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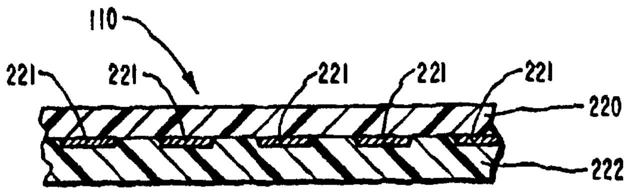

(57) Abstract

An electromagnetic transducer diaphragm (110) having an electrical conductor layer (221), with a conductor pattern, positioned between two insulating layers (220, 222) of a flexible, electrically insulating material bonded together to protect the diaphragm. An electrical current can flow through the conductors to produce magnetic and electrostatic fields around said conductors which interact with an electromagnetic field to produce mechanical displacement of the diaphragm which is turn produces an audio signal. Non-ferrous supports can be used to support the diaphragm. A magnet or magnets may be used to create the electromagnetic field. The magnets can be bonded to the cross arms of the non-ferrous support.

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PLANAR ELECTROMAGNETIC TRANSDUCER

BACKGROUND OF THE INVENTION

This invention relates to a planar electromagnetic transducer that is capable of transforming an electrical signal into movement of a diaphragm. It is also capable of transforming the movement of a diaphragm into an electrical signal. It can be used in loudspeakers, headphones, microphones, or other devices of a similar nature.

A discussion of the advantages and disadvantages of planar electromagnetic loudspeakers, and a description of the state of the art, is contained in U.S. Patent 4,837,838, to Thigpen, entitled "Electromagnetic Transducer of Improved Efficiency."

Thigpen also discloses an electromagnetic transducer in which an electrically conductive diaphragm is positioned between two sets of magnetic assemblies. The magnets within the assembly are affixed in elongated U-shaped channels of ferrous material. The ferrous frame contributes to the difficulties assembling the large, powerful magnets to within the frame. The electrical conductor elements are locked on the outside of the diaphragm. The conductors are thus exposed to environmental damage and also present a shock hazard to persons inadvertently contacting the diaphragm.

SUMMARY OF INVENTION

The electromagnetic transducer disclosed herein improves on the state of the art planar electromagnetic transducer diaphragms by providing an additional layer of insulating material over the conductors. This layer provides protection of the conductors against oxidation or other environmental damage, which allows the transducer to operate in a wider range of environments, such as high humidity or corrosive atmospheres. The insulating layer also protects against mechanical damage, such as abrasion, to the conductors, and prevents open circuits in the conductive pattern. The additional layer of insulating material also prevents the conductors from contacting the magnet assembly or other conductive parts of the transducer, reducing the possibility of short circuits and eliminating potential shock hazards.

Furthermore, the insulating layer may comprise multiple layers. These multilayers maybe fabricated of different materials. Thus, the resonant frequency of the diaphragm, may be controlled. In addition, different regions of the diaphragm may have different resonant frequencies so that any frequency response peaks are eliminated or less pronounced. Similarly, the insulating layers can be used to minimize the effect of changes in ambient temperature on the diaphragm by selecting insulating materials having appropriate temperature coefficients.

The inclusion of insulating layers over the conductors also permits the coil formed by the conductors on the diaphragm to have multiple conductors not only in the plane of the diaphragm, but also perpendicular to the plane of the diaphragm. This stacking of coils provides more conductors within the magnetic or electrostatic flux field of the transducer, with a resulting increase in efficiency.

The electromagnetic transducer disclosed herein invention also provides an improved means for producing the magnetic field in which the diaphragm is placed. A non-ferrous support for the magnets is used. The non-ferrous support does not distort the magnetic field and can provide additional protection against a short circuit with the conductors on the diaphragm if an insulating plastic is used as the non-ferrous support. The non-ferrous support can also provide environmental protection to the magnets. The support can be, for example, crossarms to which the magnets are attached, or a frame or block which supports the magnets.

The magnetic assembly can be produced using a novel technique that eliminates the difficulties associated with assembling a rigid structure having powerful permanent magnets. These magnets produce strong opposing forces between adjacent magnets on the same side of the diaphragm, and strong attractive forces between magnets on opposite sides of the diaphragm. This assembly technique results in a precisely aligned magnet structure, and a resulting improvement in the linearity and efficiency of the transducer.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 depicts an embodiment of the inventive transducer when viewed from the front;

Fig. 2 is a cross-sectional view of the transducer at the cut point indicated in Fig. 1;

Fig. 2A depicts the cross-section of the diaphragm in greater detail;

Fig. 3 depicts a possible means for supporting the magnets of the transducer;

Fig. 4 depicts an alternative magnet support structure;

Fig. 5 depicts a possible pattern of conductors on the diaphragm;

Fig. 6 depicts an alternative arrangement of conductors within the diaphragm allowing more than a single conductor layer;

Fig. 7 is an exposed view at the point indicated in Fig. 1, depicting how distinct patterns of conductors are connected to an outside signal source; and

Fig. 8 depicts how multiple instances of the transducer can be connected to form a system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 depicts an embodiment of the planar electromechanical transducer as seen from the front of the transducer. Fig. 2 is a cross-sectional view of the transducer at the cut indicated on Fig. 1. With reference to Fig. 1, the major components of this embodiment of the electromagnetic transducer are a multilayered diaphragm 110, a frame 101 supporting diaphragm 110, and two magnet assemblies, one on each side of diaphragm 110. The front magnet assembly has a number of elongated permanent magnets 105 supported by cross-arms 102, while the back magnet assembly has permanent magnets 106 supported by cross-arms 103. The frame 101 and front and back magnet assemblies (i.e. magnets 105 with cross-arms 102 and magnets 106 with cross-arms 103) are joined together by screws 104 and spacers 111 and 112 as depicted in Fig. 2.

