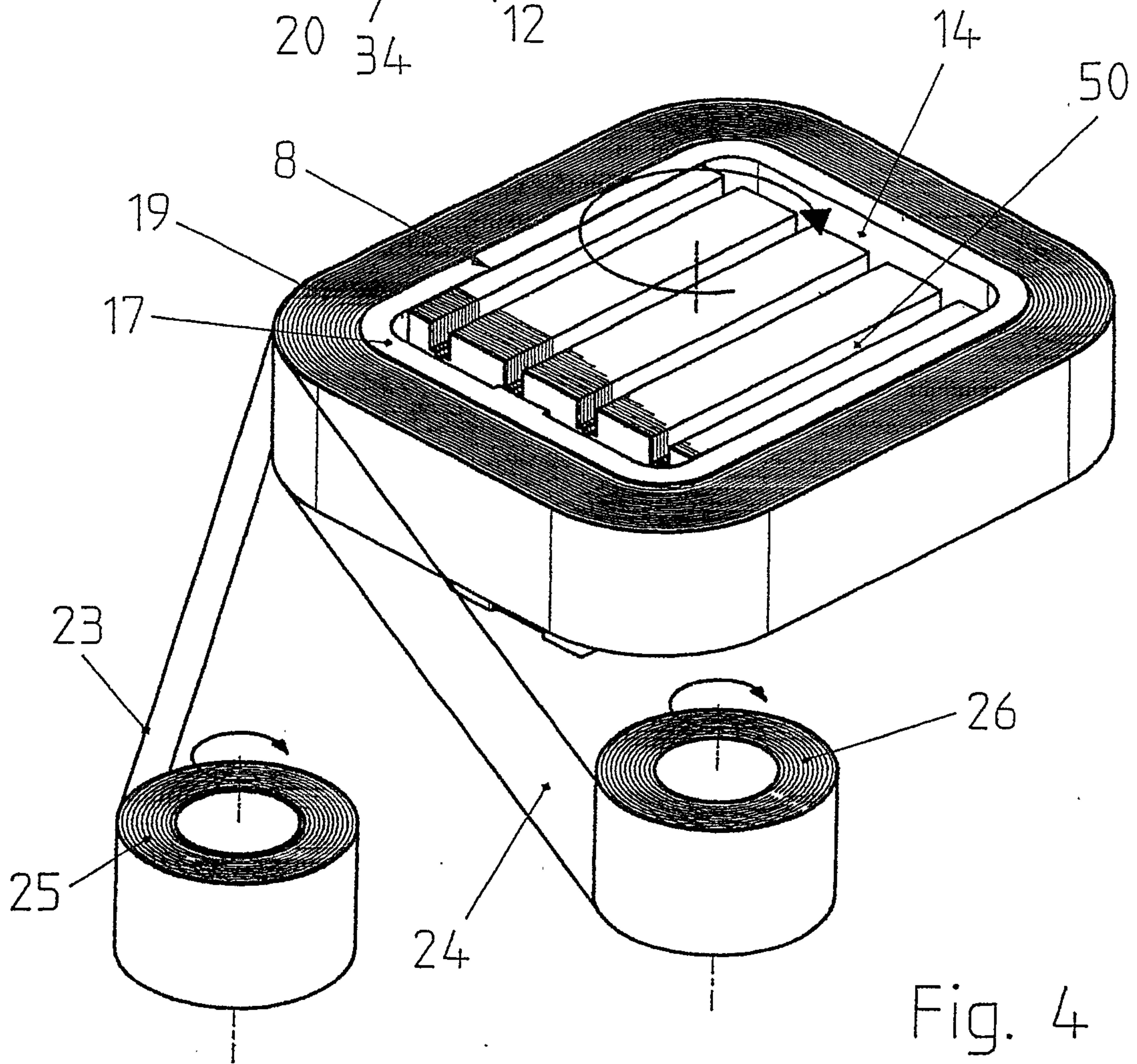
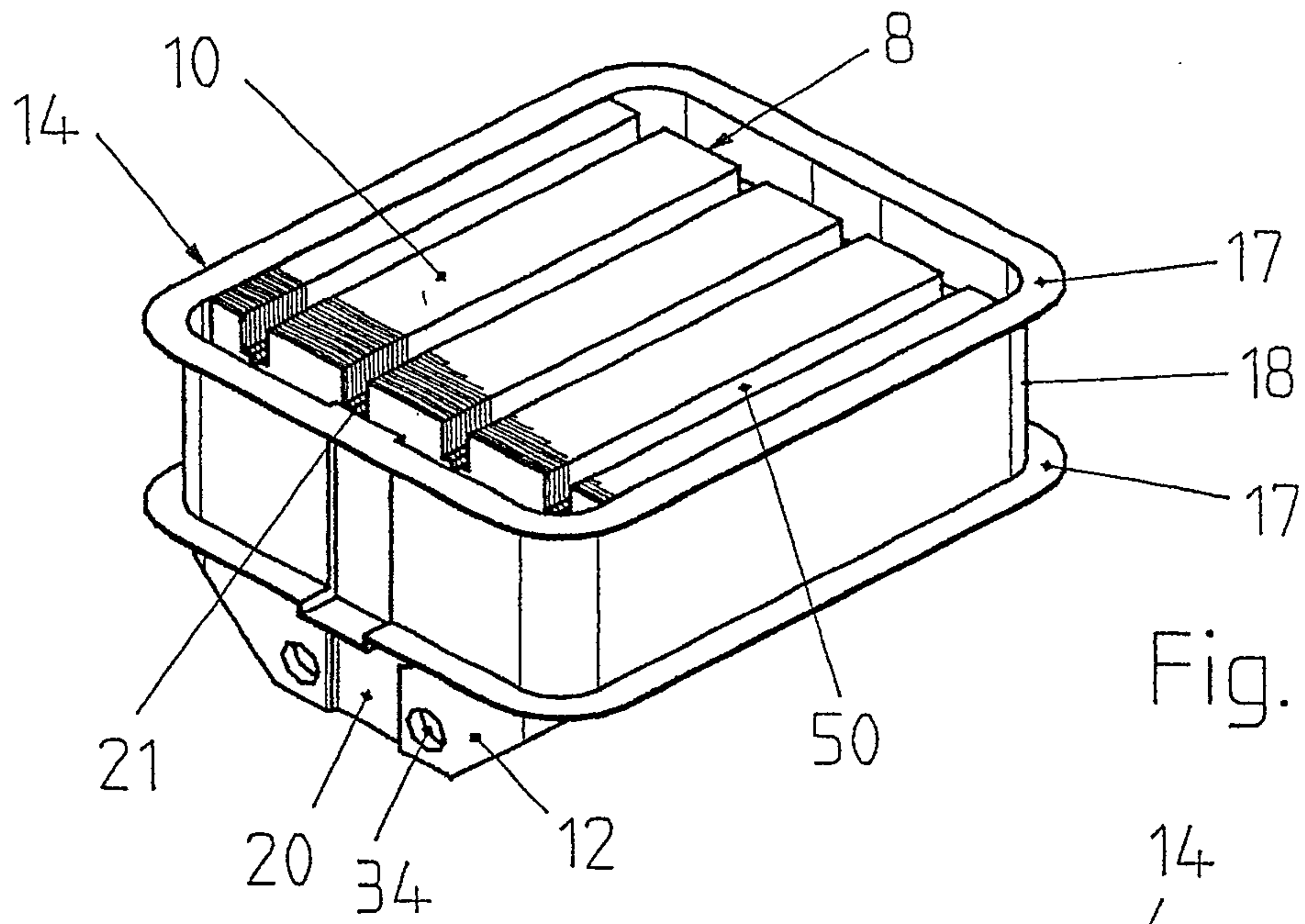


