



Europäisches Patentamt
European Patent Office
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(11) Publication number:

**0 292 597
A1**

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: **87107810.1**

(51) Int. Cl.4: **B41J 3/16**

(22) Date of filing: **29.05.87**

(43) Date of publication of application:
30.11.88 Bulletin 88/48

(84) Designated Contracting States:
DE FR GB

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EP 0 292 597 A1

(54) **Magnetic print head comprising at least one linear array of magnetic printing elements.**

(57) A linear array (1,2) of magnetic printing elements (3) for forming a magnetic print head is formed by a thin flexible magnetic foil (8) out of which a comb-like structure (10) of magnetic elements (3) is etched. One half of a winding structure is provided

as printed circuit on a first flexible foil (14) together with ground (17) and control (18) lines. A second foil (15) carries in printed circuit form a complementary winding structure with the second half of the winding. Superimposed in sandwich structure is the

magnetic foil arranged between the two printed circuits foils. By connecting the end areas of the half winding structures, e.g. by soldering, a complete continuous winding or coil resp. is formed around each single magnetic element (3). Thus a coil with many turns is possible.

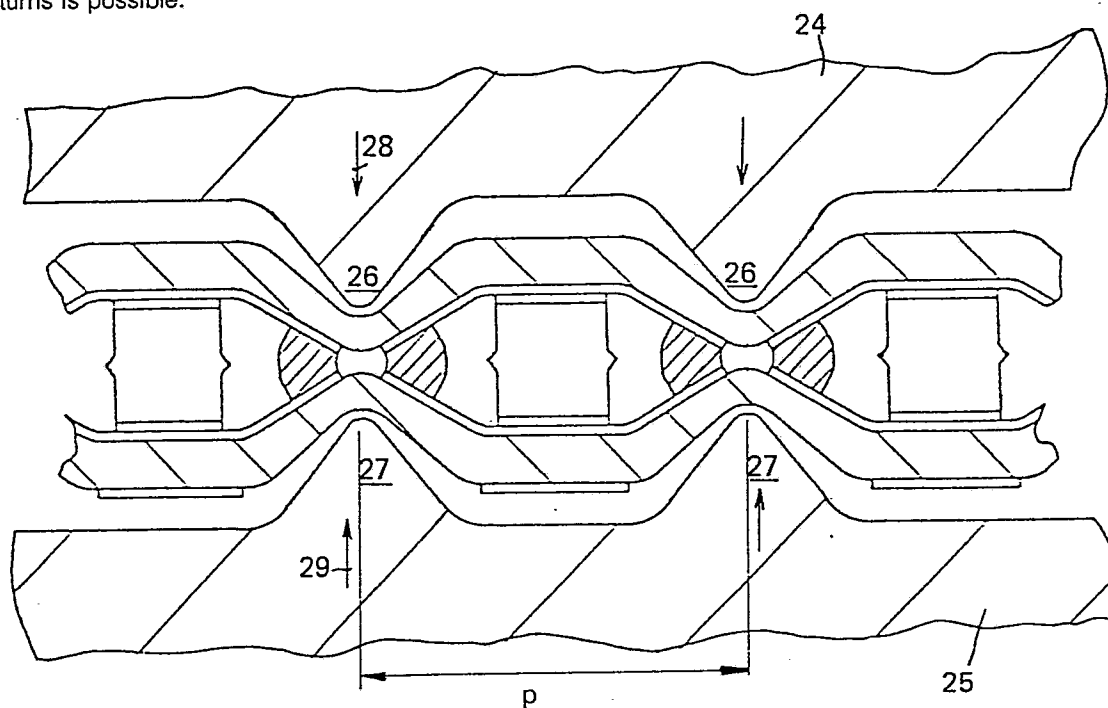


FIG. 6 A

MAGNETIC PRINT HEAD COMPRISING AT LEAST ONE LINEAR ARRAY OF MAGNETIC PRINTING ELEMENTS

The invention relates to a magnetic print head comprising at least one linear array of magnetic printing elements, each of said magnetic printing elements being surrounded by electrical windings controlling the magnetic flux in each of said magnetic printing element, said windings being attachable to electric control circuits.

Such a magnetic print head is known for example from USP 4 370 661. It describes a linear array of magnetic tips interrupted by gaps. In each of these gaps two electrical conductors are threaded. One conductor belongs to a digit line and one conductor belongs to a word line. When a coincidence of currents occurs flowing in the same direction at the same time, a magnetic flux is generated which is strong enough to magnetize the magnetic image carrier. When only one current at a time flows in either the digit or the word line the generated magnetic flux field in one gap is not strong enough to magnetize the magnetic image carrier. No magnetizing field at all is generated when either no current flows or the current of equal strengths flows in opposite direction in the digit or the word line respectively.

In accordance with this known structure the electrical conductors leading the current are provided as printed circuit lines on a flexible substrate. Two of those substrates are superimposed so that in each gap one digit line and one word line is provided. Thus, not more than only two electrical conductors per gap can be and are provided. If for example 8-10 Ampere-turns are required for generating a magnetic field strong enough to magnetize the magnetic image carrier, then the current per conductor has to be relatively high. That means that the printed circuit line conductor has to have a large cross section, i.e. it must be wide and thick. Furthermore, the heat generating and heat dissipation is obviously relatively high.

The invention as claimed overcomes these drawbacks. It solves especially the problem of having enough ampere-turns for a sufficiently high magnetizing field, of having low heat generating by low current flow through relative large cross sections of the current lines, and of providing easy and relatively simple manufacturing by using proved manufacturing techniques, this combined with high precision.

In advantageous manner it is characterizing for the magnetic printing head in accordance to the invention, that its linear array of printing elements comprises a thin flexible foil of magnetic material out of which adjacent to one edge a comb-like structure of magnetic elements is worked out, e.g.

by etching, a first thin flexible foil means which is provided in one side with a structure of a first half of the electrical windings, and which is provided on its reverse side with connecting ground and control lines, a second thin flexible foil on which is provided on one side the complementing second half of the electrical windings, both foils carrying that halves of the electrical windings being performed as printed circuits, the first and the second foil carrying the halves of the electrical windings being connected, e.g. by soldering, such that a separate continuous winding surrounds each single magnetic element, and the continuous winding being arranged as close as possible to the open tip ends of the magnetic elements.

Improvements and further developments of the invention are defined in the subclaims as well as in the method claims pertaining to the production of the head in accordance to the present invention.

The magnetic print head comprising at least one linear array of printing elements, and the method for producing it, as well as their advantageous improvements will be described in the following with references to the drawing, showing embodiments of the invention, and in which

Fig. 1 shows schematically in a side view a cross section of the linear array of printing elements;

Fig. 2 shows an enlarged top view of a part of the flexible magnetic foil with the worked out comb-like structure of magnetic elements;

Fig. 3 shows an enlarged top view of a part of a printed circuit foil carrying the structure of one half of the windings and the ground and control lines;

Fig. 4 shows an enlarged top view of a part of a printed circuit foil carrying the structure of the second half of the windings, complementary to said of Fig. 3;

Fig. 5 shows an enlarged cross section bottom view of the superimposed foils before connecting the half windings into complete windings;

Fig. 6A shows an enlarged cross section bottom view of a part of the connected foils, and tools for performing this connection;

Fig. 6B shows a structure similar to that of Fig. 6A but showing a second copper deposited on the outside of the winding foils for reinforcing the electrical lines;

Fig. 7 shows an enlarged top view of a part of a printed circuit foil of a second version, carrying one half of the windings and the ground line, similar to said of Fig. 3, but for edge connection;

Fig. 8 shows an enlarged top view of a part of a printed circuit foil of said second version, carrying the second half of the windings, complementary that of Fig. 7 and similar to that of Fig. 4;

Fig. 9 is an enlarged view of a part of a separate printed circuit foil carrying control lines and associated connection pads for forming in superimposition the over edge connection to the foil shown in Fig. 7, and

Fig. 10 shows schematically in a side view, similar to that of Fig. 1 a cross section of a second version of a linear array of printing elements, especially showing a different return flux design.

