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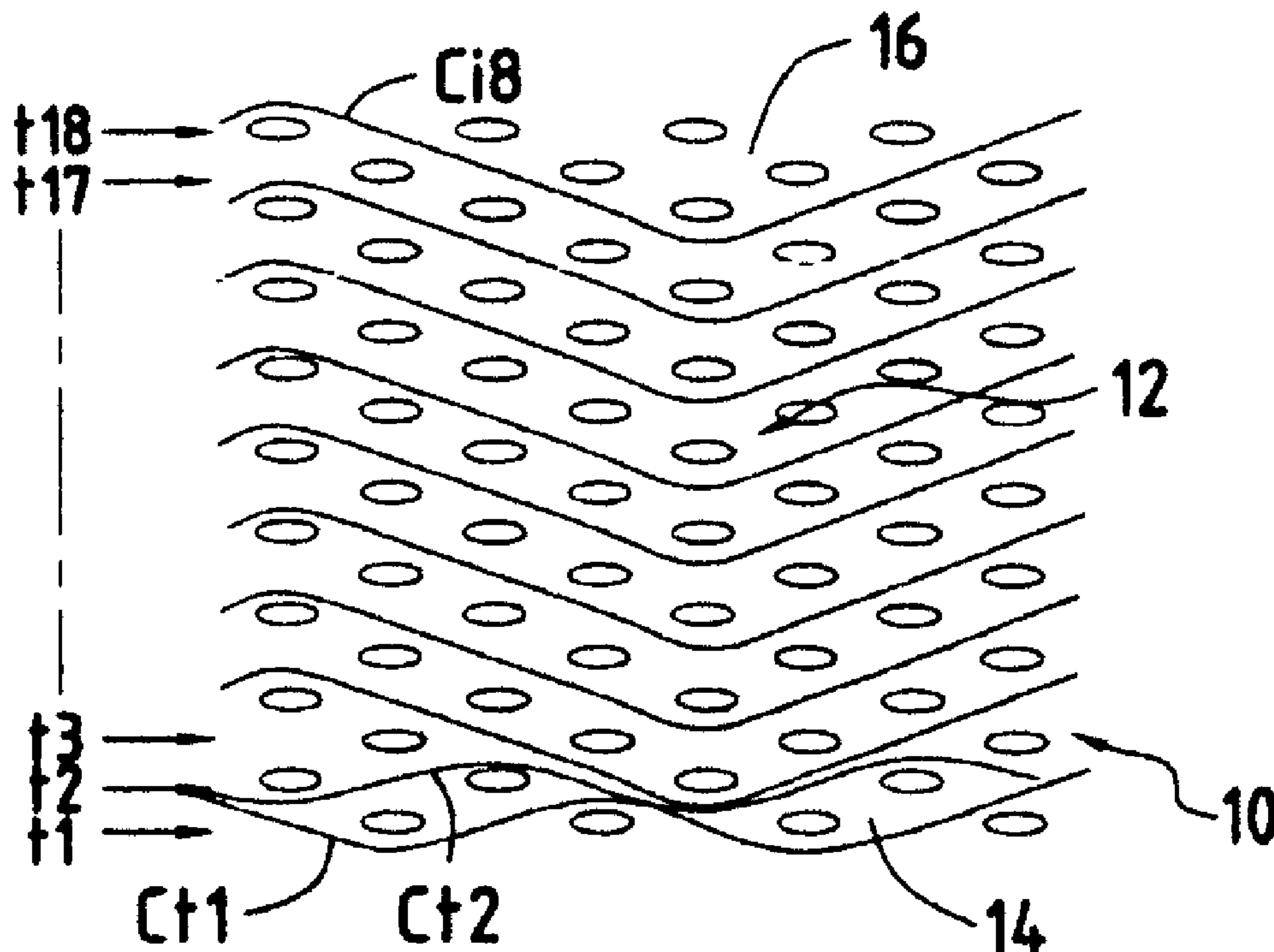
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(54) Titre : TEXTURE DE FIBRES DE RENFORCEMENT PERMETTANT DE REALISER UNE PARTIE EN MATERIAU COMPOSITE

(54) Title: A FIBER REINFORCING TEXTURE FOR MAKING A COMPOSITE MATERIAL PART



(57) Abrégé/Abstract:

A fibrous reinforcement structure (10), woven as a single piece for the manufacture of a composite part, has an internal portion (12), or core, produced by three-dimensional weaving with yarns comprising discontinuous fibres, and a portion (14, 16) adjacent to an outer surface, or skin, produced by weaving with yarns formed from continuous filaments.

## A B S T R A C T

5 A fiber reinforcing texture (10) woven as a single  
part for fabricating a composite material part having an  
inner portion (12), or core, made by three-dimensional  
weaving with yarns made up from discontinuous fibers, and  
a portion (14, 16) adjacent to an outside surface, or  
10 skin, made by weaving with yarns made up from continuous  
filaments.

**A FIBER REINFORCING TEXTURE  
FOR MAKING A COMPOSITE MATERIAL PART**

Background of the invention

5           The invention relates to making composite material parts and particularly to making fiber reinforcing textures for such parts.

          The field of application of the invention is more particularly making thermostructural composite material  
10 parts, i.e. parts made of a material having mechanical properties that make it suitable for constituting structural elements and having the ability to conserve these properties at high temperatures. Thermostructural composite materials are typically carbon/carbon (C/C)  
15 composite materials having carbon fiber reinforcement densified by a carbon matrix, and ceramic matrix composite (CMC) materials having refractory fiber reinforcement (carbon fiber or ceramic fiber) densified by a ceramic matrix. Thermostructural composite material  
20 parts are used in particular in the fields of aviation and space.

          For parts made of composite material that present a certain thickness, it is common practice to make the reinforcing texture out of a plurality of superposed  
25 layers that are bonded together so as to avoid the layers separating, in particular by performing three-dimensional weaving.

          Furthermore, in particular for a composite material part that is obtained by densifying the fiber reinforcing  
30 texture by chemical vapor infiltration (CVI), it can be useful to provide easy access for the gas to the core of the fiber texture or to ensure that the fiber texture presents porosity that is relatively uniform in order to achieve densification that departs as little as possible  
35 from being uniform. In the event of access being difficult to the pores in the fiber texture, or in the presence of pores of very different sizes, then the

smaller pores become filled in more quickly and a strong densification gradient is inevitable, thereby affecting the properties of the composite material.

Document EP 0 489 637 proposes making a fiber  
5 reinforcing texture for a thermostructural composite material part by using a yarn made up from discontinuous fibers with substantially no twist, yarn cohesion being provided by a covering yarn. The texture can be made by three-dimensional weaving. The covering yarn is made of  
10 a temporary or sacrificial material that is eliminated after weaving, thereby allowing the discontinuous filaments to bulk up, which enhances subdivision of the pores of the woven texture and, in combination with three-dimensional weaving, encourages access for the gas  
15 to the core of the fiber structure during subsequent densification by CVI.

Nevertheless, when fabricating composite material parts that are to present a surface state that is very smooth, it is necessary to trim the surface after an  
20 initial stage of partial densification, also known as a consolidation stage, in order to eliminate the irregularities created at the surface by the bulking up of the discontinuous filaments that are released once the covering yarn is eliminated. It can also be necessary to  
25 add a ply of two-dimensional cloth prior to continuing densification in order to obtain a desired surface state.

#### Object and summary of the invention

An object of the invention is to remedy the  
30 drawbacks represented by those additional operations, and more generally to propose a fiber texture for constituting reinforcement in a composite material part and satisfying constraints concerning easy infiltration by a gas during CVI densification and constraints  
35 concerning the appearance and/or the particular properties desired for the resulting part.

This object is achieved with a fiber texture for reinforcing a composite material part, the fiber texture being woven as a single part and having an inner portion, or core, and a portion adjacent to an outside surface, or skin, wherein texture the core is made by three-dimensional weaving with yarns that are made up, at least in the majority, from discontinuous fibers, and the skin is made by weaving with yarns made up from continuous filaments.

Densification of the fiber texture by CVI is thus encouraged all the way to the core, while avoiding a steep densification gradient between the core and the skin, while at the skin a surface state is preserved that is free from significant irregularities.

In an embodiment, the core is made by interlock weaving, thereby providing easier access for the gas to the core of the preform, while the skin is made by weaving with a plain, satin, or twill type weave, thus serving to limit surface irregularities. The weaving of the skin may comprise 2D weaving, with the interlock weaving providing the interlacing between the weft layers all the way to the skin, or the weaving of the skin may comprise multi-layer 3D weaving.

In another embodiment, the core and the skin may be made by multi-layer 3D weaving using different weaves, for example a satin type weave in the core portion and a plain or twill type weave in the skin portion. A plain type weave in the skin gives easier access to gas through the skin compared with a satin type weave and thus encourages CVI densification all the way to the core.

In yet another embodiment, the skin is made with a structure having a lower count than the structure with which the core is made, thereby providing easier access for the gas through the skin towards the core of the preform.

It is possible to vary simultaneously the 3D weaving technique and the structure between the core and the skin.

It is also possible to form the various portions of the fiber texture with yarns of different chemical natures so as to give them particular desired properties, in particular resistance to wear or to oxidation.

The weaving of the core portion may be performed with yarns that are made up from discontinuous fibers with substantially no twisting and at least one sacrificial covering yarn that provides the yarn with cohesion.

The invention also provides a composite material part having a fiber reinforcing texture as defined above that is densified by a matrix.

In accordance with an aspect of the present invention, there is provided a fiber texture for reinforcing a composite material part, the fiber texture being woven as a single part and having an inner portion, or core, and a portion adjacent to an outside surface, or skin, wherein the core of the texture is made by three-dimensional weaving with yarns that are made up, at least in the majority, from discontinuous fibers, and the skin is made by weaving with yarns made up from continuous filaments.

In accordance with another aspect of the present invention, there is provided a fiber texture for reinforcing a composite material part, the fiber texture being woven as a single part and having an inner portion, or core, and a portion adjacent to an outside surface, or skin, wherein the core of the texture is made by three-dimensional weaving with yarns that are made up, at least in a greater percentage, from discontinuous fibers than from continuous filaments, and the skin is made by weaving with yarns made up from continuous filaments.

In accordance with another aspect of the present invention, there is provided a composite material part

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comprising a fiber reinforcing texture as described above, densified by a matrix obtained at least in part by chemical vapor infiltration.

5 Brief description of the drawings

The invention can be better understood on reading the following description made with reference to the accompanying drawings, wherein:

- 10       • Figures 1 to 3 show interlock and multi-layer three-dimensional weaves;
- Figures 4A to 4H show different successive weave planes of a fiber reinforcing texture in a first embodiment of the invention;
- 15       • Figures 5A to 5H show different successive weave planes of a fiber reinforcing texture in a second embodiment of the invention;
- Figures 6A to 6H show different successive weave planes of a fiber reinforcing texture in a third embodiment of the invention; and
- 20       • Figures 7A to 6L show different weave planes of a fiber reinforcing texture in a fourth embodiment of the invention.

Definitions

- 25       The term "continuous filament" is used herein in

conventional manner to designate fiber elements that are of very great length relative to their diameter. Thus, by way of example, in a reinforcing texture constituting a preform for a composite material part and made from  
5 continuous filaments, at least a very large majority of them extend continuously in the preform, being interrupted only at the geometrical boundaries of the preform. With continuous filaments that are not natural, they are conventionally obtained by spinning a synthetic  
10 material, possibly followed by one or more physico-chemical operations (stretching, oiling, heat treatment, ...).

Yarns made up from continuous filaments, or multifilament yarns, are formed by assembling together  
15 continuous filaments side by side, with or without twisting.

The term "discontinuous fibers" is used herein in conventional manner to designate fiber elements that, for fibers that are not natural, are formed by cutting or  
20 stretch-breaking continuous filaments. Discontinuous fibers or short fibers generally have a length of a few millimeters to a few tens of millimeters.

Yarn made up from discontinuous fibers, or "fiber yarn", is made by assembling discontinuous fibers  
25 together by twisting or by covering, where covering consists in providing cohesion by winding a covering yarn around an assembly of discontinuous fibers that need not be twisted or that may be twisted only slightly.

The term "two-dimensional weaving" or "2D weaving"  
30 is used herein to designate a conventional weaving technique in which each warp yarn passes from one side to the other of yarns in a single weft layer.

The term "three-dimensional weaving" or "3D weaving" is used herein to designate a weaving technique in which  
35 at least some of the warp yarns interlace weft yarns in a plurality of weft layers, thereby bonding them together.

The term "interlock weaving" is used herein to designate a 3D weave in which each warp layer interlaces a plurality of weft layers with all of the yarns of a given warp column having the same movement in the weave plane. Figure 1 is a view of one of eight planes of an interlock weave having seven warp layers and eight weft layers. In the interlock weave shown, a weft layer  $T$  is made up of two adjacent weft half-layers  $\underline{t}$  that are offset from each other in the warp direction. There are thus 16 weft half-layers in a staggered configuration. Each warp interlaces three weft half-layers. Below, the term "layer" is used either to designate a complete layer of weft yarns or a half-layer of weft yarns, unless specified to the contrary.

It is also possible to adopt a weft configuration that is not staggered, with the weft yarns of two adjacent weft layers being aligned on the same columns.

The term "multilayer weaving" is used herein to designate 3D weaving with a plurality of weft layers in which the basic weave of each layer is equivalent to a conventional 2D weave, such as a weave of the plain, satin, or twill type, but with certain points of the weave interlacing the weft layers to one another. Figure 2 shows a plane of multilayer cloth of the plain type, or "multiple-plain cloth" in which the warp yarns are deflected from time to time from their conventional 2D weave path associated with one weft yarn to take hold of a yarn of an adjacent weft yarn and form particular interlacing points  $PT$  interlacing two adjacent weft layers. At a particular interlacing point  $PT$ , the warp yarn passes around two weft yarns situated in the same column in two adjacent weft layers.

Figure 3 shows a plane of a multilayer cloth of the satin type, or "multiple-satin cloth", wherein each warp yarn is deflected in alternation in one direction and in the other in order to take in alternation, one weft yarn in  $\underline{n}$  in a first layer of weft yarns, and one weft yarn in

$n$  of a second layer of weft yarns adjacent to the first,  $n$  being an integer greater than 2, thereby bonding together the two layers by two satin interlacing points PS. In the example,  $n=16$ .

5        In a satin type weave, "pitch" designates the gap between two satin interlacing points of a given warp yarn measured as a number of weft columns. In the example of Figure 3, this pitch alternates between 6 and 10, giving a mean multiple satin pitch of 8,  $n/2$ .

10       In the weaves of Figures 2 and 3, the weft yarns are not in a staggered configuration, the weft yarns of two adjacent weft yarn layers being aligned on the same columns. Nevertheless, it is possible to have a staggered weft arrangement as shown in Figure 1, the  
15       interlace points being made between two adjacent weft half-layers.

      It should be observed that an interlace using a single warp yarn in a multiple plain or multiple satin weave is not restricted to the two adjacent weft layers,  
20       but may extend over a depth of more than two weft layers.

      The term "structure" is used herein to designate the number of yarns per unit length both in the weft direction and in the warp direction, so that a structure of low count (an open structure) has a smaller number of  
25       yarns per unit length, thereby producing a cloth that is more open, as compared with a structure of high count (a close structure).

      By convention and for convenience, throughout the specification below and in the drawings, only those warp  
30       yarns that are deflected from their paths take hold of weft yarns of one or more weft layers are mentioned and shown. Nevertheless, it is possible to invert roles between warp and weft, and such inversion should be considered as also being covered by the invention.

35

#### Detailed description of embodiments of the invention

      The field of application of the invention is that of

making thick fiber textures suitable for constituting fiber reinforcement, or preforms for use in fabricating composite material parts.

5 Making the fiber texture by 3D weaving makes it possible, in a single textile operation, to obtain interlinking between the layers, and thus to have a fiber texture and a resulting composite material part that present good mechanical behavior.

10 When the part is obtained by densifying the fiber texture at least in part by chemical vapor infiltration (CVI), and in order to obtain mechanical properties that are as uniform as possible within the part, it is advantageous to encourage densification with a densification gradient that is as small as possible  
15 between an inner portion or core of the fiber texture and an outer portion or skin thereof, i.e. a portion of the fiber texture that is adjacent to an outside surface.

For this purpose, and in order to encourage access of the reaction gas to the core of the preform during a  
20 CVI process, the core portion is woven with yarns that are made up, at least in the majority, from discontinuous fibers that enable porosity to be subdivided by the fibers bulking up. It is possible to use yarns made up from discontinuous fibers without twisting or with very  
25 little twisting, together with a sacrificial covering yarn that gives cohesion to the yarns, the discontinuous fibers forming the majority of the yarns even if the covering yarn is made of continuous filaments. It is also possible to use yarns made up from discontinuous  
30 fibers that are twisted together, known as discontinuous fiber yarns.

It is also advantageous to encourage obtaining a surface state, after densification, that is free from irregularities, i.e. a good state of finish so as to  
35 avoid or limit finishing operations by machining.

To this end, the skin is made by weaving yarns made up from continuous filaments so as to avoid any bulking

up of discontinuous fibers. This applies to the layer of weft yarns defining the outer portion of the skin and possibly also one or more layers of the adjacent layers of weft yarns. This also preferably applies to the warp  
5 yarns that come flush to the surface of the skin.

In an embodiment of the invention, the core is made by three-dimensional weaving of the interlock type, and the skin is made by weaving with a plain, satin, or twill type weave. The interlock weaving in the core encourages  
10 access for the gas during a CVI process, since it provides easy communication between a plurality of layers of cloth. The weaving of the skin may comprise two-dimensional weaving with a plain, satin, or twill weave, the interlock weaving of the core portion then extending  
15 part way into the skin, or it may comprise multilayer weaving using a plain, satin, or twill type weave.

In another embodiment, the core and the skin are made by multilayer weaving using different weaves. The core may be made by multilayer weaving with a satin type  
20 weave and the skin by multilayer weaving with a plain or twill type weave.

Still for the purpose of encouraging access for the reaction gas, the skin may be made with a structure presenting a count that is lower than the count of the  
25 structure of the core.

It can also be desirable to use yarns of different chemical kinds in the core and in the skin in order to impart particular properties to the resulting composite material part, in particular properties that differ in  
30 terms of resistance to oxidation or to wear.

Thus, for a part made of thermostructural composite material with refractory fiber reinforcement, it is possible to make a preform with carbon fibers in the core and with ceramic fibers, e.g. silica carbide (SiC)  
35 fibers, in a skin so as to increase the wear resistance of the composite part in that skin.

Examples of fiber structures in accordance with the invention are described below. In all of these examples, the weaving is performed on a Jacquard type loom.

5    Example 1

Figures 4A to 4H show portions of eight successive planes of a weave of a fiber structure obtained by 3D weaving, the weft yarns being shown in section.

10    The fiber structure 10 comprises nine layers of weft yarns, i.e. 18 half-layers t1 to t18. In the core 12 situated between the opposite skins 14 and 16, the 3D weaving is of the interlock type with yarns made up in the majority from discontinuous carbon fibers held by a covering yarn sacrificial material, as described in  
15    EP 0 489 637, and with a 10/10 structure per layer (10 yarns per centimeter in both the weft and the warp directions). The covering yarn is constituted, for example, by a soluble polymer such as a polyvinyl alcohol or a polymer that can be eliminated by heat treatment  
20    without affecting the carbon of the fibers, such as a polyethylene or a polyvinyl acetate. In the skins 14 and 16, the weaving is two-dimensional with a plain type weave using yarns made up from continuous carbon filaments and with a 5/5 structure per layer. The  
25    interlacing by weaving with a plain weave applies only to the half-layers t1 and t2 and the half-layers t17 and t18 of the weft yarns. It should be observed that the interlock 3D weaving in the core extends as far as the weft half-layers t1 and t18 of the skins so as to bond  
30    these half-layers with the layers of the core.

In this example, the yarns made of continuous filaments are the yarns of the weft half-layers t1, t2, t17, and t18 and the warp yarns of the plain weaves at the surface, i.e. the warp yarns Ct1, Ct2 and the warp  
35    yarns Ct17, Ct18 in Figures 4A and 4B. The warp yarns of the interlock weaving that take hold of the yarns of the half-layers t1 and t18 and that therefore come flush with

the surface of the skin could equally well be made of continuous filaments (warp yarns Ci1 and Ci3 in Figures 4B and 4A).

In this example, in addition to the type of yarn being varied between the core and the skin, the 3D weaving and the structure are also varied. The interlock 3D weaving and the use of yarns made up from discontinuous fibers in the core serve to minimize a CVI densification gradient between the skins and the core. A plain weave and the use of yarns made up from continuous filaments in the skin help to obtain a surface state that is relatively smooth, and a plain weave with a lower count structure in the skins encourages access for a reaction gas through the skins.

#### Example 2

Figures 5A to 5H show portions of successive planes of a fiber texture 20 obtained by 3D weaving, this texture differing from that of Example 1 in that multi-layer weaving is performed in the skins 24 and 26 with a weave analogous to a multiple plain weave over a thickness of two weft half-layers, the 3D weaving in the core portion 22 being of the interlock type with each warp yarn extending over a depth of three half-layers of weft yarns, the weft yarns being disposed in a staggered configuration.