Fig. 2



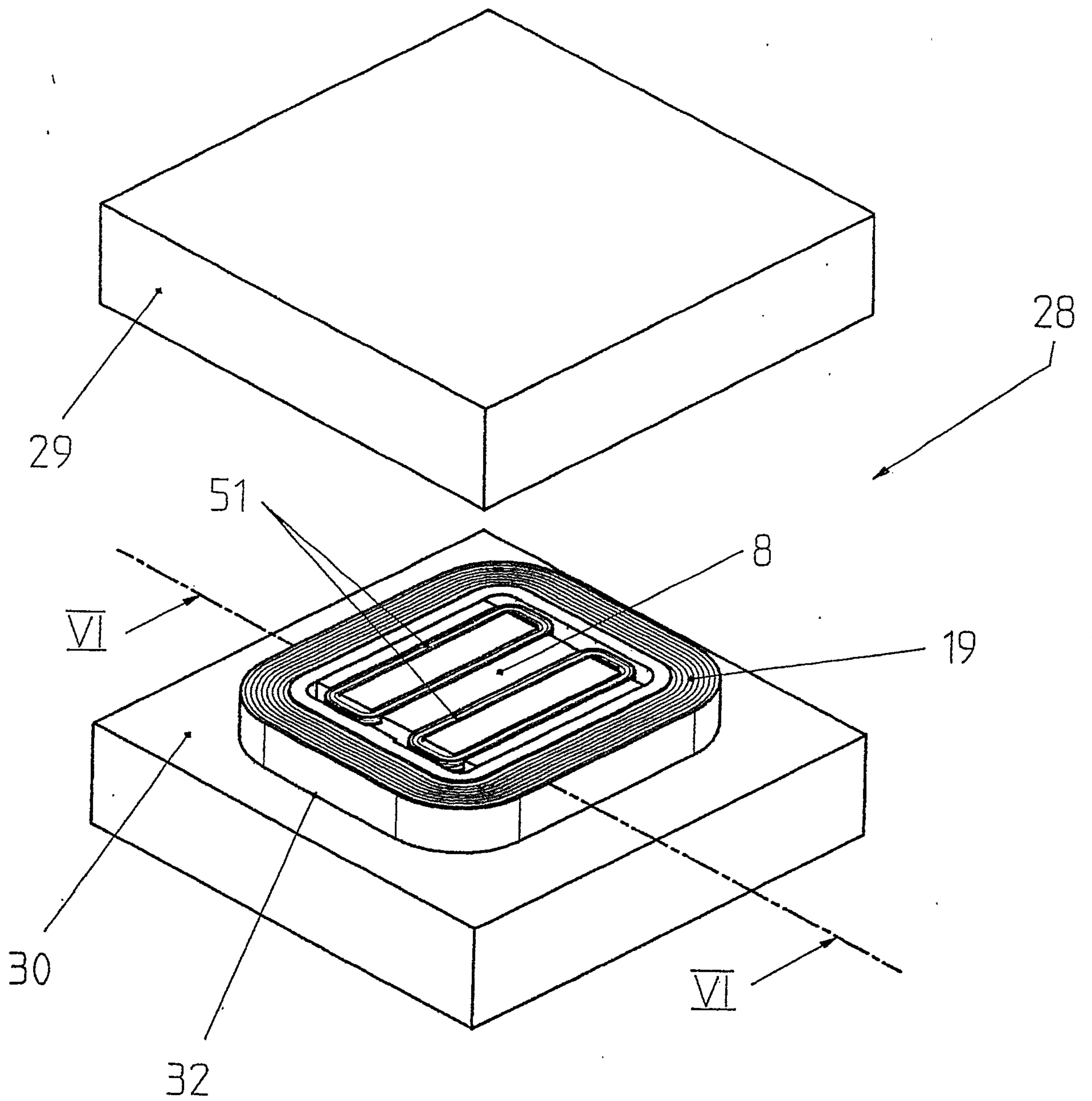


Fig. 5