Fig. 1 shows schematically in a side view a cross section of two linear arrays 1 and 2. Linear array 1 belongs for example to the odd head, and linear array 2 belongs to the even head. Odd and even head are staggered for one pitch, that means for one spacing between two magnetic elements 3 so that the double picture element density is given. The magnetic elements 3, if energized, magnetize a drum like image carrier 4 in its surface area 5 immediately below the tip ends 6 of the magnetic elements 3.

Linear array 1 and 2 is formed identically and as already mentioned arranged in a block like form staggered to each other. In the design shown in Fig. 1 both arrays 1 and 2 are connected by an appropriate layer like material 7.

Magnetic element 3 is part of a thin flexible foil 8. This thin flexible foil of magnetic material is preferably made out of amorous material. This might be a NiFe alloy as for example Permalloy. If for practical reasons foil 8 is not available or can not be produced or processed in one piece then a super-imposition of two foils, e.g. two 30 μm thick Permalloy foils can be used. Thus a thickness of 60 μm for a magnetic foil is given. This has been found a well suited and dimensioned material to form magnetic elements 3 out of it.

As shown in Fig. 2 out of foil 8 relatively close to the lower part 9 a comb-like structure 10 is worked out. The working out can be done for example by etching. The comb-like structure 10 separates the lower part 9 from the upper part 11 of magnetic foil 8. The magnetic elements 3 of the comb-like structure 10 are separated by gaps 12. The gaps 12 might have a gap lengths g_l of 151,66 μm and the magnetic elements 3 might have a tooth widths of 60 μm . Both together add up to a pitch p forming the masher for the picture density of 211,66 μm . This corresponds to 1/120" or 120 pel (picture elements per inch). Along cut line 13 the lower part 9 and the upper part 11 will be separated later so that out of the comb-like structure 10 the tip end 6 of the magnetic elements 3 are open to the outside.

As can be seen from Fig. 1 magnetic foil 8 is surrounded in area W by a first foil 14 and a second foil 15. First foil 14 is shown in more detail and in a section cut out of it in Fig. 3. Foil 14 is a thin flexible foil, e.g. a polyimide foil of 12,5 μm thickness. It carries on 1 side electrical conductors 16. Those are copper lines provided on the upper side of foil 14 in well known printed circuit technique. As Fig. 3 shows clearly the lines 16 are separated from each other but form a parallel pattern that is repeated on that foil as often as it is necessary to form a first half of all the electrical windings of 1 linear array. On the reverse side of foil 15 ground lines 17 and control lines 18 are provided. Also those lines are copper lines printed in well known manner on the foil 14. Ground line 17 for example is attached to a pad 19 which forms a hole in foil 14 for through-hole connection. On the other end of the formed half winding structure a second pad 20 is provided that in similar fashion is connected via a hole by through-hole plating connection to control line 18.

The copper lines 16 may have a thickness of about 5 μm , may have a width of about 15 μm and a distance to each other of about 10 μm . They are staggered, as can be seen from Fig. 3 in a step like fashion. The end areas 21 of each single electric line 16 are covered with tin or lead tin alloy which is used to form the connection with the second half winding, when a soldering process is used.

The second half winding is provided on 1 side of the second foil 15. A section of this foil 15 showing the design of the half winding consisting of lines 16 is shown in Fig. 4. The design is complementary to that of Fig. 3 so that if both sides are superimposed face to face their end areas 21 match each other in such a way that upon completion of the connection between the two foils a continuous winding is formed starting from the lower hole plated pad 19 via all the lines 16 within one winding up to the upper hole plated pad 20. Also foil 15 is provided with its lines 16 in well known printed circuit technique.

Fig. 5 shows in a bottom view an enlarged cross section of the superimposed magnetic foil 8 with its magnetic elements 3 in the middle and underneath the first thin flexible foil 14 carrying one half of the electrical winding and the ground 17 and control 18 lines, and on top of it the foil 15, the second thin flexible foil on which the complementary second half of the winding is provided. This super-position is shown before the connection between the two half winding carrying foils 14 and 15 is performed. As already said in the end area 21 of the circuit lines 16 tin or lead tin alloy is provided. This tin might have the form of small tin balls 22. Between the foil 8 with its magnetic elements 3

and the two foils 14 and 15 respectively and especially their conductor lines 16 on both sides insulation layers 23 are provided. Thus the circuit lines 16 are electrically insulated from the magnetic elements 3. Again the partitioning or pitch distance p is clearly visible.

For forming a complete continuous winding the electrical lines 16 of the two separate half windings carried on the two foils 14 and 15 have to be connected. In Fig. 6A in a similar view as in Fig. 5 the result of this connection is shown. The connection is done by soldering. For the soldering process two identical soldering irons 24 and 25 are provided. Those soldering irons 24, 25 are provided with heating ribs 26 and 27 distanced from each other for the pitch spacing p . There are so many heating ribs 26 and 27 provided in the two soldering irons 24 and 25 as are necessary to connect the foils 14 and 15 of a complete linear array. If the two soldering irons 24 and 25 are approached to each other in accordance to the arrows 28 and 29, the hot tips of the heating ribs 26 and 27 press the foils together, heat the tin balls 22, melt them and thus connect the two half windings. The heating ribs 26 and 27 are constructed such that at the same time two adjacent tin balls 22 of two different half windings are melted and connected at the very same time. The soldering irons 24 and 25 with their heating ribs 26 and 27 may be made from steel and machined in the desired design to have a micro-mechanical profile as shown.

The structure as shown in Fig. 5 and in Fig. 6A shows the electrical lines 16 on the inside of both foils 14 and 15, facing each other and directly opposite to the magnetic elements 3 of the magnetic foil 8. An in principle opposite arrangement is shown in Fig. 6B. The printed circuit foil 14 and 15 have the conductors 16 of their respective half windings on their outside. Thus they are not immediately oppositely faced to the magnetic elements 3 of the magnetic foil 8. Thus the foils themselves can serve as insulating layer to the magnetic element 3. At both half winding ends 30 a through hole plating 31 is provided so that a connection through the foil 14 or 15 respectively is made to tin balls 32. In that tin ball area 32 the two halves are connected. The soldering of those two foils with through hole plating is again formed by the already described two soldering irons 24 and 25. With this design a probably better heat transfer to the soldering points is given. This design has furthermore the advantage that an additional copper layer 33 can be applied by electrodeposit to the conductor lines 16 thus reinforcing and enlarging the lines. Also possible cracks in the copper layer caused by the bending of the copper during soldering can be overcome by this design.

When the foils 14 and 15 are connected to a

complete winding that surrounds individually each magnetic element 3, and casted or molded into plastic 7, this finished assembly is cut off along line 13 indicated in Fig. 2 for the comb-like structure 10 of the magnetic foil 8. Thus the tip ends 6 as shown in Fig. 1 are provided. Now a non-magnetic material, for example a wear resistant plastic layer 34 is applied and the upper part 11 of the magnetic foil 8 is bent over in a U-shaped form as shown in Fig. 1. Thus a yoke is provided to form the common return path for the magnetic flux to the printing drum 4. To reinforce the common magnetic yoke formed by upper part 11 of foil 8 a magnetic reinforcing block 35 is provided. This block is made in such a dimension that the leakage flux is minimized and the return flux density in drum 4 is reduced to 1/100 of the writing head density.