Diaphragm 110 has three layers as depicted in Fig. 2A. An electrical conductor layer 221 is enclosed between two electrically-insulating layers 220 and 222. The electrical conductor layer 221 has one or more conductors (in this embodiment layer 221 has a plurality of conductors in the form of coils - see Fig. 5). In operation, electrical conductor layer 221 is suspended within an electromagnetic field. When an electrical current flows through the conductors, both magnetic and electrostatic fields develop around each conductor. These fields interact with the electromagnetic field in which the diaphragm is suspended, resulting in a force that displaces the diaphragm either toward the front or rear of the transducer, depending on the direction and magnitude of the current flowing through the conductors. This mechanical displacement of the diaphragm moves the surrounding air to create an audio signal corresponding to the electrical signal applied to the conductors, so that the transducer acts as a loudspeaker. A smaller version of the transducer could be used in a headphone.

Without any changes, this embodiment of the transducer can also generate an electrical signal based on the displacement of the diaphragm, as might be caused by audio vibrations from the surrounding air, permitting its use as a microphone. In this case, the movement of the conductors within the electromagnetic field induces a current flow in the conductors. These two modes of operation are common to most electromagnetic transducers. To simplify the following discussion, only the mode of operation where an electrical input signal causes the displacement of the diaphragm is discussed, but it should be kept in mind that the transducer can also be used to generate an electrical signal and, therefore has other applications (e.g. as a microphone).

Although a preferred embodiment uses permanent magnets to generate the electromagnetic field, a number of other techniques exist. For example, the electromagnetic field can also be formed by one or more electromagnets or can be an electrostatic field, such as a field found between two charged plates.

In the preferred embodiment, the electromagnetic field is generated by the use of permanent magnets 105 and 106 supported by cross-arms 102 and 103 as shown in Fig. 2. Permanent magnets 105 are arranged so that they have the same polarity (either north or south) toward diaphragm 110 and permanent magnets 106 are arranged so they have the opposite polarity as magnets 105 toward diaphragm 110. The center-to-center spacing between magnets 105 is uniform and identical to the center-to-center spacing between magnets 106. Magnets 105 are offset from magnets 106 so that the centerline of each magnet 105 corresponds to the center of the space between two magnets 106 as shown in Fig. 2. This results in a linear pattern for the lines of flux between magnets 105 and 106.

There are a number of ways of attaching permanent magnets 105 and 106 to support cross-arms 102 and 103. In this preferred embodiment of the invention, as shown in Fig. 2, the castings of magnetic material 210 are bonded to backings 211 made of non-ferrous material, such as fiberglass or plastic. Magnetic material 210 can be bonded to backings 211 by epoxy resin or any other suitable means of bonding or attachment. Backings 211 are bonded to the cross-arms 102 or 103 using epoxy resin, plastic rivets or screws, or any other suitable means of attachment. Preferably the backing or other attachment means is made from a non-ferrous material so as to minimize any adverse effect on the linearity of the magnetic field. Non-ferrous material can also be used for cross-arms 102 and 103 to minimize unwanted coupling of magnetic fields of two adjacent magnets. The non-ferrous cross-arms provide the non-ferrous support for magnets 105 and 106. This non-ferrous support and the magnets form the magnetic assembly. Other forms of support for the magnetics can be used (e.g. see Fig. 4). As depicted in Fig. 3, the magnetic material (e.g. magnets) 351 can be enclosed in enclosure 352 which is a rectangular tube plastic extrusion (or other form of enclosure). Other enclosures or partial enclosures of non-ferrous material can be used to enclose or partially enclose the magnetic material. The enclosure (or partial enclosure) can be color-coded to indicate the frequency range of the transducer or for other informational purposes. The non-ferrous material used for the support can be any non-ferrous material which has sufficient structural integrity to support magnets 105 and 106. Fiberglass and plastic are well suited for this purpose.

As depicted in Fig. 2, cross-arms 102 and 103 are attached to frame assembly 101 with screws 104. Frame 101 supports diaphragm 110. Spacers 111 and 112 separate cross-arms 102 and 103 from frame 101 by a fixed distance. The distance between diaphragm 110 and magnets 105 and 106 can be varied to produce transducers with different frequency response characteristics. An increase in distance results in a transducer with a lower frequency response.

Fig. 4 depicts an alternative means for supporting the magnets. Instead of cross-arms, a formed block of non-ferrous material 400 is used. The block functions as a frame which supports the magnets. Any plastic or other non-ferrous material with suitable strength can be utilized for this support. The block can be formed by many different methods including, but not limited to, thermo-forming, vacuum forming, injection molding, or machining. Machined into block 400 are channels 402 to hold magnets 401, and openings 403 that allow the sound produced by the transducer to leave the transducer. Magnets 401 are bonded to block 400 in channels 402 using epoxy resin or any other suitable means of attachment. Raised portions 404 of block 400 act as spacers 111 and 112 (depicted in Fig. 2) to provide a means of attachment to frame 101 supporting diaphragm 110.

A preferred technique for constructing the magnets is to use unmagnetized Alnico (aluminum, nickel and cobalt) alloy material, either precast into the desired elongated shape if the magnets are to be bonded to a non-ferrous backing support or as a powder poured into an extruded rectangular tube support. After all parts of the magnet assembly have been connected together, the entire assembly can be placed within an electromagnet or solenoid powered by the discharge of a capacitor bank. Activation of the electromagnet or Solenoid produces a large electromagnetic pulse that magnetizes the magnetic material of the assembly with the desired polarity.

As shown in Fig. 2A, diaphragm 110 has an electrical conductor layer 221 (i.e. conductors 221) positioned between two layers of electrically-insulating material 220 and 222. The materials for insulating layers 220 and 222 preferably are thick enough to prevent damage at the maximum excursion of diaphragm 110. However, if the materials are not flexible enough, a strong input signal will be necessary to produce the desired diaphragm displacements, resulting in low speaker efficiency. A 1 mil thin-film polyester, such as Mylar, for layer 220 and a 1 mil thin-film silent such as Kapton Type H, for layer 222 (both manufactured by E. I. DuPont de Nemours & Co., Inc. of Wilmington, Delaware) have proven satisfactory. Different thicknesses and a broad range of electrically insulating materials can be used. Different electrically insulating materials can be used to alter the frequency response of the transducer. Because of the natural attraction between the Mylar and the Kapton layers, no adhesive or other means is needed to bond the two layers together. Preferably, the insulating materials are different and have an attraction to each other that facilitates bonding. Electrical conductor layer 221 is positioned between (and in this embodiment is enclosed by) insulating layers 220 and 222.