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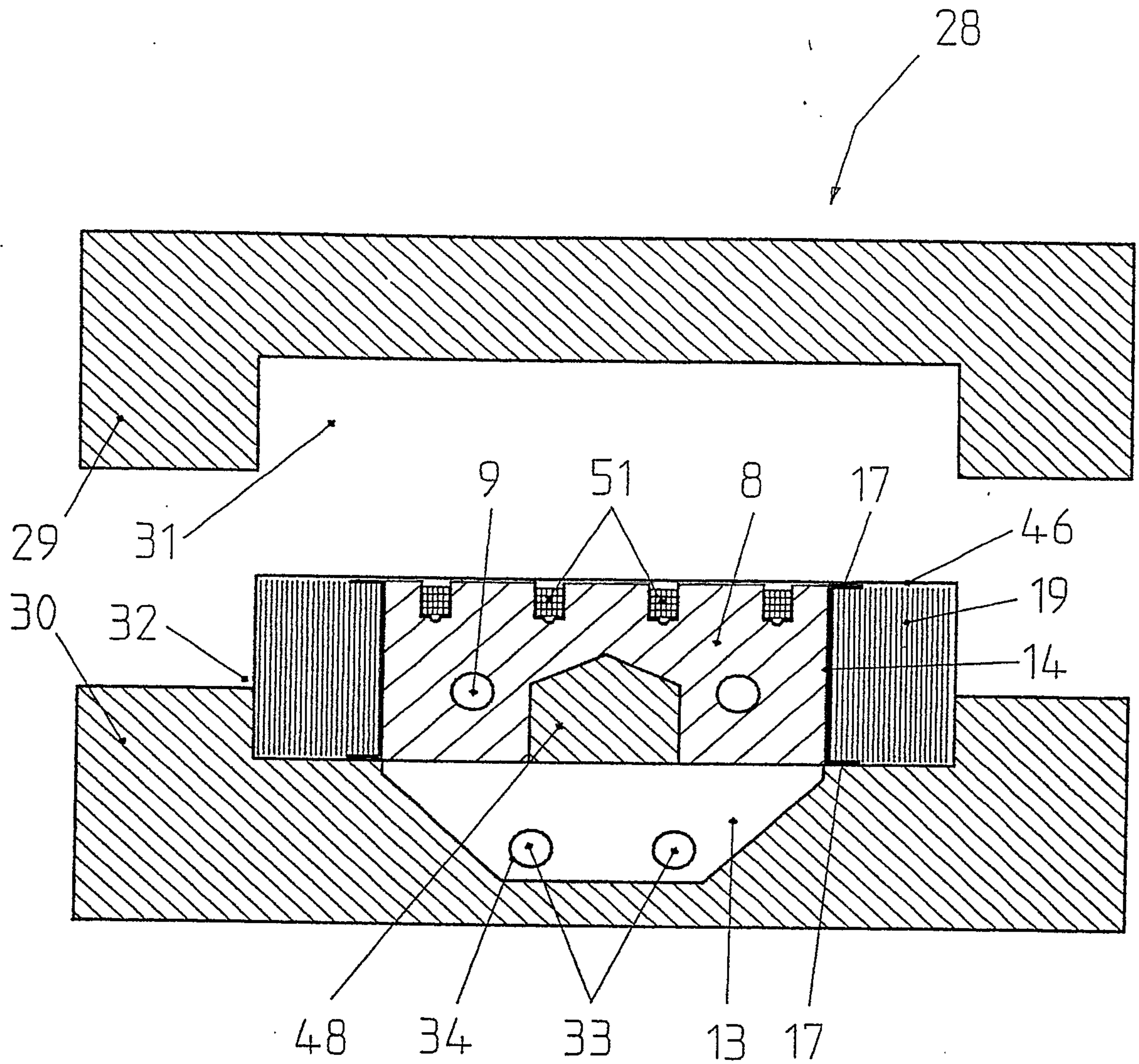


Fig. 6