As shown in Fig. 1, the height of foil 15 carrying only the complementary half winding is covering only about the winding area W . Foil 14 carrying also the ground line 17 and the different control lines 18, is arranged such that it surpasses the U-like magnetic yoke and goes on top of block 35. There a decode/drive chip 36 is provided. This chip is connected to the control lines 18 and the ground line 17. It furthermore provides the connection to other needed electrical controlling and driving circuits.

In Fig. 7, 8 and 9 a second version of the printed circuit foils forming the winding respectively the coils of the different magnetic elements 3 is shown. Fig. 7 shows a section of a foil 37 that carries one half of the winding. It shows one wide ground line 38 that is connected to connecting lines 39 that lead to each upper beginning of one half-winding structure. The lower end of that half-winding structure is connected to printed circuit lines 40 that lead away from the winding structure to the lower part of foil 37. Lateron after superimposition and connecting the two half-windings as already described, along a cut line 41 also the connecting lines 40 are cut off. That means that those connecting lines 40 reach the edge of foil 37. At this edge they are lateron connected to a second foil 44 having control lines 42 connected to connecting pads 43. That is shown in Fig. 9.

For forming the first thin flexible foil means foil 37 and foil 44 are superimposed such that they form more or less one foil compound having the first half of the electrical winding together with the ground line structure on one side (see Fig. 7) and having on the reverse side the control line structure as shown in Fig. 9. Along the cut line 41 the control lines 42 are connected with the connecting lines 40. The spacing corresponds exactly to the pitch p of the magnetic elements 3 already seen in different figures. Thus the two foils shown in Fig. 7 and Fig. 9 form a second version of the foil 14

shown in Fig. 3.

In Fig. 8 a section of a foil 45 is shown provided with printed circuit lines 16 as already shown in Fig. 4. As the scale is different the section view of Fig. 7 and Fig. 8 shows a half-winding structure with sixty lines for every half-winding. The same number is shown in Fig. 7. If foil 45 is then superimposed as complementary second half over the structure shown in Fig. 7, certainly including in between the corresponding magnetic foil 8 as already described, those magnetic elements then will be surrounded by a continuous coil or winding respectively of sixty turns.

If the foil means formed from the combined foil 37 and 44 is used, as for example in the assembling as shown in Fig. 1 than the connecting pads 43 (see Fig. 9) will be immediately underneath the decode/drive chip 36 whereas on the under side of that foil means the ground line 38 will be applied to a coil ground connection 46 at the ultimate edge area of that foil means.

Fig. 10 shows as slightly different design from the head assembly shown in Fig. 1. The difference is that the design of the return flux is differently shaped. The magnetic foil 8 with its part 47 is sliding on the surface 5 of magnetic drum forming the image carrier 4. Thus foil 8 resting with its relatively long part 47 on surface 5, itself forms the return flux means. No magnetic reinforcement block as in Fig. 1 is needed therefore. By an appropriately shaped inner plastic part 48, over which foil 8 is guided in its direction turning area 49, foil 8 is given the direction to form an appropriately arced slope for resting with its part 47 on surface 5 on image carrier 4. By an appropriately shaped outer plastic part 50 foil 8 is held in its shown position. Furthermore, this outer plastic part is used to have attached to it the printed circuit foil means carrying ground and connector lines to chip 36 and coil ground connection 46.

A magnetic printing head for writing on a image carrier 4 of a length (or width respectively) of 30 cm, would have to include three linear arrays 1 for the odd heads and three linear arrays 2 for the even heads, attached to each other precisely so that the magnetic elements 3 are all in line and in exact spacing arranged. This on the other hand provides that it would be possible to have masks for producing printed circuit foils in a widths about 10 cm in one piece. This is feasible with techniques nowadays available.

Claims

1. Magnetic print head comprising at least one linear array (1,2) of magnetic printing elements (3), each of said magnetic printing elements being sur-

rounded by electrical windings (16,17) controlling the magnetic flux in each of said magnetic printing element, said windings being attachable to electric control circuits (36), characterized in that

said linear array of printing elements comprises

a) a thin flexible foil (8) of magnetic material out of which adjacent to one edge (9) a comb-like structure (10) of magnetic elements (3) is worked out, e.g. by etching;

b) a first thin flexible foil means (14;37,44) which is provided on one side with a structure of a first half of the electrical windings (16), and which is provided on its reverse side with connecting ground (17;38,39) and control (18;40,42) lines;

c) a second thin flexible foil (15,45) on which is provided on one side the complementing second half of the electrical windings;

d) both foils (14;37,44;15,45) carrying said halves of the electrical windings being performed as printed circuits;

e) said first and said second foil carrying said halves of the electrical windings being connected, e.g. by soldering such that a separate continuous winding surrounds each single magnetic element (3), and

f) said continuous windings being arranged as close as possible to the open tip ends (6) of said magnetic elements (3).

2. Magnetic print head as in claim 1, wherein said magnetic material of said foil of magnetic material is amorphous and preferably made of a NiFe alloy as e.g. permalloy.

3. Magnetic print head as in claim 2, wherein said magnetic foil has a thickness in the order of the width of the tip of each individual magnetic element.

4. Magnetic print head as in claim 2 or 3 wherein said magnetic foil consists of two foils closely attached and fixed to each other.

5. Magnetic print head as in anyone of the preceding claims, wherein the printed lines (16) forming said half-windings are closer to the magnetic element (3) than their supporting foils (14,15) (Fig. 5, Fig. 6A).

6. Magnetic print head as in anyone of the preceding claims, wherein the end areas (21,30) of each printed electric line (16) forming part of said half-windings are covered with tin (22,32), said tin being used to form the connection between said half-windings.

7. Method for producing a magnetic print head comprising a linear array (1,2) of printing elements (3), each of said printing elements consisting essentially of a magnetic element (3) and a surrounding electric winding (16), said electrical winding generating and controlling the magnetic flux in each of said magnetic elements, and said electrical windings being attachable to electric control cir-

cuits (36), said method especially for producing a magnetic print head as in anyone of the claim 1 to 6,

being characterized by

a) etching out of a thin and flexible magnetic foil (8) a comb-like structure (10) of magnetic elements (3) adjacent to one edge (9,13) of said foil;

b) said foil consisting out of an amorphous NiFe alloy such as permalloy;

c) providing a first thin flexible foil means (14;37,44) with printed circuit lines (16) forming a first half of said electrical windings on one side and providing said same foil with printed circuit lines forming connecting ground (17;38,39) and control (18;40,42) lines on its reverse side;

d) providing a second thin flexible foil (15,45) with printed circuit lines (16) which form a complementary second half of said electrical windings;

e) placing said magnetic foil between said first and said second foil carrying said half-winding structures; and

f) connecting said two printed circuit lines carrying foils such that each single magnetic element is surrounded by a complete and separate continuous electric winding.

8. Method as in claim 7, wherein said connecting is performed by soldering together the end areas (21,30) of each printed circuit line forming said half-windings on said two oppositely arranged printed circuit foils.

9. Method as in claim 7 or 8 wherein said soldering is performed by two soldering irons (24,25) which are provided with micro-mechanically formed heating ribs (26,27), said heating ribs having a distance (p) corresponding to the spacing of the magnetic printing elements (3), said two soldering irons being approached (28,29) to each other such that the ribs facing each other are close enough for pressing the half-winding line end areas together and allowing heat transfer for soldering in these areas.