When multi-layer weaving is performed in the skin, there is no need for the interlock weaving to cover all of the weft layers of the skin. It can suffice for a single weft layer or half-layer situated at the interface between the core and the skin to be involved both with the interlock weaving and with the multi-layer weaving in order to obtain interlacing by 3D weaving between all of the weft yarns. Nevertheless, in the example shown, the interlock weave involves all of the half-layers of weft yarns.

As in Example 2, the weaving in the core is performed with yarns made from discontinuous fibers held together by a sacrificial covering yarn, while the weaving in the skin is performed with yarns made up from continuous fibers. Thus, for example, in the embodiments shown in Figures 5A to 5H, the yarns made up from continuous filaments are the yarns in the weft yarn half-layers t1, t2, t17, and t18, together with the warp yarns of the multiple-plane weaving and of the interlock weaving that engages the yarns of the half-layers t1 and t18 (i.e. warp yarns Ct1, Ct8, Ci1, Ci8 in Figures 5B and 5C).

#### Example 3

Figures 6A to 6H show portions of successive weft planes in a texture 30 obtained by three-dimensional multi-layer weaving, this texture differing from that of Example 1 in that the same interlock 3D weaving is performed in the core 32 and in the skins 24 and 36.

In the core 32, the weaving is performed using yarns made up from discontinuous fibers united by a sacrificial covering yarn, whereas in the skins 24 and 36, i.e. over one or two extreme weft half-layers, the weaving is performed using yarns made up from continuous filaments. In the example shown, the yarns made up from continuous filaments are the yarns of the weft yarn half-layers t1, t1, t17, and t18, and the warp yarns that engage the yarns of the half-layers t1, t18 (warp yarns C1 and C7 in Figures 6B and 6A).

In this example only the type of yarn varies between the core and the skin.

#### Example 4

Figures 7A to 7L show successive layer planes of a texture 40 obtained by multi-layer 3D weaving, comprising 12 layers of weft yarns U1 to U12. The table below summarizes the weaves and the structures of the 3D

weaving used, with the variation in the weave of the texture 40 being symmetrical about a midplane between its skins 44, 46 that are situated on either side of the core 42. It should be observed that the weft yarns are not disposed in a staggered configuration, but that certain weft layers have numbers of weft yarns that differ from the numbers in other weft layers (weft structure variation).

| Weft yarn layers | Multi-layer weave | Structure |
|------------------|-------------------|-----------|
| U1               | Plain             | 6.6/6.6   |
| U2               | Multiple-plain    | 6.6/6.6   |
| U3               | Multiple 5-satin  | 8/8       |
| U4               | Multiple 5-satin  | 8/8       |
| U5               | Multiple 6-satin  | 10/10     |
| U6               | Multiple 6-satin  | 10/10     |
| U7               | Multiple 6-satin  | 10/10     |
| U8               | Multiple 6-satin  | 10/10     |
| U9               | Multiple 5-satin  | 8/8       |
| U10              | Multiple 5-satin  | 8/8       |
| U11              | Multiple plain    | 6.6/6.6   |
| U12              | Plain             | 6.6/6.6   |

10

As can be seen in the figures, the multiple-satin weaving is performed by taking in alternation a weft yarn from a first layer and a weft yarn from a second layer adjacent to the first.

15 In the core portion 42 (corresponding to weft layers U3 to U10), the yarns used for the warp and the weft are yarns made up from discontinuous carbon fibers held together by a sacrificial covering yarn. In the skin portions 44, 46 (weft layers U1, U2 and U11, U12, the  
20 yarns are made up from continuous carbon filaments, i.e. the weft yarns U1, U2, U11, and U12 and the warp yarns in the plane and multiple-plane weaving.

Thus, in this example, the type of yarn, the multi-layer 3D weave, and the structure all vary between the core 42 and the skins 44, 46. It should be observed that the variation in the weave and in the structure is

5 somewhat progressive by adopting a 5-satin for the weft layers U3, U4 and U9, U10, lying between the 6-satin of the layers U5 to U8 and the plain weave of the skins, so as to avoid having too sharp a discontinuity between the core and the skin.

10 A multiple-satin weave in the core gives rise to reduced warp shrinkage and better mechanical behavior parallel to the weft layers, particularly in the warp direction, in comparison with an interlock weave.

When densification is performed by CVI, a plain  
15 weave in the skin gives easier access to the gas through the skin, in comparison with a satin type weave.

Nevertheless, in a variant, it is possible to use a twill-type weave for weaving the skin.

Fiber textures as obtained by the method of the  
20 invention are suitable for making composite material parts that are obtained by densifying the fiber textures by CVI, in particular parts made of thermostructural composite material having fiber reinforcements constituted by carbon fibers and a matrix of carbon  
25 and/or of ceramic.

## CLAIMS

1. A fiber texture for reinforcing a composite material part, the fiber texture being woven as a single part and having an inner portion, or core, and a portion adjacent to an outside surface, or skin, wherein the core of the texture is made by three-dimensional weaving with yarns that are made up, at least in a greater percentage, from discontinuous fibers than from continuous filaments, and the skin is made by weaving with yarns made up from continuous filaments.
2. The texture according to claim 1, wherein the core is made by three-dimensional weaving of an interlock type and the skin is made by weaving with a plain, satin, or twill weave.
3. The texture according to claim 2, wherein the weaving of the skin comprises two-dimensional weaving with a plain, satin, or twill weave and the interlock weaving of the core extends to the skin to bond the skin to the core.
4. The texture according to claim 2, wherein the weaving of the skin comprises multi-layer three-dimensional weaving with a plain, satin, or twill weave.
5. The fiber texture according to claim 1, wherein the core and the skin are made by multi-layer weaving with different weaves.
6. The fiber texture according to claim 5, wherein the core is made by multi-layer weaving with a satin weave and the skin is made by three-dimensional weaving with a plain or twill weave.

7. The texture according to any one of claims 1 to 6, wherein the skin is made with a lower-count structure than that with which the core is made.

5 8. The texture according to any one of claims 1 to 7, wherein the core and the skin of the fiber texture are made with yarns of different chemical natures.

10 9. The texture according to any one of claims 1 to 8, wherein the weaving of the core is performed with yarns each made up from substantially twist-free discontinuous fibers together with at least one sacrificial covering yarn providing cohesion for the yarns.

15 10. A composite material part comprising a fiber reinforcing texture according to any one of claims 1 to 9, densified by a matrix obtained at least in part by chemical vapor infiltration.

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FIG.1

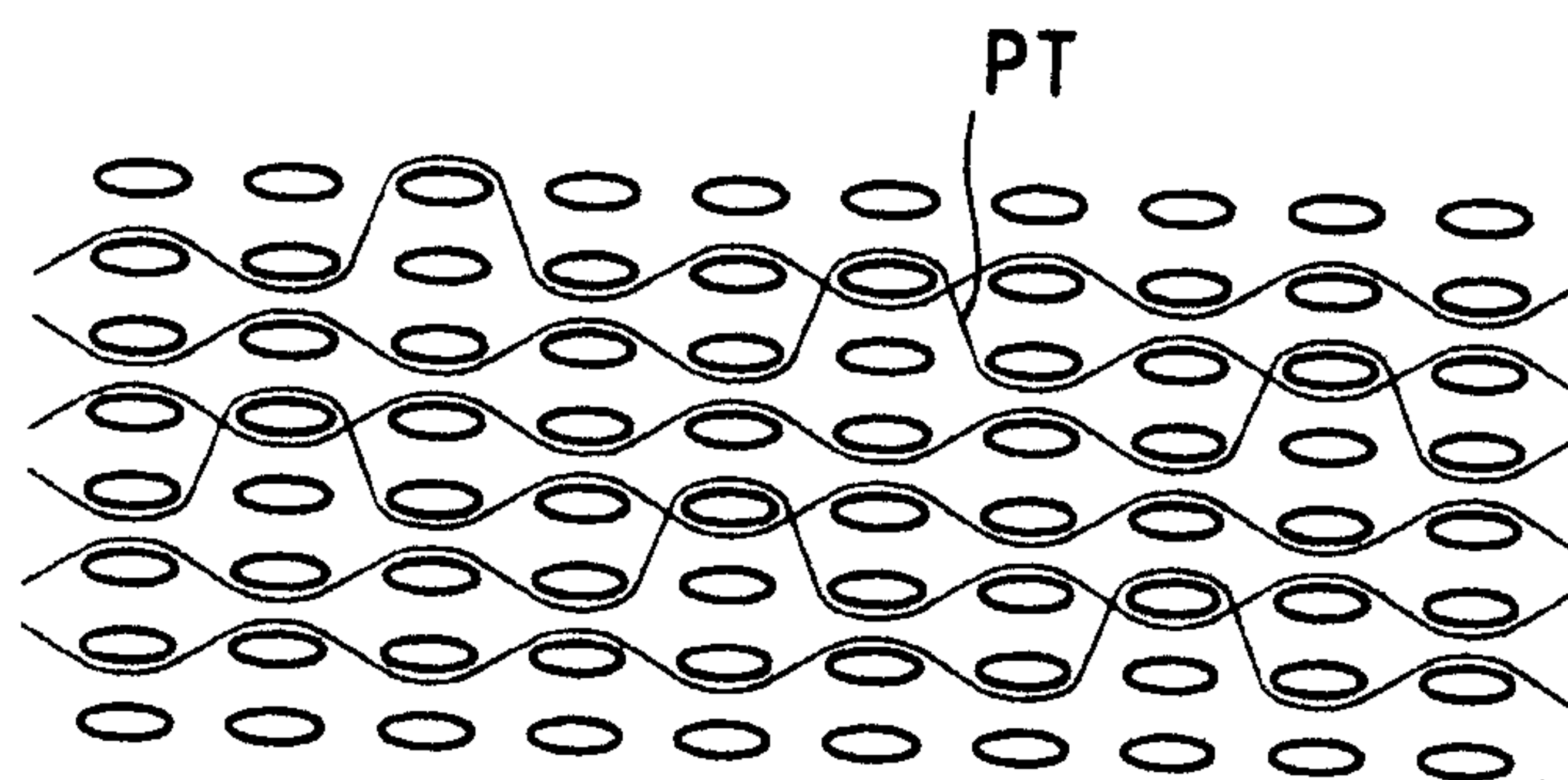
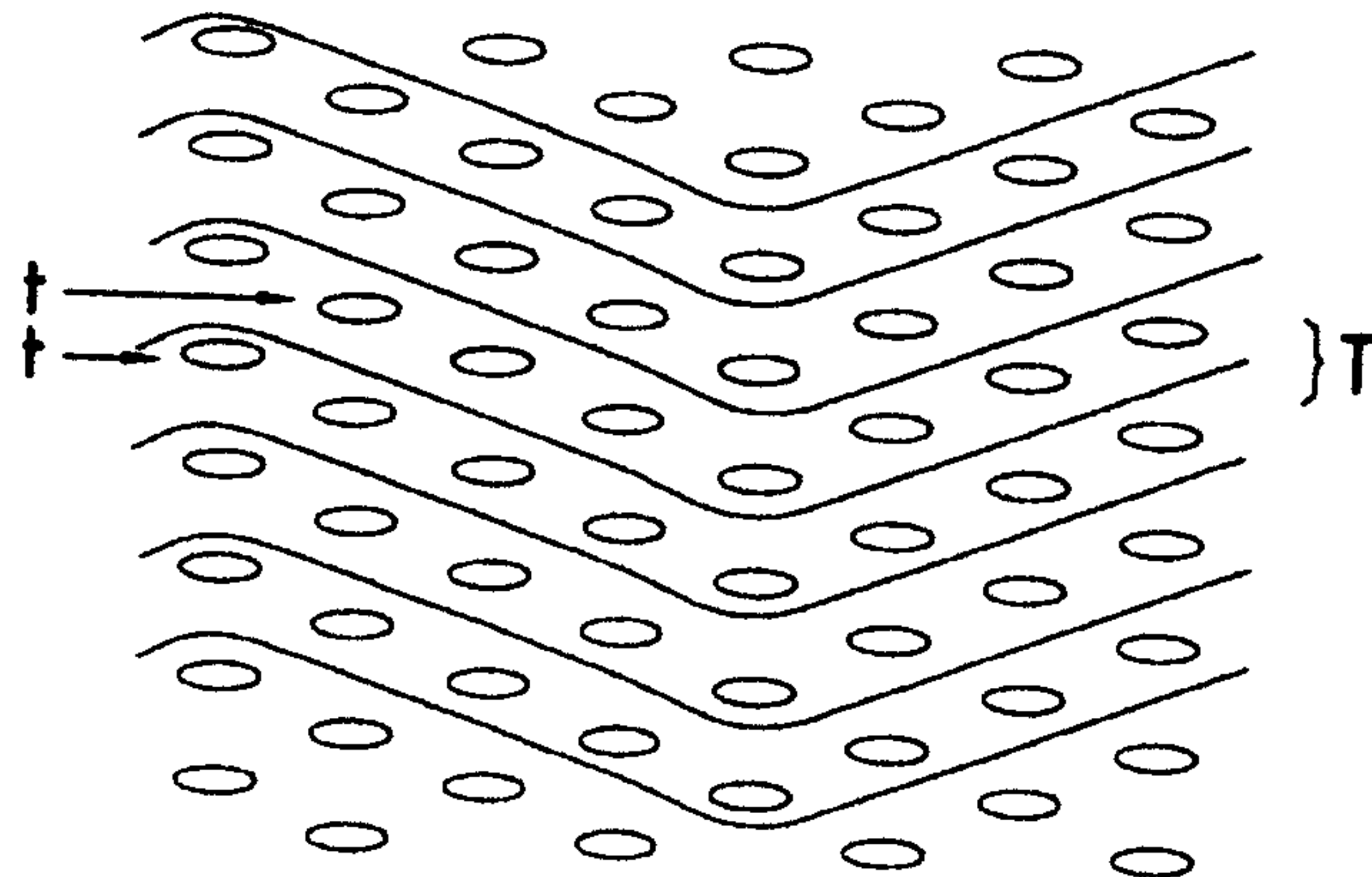