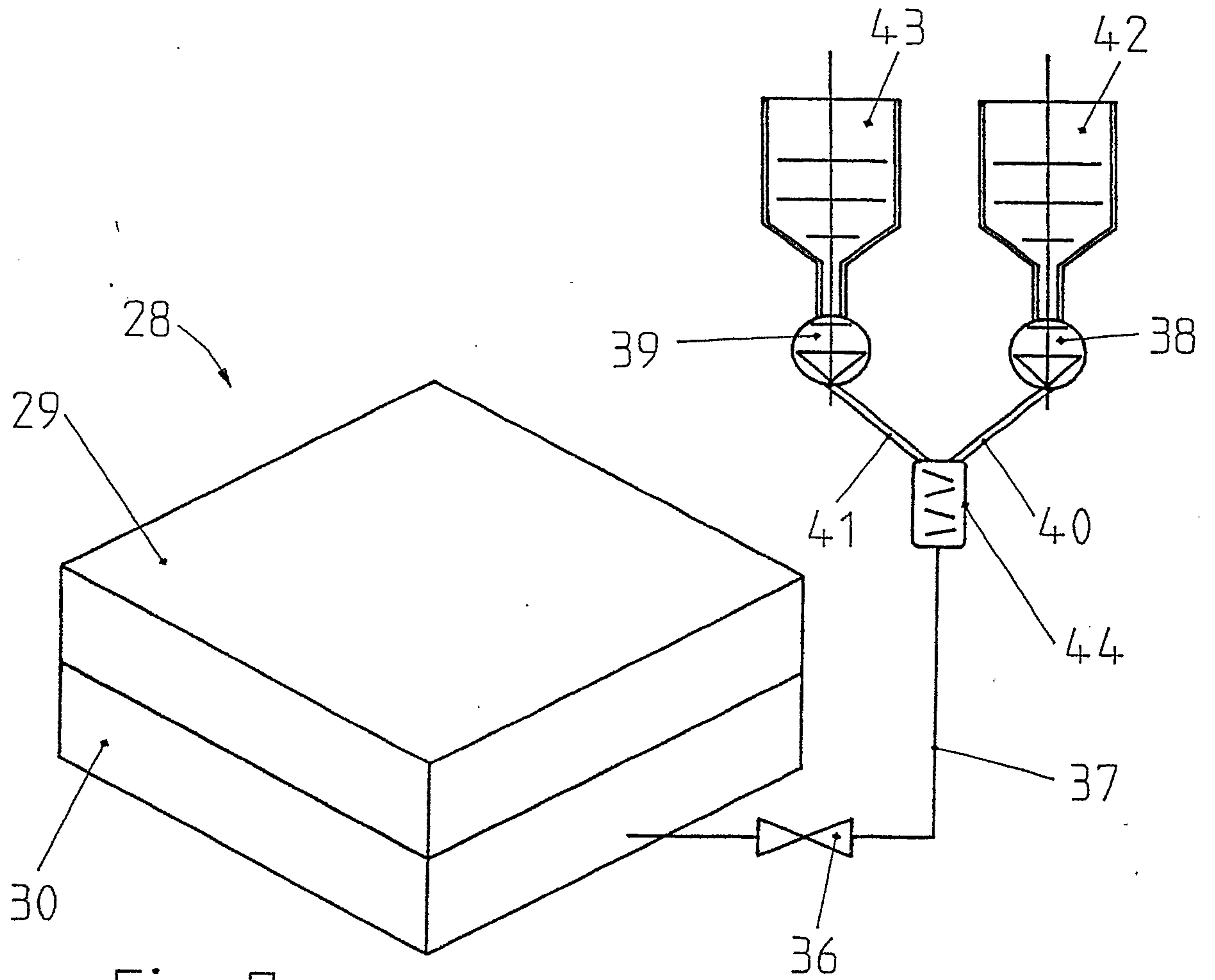


Fig. 7

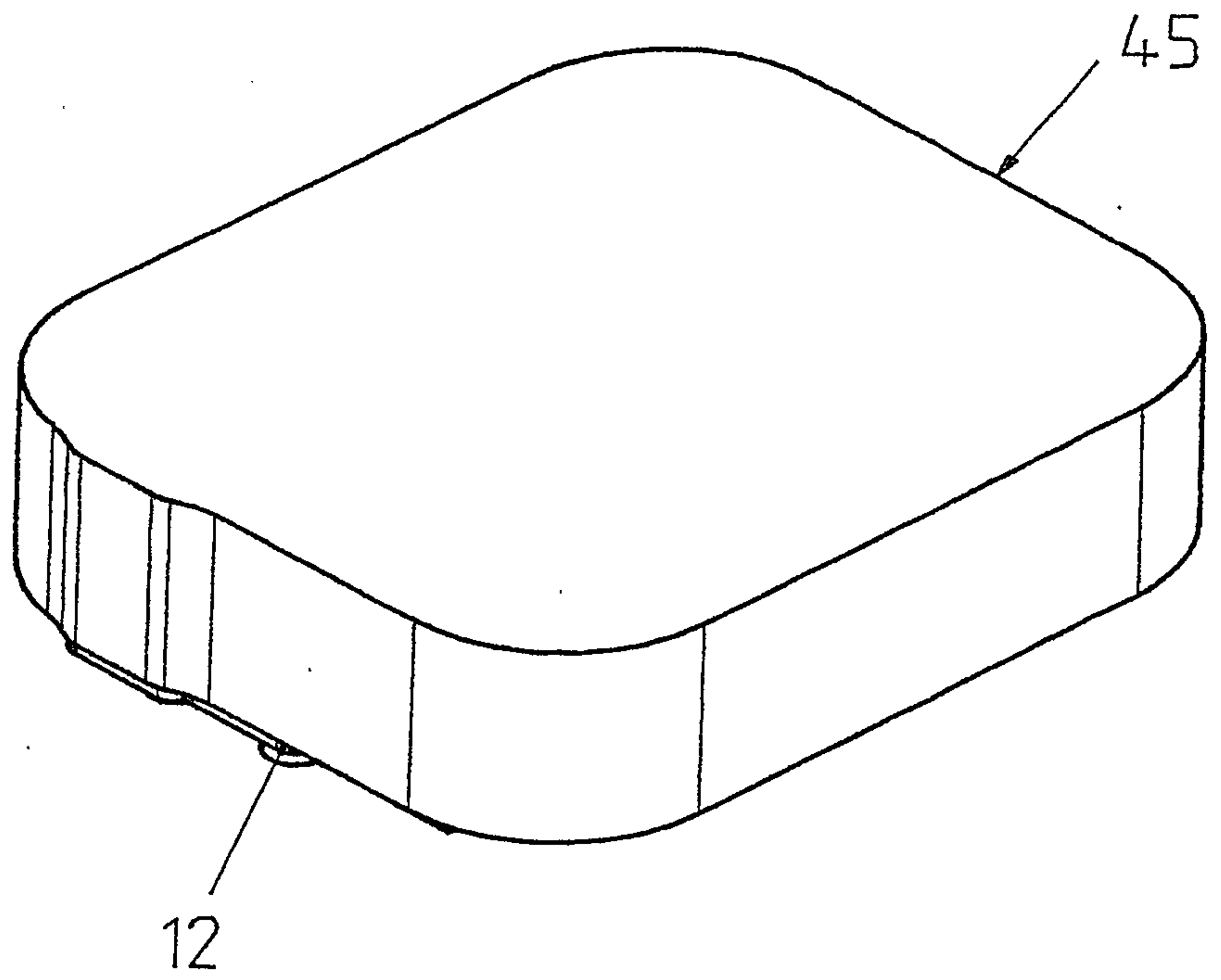