10. Method as in claim 9, wherein one single rib of each soldering iron is used to solder two adjacent half-winding line end areas at the very same time.

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FIG. 1

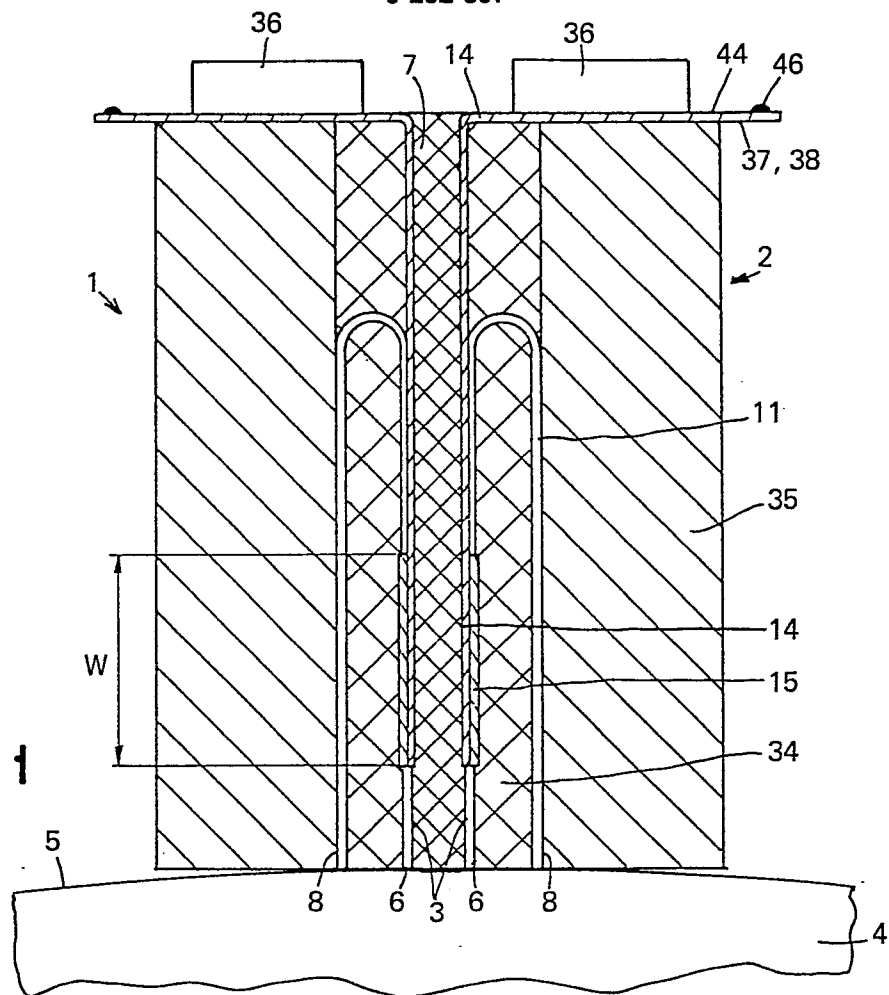
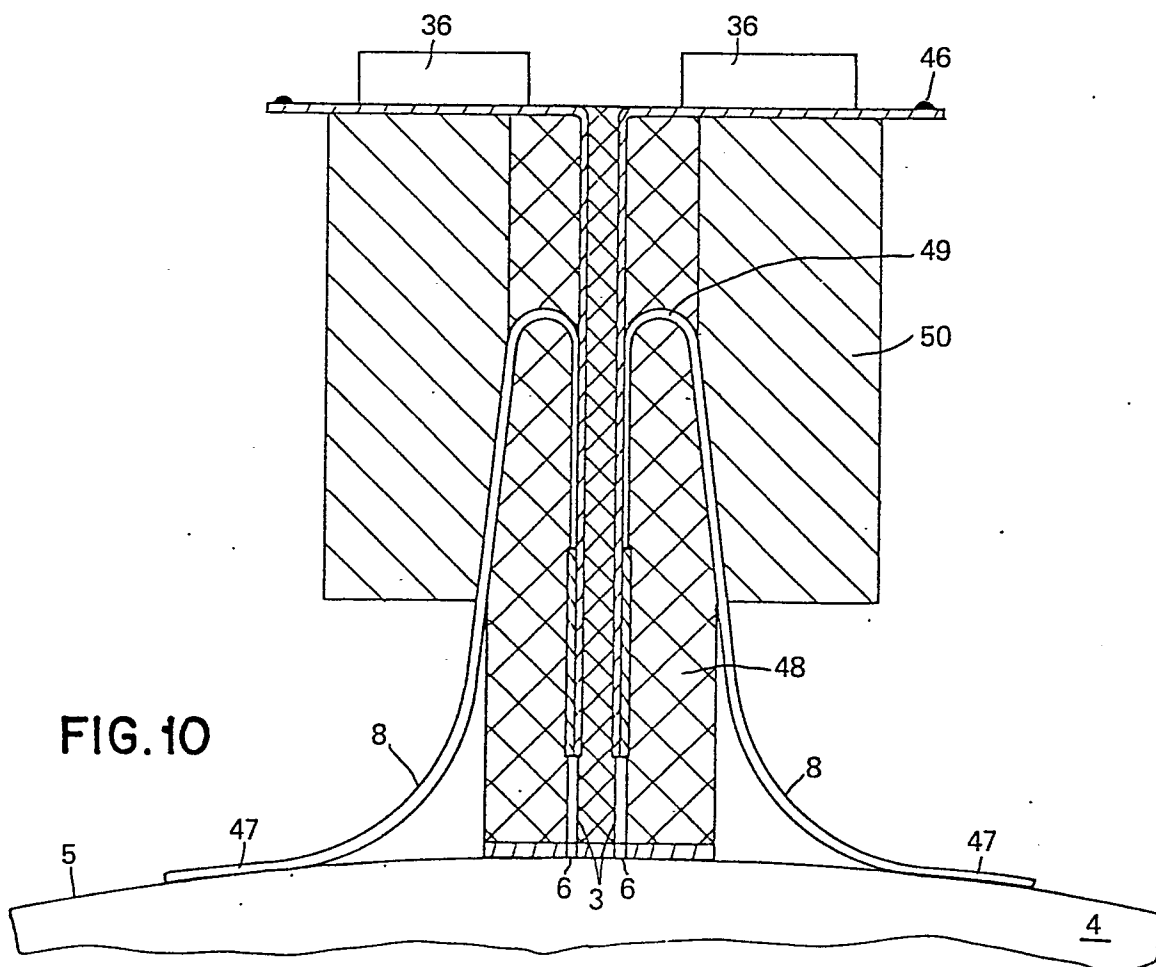