FIG.2

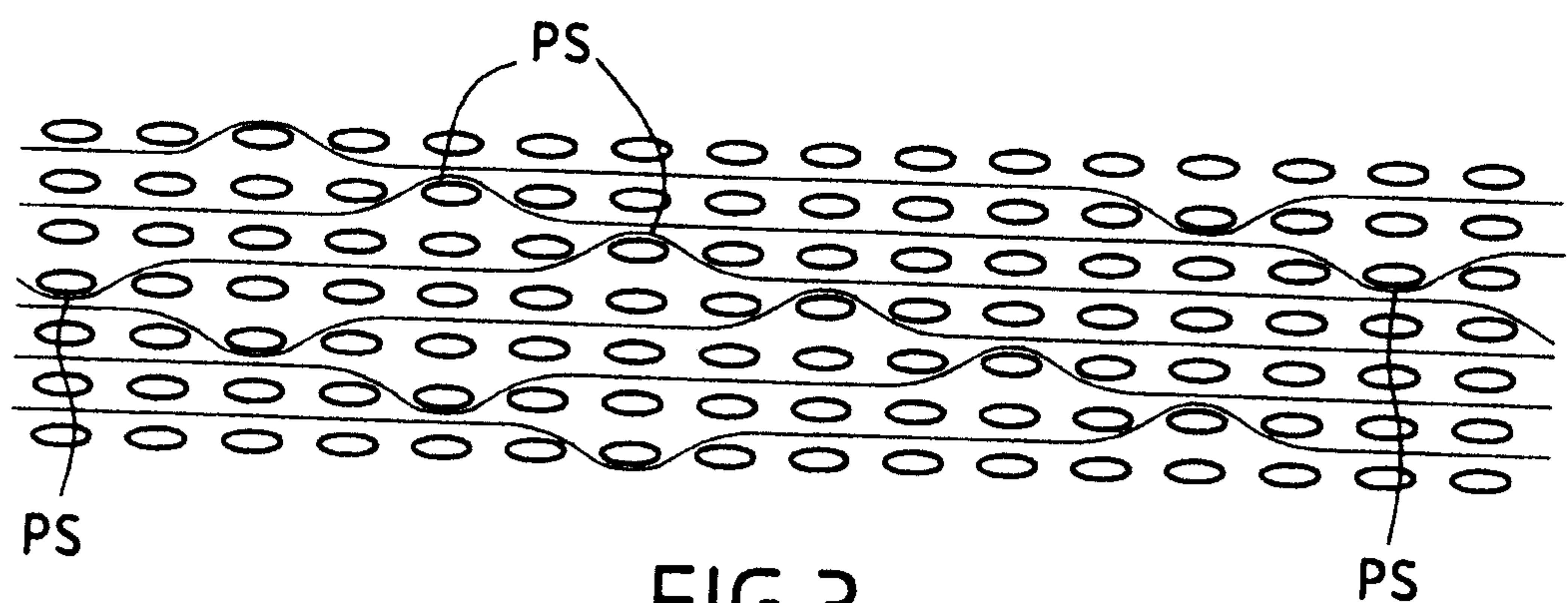


FIG.3

2/8

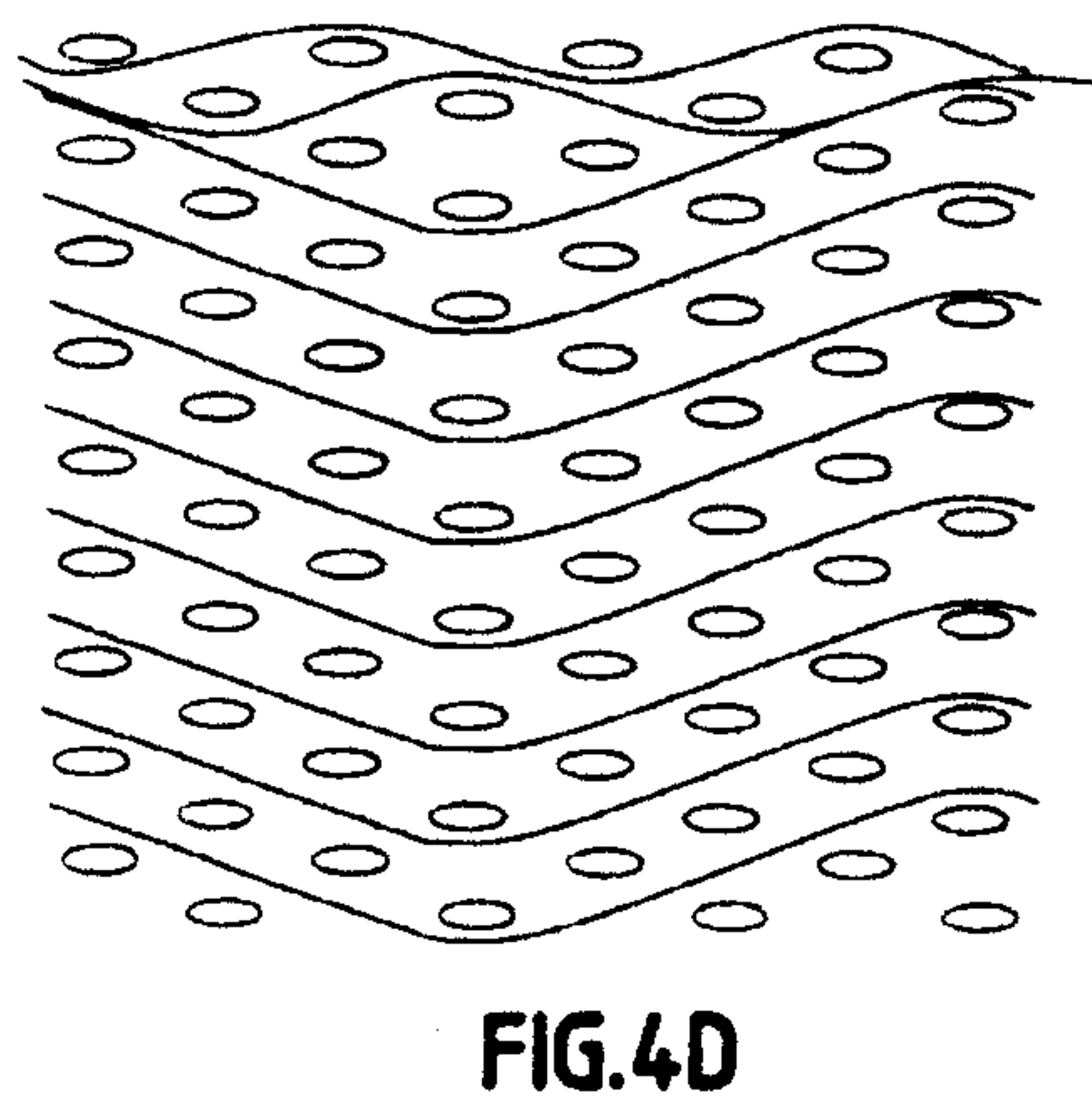
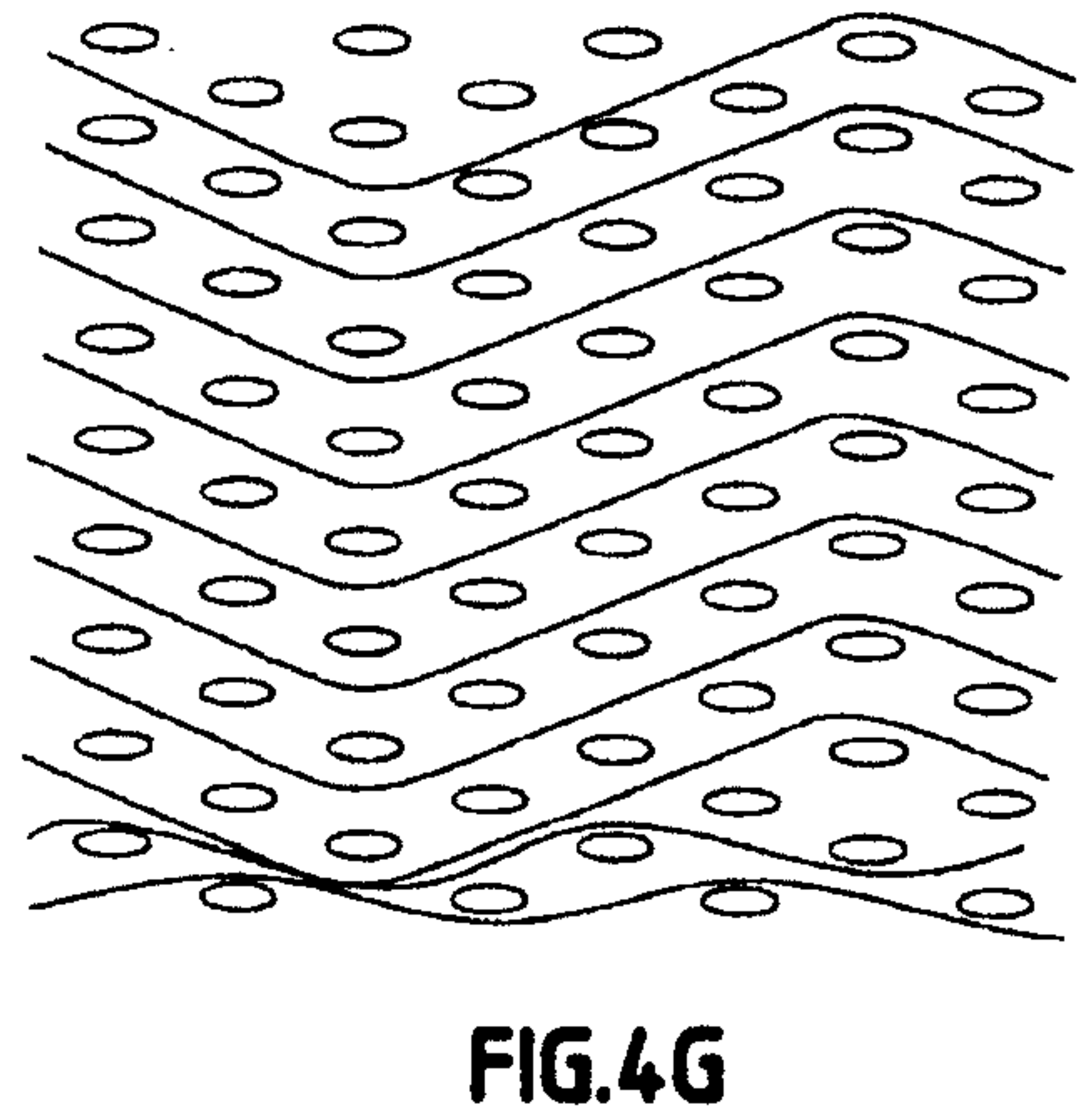
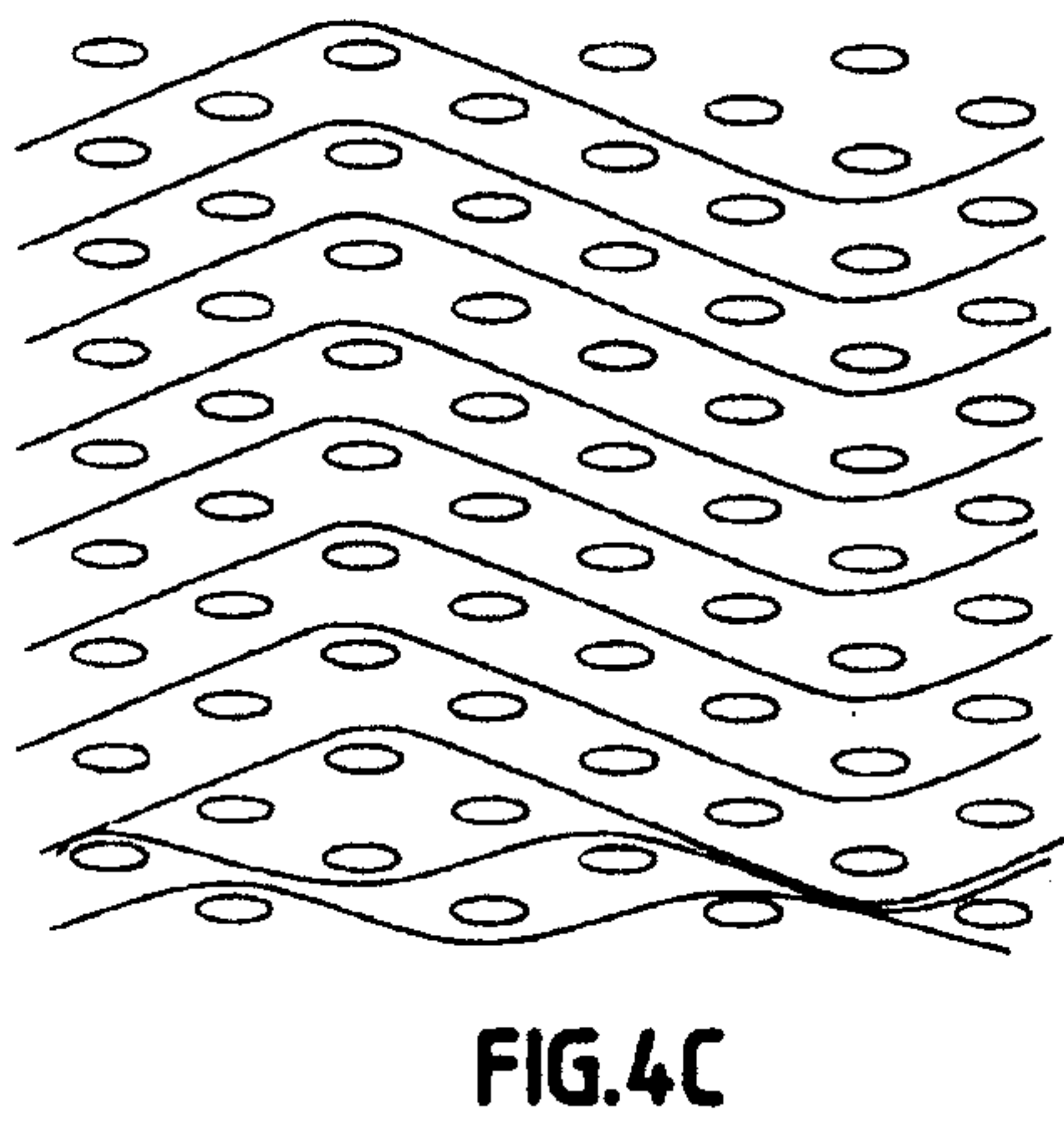
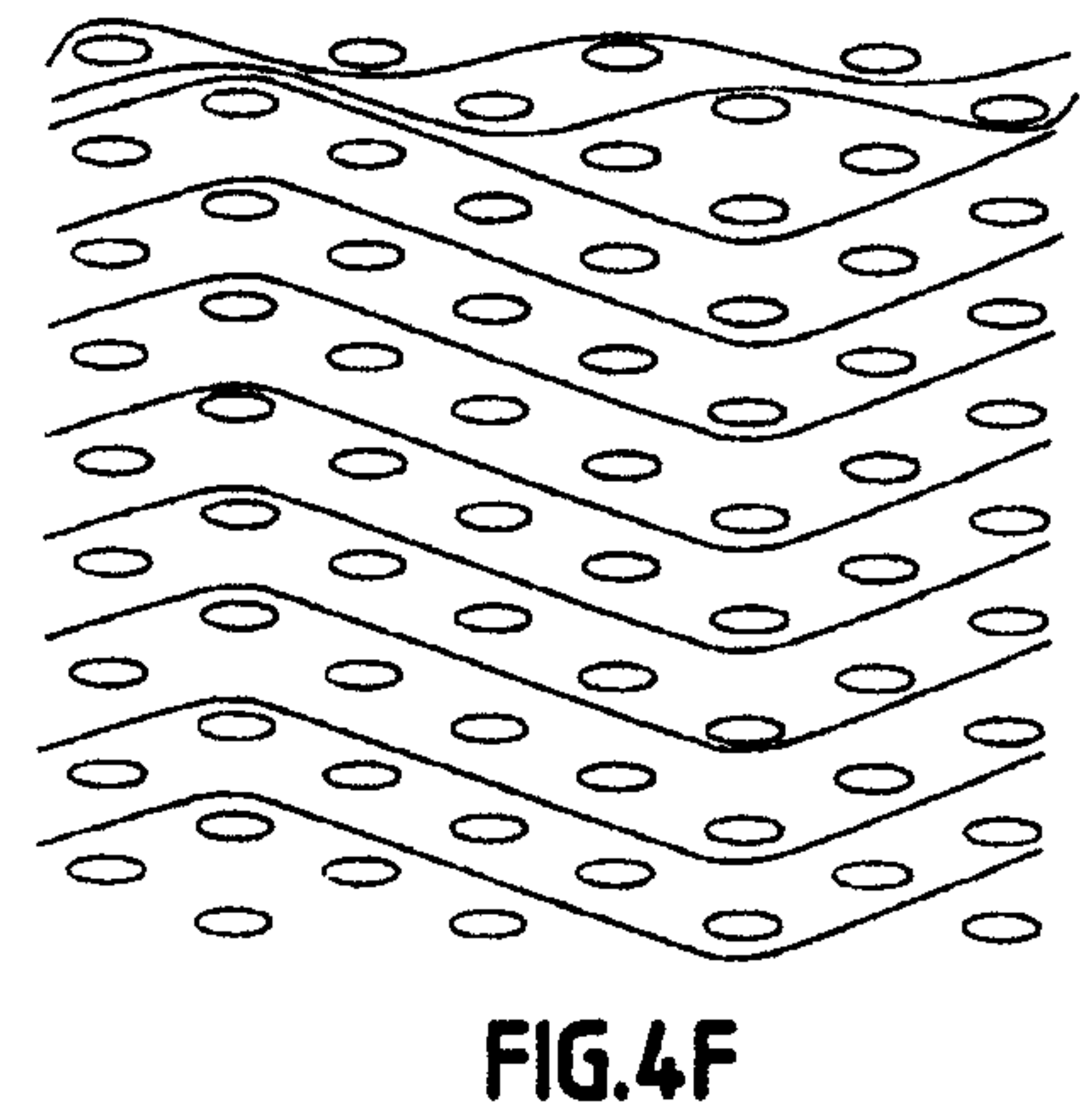
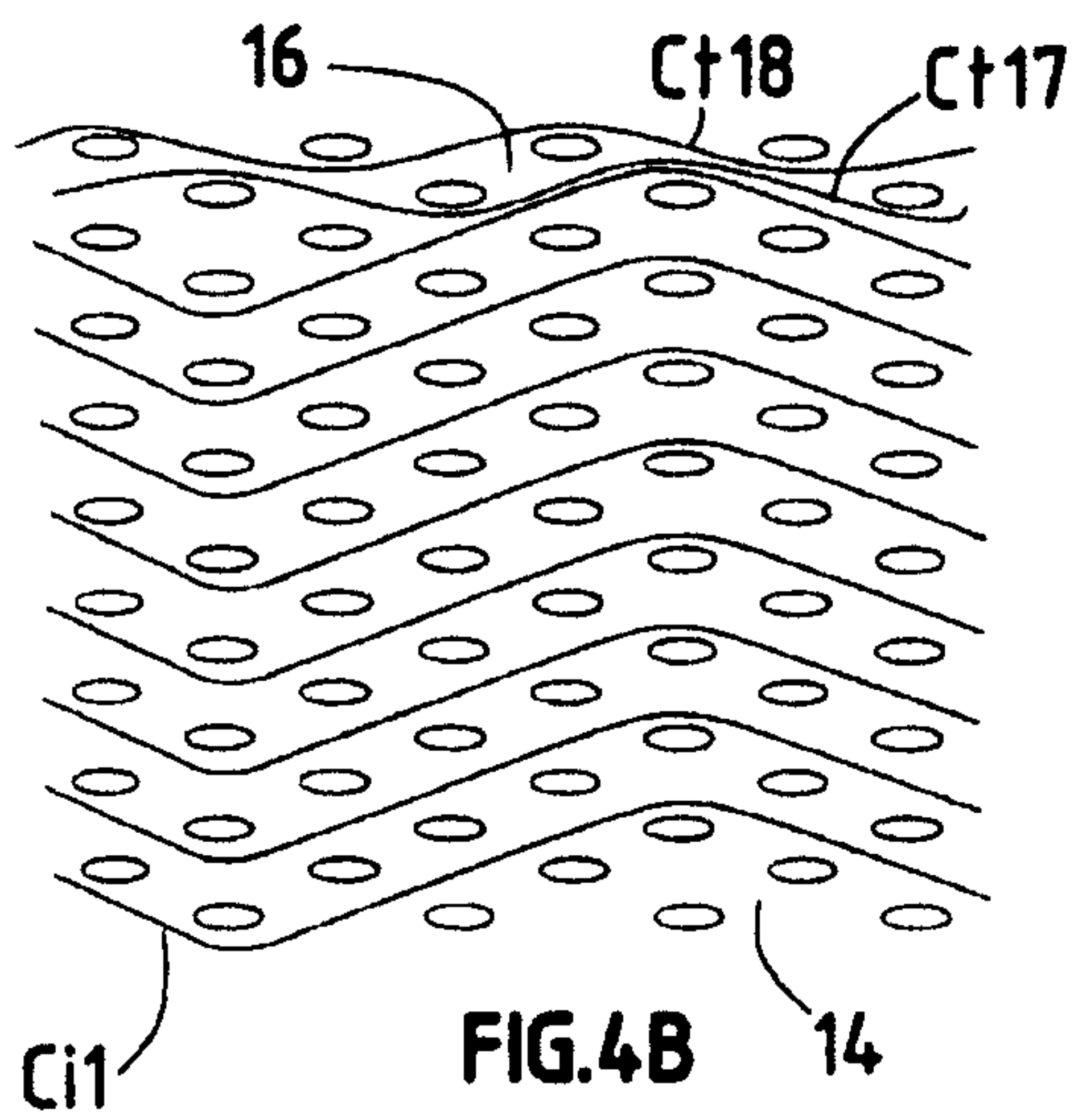
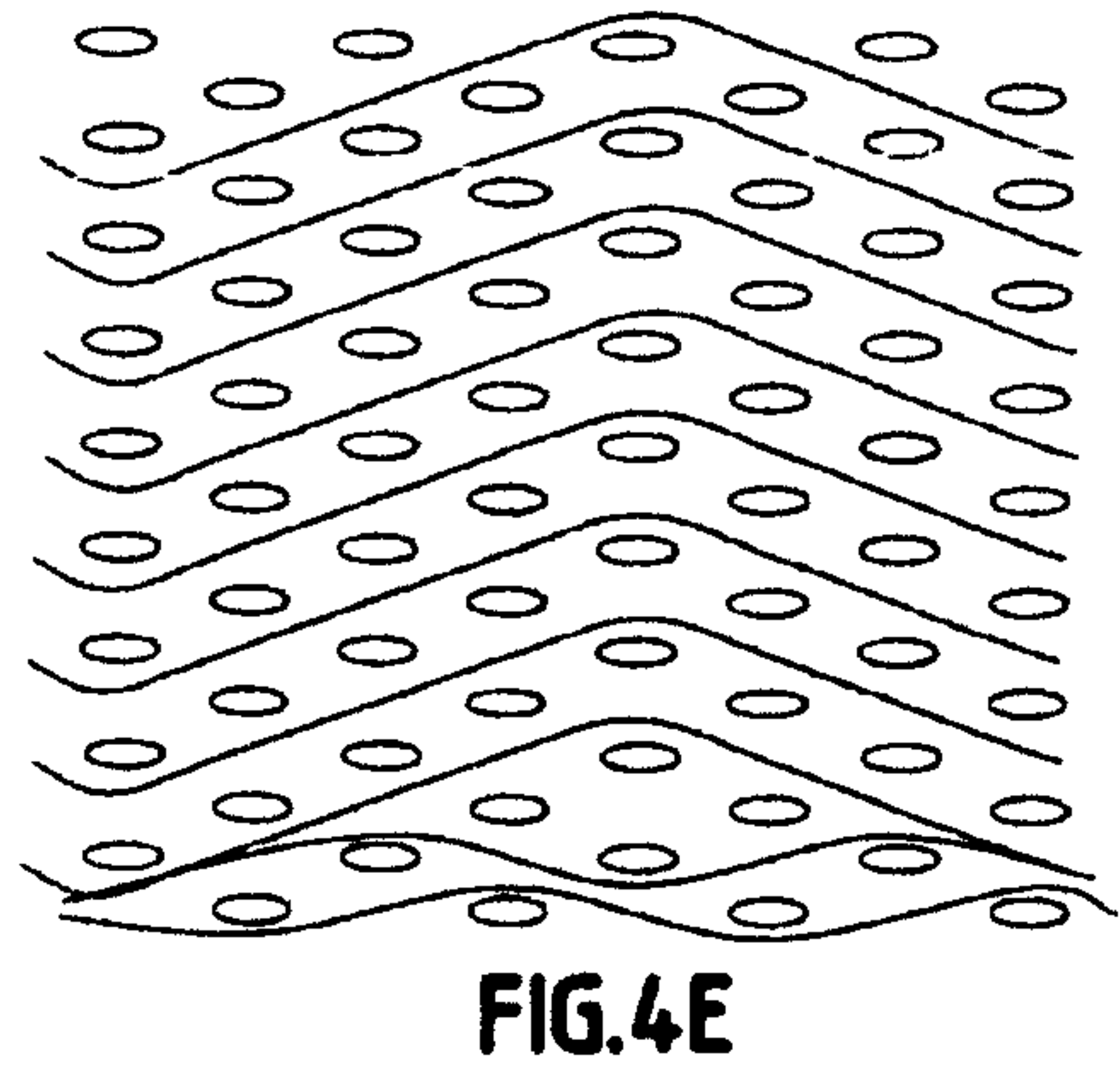
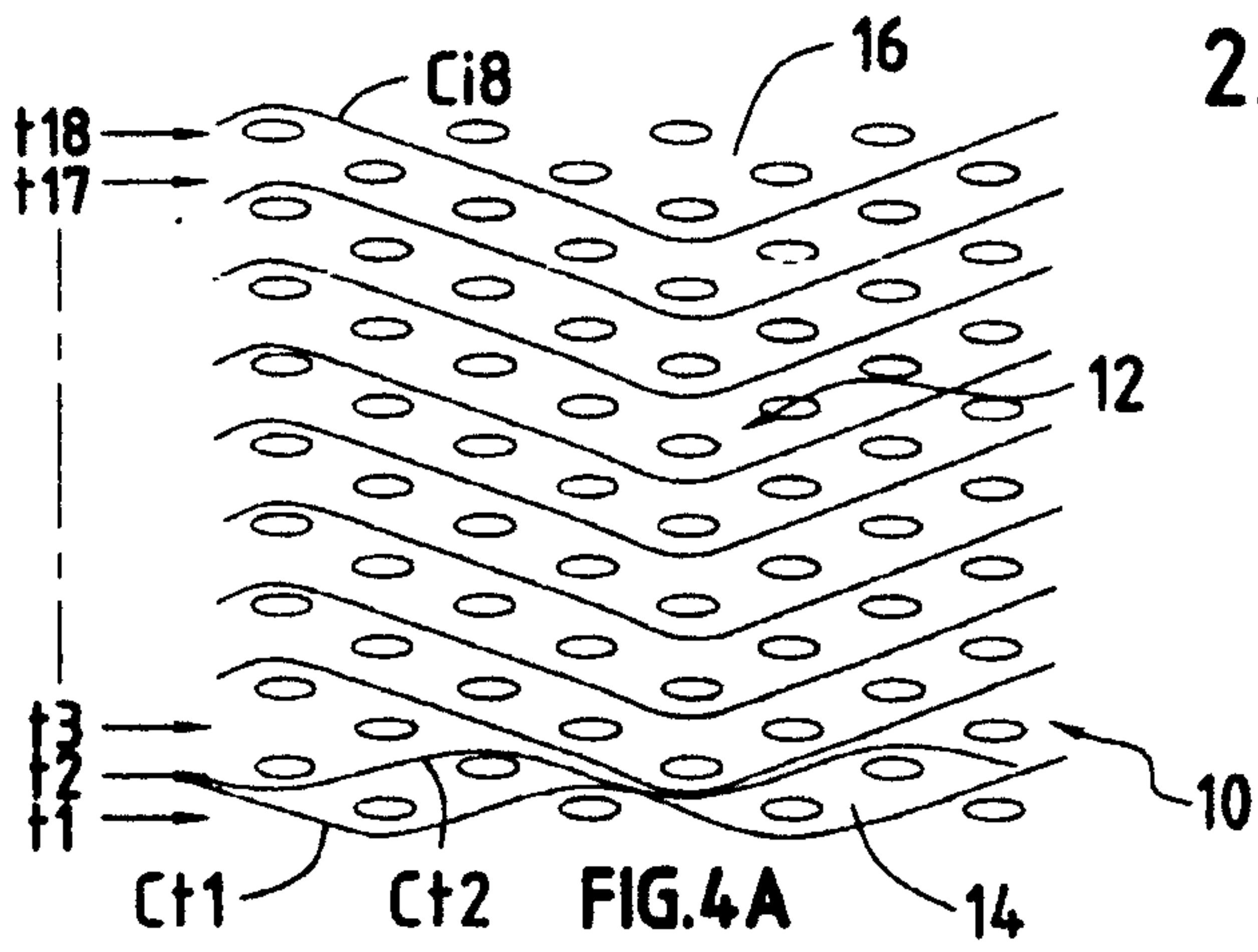
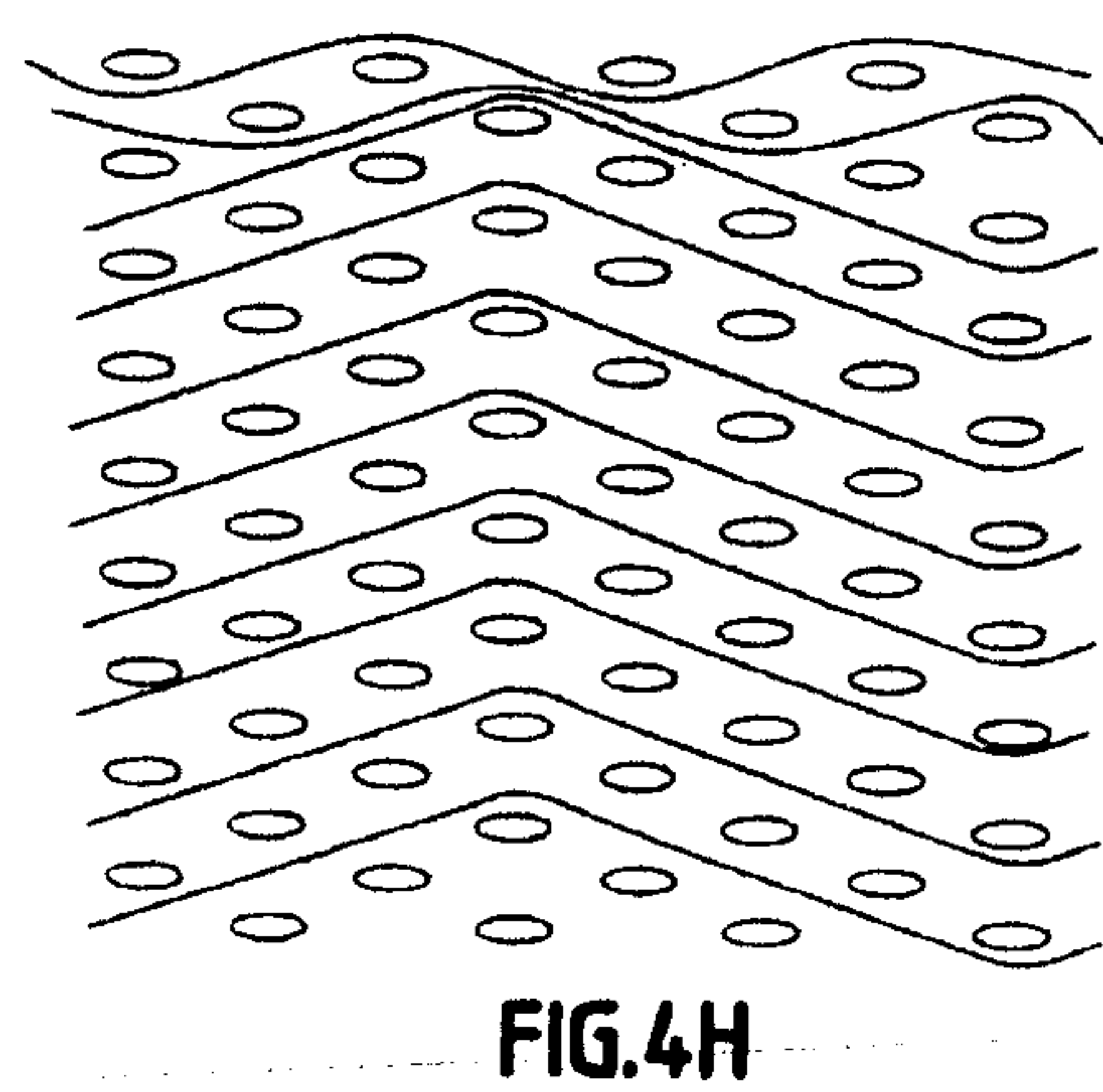