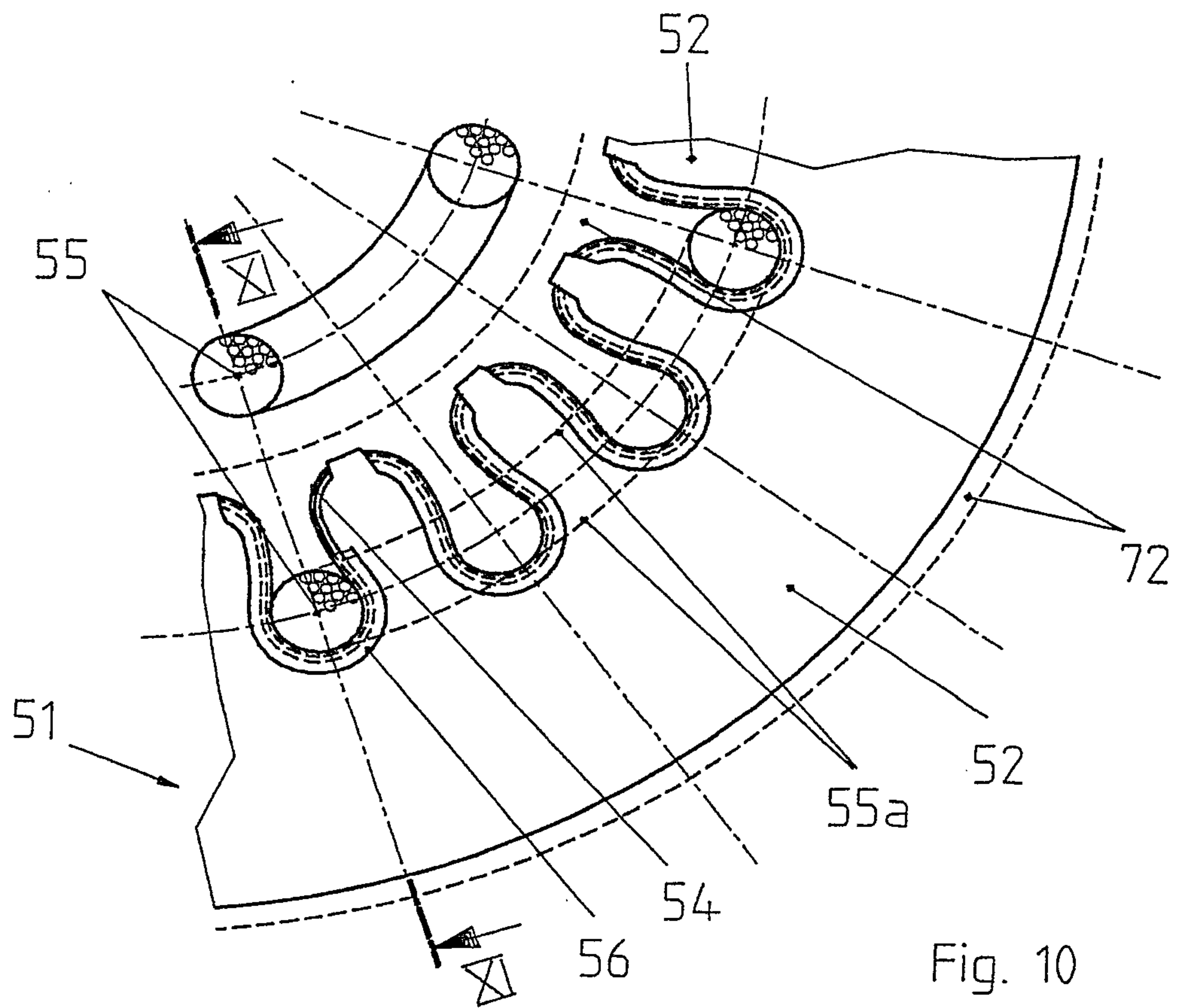
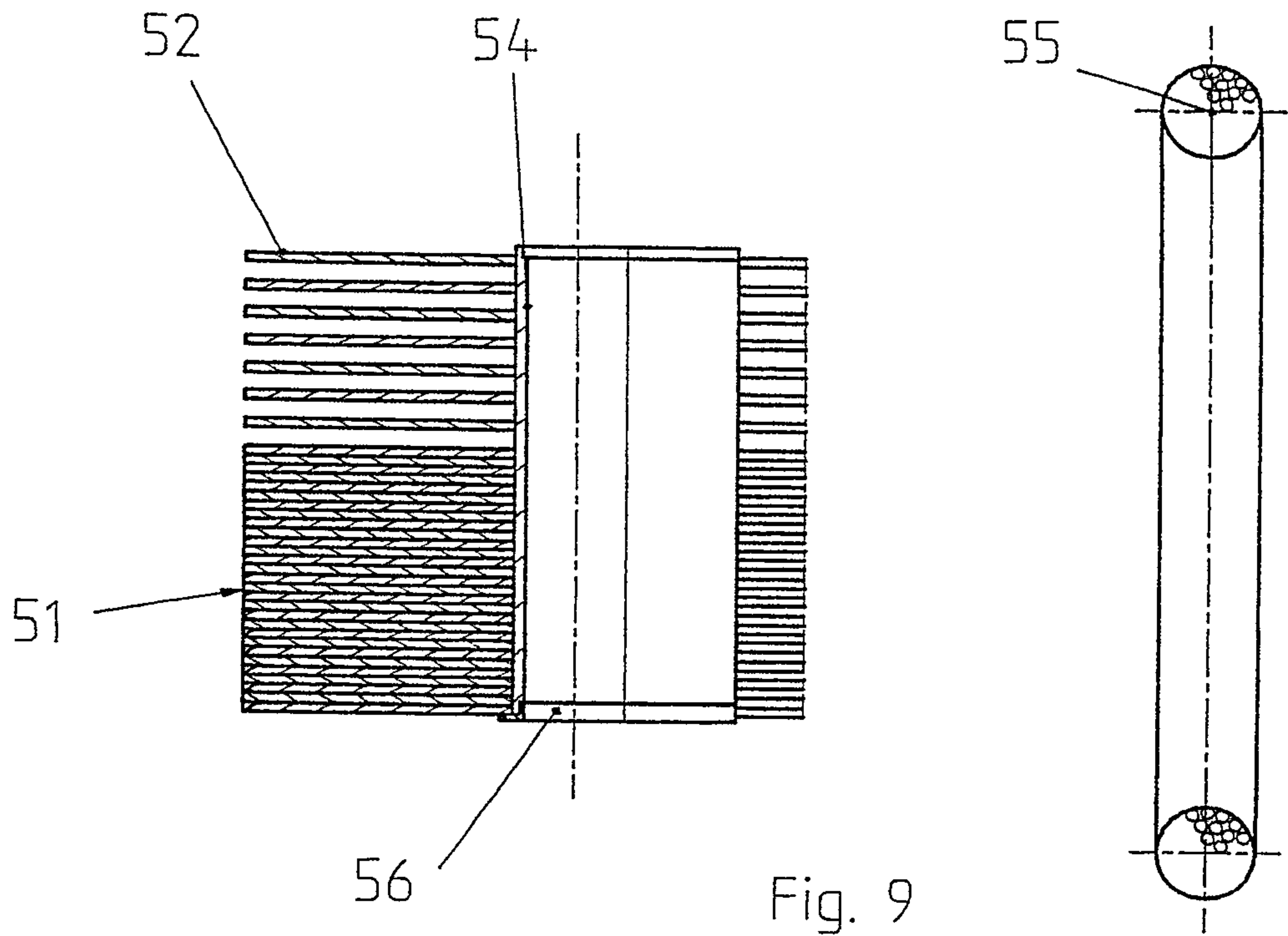