FIG. 10



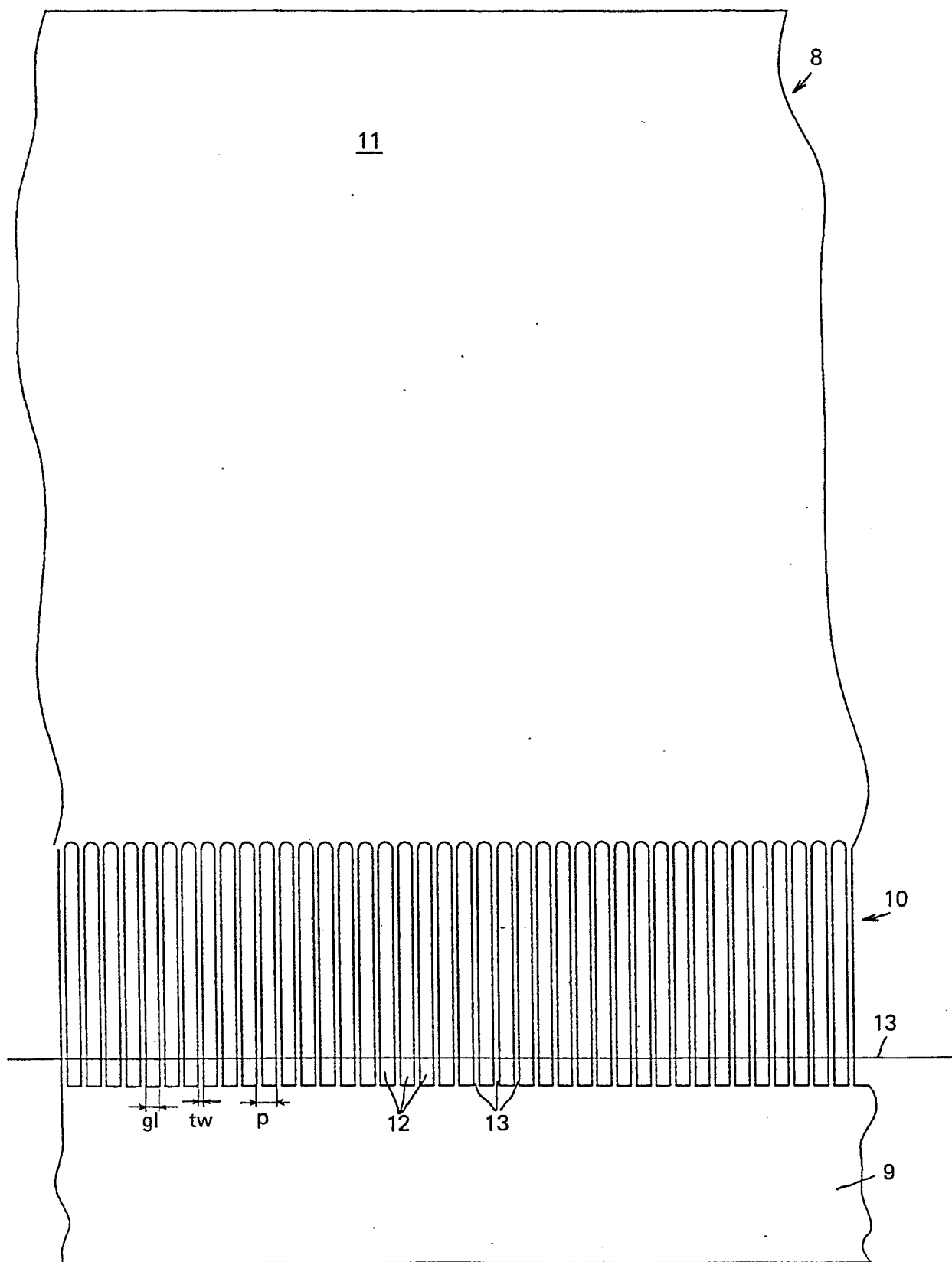


FIG. 2

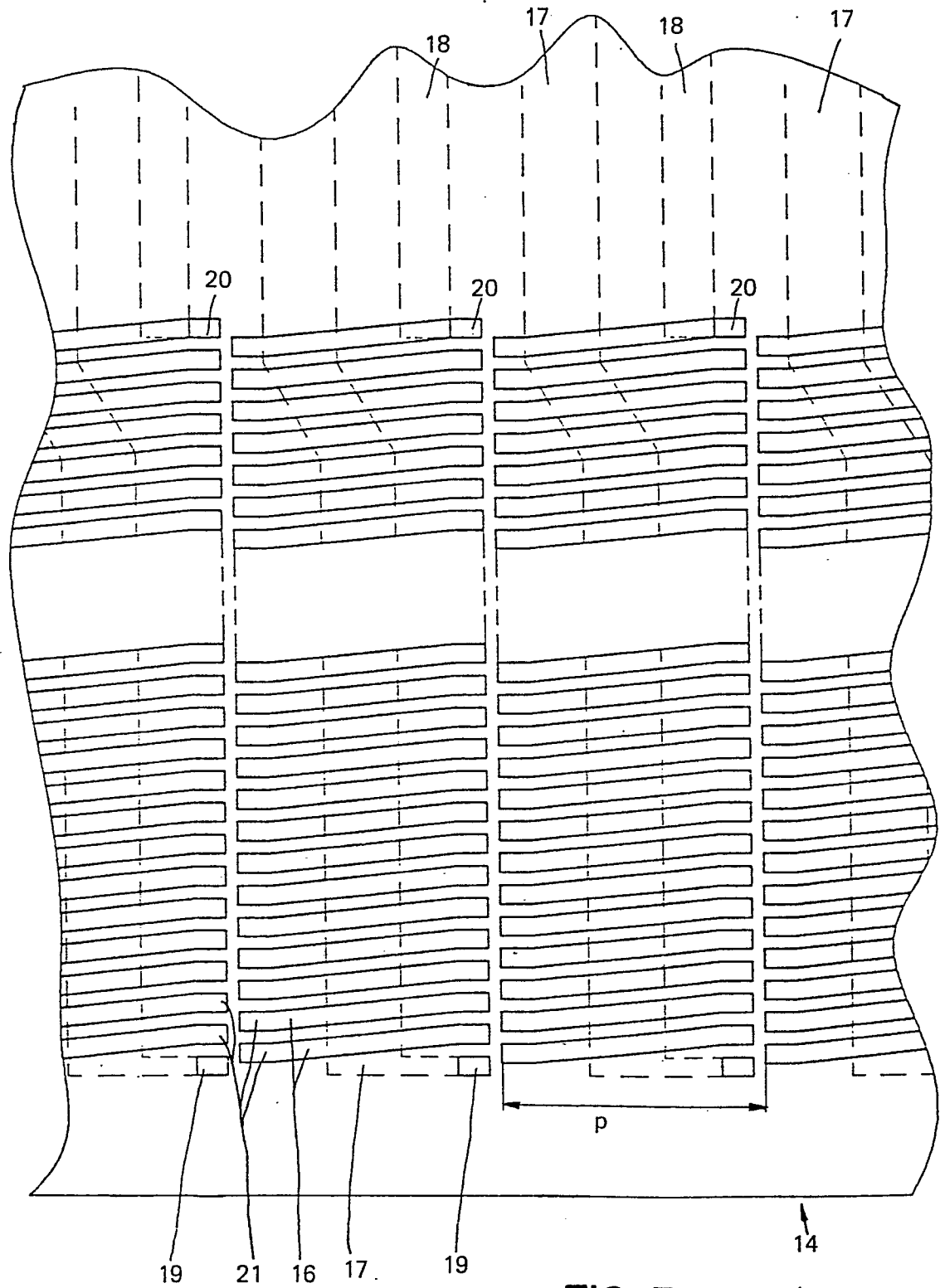


FIG. 3

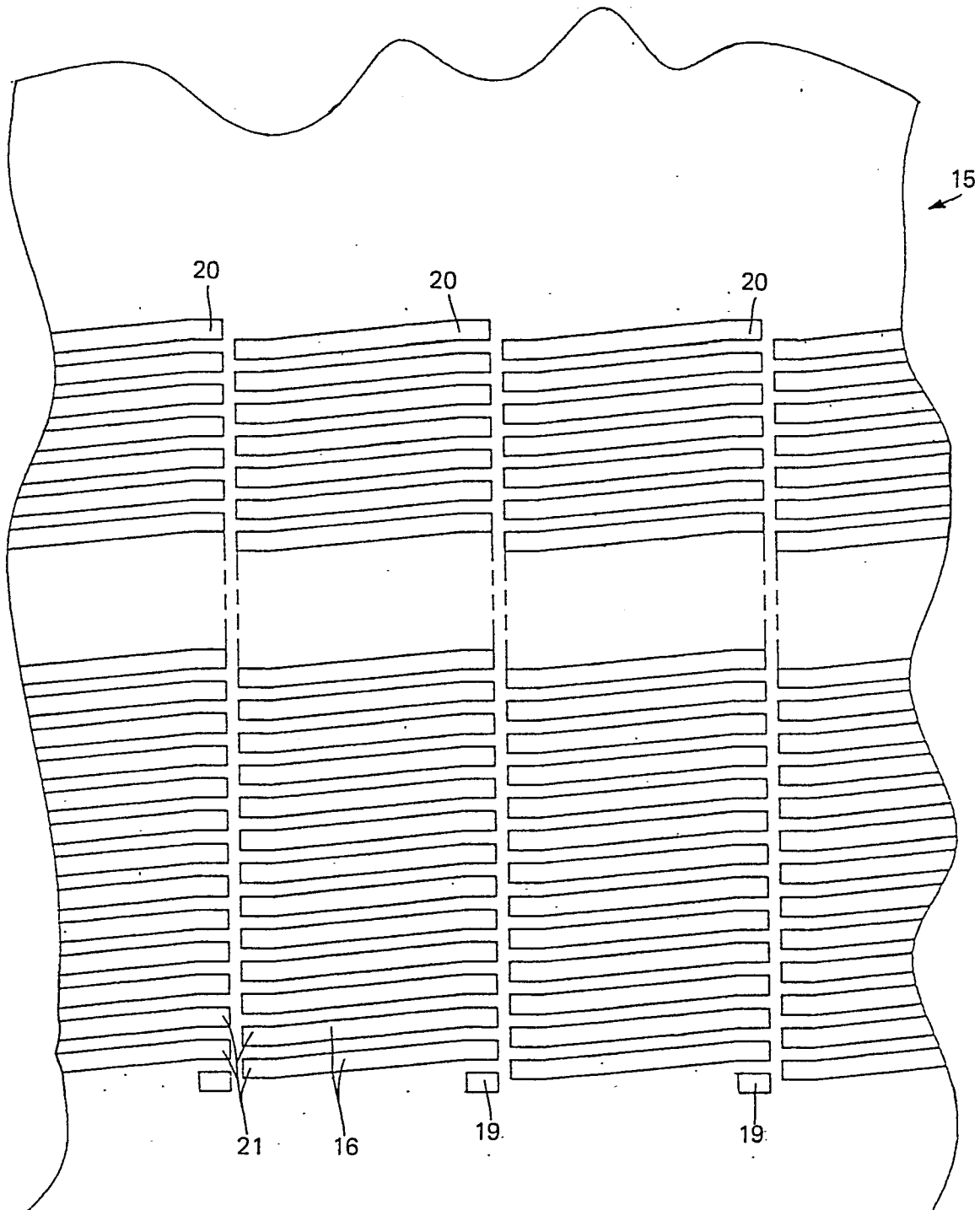


FIG. 4

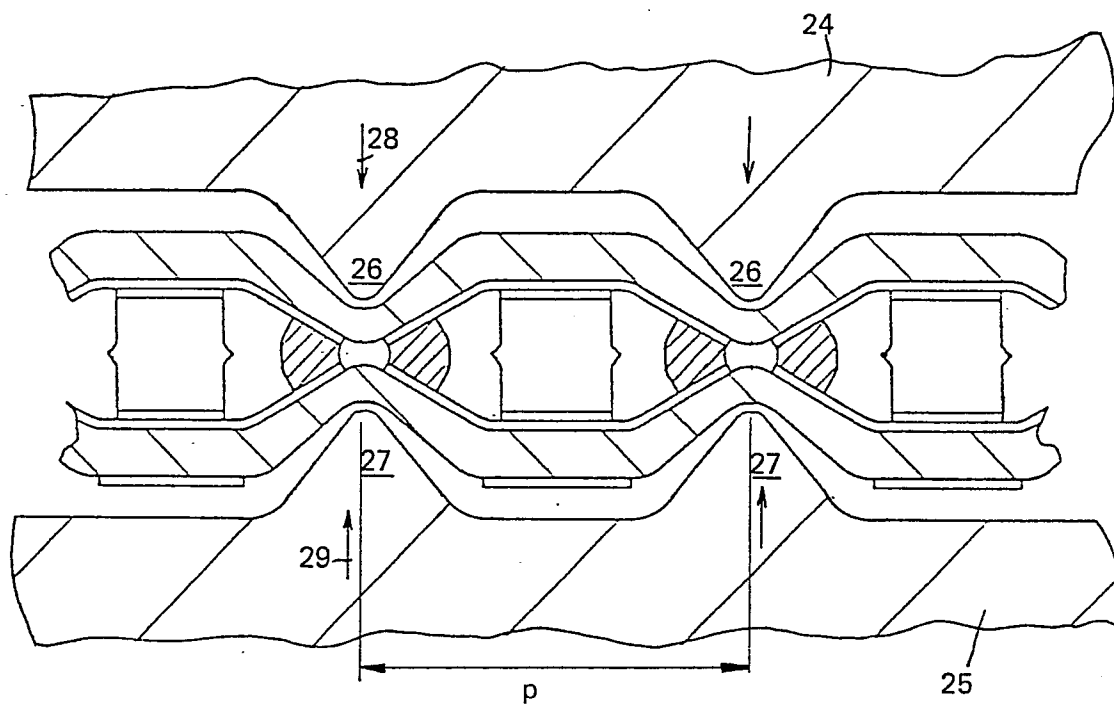


FIG. 6 A

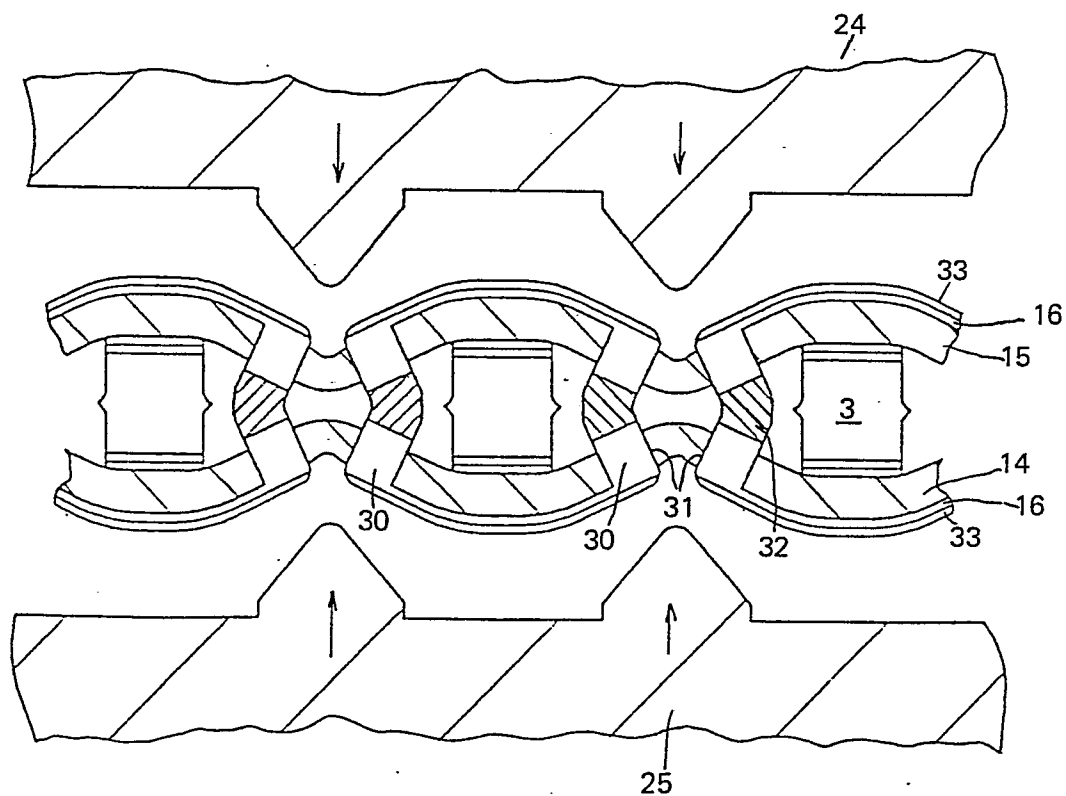