Electrical conductor layer 221 can be produced from light gauge wires sandwiched between insulating layers 220 and 222. The conductor layer may be formed by printing or plating the wires to one of the insulating layers, or by laminating or vapor depositing a metallic coating on one of the insulating layers, and then removing the metal by etching (or a similar process) from those areas where conductors are not desired.

Any other means for producing one or more electrical conductors for the electrical conductor layer can be used.

For example, a metal removal method using an aluminized Mylar such as Colortone from Hurd Hastings can be employed to form one of the insulating layers and the conductors. A pattern consisting of the negative of the desired conductor pattern is printed on a sheet of paper using either an electrostatic copier or a laser printer. The side of the paper with the pattern is then placed against the aluminized side of the Mylar, and both are run through a heat and pressure fuser similar to one found on an electrostatic copier or laser printer. This results in the aluminum bonding to the negative pattern because of the pattern's higher temperature. When the paper and the Mylar are separated, the desired conductor pattern remains on the Mylar.

As mentioned previously, diaphragm 110 is supported by frame 101. As seen in Fig. 2, frame 101 can be made from identical subframes 201 and 202. Diaphragm 110 is sandwiched between the two subframes, with double-sided adhesive strips 203 used to further secure diaphragm 110 to subframes 201 and 202.

As depicted in Fig. 5, the electrical conductors of layer 221 of diaphragm 110 are in the form of separate coils 312. When a voltage is placed across terminals 301 and 302, an electrical current flows such that the vertical direction of the current in coil region 313 is opposite the vertical direction of the current flowing in region 314. The length of coils 312 is such that horizontal conductor regions 310 and 311 are outside the principle magnetic flux field produced by magnets 105 and 106.

The width of each coil 312 is identical to the center-to-center spacing of magnets 105 (which, as previously discussed, is also the center-to-center spacing of magnets 106). Diaphragm 110 is positioned in frame 101 such that the center of each coil 312 corresponds to the center of each front magnet 105. The number of vertical conductor lines in regions 313 and 314 of coils 312 depends on the width of the conductor. A smaller conductor line width enables the placement of more conductor lines in the regions and thereby results in an increased impedance for the coils and also increases the force between the coil and the magnets, thus improving the efficiency of sound production.

Fig. 6 illustrates how the diaphragm can be further layered to permit a plurality of conductor layers. Fig. 6 depicts an implementation with three conductor layers 605, 606, and 607, contained within electrically insulating layers 601, 602, 603, and 604. Using a plurality of conductor layers such as shown in Fig. 6 allows more vertical conductors to be placed within the electromagnetic field, thereby improving the efficiency of the transducer. The depiction of three conductor layers in Fig. 6 is merely illustrative of how the invention allows a plurality of conductor layers, and should not be viewed as limiting the scope of the invention to a particular number of conductor layers.

As seen in Fig. 5, each coil has two terminals 301 and 302. Fig. 7 shows one possible way of connecting these coils together and to the signal source. Double-sided printed circuit card 701 contains conductive traces 702 and 703 on one side and plated-through holes 704 and 705 which provide an electrical connection to contact points 301 and 302 on the side of card 701 opposite the conductive traces 702 and 703. Contact point 705 is pressed against coil terminal 301 and contact point 704 is pressed against coil terminal 302 to provide the necessary electrical connections. Depending on the pattern of traces 702 and 703, the coils can be connected in series, parallel, or any other series-parallel configuration. A configuration means, such as switches, can be used to select different series-parallel configurations, allowing the user to alter the impedance of the transducer to match the signal source.

Fig. 8 illustrates how two or more planar electromagnetic transducers can be combined to form a system capable of handling higher power, producing more acoustic energy, or providing better frequency response. Each transducer 801 is attached to a frame 802, which can be made of a material such as plastic, for good protection against environmental concerns, or wood, providing a pleasing appearance for a loudspeaker used in a home audio system.

The individual transducers of the system can be connected either as a series electrical circuit, giving a system impedance equal to the sum of the impedances of the transducers; a parallel circuit, giving a system impedance equal to the impedance of an individual transducer divided by the number of transducers; or a series-parallel circuit, giving an impedance somewhere between these two values. A configuration means, such as switches, can be used to select different series-parallel configurations, allowing the user to alter the impedance of the transducer to match the signal source.

Alternatively, the individual transducers can be configured with different frequency responses by using different materials for the diaphragm or by varying the distance between the diaphragm and the magnets. A frequency selective network, such as a cross-over network commonly employed in conventional speaker systems, can be used to route the appropriate frequency ranges from the input signal to the proper transducers. The techniques for connecting multiple transducers using a frequency selective network is well known to persons with ordinary skills in the art. To aid in the identification of transducers with particular frequency ranges, their diaphragms can be constructed from color-coded material and the magnet assemblies can be similarly color-coded.

It is to be understood that the above described arrangements are merely illustrative of numerous and varied other arrangements which may constitute applications of the principles of the invention. Such other may be readily devised by those skilled in the art without departing from the spirit or scope of this invention.

WHAT IS CLAIMED IS:

1. A flexible diaphragm for an electromagnetic transducer having interior and exterior regions comprising:

(a) a first insulating layer of flexible electrically-insulating material,

(b) a second insulating layer of flexible electrically-insulating material,

(c) an electrical conductor layer comprised of a conductor pattern and positioned between said first insulating layer and said second insulating layer,

wherein said exterior regions are free of an electrical conductor layer.

2. A flexible diaphragm as in claim 1, wherein at least one of said first and second insulating layers is formed of one of Kapton or Mylar.

3. A flexible diaphragm as in claim 1, wherein said second insulating layer is made of ink of the type used by an electrostatic copier.

4. A flexible diaphragm as in claim 1, wherein said second insulating layer covers only the conductor pattern portion of said electrical conductor layer.

5. A flexible diaphragm as in claim 1, wherein said conductor pattern is in the form of a coil.

6. A flexible diaphragm as in claim 1, wherein said first and second insulating layers are bonded together by the natural attraction of the materials forming said first and second insulating layers.