Fig. 8



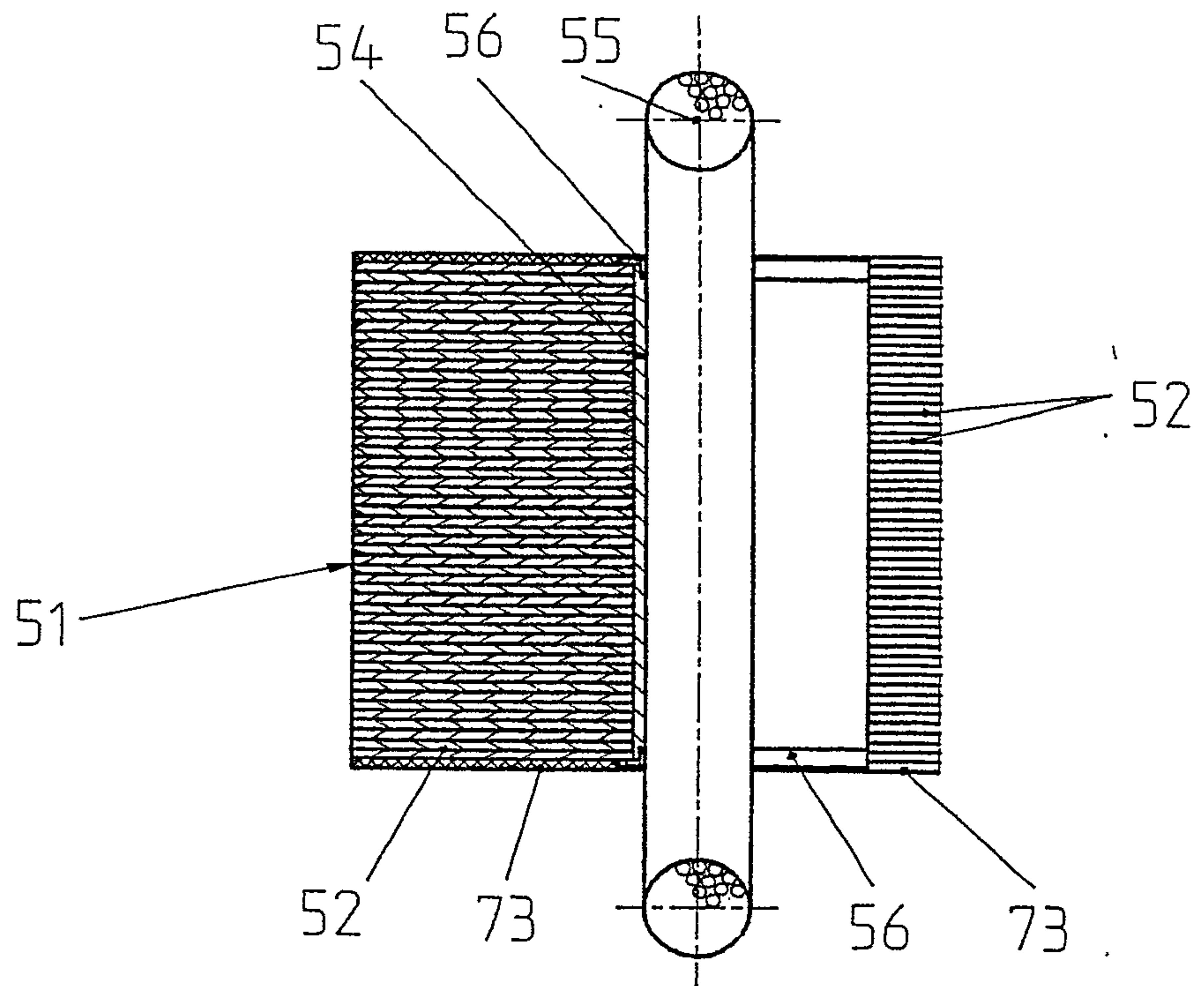


Fig. 11