FIG. 4



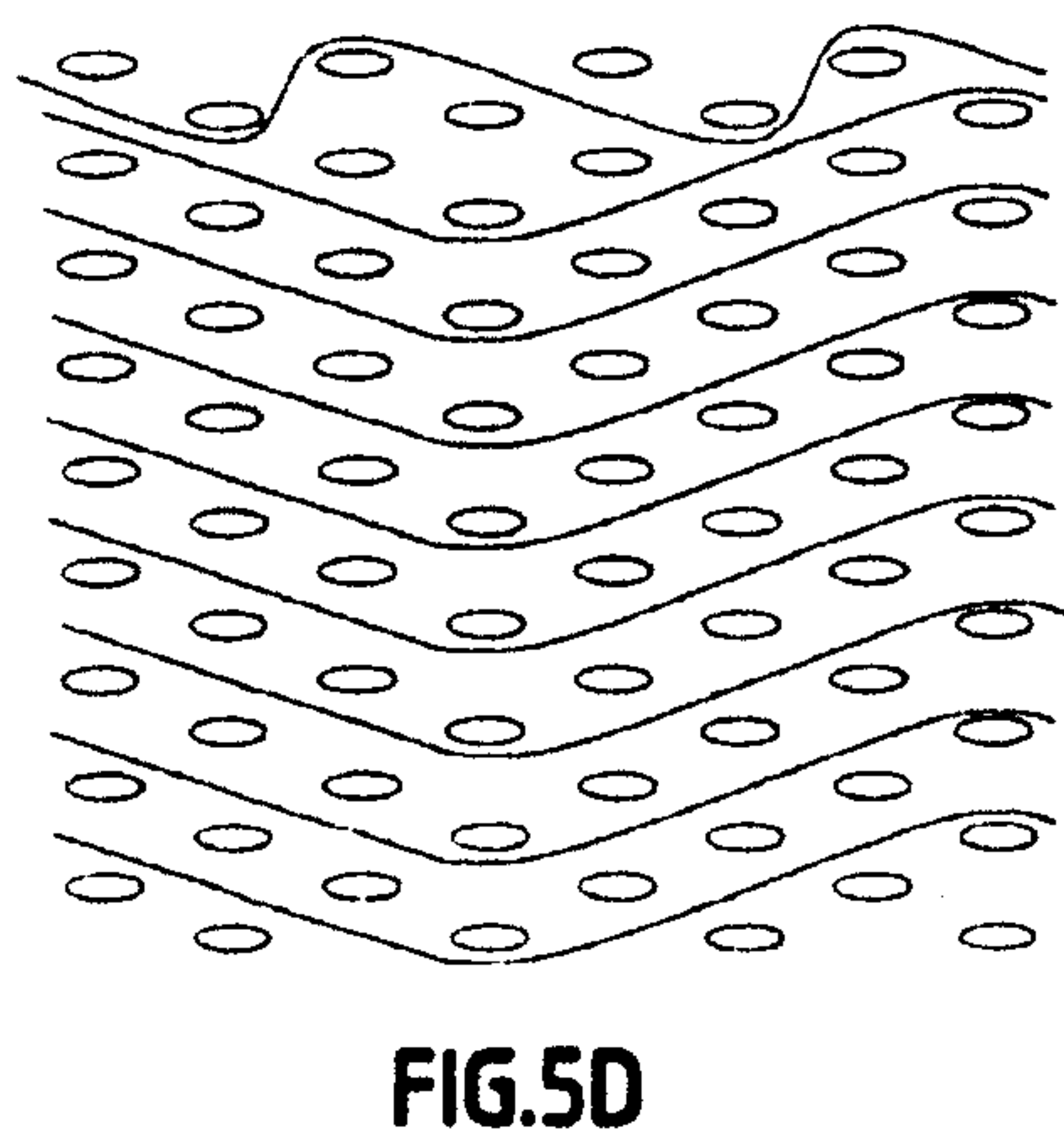
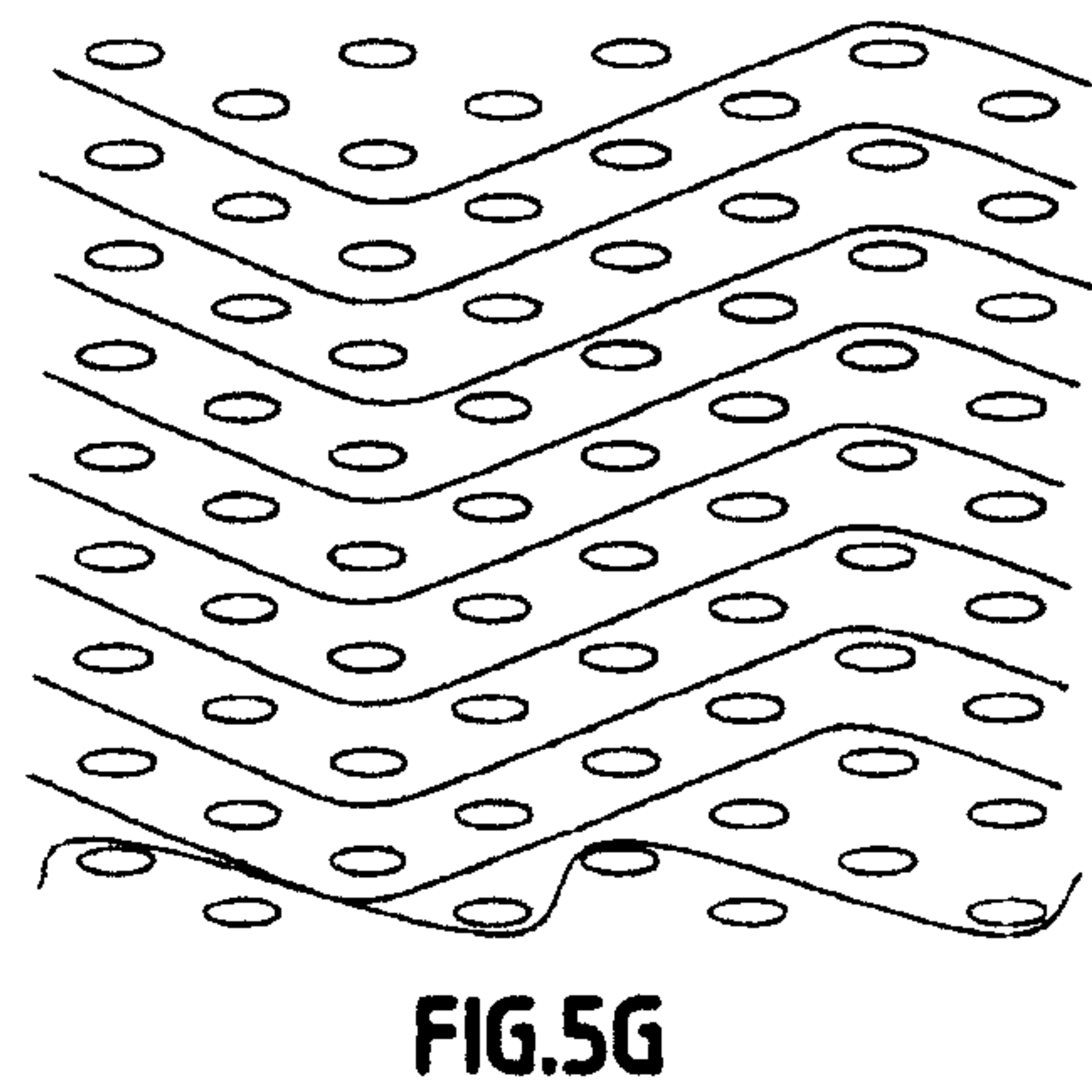
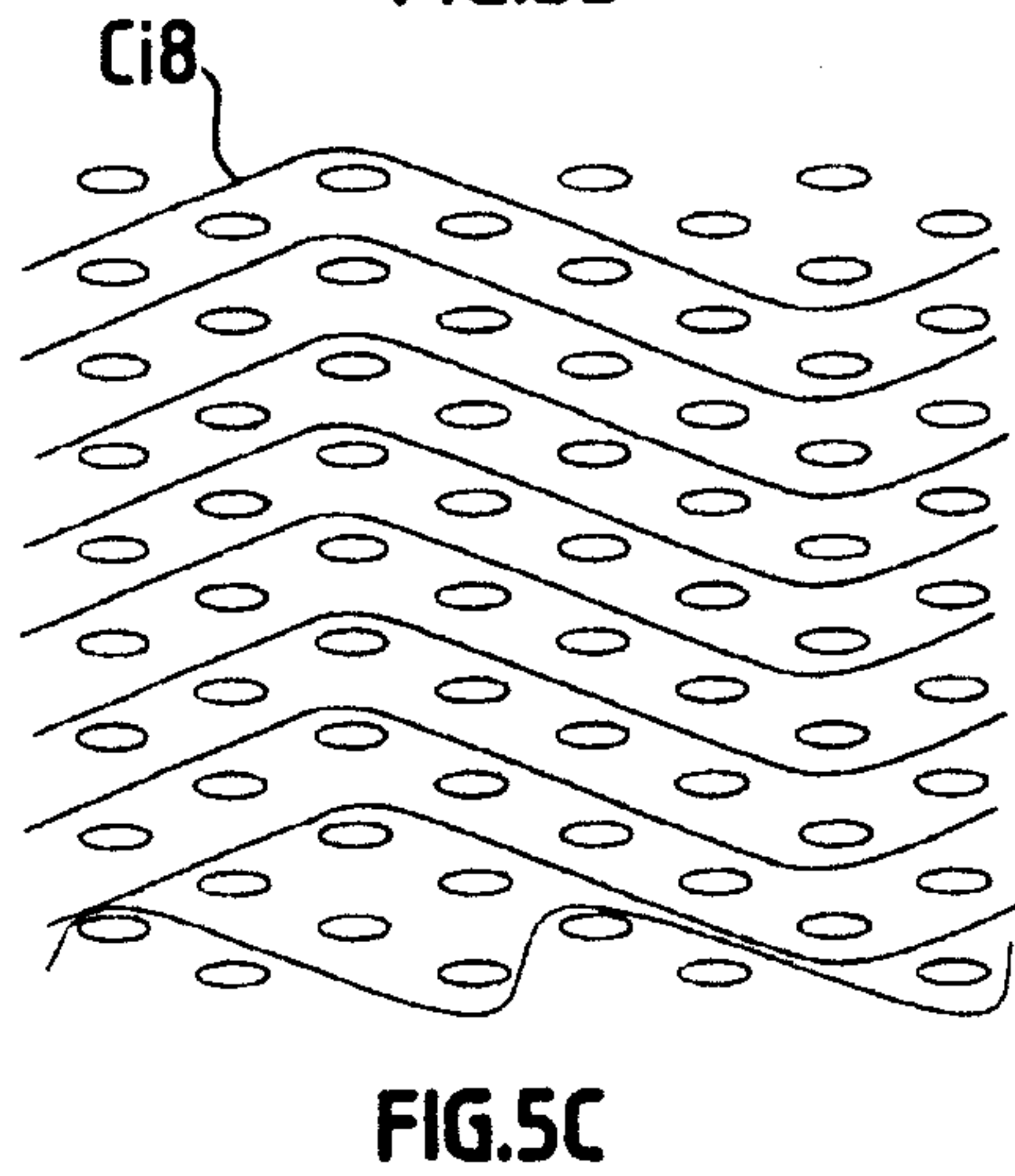
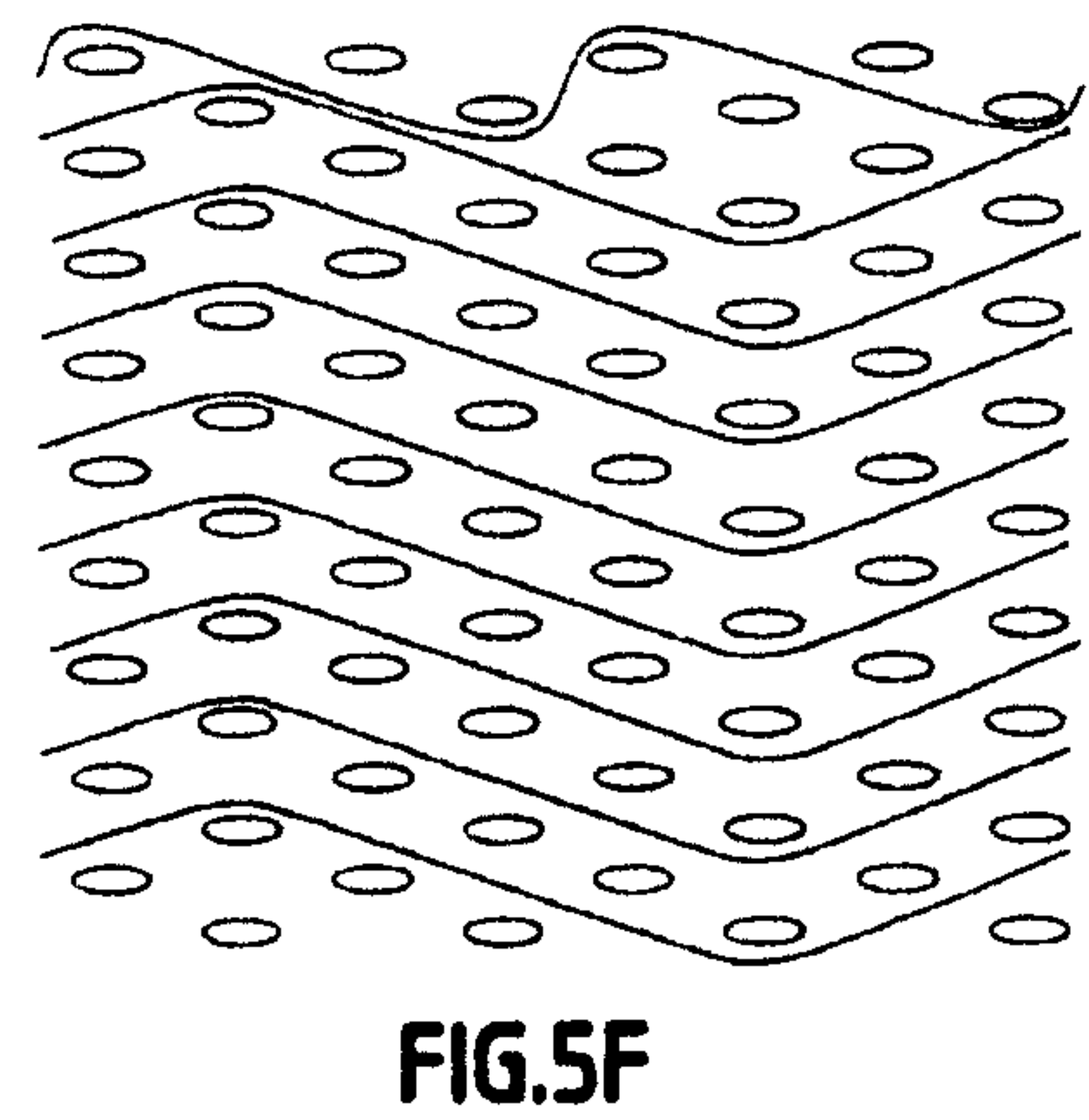
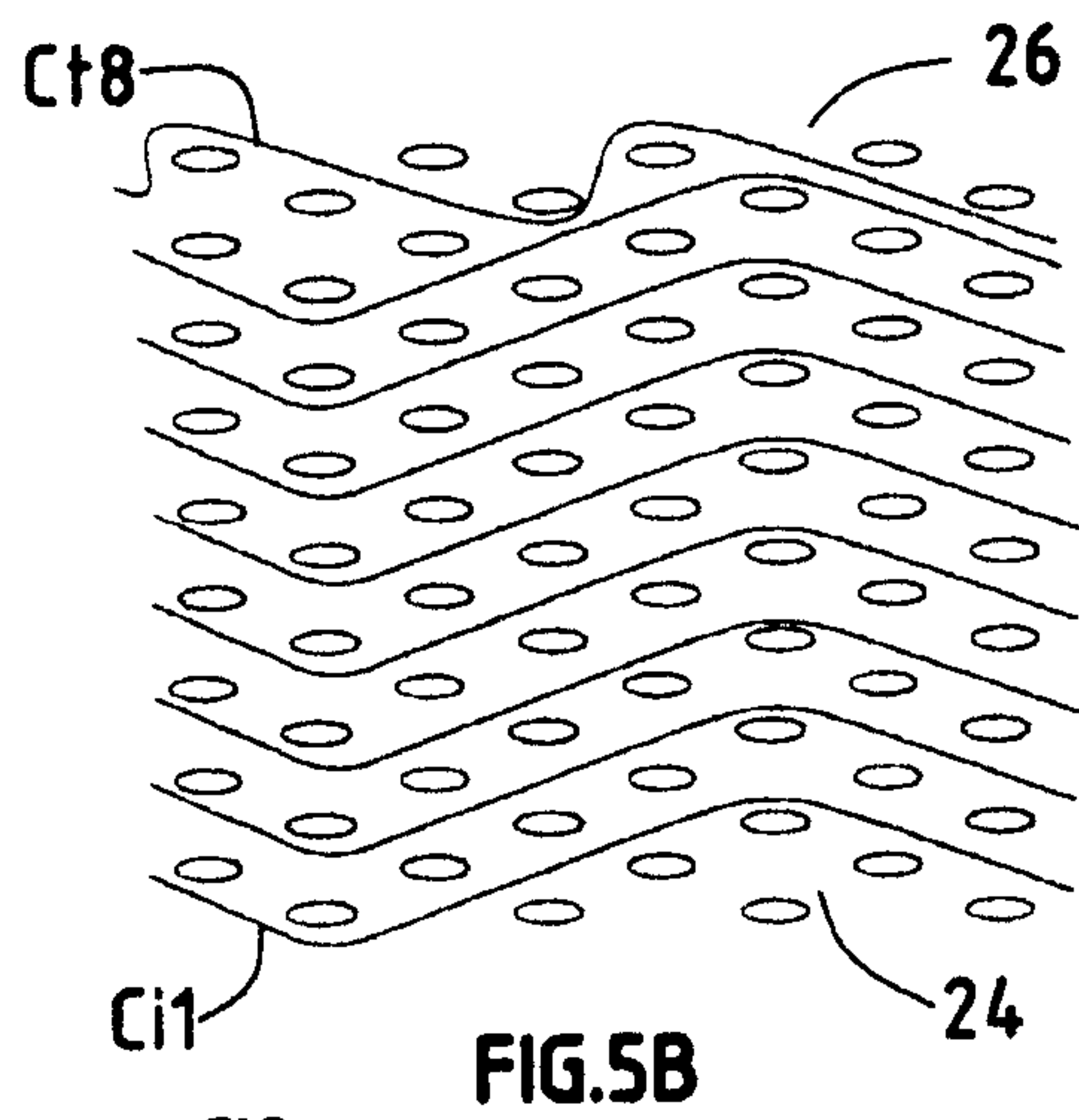
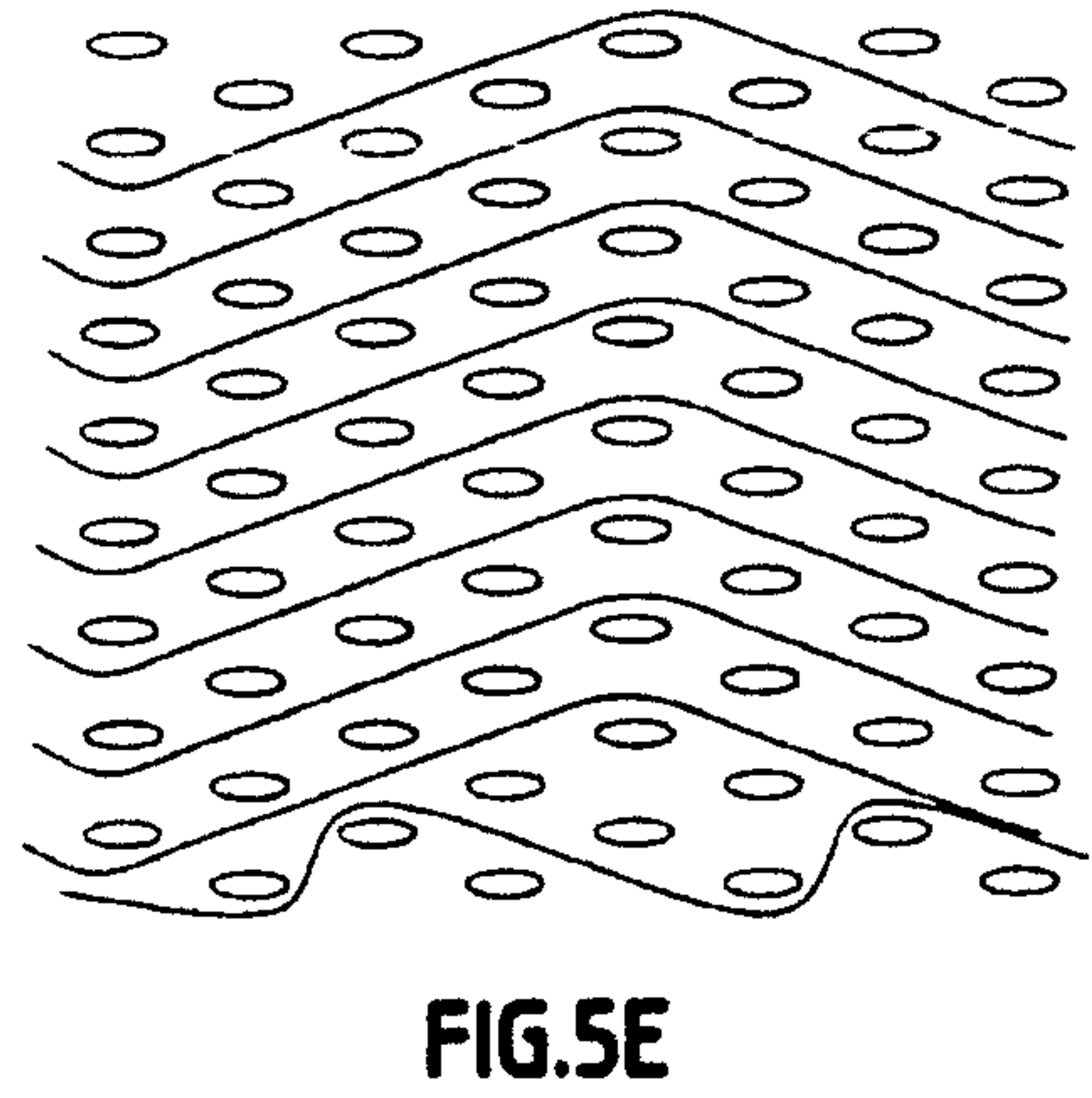
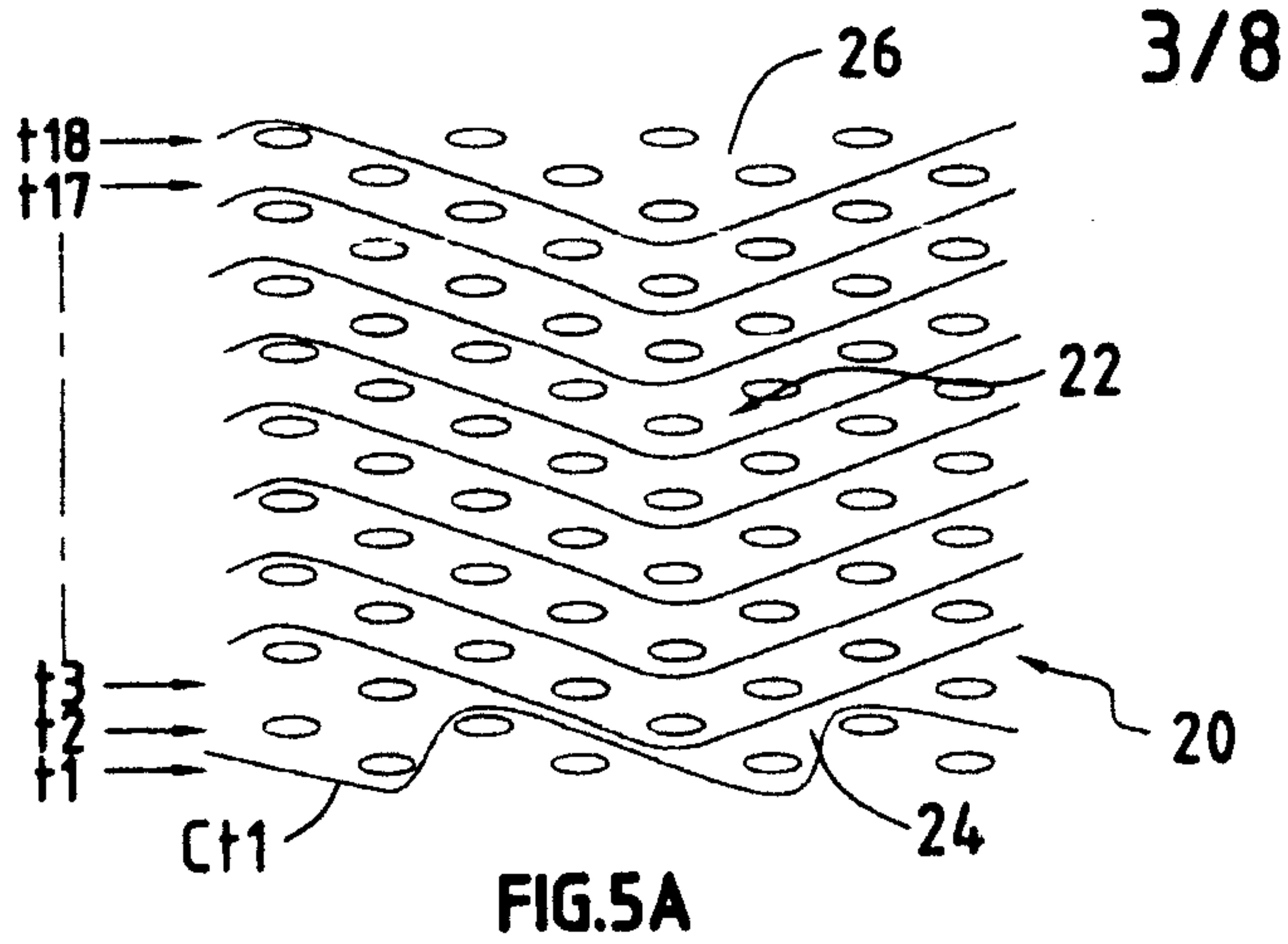
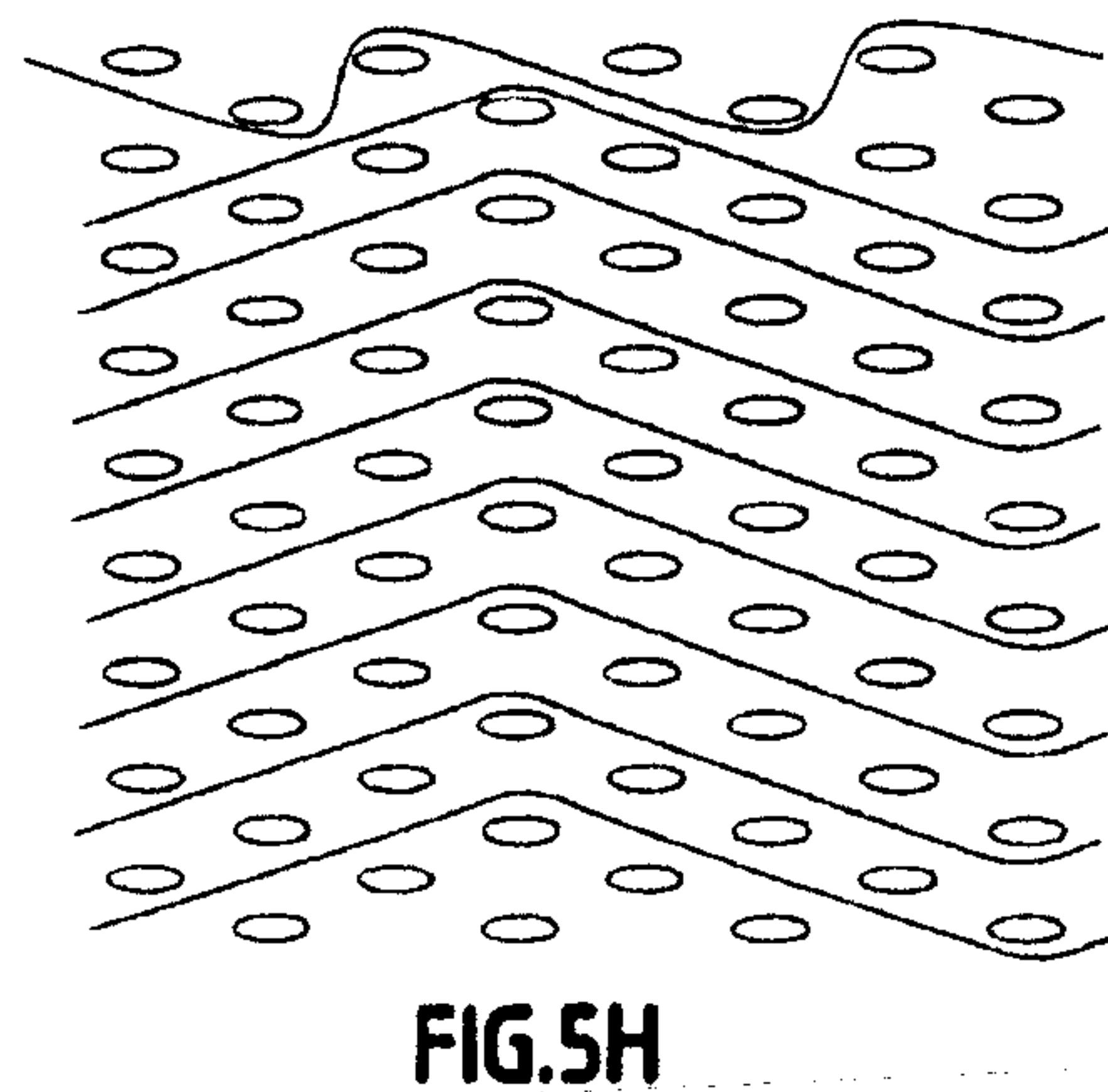