7. A flexible diaphragm as in claim 1 further comprising:

(d) a third insulating layer of flexible electrically-insulating material, and

(e) a second electrical conductor layer comprised of a conductor pattern and positioned between said second insulating layer and said third insulating layer,

wherein said exterior regions are free of an electrical conductor layer.

8. A flexible diaphragm as in claim 7, wherein at least one of said second and third insulating layers is formed of one of Kapton or Mylar.

9. A flexible diaphragm as in claim 7 further comprising:

(f) a fourth insulating layer of flexible electrically-insulating material, and

(g) a third electrical conductor layer comprised of a conductor pattern and positioned between said third insulating layer and said fourth insulating layer,

wherein said exterior regions are free of an electrical conductor layer.

10. A flexible diaphragm as in claim 9, wherein at least one of said third and fourth insulating layers is formed of one of Kapton or Mylar.

11. A flexible diaphragm as in claim 1 adapted to act in a microphone wherein a mechanical displacement of said diaphragm within an electromagnetic field produces an electrical current flow through said conductor layer.

12. A flexible diaphragm as in claim 11, wherein said mechanical displacement is produced by an audio signal.

13. A flexible diaphragm as in claim 11, wherein east one of said insulating layers is formed of one of Kapton or Mylar.

14. A flexible diaphragm as in claim 11, wherein said conductor pattern is in the form of a coil.

15. An electromagnetic transducer comprising:
(a) a flexible diaphragm having interior and exterior regions comprised of
(i) a first insulating layer of flexible electrically-insulating material,
(ii) a second insulating layer of flexible electrically-insulating material, and
(iii) an electrical conductor layer comprised of a conductor pattern and positioned between said first insulating layer and said second insulating layer,
wherein said exterior regions are free of an electrical conductor layer;
(b) means for supporting said diaphragm; and
(c) means for generating an electromagnetic field in which said diaphragm is placed.

16. An electromagnetic transducer in accordance with claim 15, wherein said electrical conductor layer comprises at least one conductor through which an electrical current can flow to produce magnetic and electrostatic fields around said at least one conductor; and wherein said magnetic and electrostatic fields can interact with said electromagnetic field to produce mechanical displacement of said diaphragm.

17. An electromagnetic transducer as in claim 16, wherein said mechanical displacement of said diaphragm produces an audio sound.

18. An electromagnetic transducer in accordance with claim 15, wherein said second insulating layer is made of ink of the type used by an electrostatic copier.

19. An electromagnetic transducer as in claim 15, wherein said means for generating an electromagnetic field comprises at least one magnet.

20. An electromagnetic transducer as in claim 15, wherein said means for generating an electromagnetic field comprises a first at least one magnet on one side of said diaphragm, and a second at least one magnet on the other side of said diaphragm.

21. An electromagnetic transducer as in claim 20, further comprising a non-ferrous support which supports said magnets.

22. An electromagnetic transducer as in claim 15, wherein said electrical conductor layer comprises a plurality of coils.

23. An electromagnetic transducer as in claim 22, wherein each coil of said plurality of coils is connected to an identical signal source.

24. An electromagnetic transducer as in claim 22, wherein said plurality of coils are connected in parallel to a plurality of signal sources.

25. An electromagnetic transducer system including a plurality of electromagnetic transducers of the type set forth in claim 15, wherein each said electromagnetic transducer has the identical frequency response and all said electromagnetic transducers operate together.

26. An electromagnetic transducer system including a plurality of electromagnetic transducers of the type set

forth in claim 15, wherein two or more of said electromagnetic transducers are optimized for different frequency response ranges.

27. An electromagnetic transducer as in claim 24, wherein two or more coils of said plurality of coils are configured to be optimized for different frequency response ranges.

28. An electromagnetic transducer comprising:

(a) a flexible diaphragm comprising

(i) an insulating layer of flexible electrically-insulating material,

(ii) an electrical conductor layer comprised of a conductor pattern,

(b) means for generating an electromagnetic field in which said diaphragm is placed, having at least one magnet; and,

(c) support means common to both the diaphragm and said at least one magnet including a one-piece formed block of non-ferrous material.

29. An electromagnetic transducer as in claim 28, wherein a first at least one magnet is positioned on one side of said diaphragm, and a second at least one magnet is positioned on the other side of said diaphragm.

30. An electromagnetic transducer as in claim 28, wherein said at least one magnet is magnetized after being affixed to said one-piece formed block of non-ferrous material.

31. An electromagnetic transducer as in claim 28, wherein said one-piece formed block includes at least one channel[s] for positioning and holding said at least one magnet.

32. An electromagnetic transducer comprising:

(a) a flexible diaphragm comprising
   (i) an insulating layer of flexible electrically-insulating material and
   (ii) an electrical conductor layer comprised of a conductor pattern;
(b) means for supporting said diaphragm; and
(c) a means for generating an electromagnetic field in which said diaphragm is placed, having at least one magnet affixed to a non-ferrous support assembly which is magnetically charged after being so affixed.

33. An electromagnetic transducer as in claim 37 wherein said at least one magnet is formed by pouring a mixture containing unmagnetized metal powder into individual non-ferrous support casings, sealing the support casings, affixing the support casings to the support assembly and then charging the entire magnetic support assembly.

34. An electromagnetic transducer as in claim 37 wherein said at least one magnet is charged in said non-ferrous support assembly by a solenoid powered by the discharge of a capacitor bank.

35. A method of constructing a flexible diaphragm for an electromagnetic transducer comprising the steps of:
(a) selecting a first insulating layer of flexible electrically-insulating material;
(b) affixing a layer of electrical conductor material on one side of said first insulating layer;
(c) printing a desired conductor pattern on said layer of electrical conductor material using a flexible electrically-insulating material;
(d) removing all portions of said layer of electrical conductor material not covered by said desired conductor pattern of flexible electrically-insulating material.

36. A diaphragm produced by the method of claim 41, wherein said first insulating layer is Mylar and said layer of electrical conductor material is aluminum.

37. A diaphragm produced by the method of claim 41, wherein said uncovered portion of said layer of electrical conductor material is removed by etching.

38. A diaphragm produced by the method of claim 41, wherein the flexible electrically-insulating material printed onto said layer of electrical conductor material is ink of the type used by an electrostatic copier.