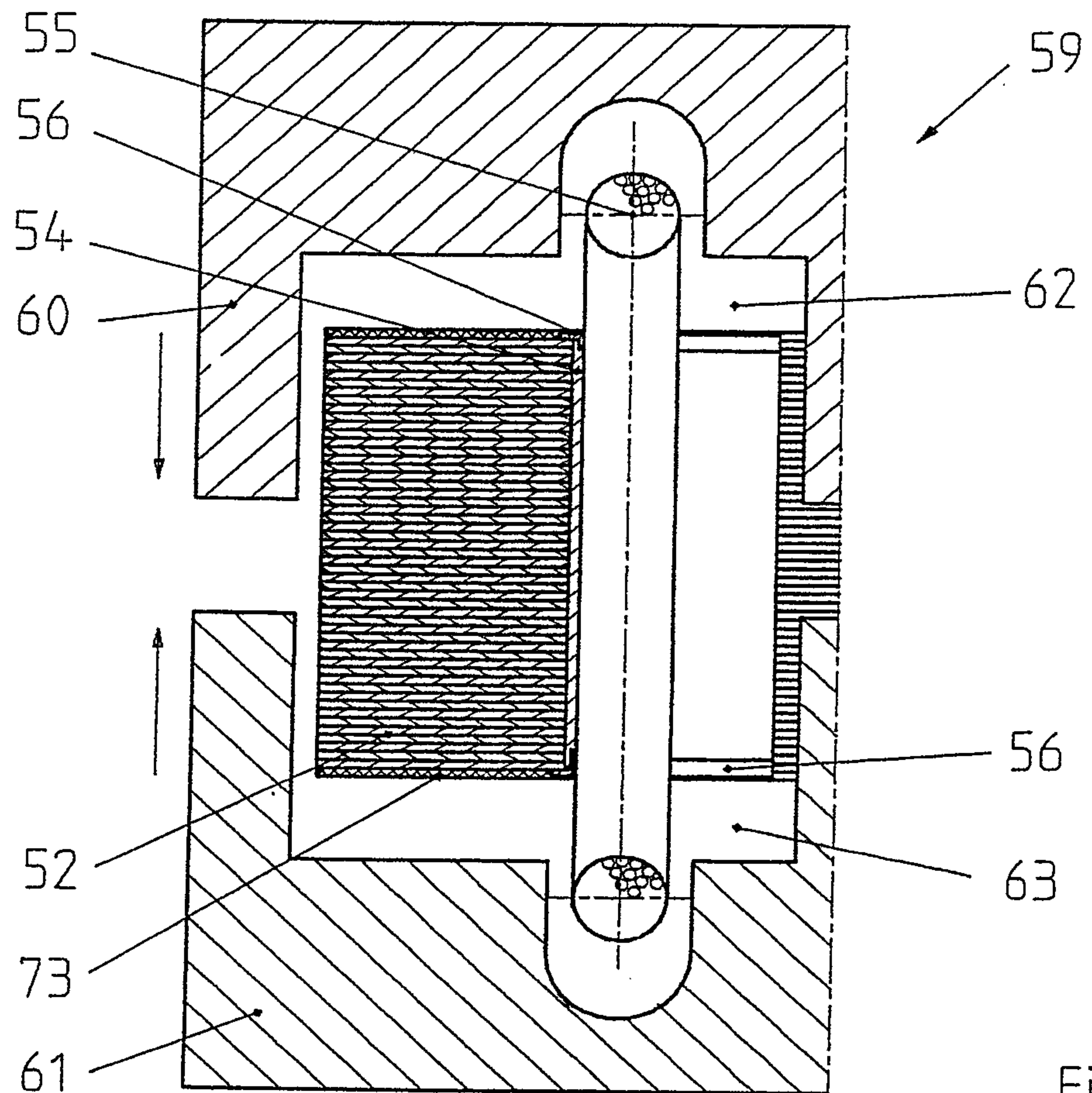
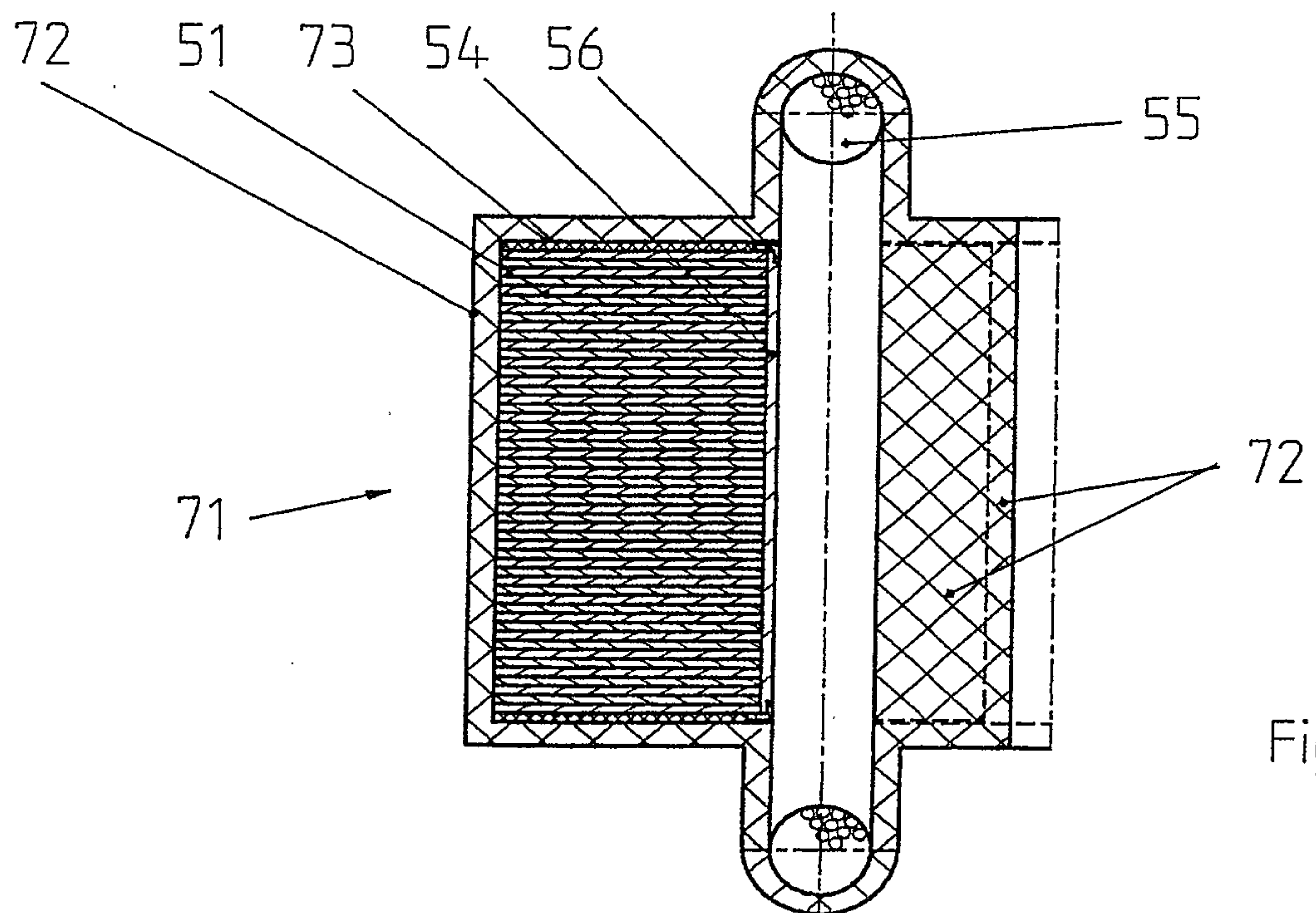
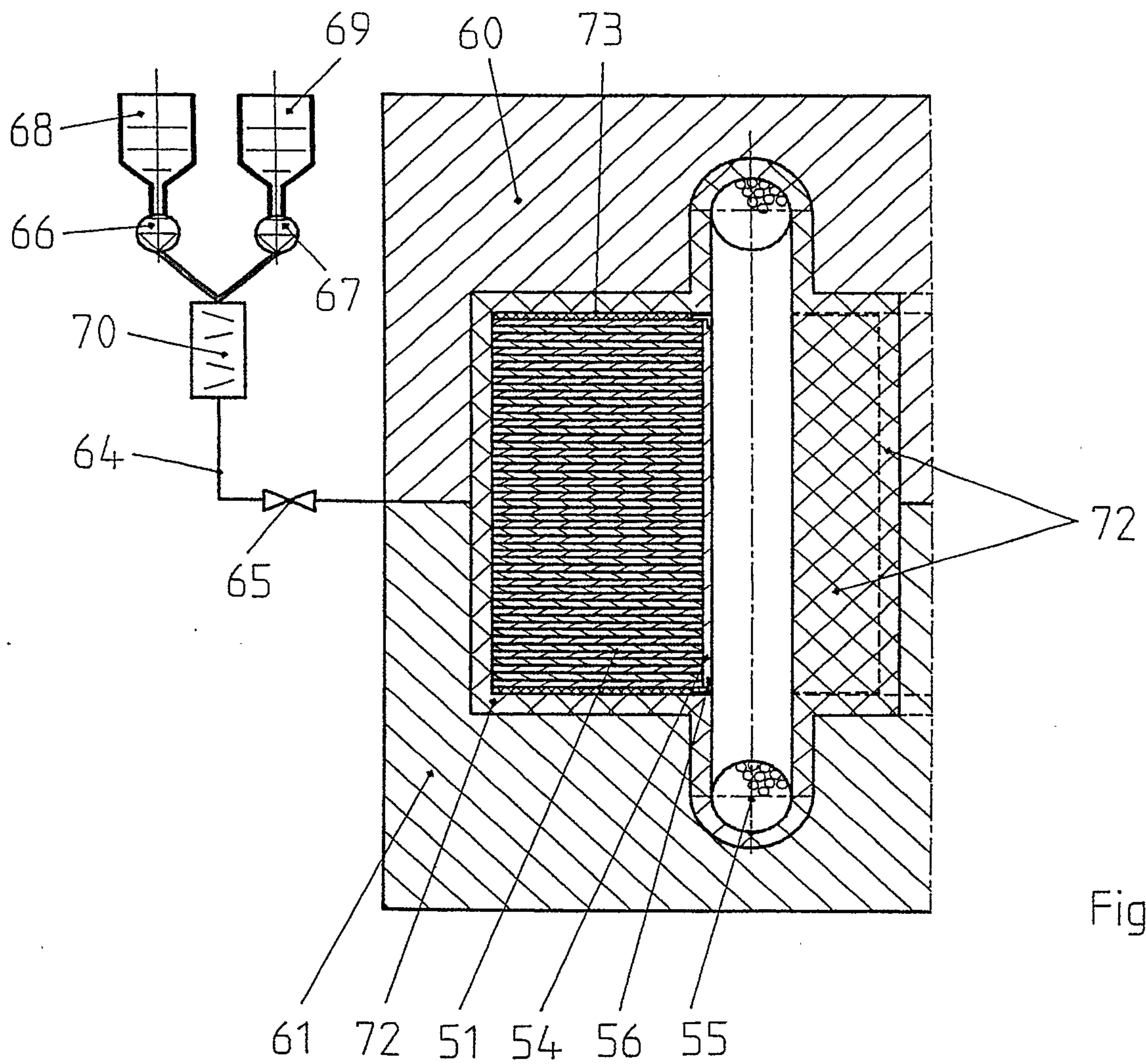


Fig. 12



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