FIG. 5



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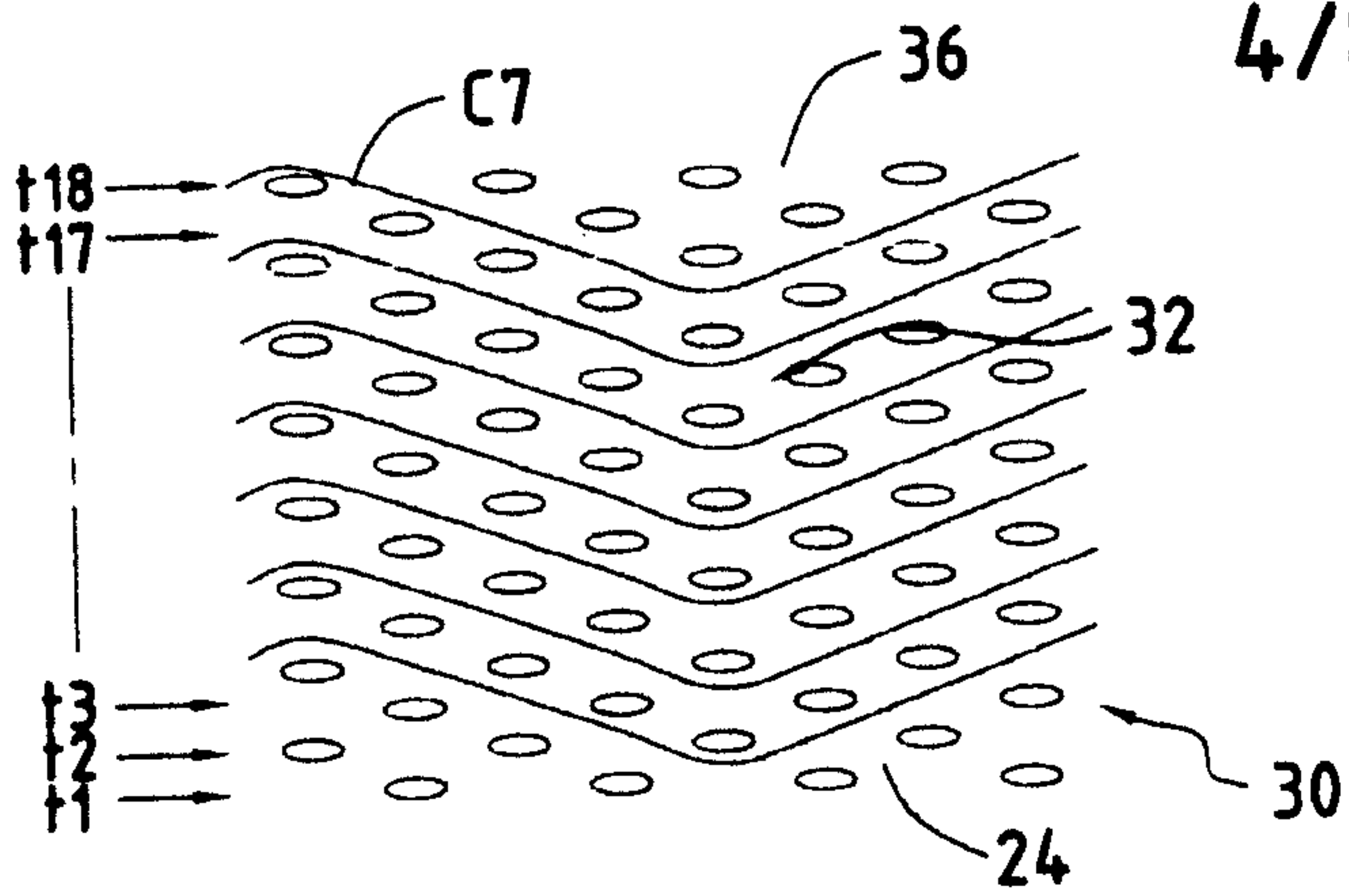