39. A diaphragm produced by the method of claim 41, wherein said flexible electrically-insulating material printed onto said layer of electrical conductor material is printed by an electrostatic copier.

40. An electromagnetic transducer system having a plurality of electromagnetic transducers as in claim 26, wherein the frequency response ranges of said plurality of electromagnetic transducers are varied by selecting different materials for said insulating layers.

41. An electromagnetic transducer system having a plurality of electromagnetic transducers with different frequency response ranges as in claim 26, wherein the different frequency response ranges are denoted on the respective diaphragms by color-coding.

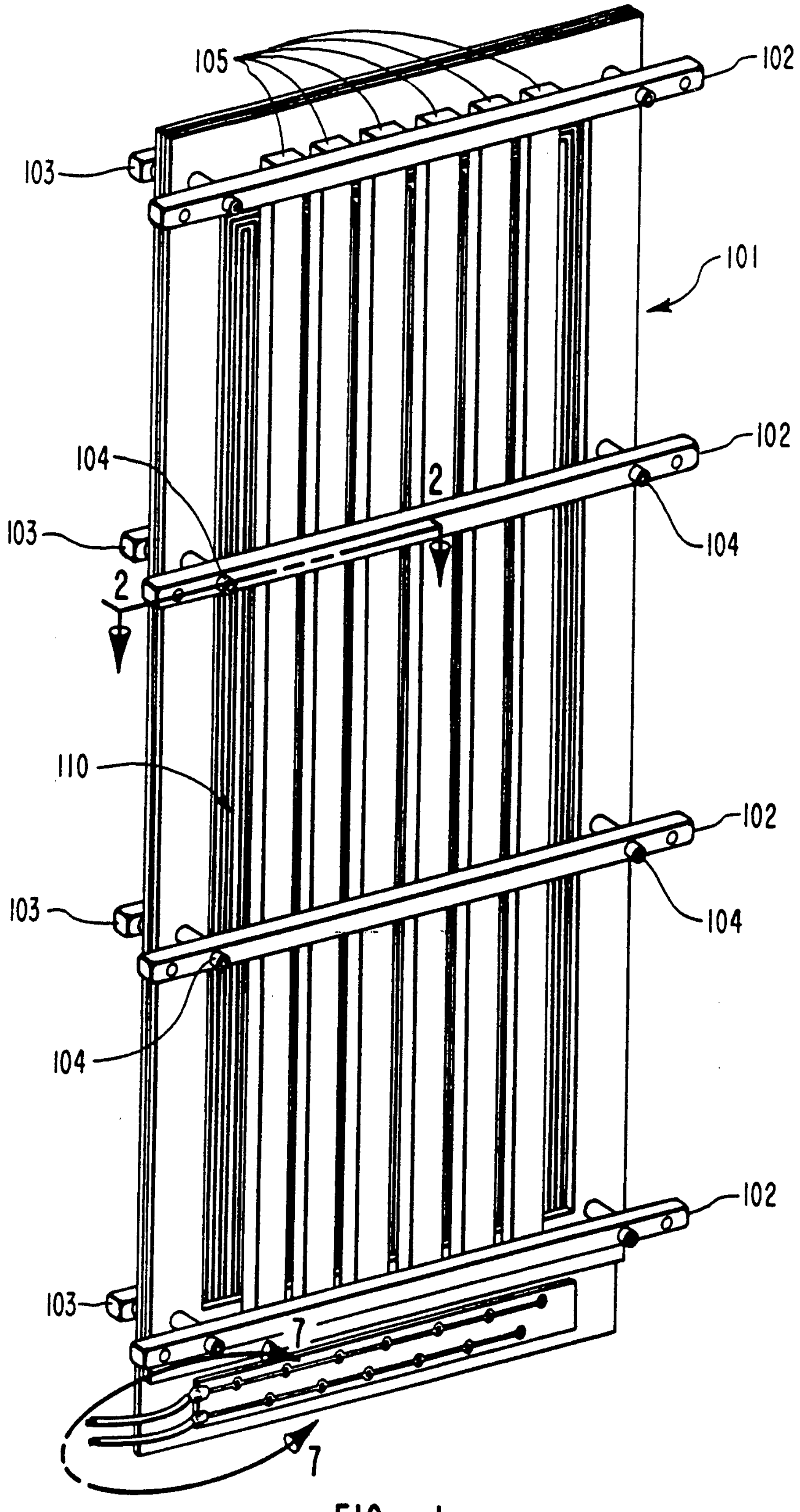

FIG. 1

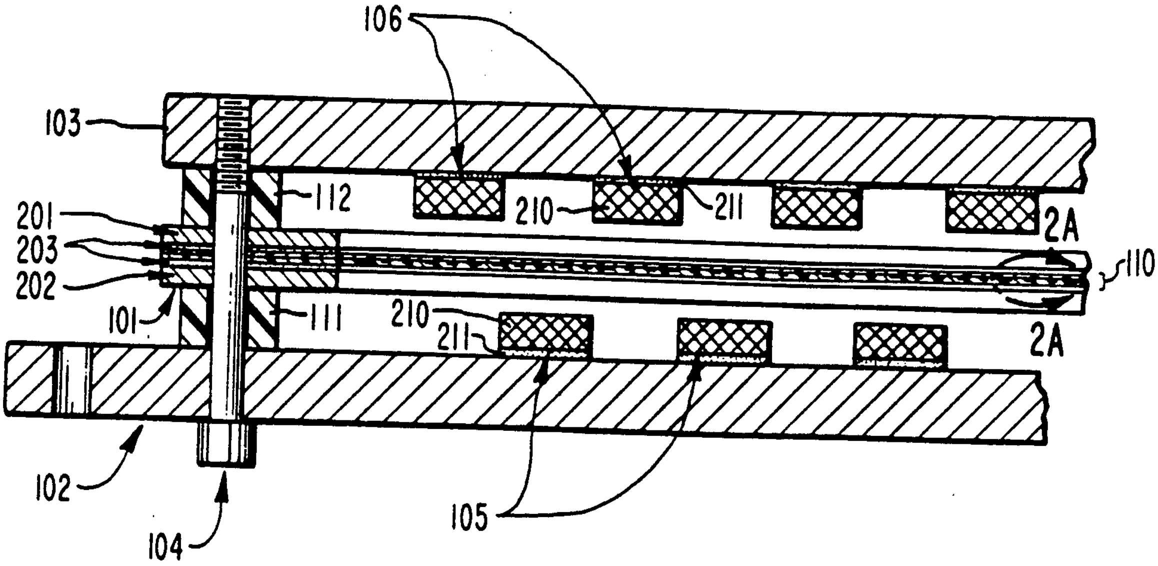
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FIG. 2