FIG. 6 B

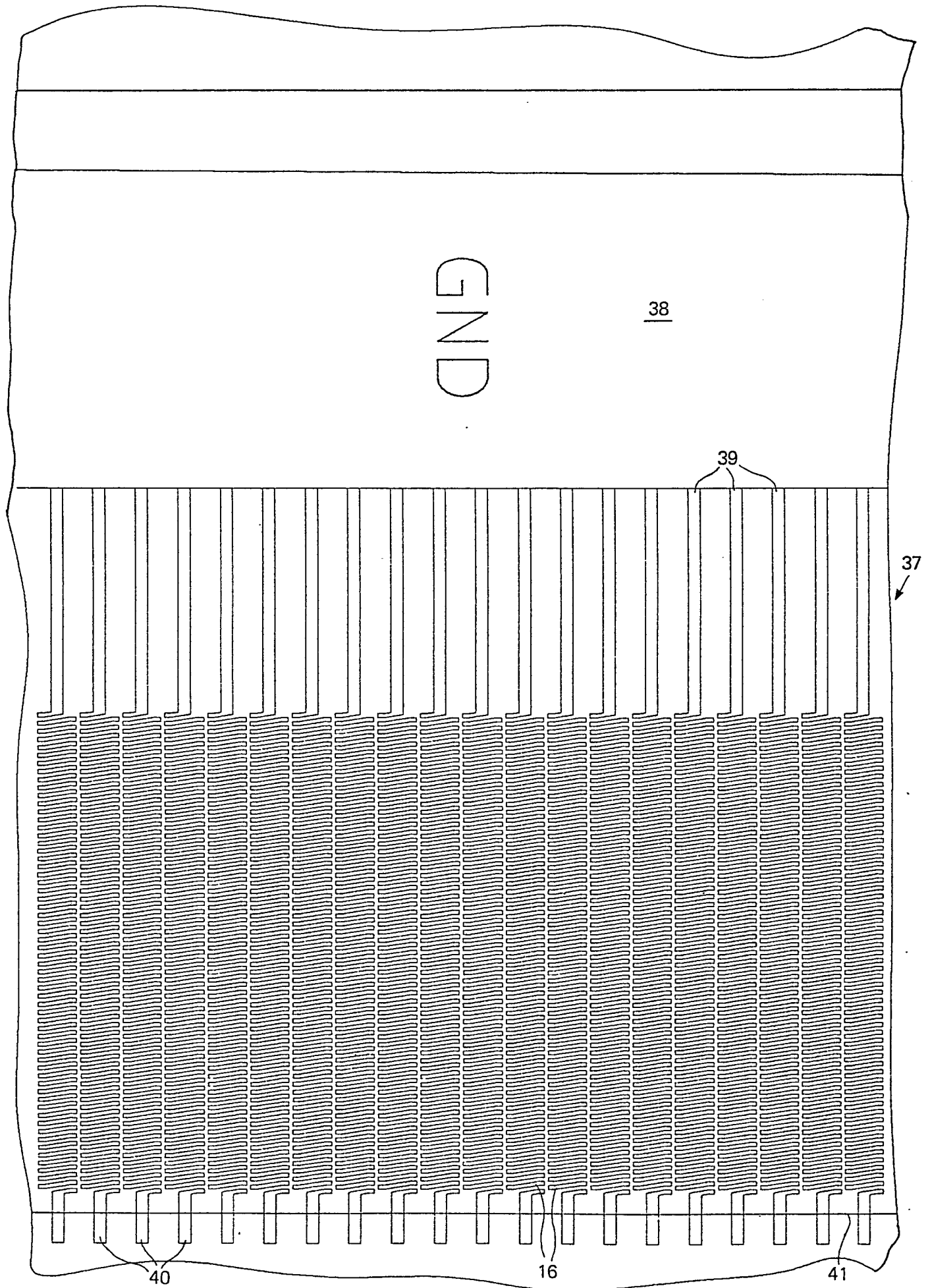


FIG. 7

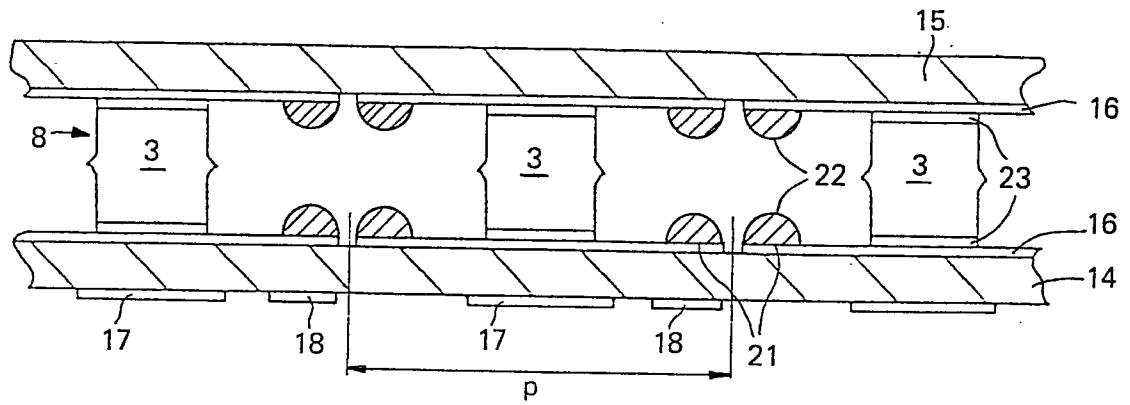


FIG. 5

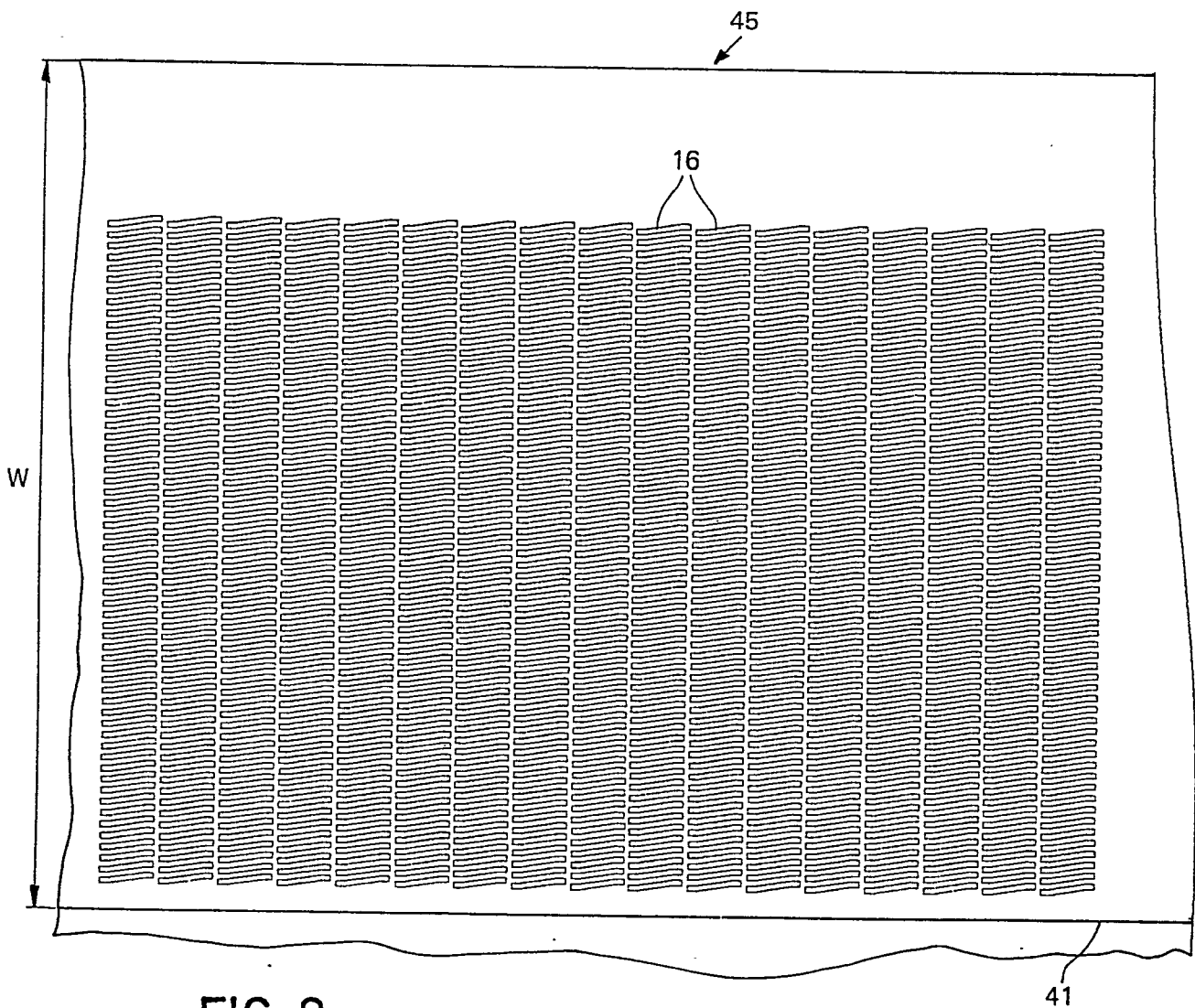


FIG. 8

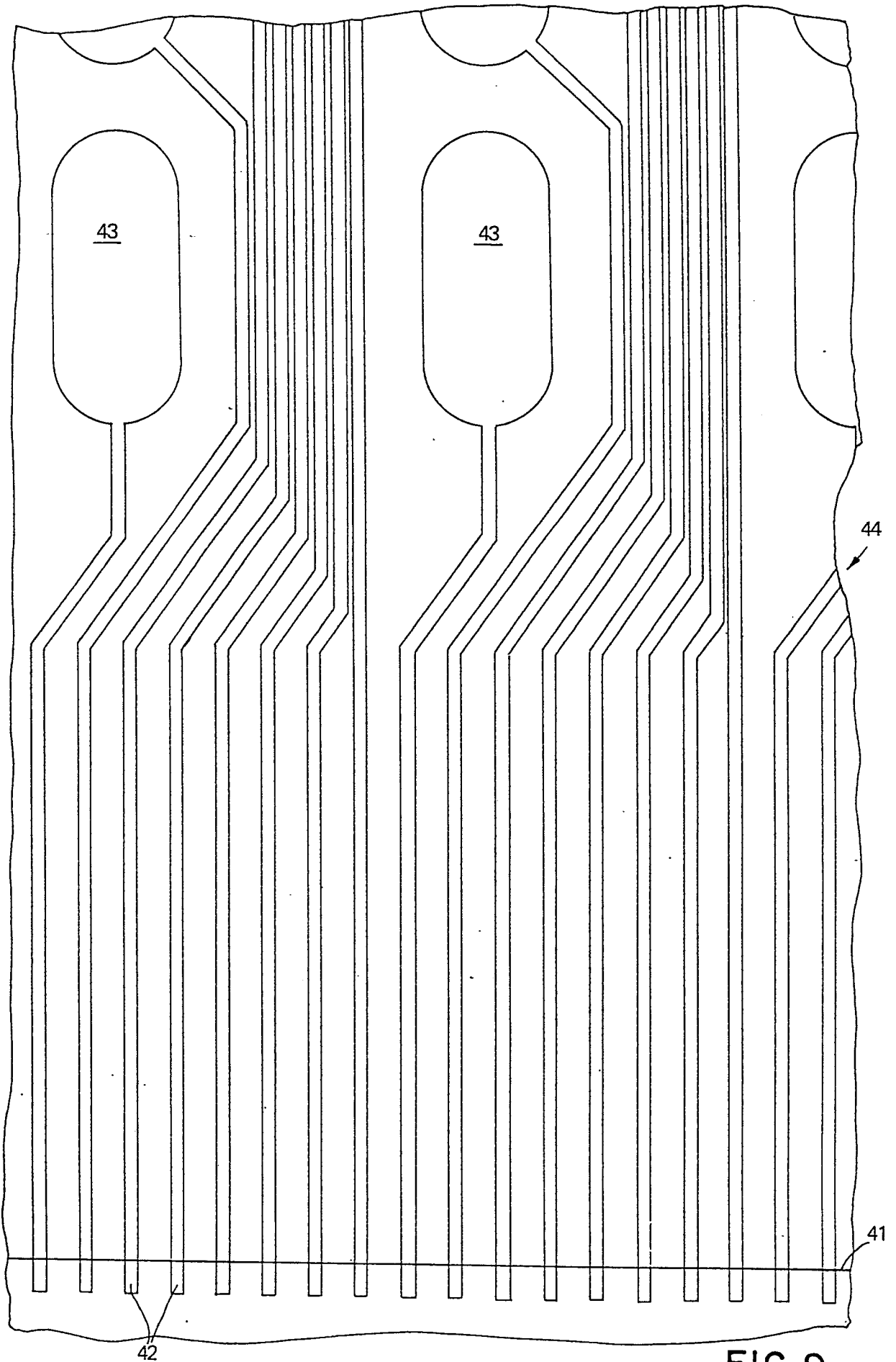


FIG. 9



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	GB-A-1 139 979 (STANDARD TELEPHONES AND CABLES LTD) * Page 1, lines 25-33,42-50,67-70; page 2, lines 4-42; figure 2 *	1-3,7	B 41 J 3/16
A	US-A-3 683 105 (M.B. SHAMASH) * Figures 10,11; column 2, lines 31-35 *	6,8,9, 10	
D,A	US-A-4 370 661 (A.E. BERKOWITZ)		
A	US-A-4 328 503 (A.E. BERKOWITZ)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 41 J G 03 G G 06 K H 05 K
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 27-01-1988	Examiner ROBERTS N.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	