FIG. 6A

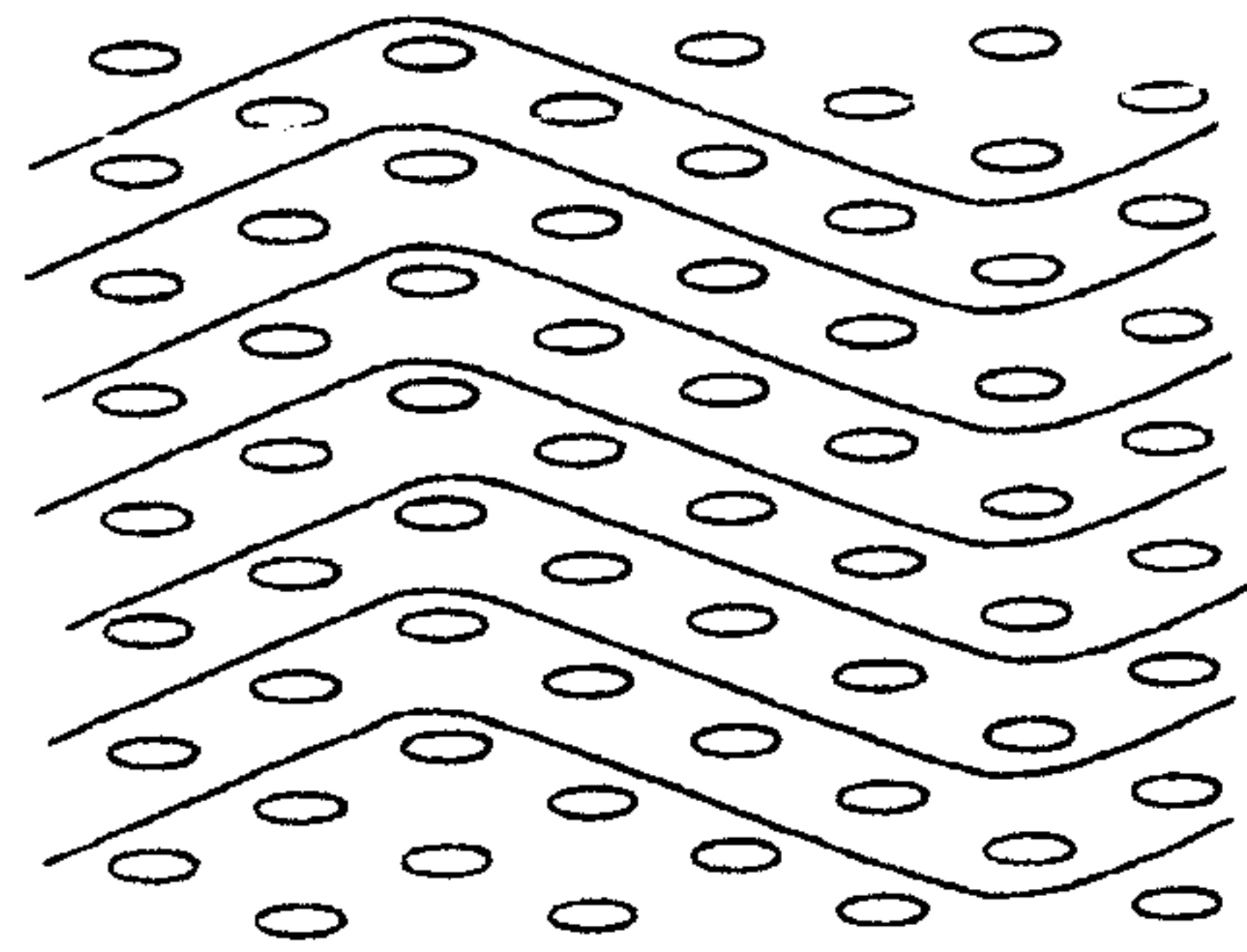


FIG. 6E

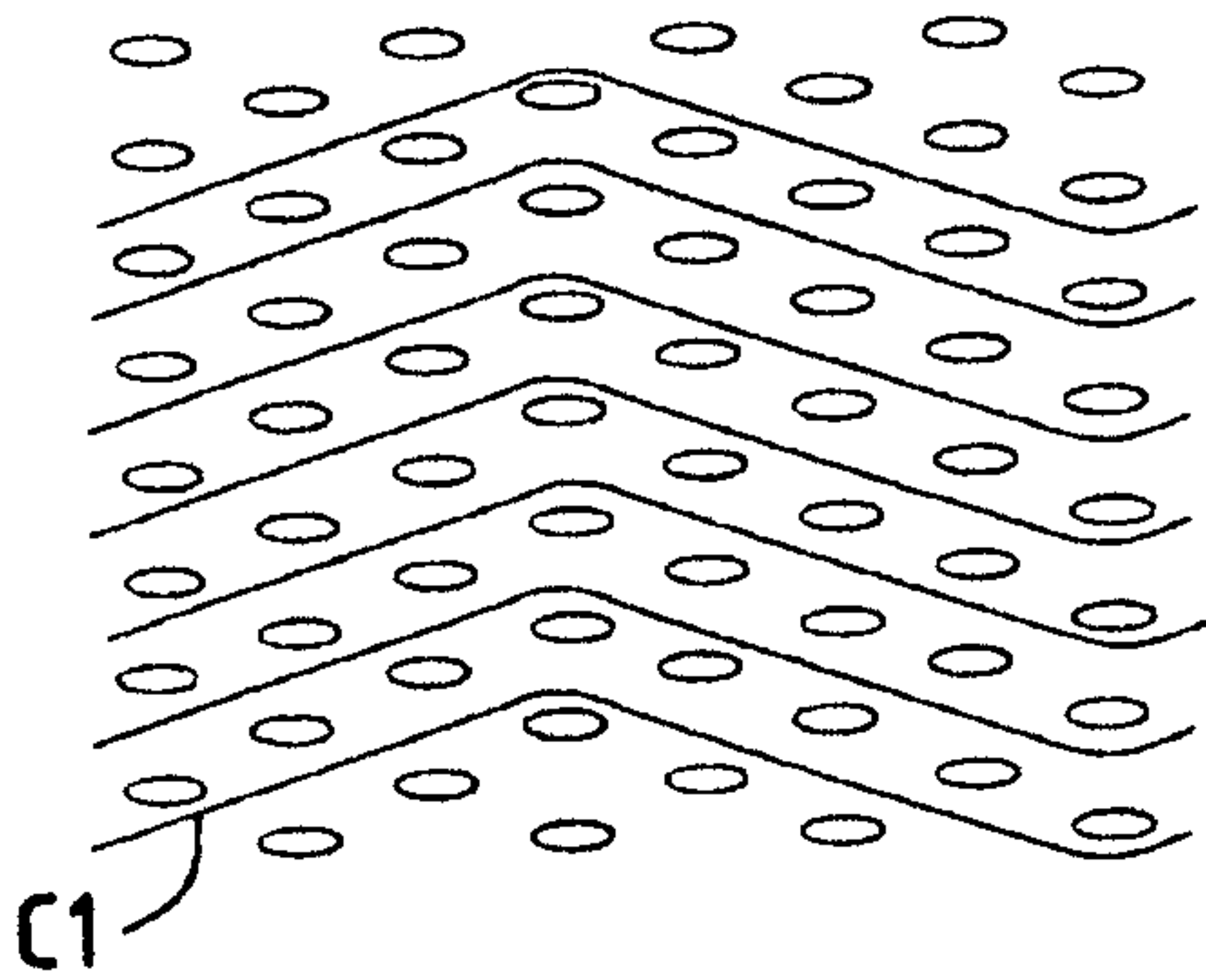


FIG. 6B

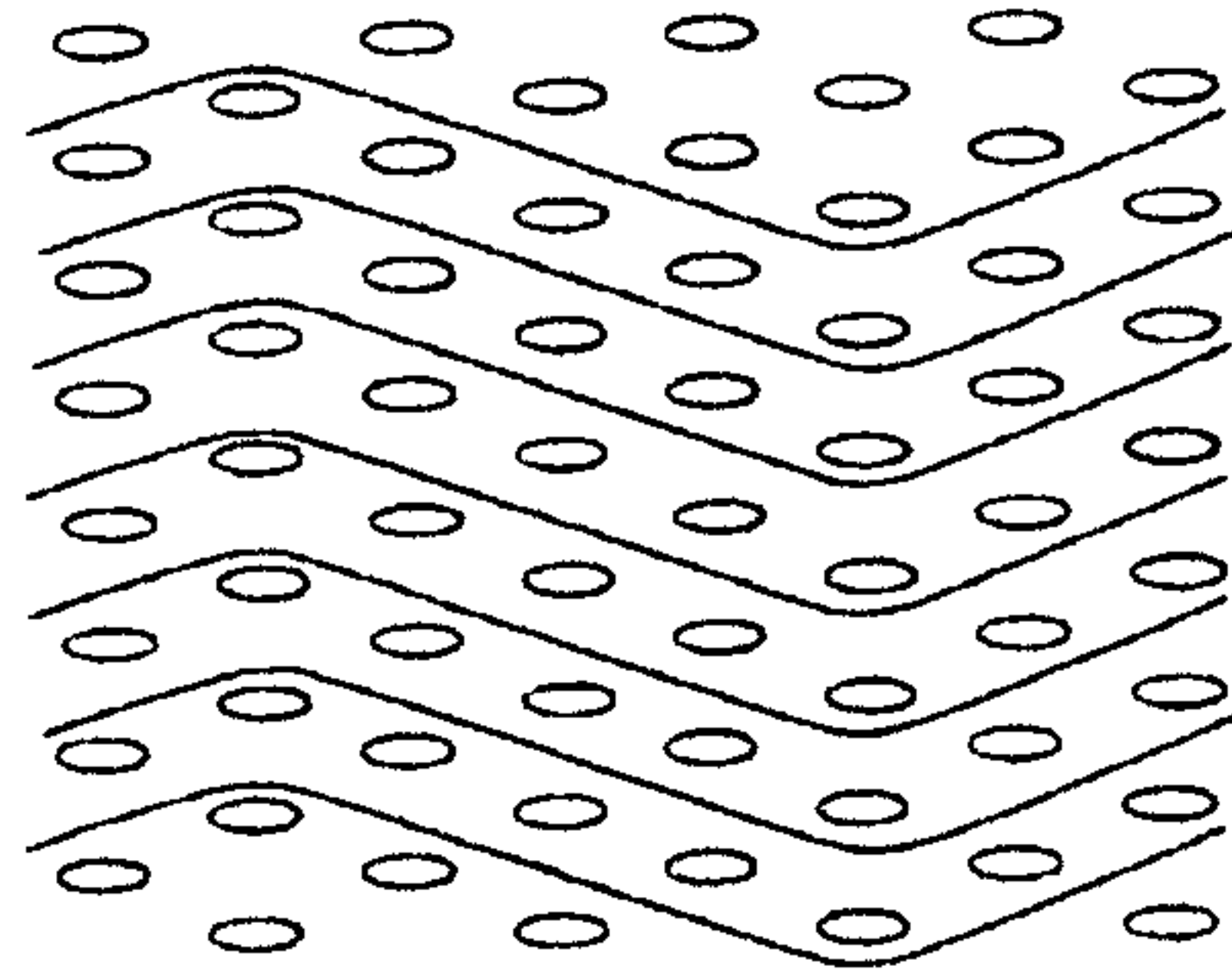


FIG. 6F

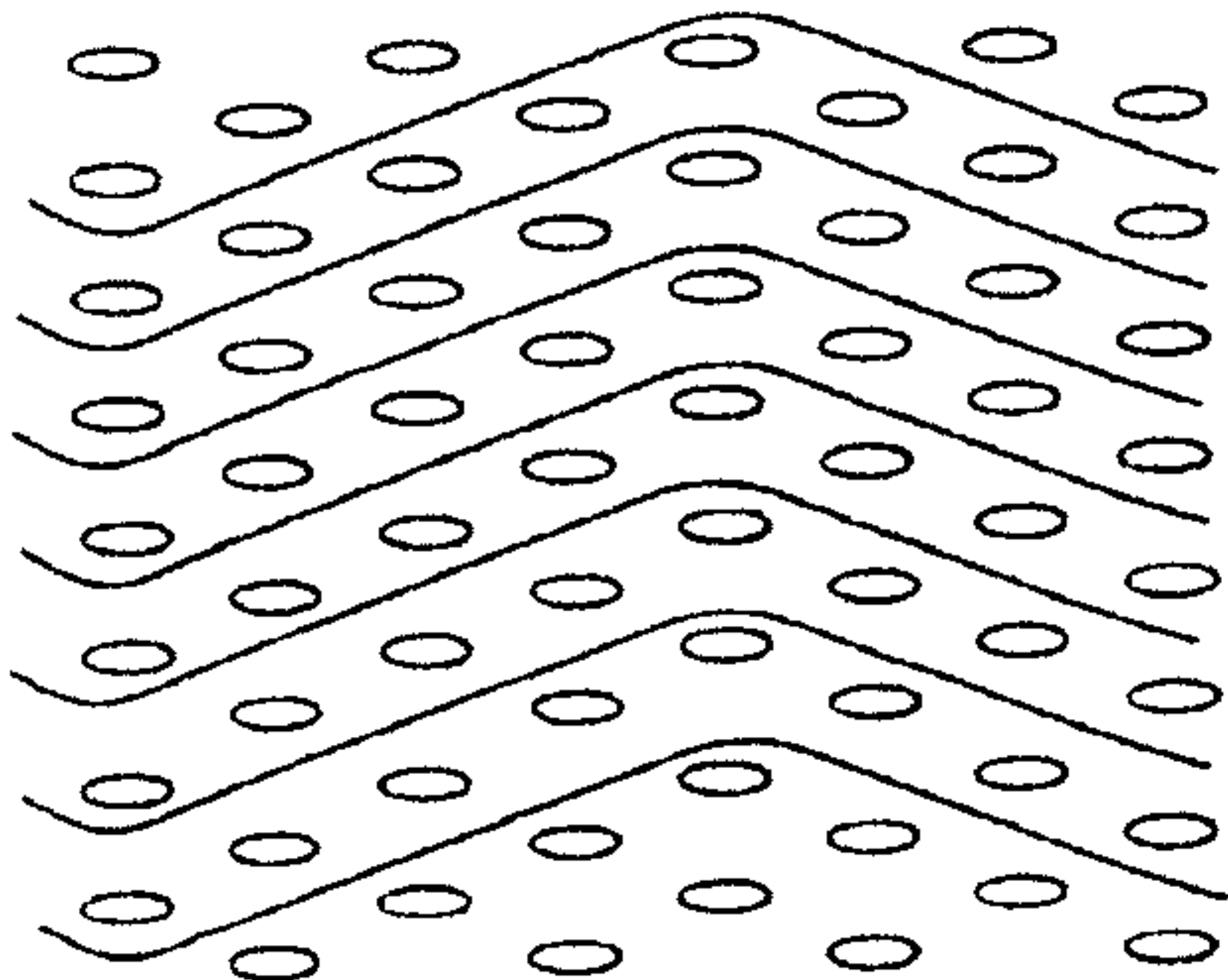


FIG. 6C

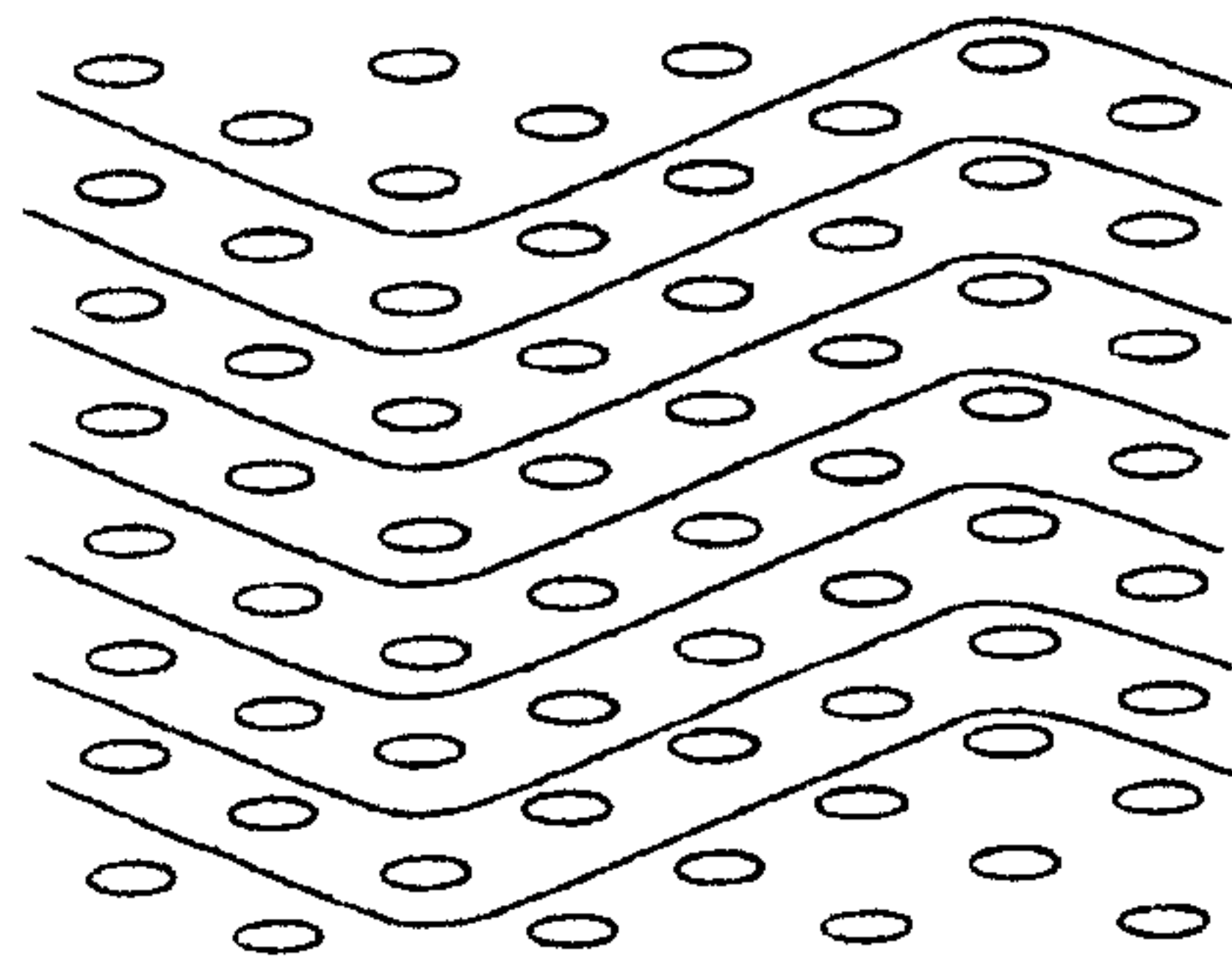


FIG. 6G

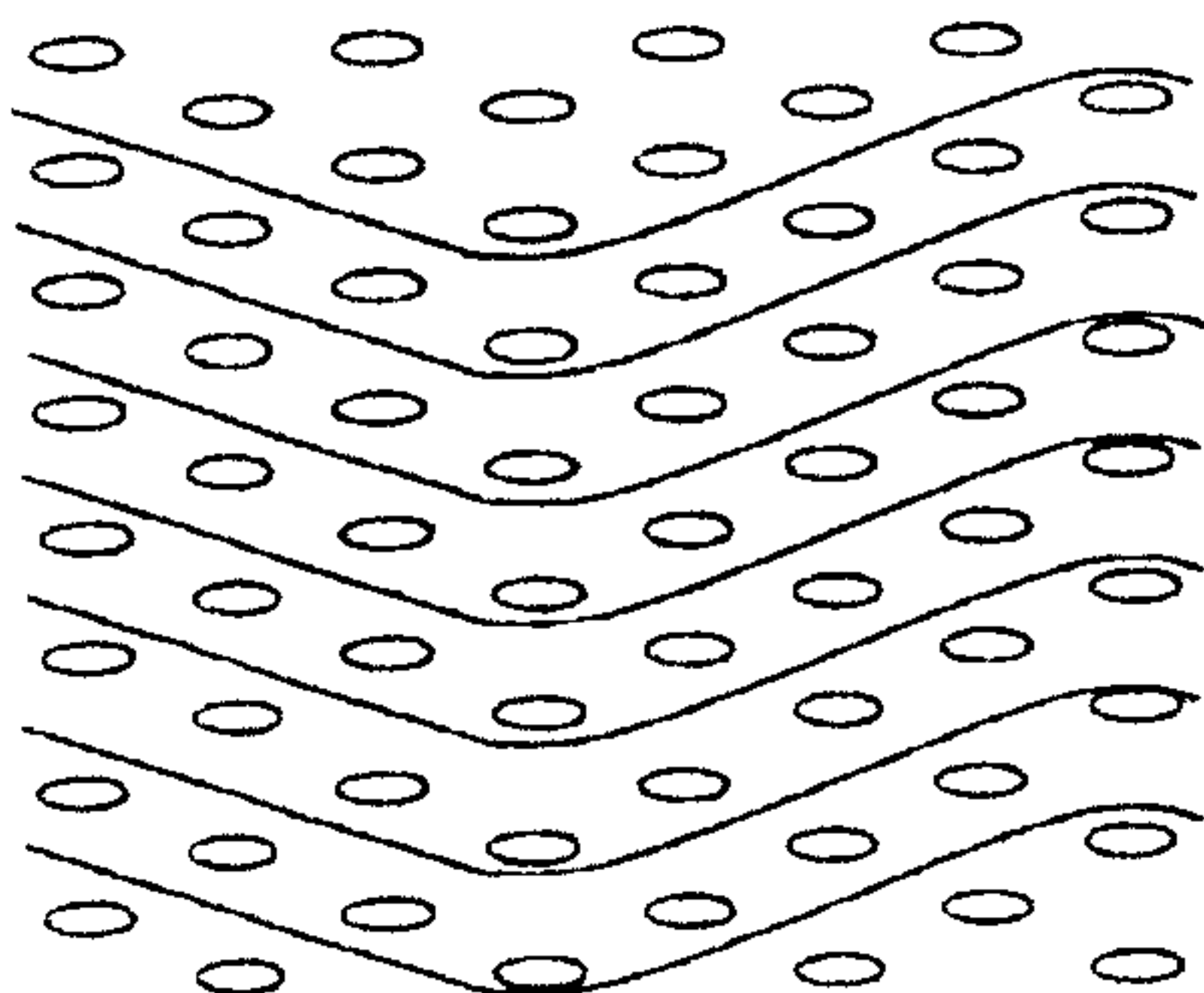


FIG. 6D

FIG. 6

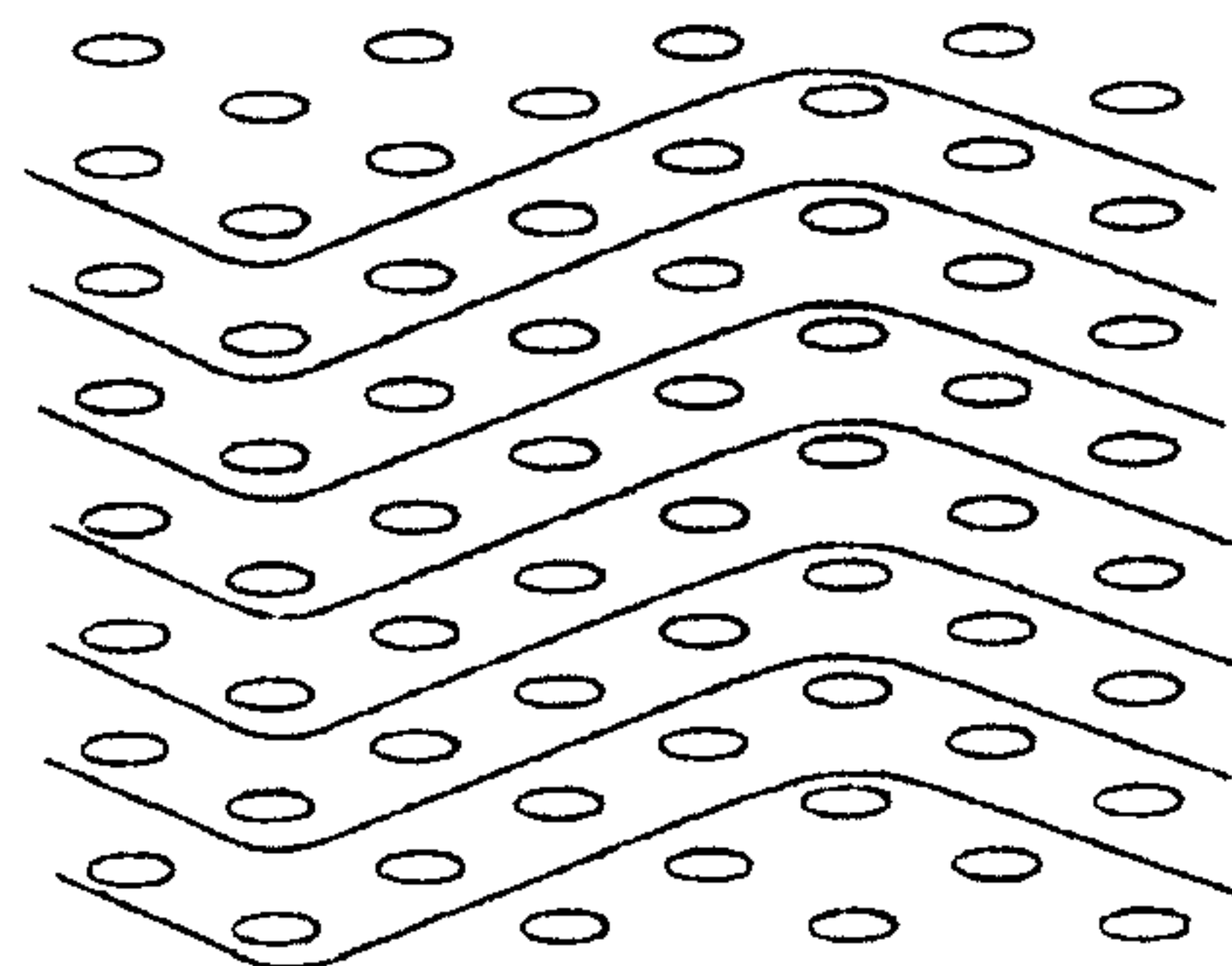
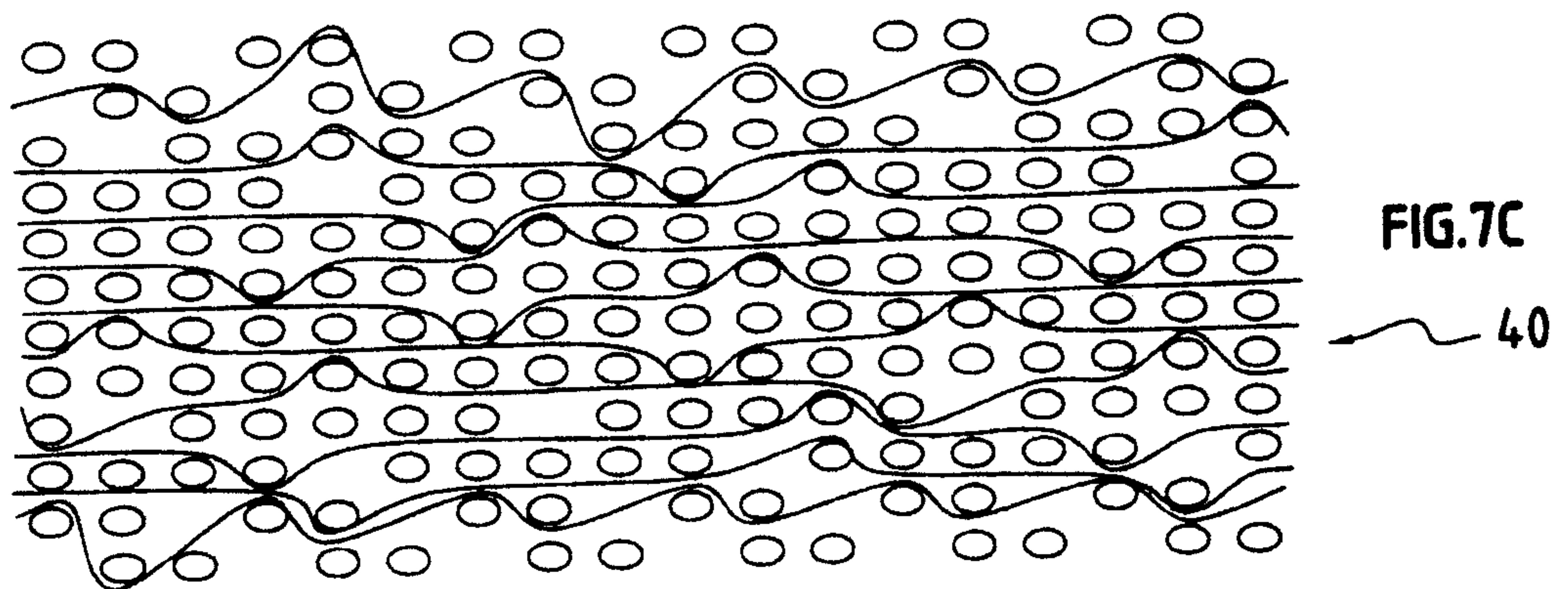
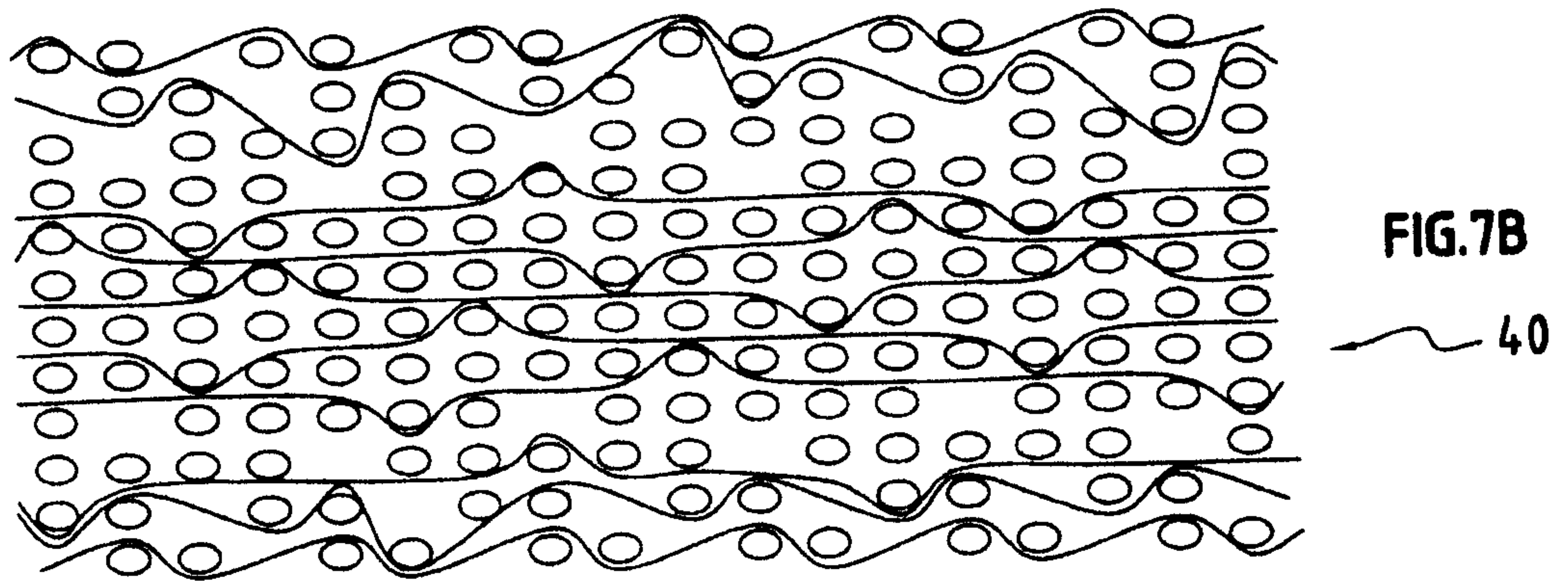