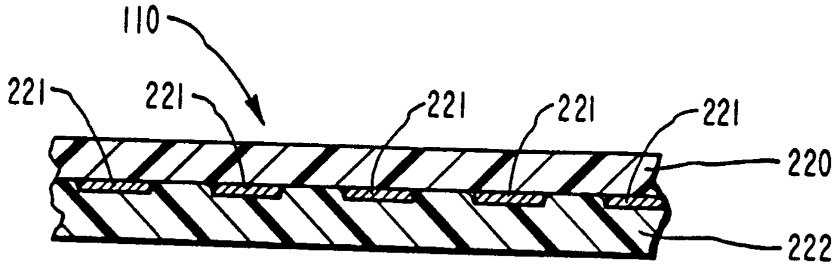
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FIG. 2A

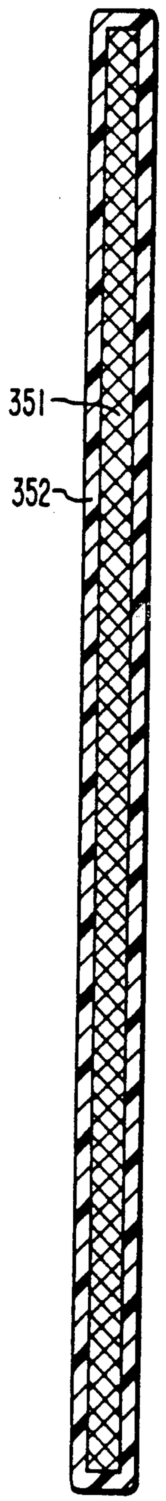

FIG. 3

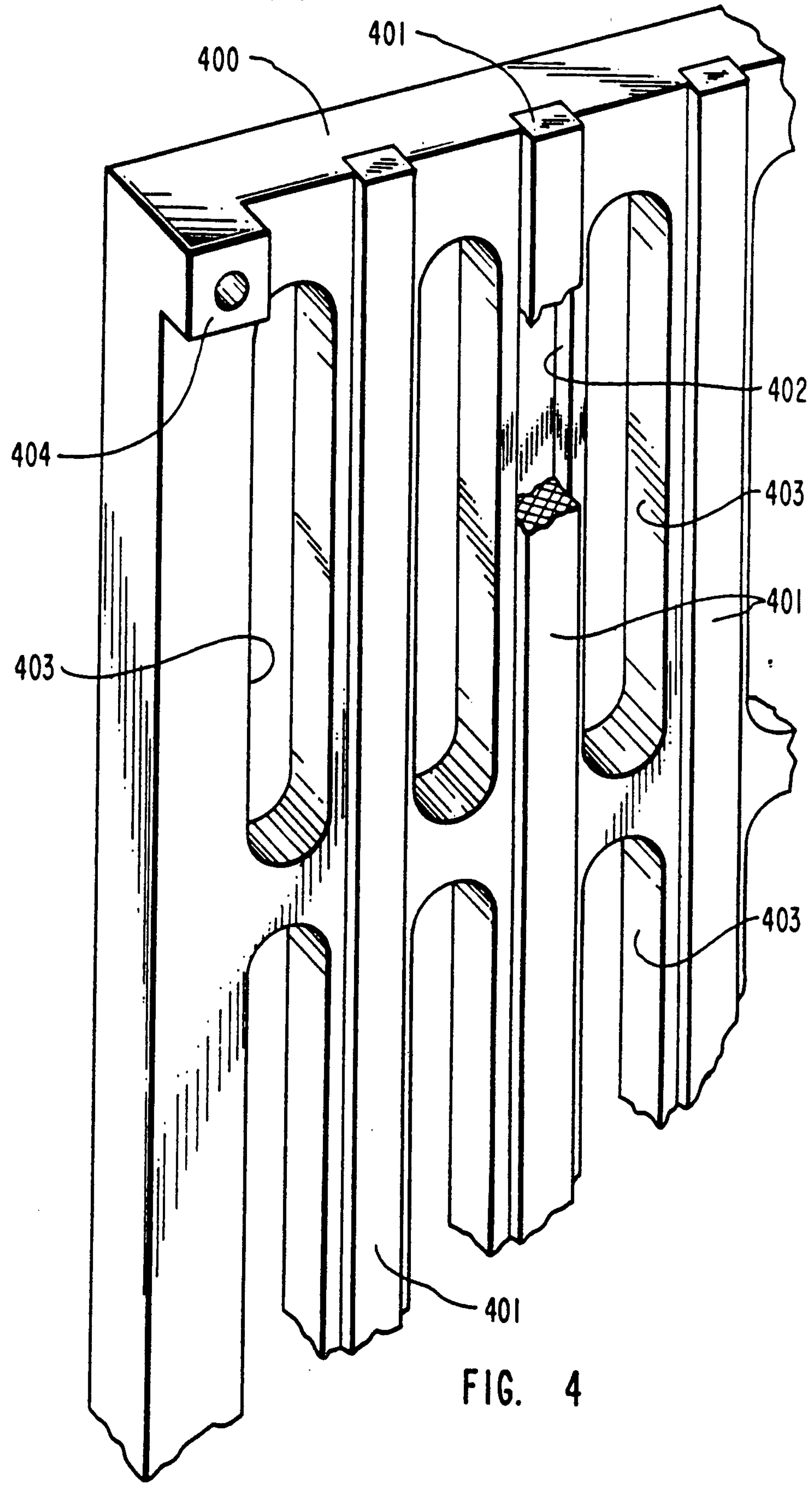

FIG. 4

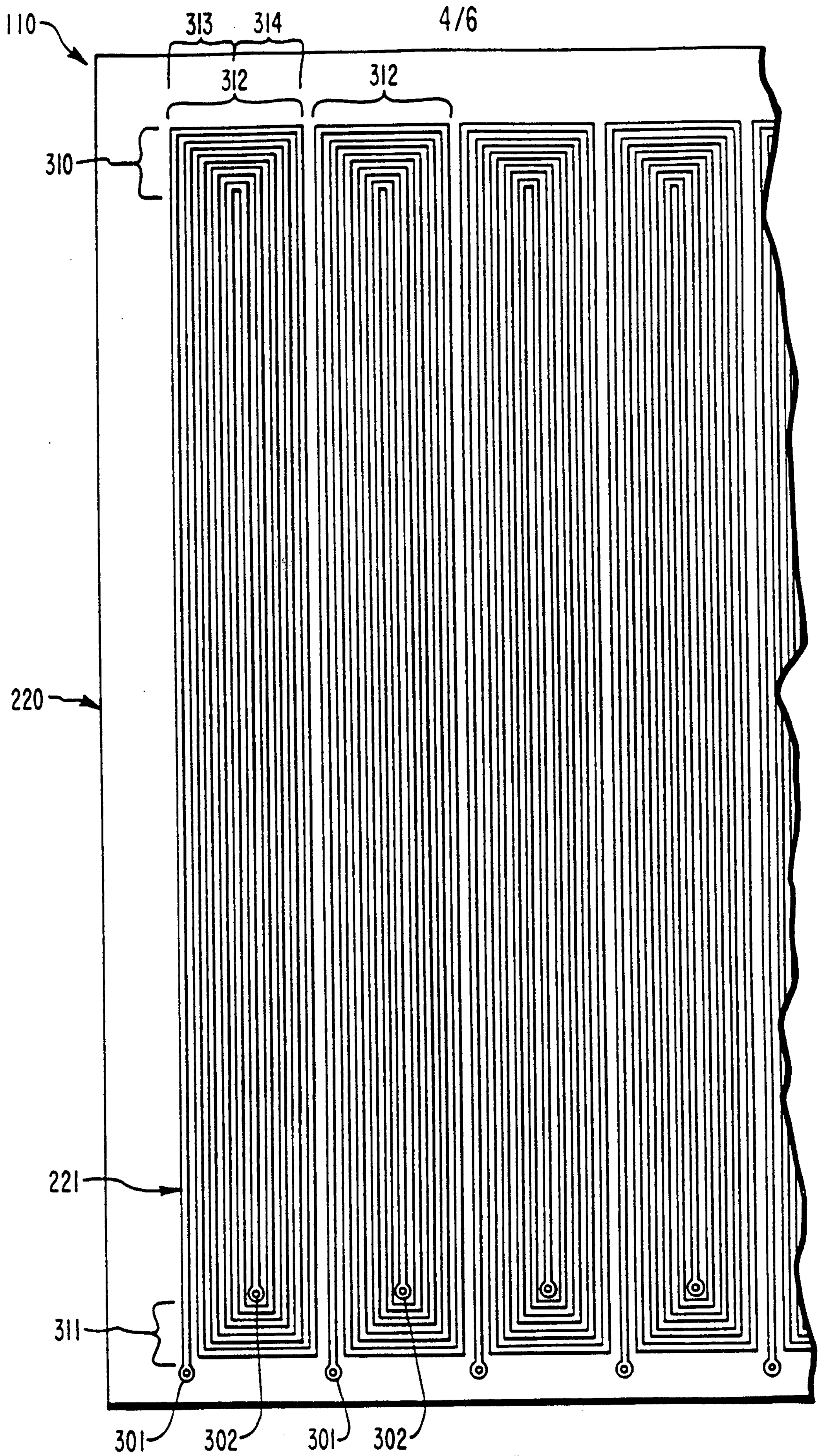

FIG. 5

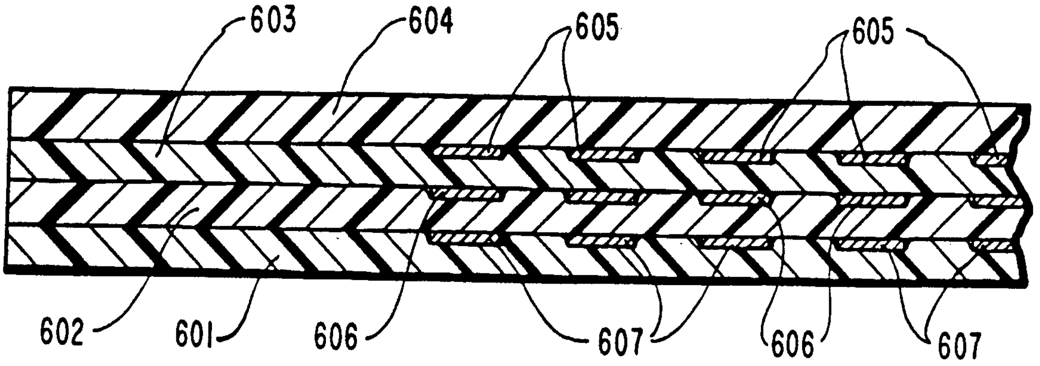
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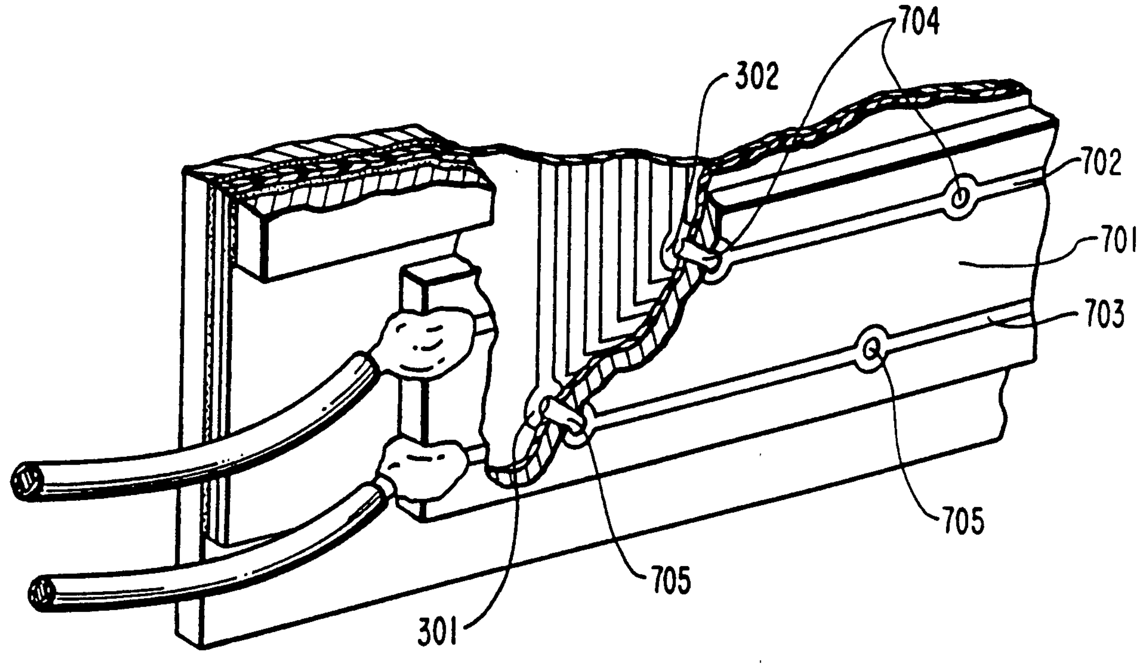
FIG. 6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301