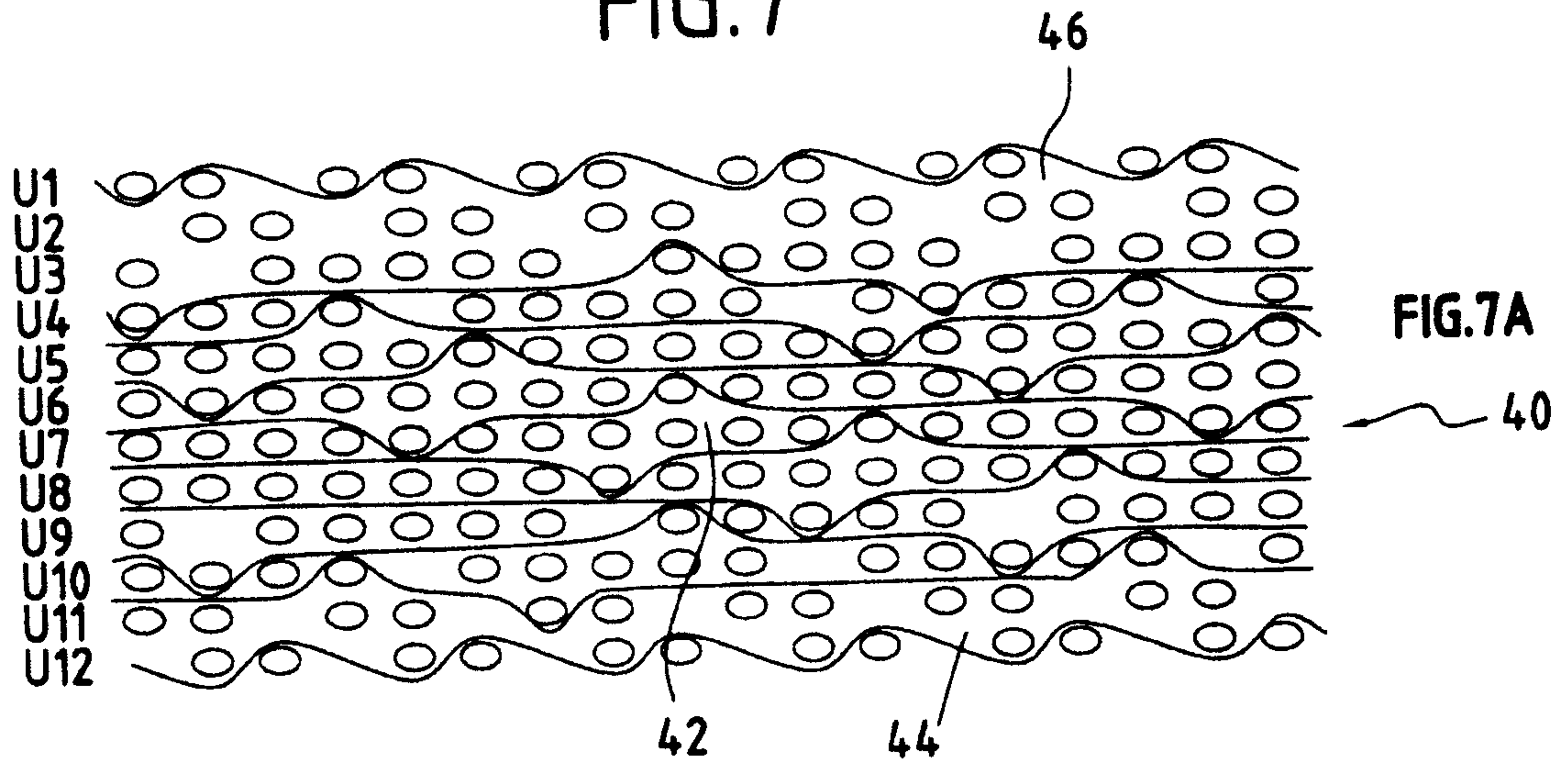


FIG. 6H

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FIG. 7



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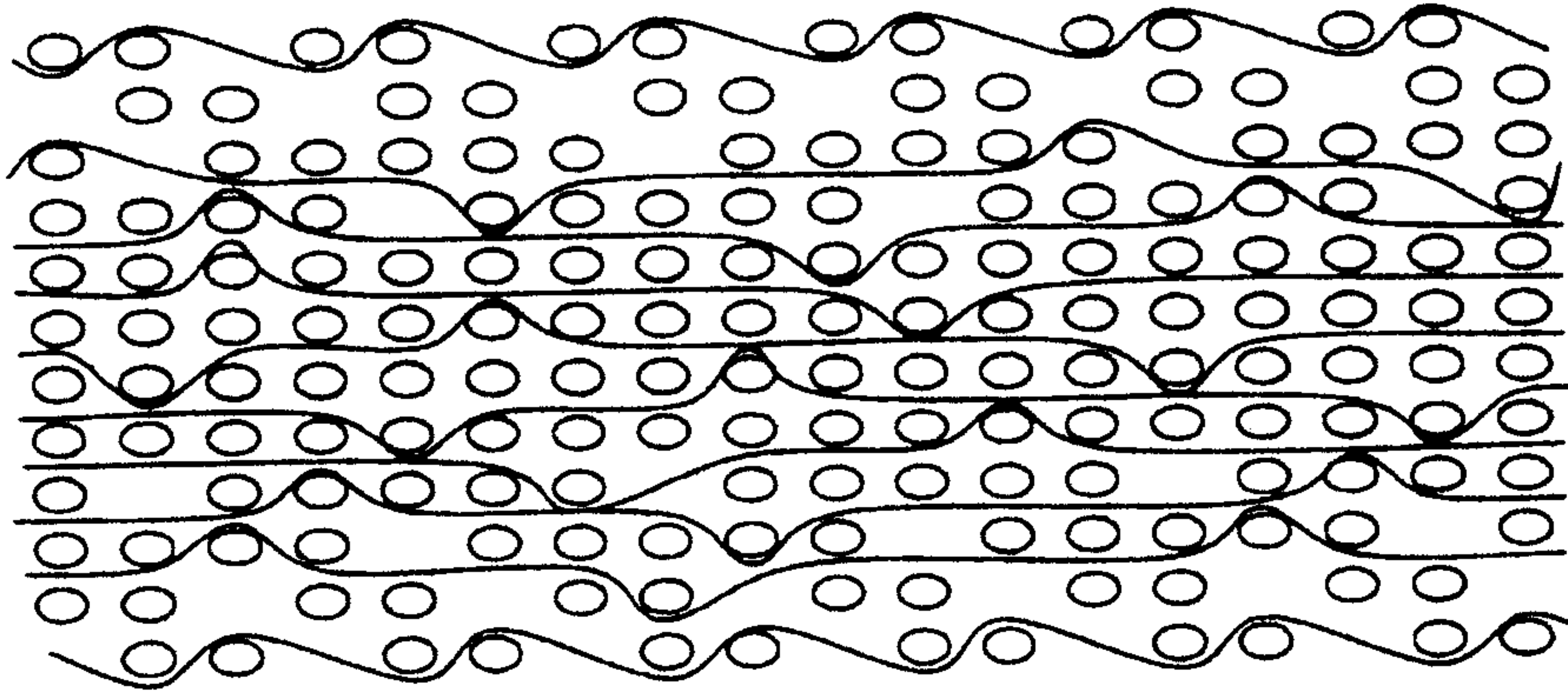


FIG. 7D

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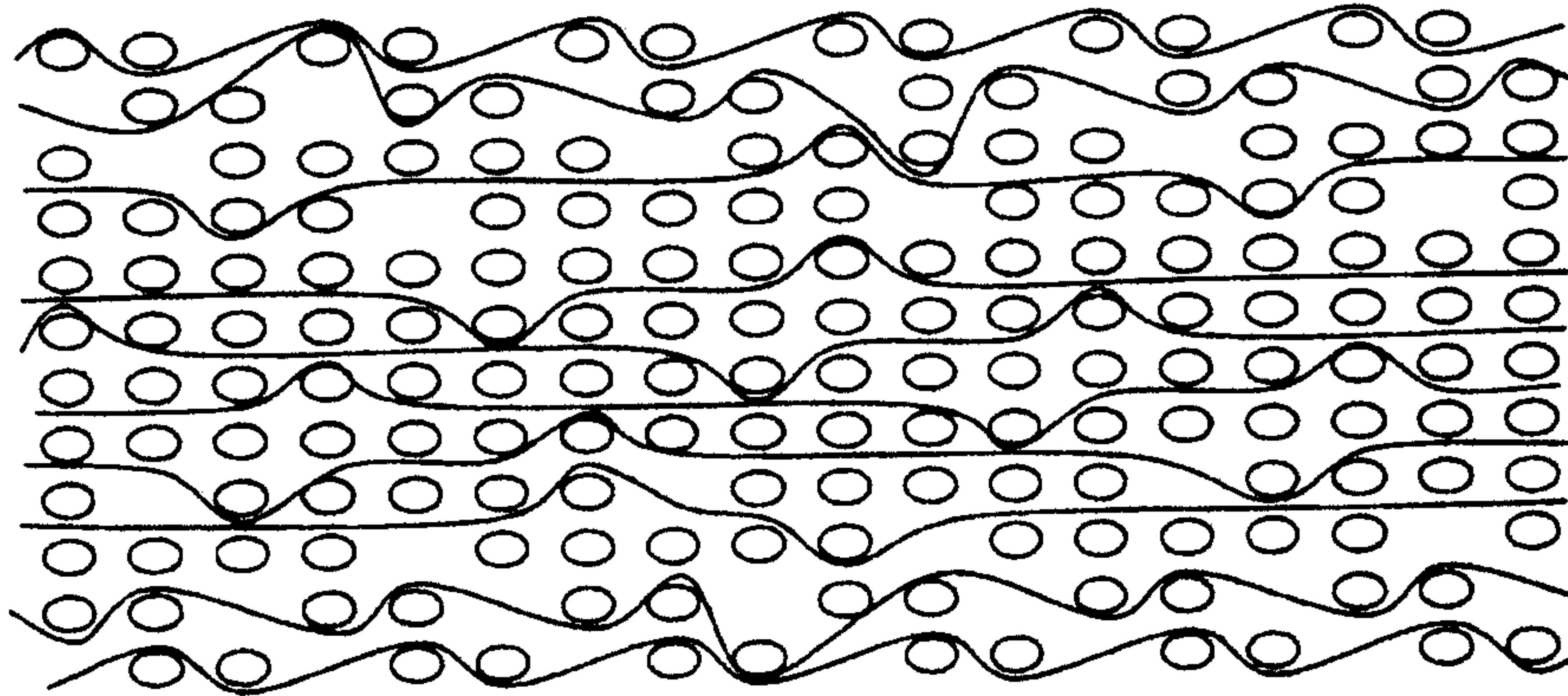


FIG. 7E

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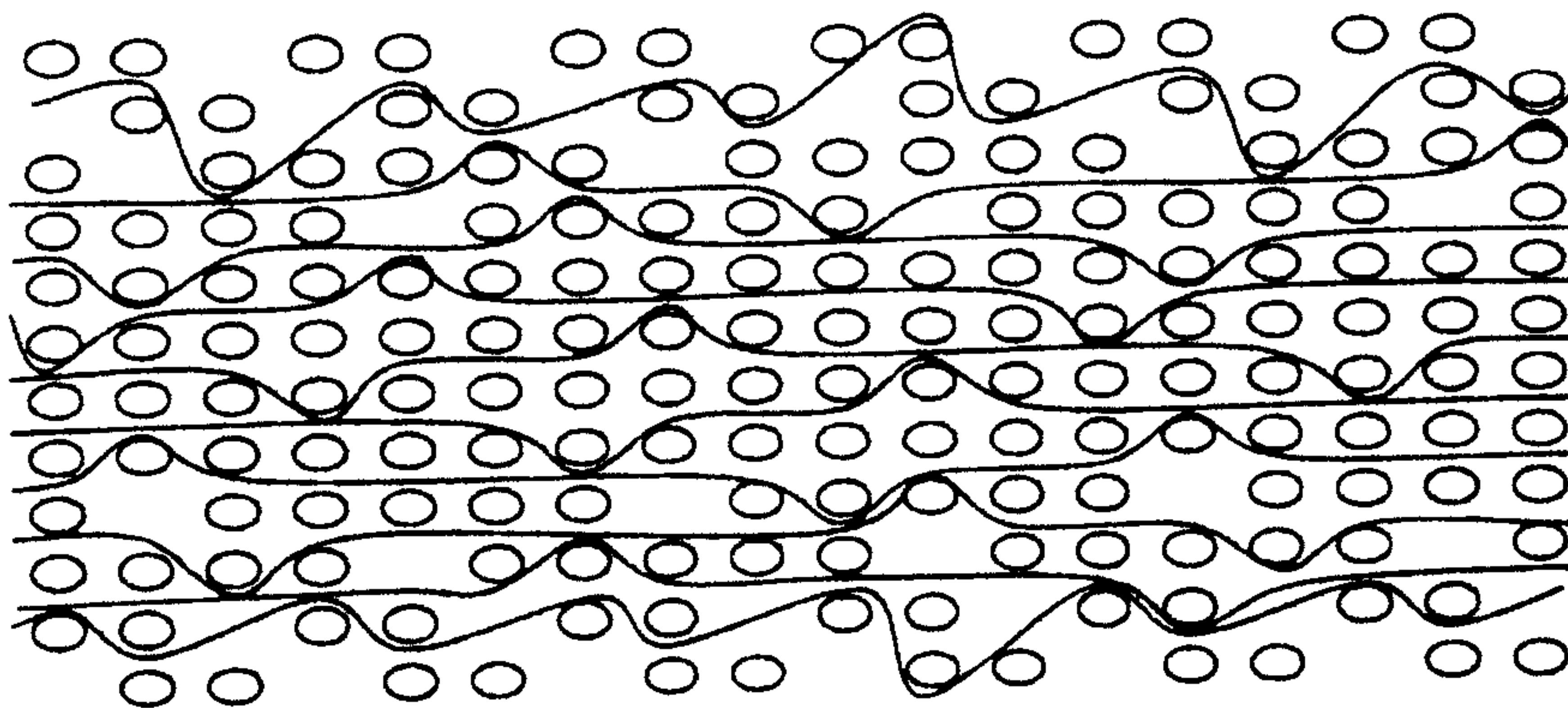