FIG. 7

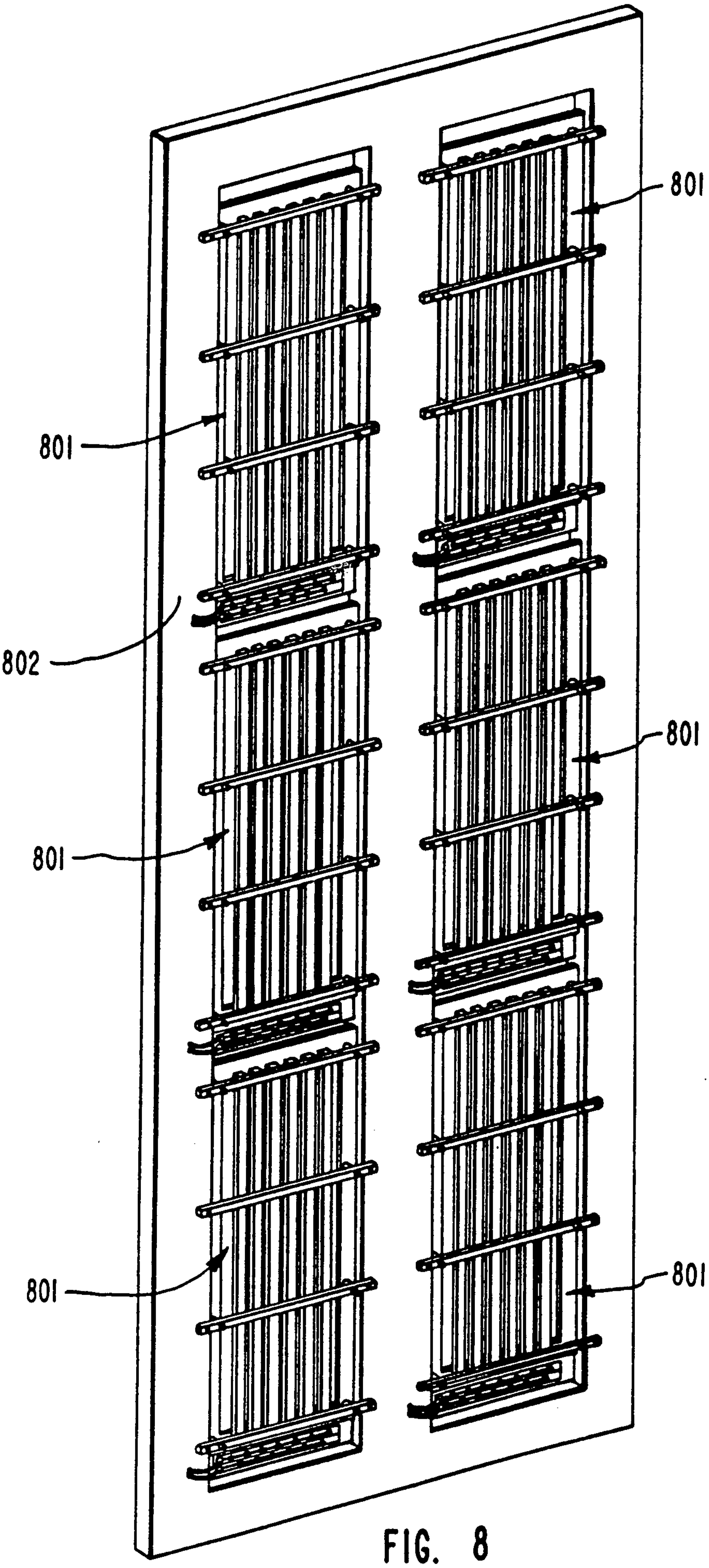

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/04012

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04R 25/00, 3/00
US CL :381/196,117
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/191,158,188,203; 360/126 181/113

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US,A, 5,003,609 (Muraoka) 26 March 1991 Figures 5 and 9.	1-4,15-32,35, 37,39,40 7,9,11,12,14
Y	US,A, 4,463,825 (Lerwill) 07 August 1984.	2,8,10,13,36
Y	US,A, 4,837,838 (Thigpen et al.) 06 June 1989 col. 6 line 4.	3,18,38
Y	US,A, 4,885,783 (Whitehead et al.) 05 December 1989 figure 7 col. 7 lines 60-65.	36
Y	US,A, 4,894,742 (Saito et al.) 16 January 1990.	33

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 JUNE 1993	17 AUG 1993

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	SINH TRAN
Facsimile No. NOT APPLICABLE	Telephone No. (703) 305-4811

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/04012

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A, 3,631,450 (Chalfant) 28 December 1971.	34