FIG. 7F

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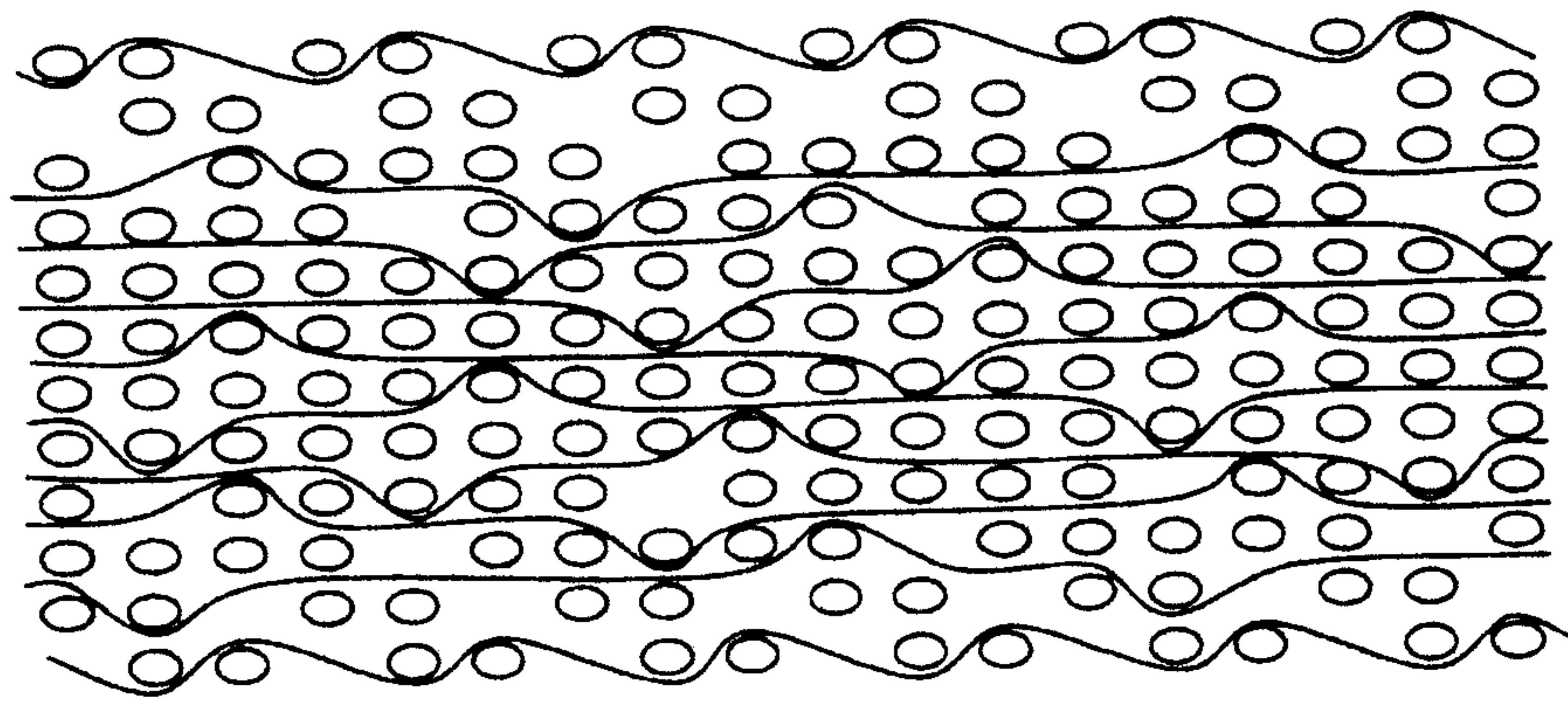


FIG. 7G

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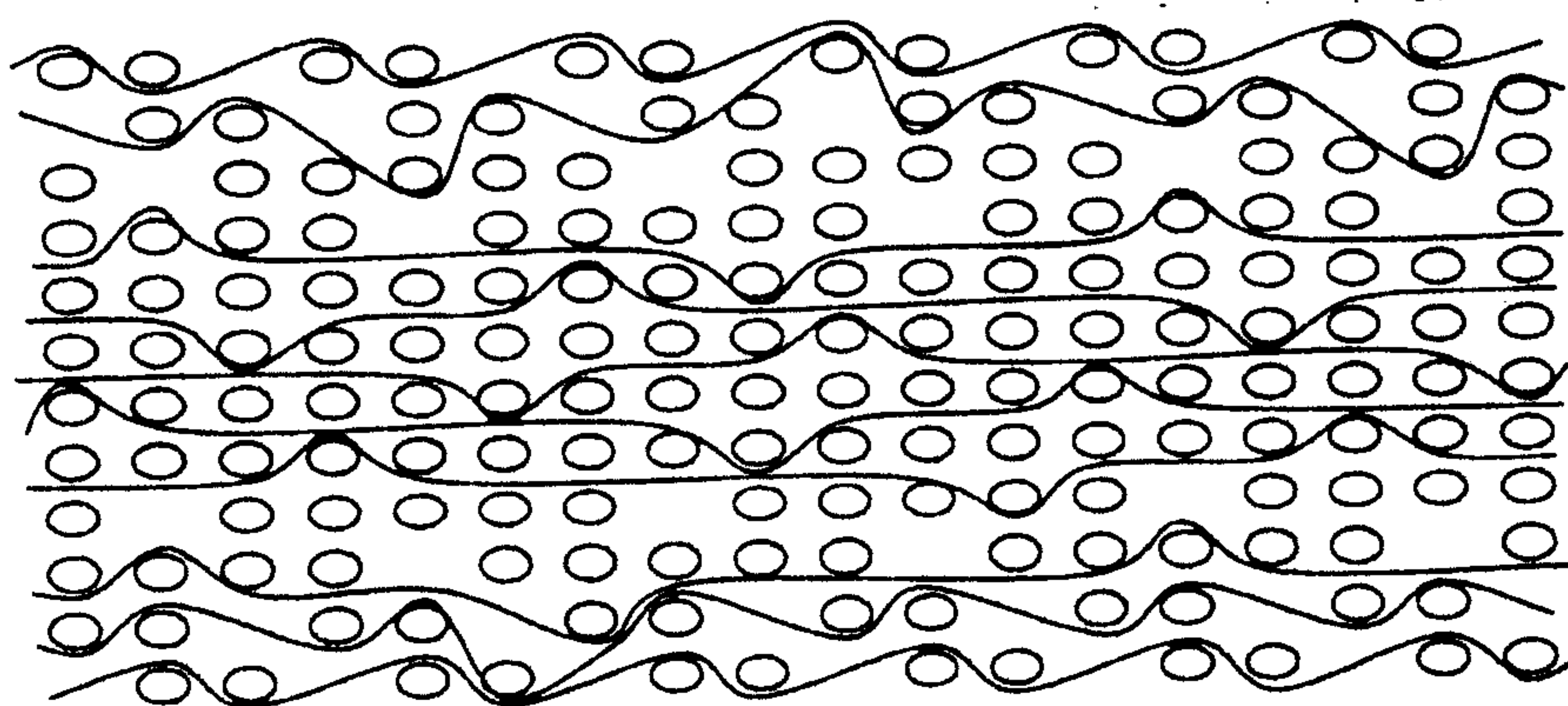


FIG. 7H

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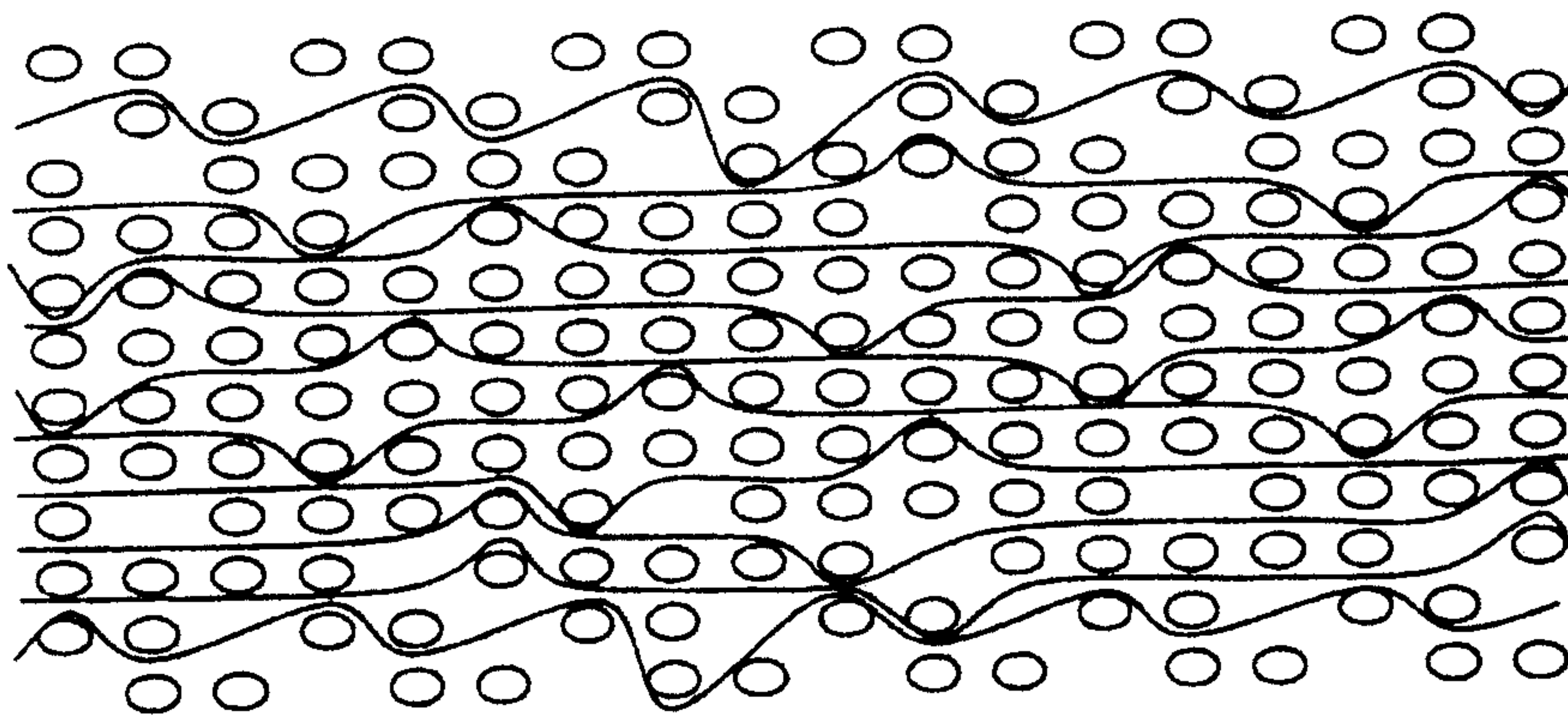


FIG. 7I

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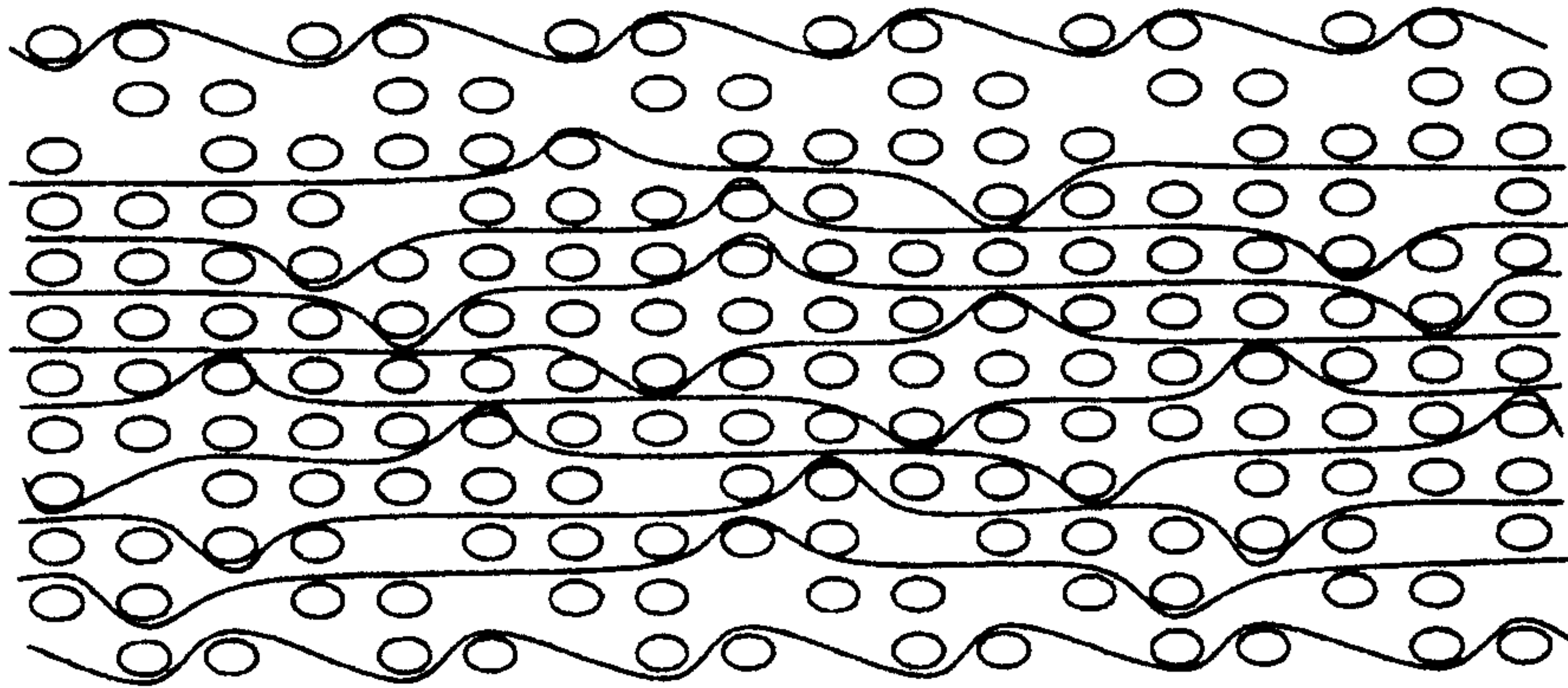


FIG. 7J

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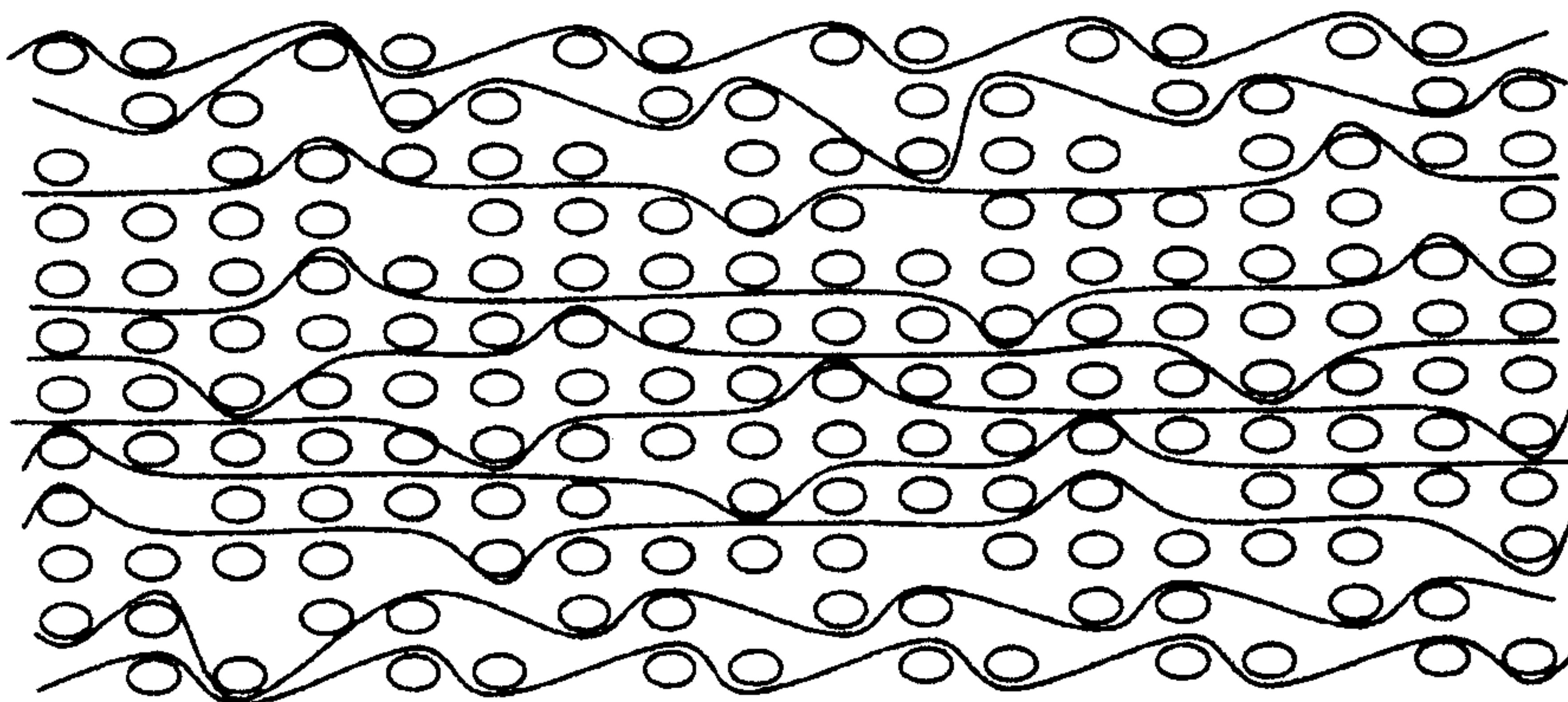


FIG. 7K

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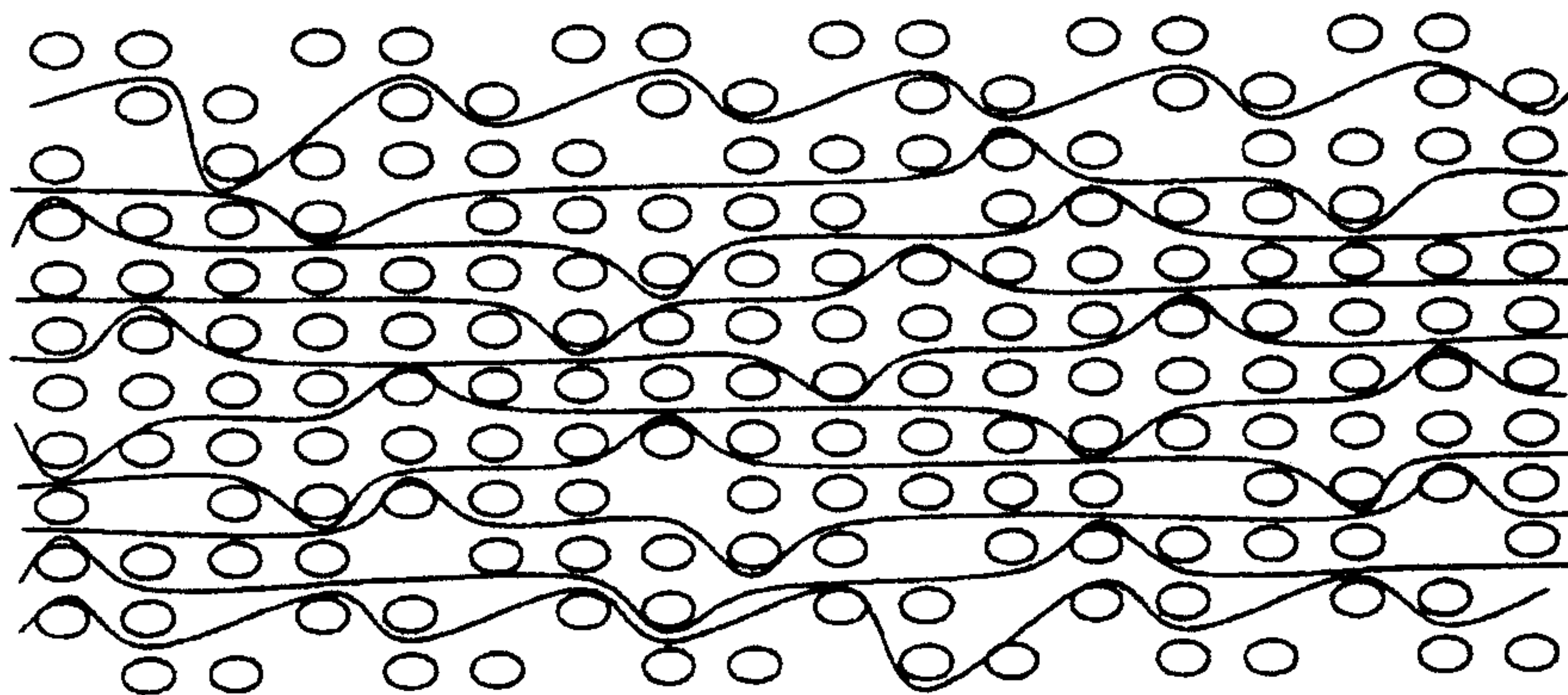


FIG. 7L

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