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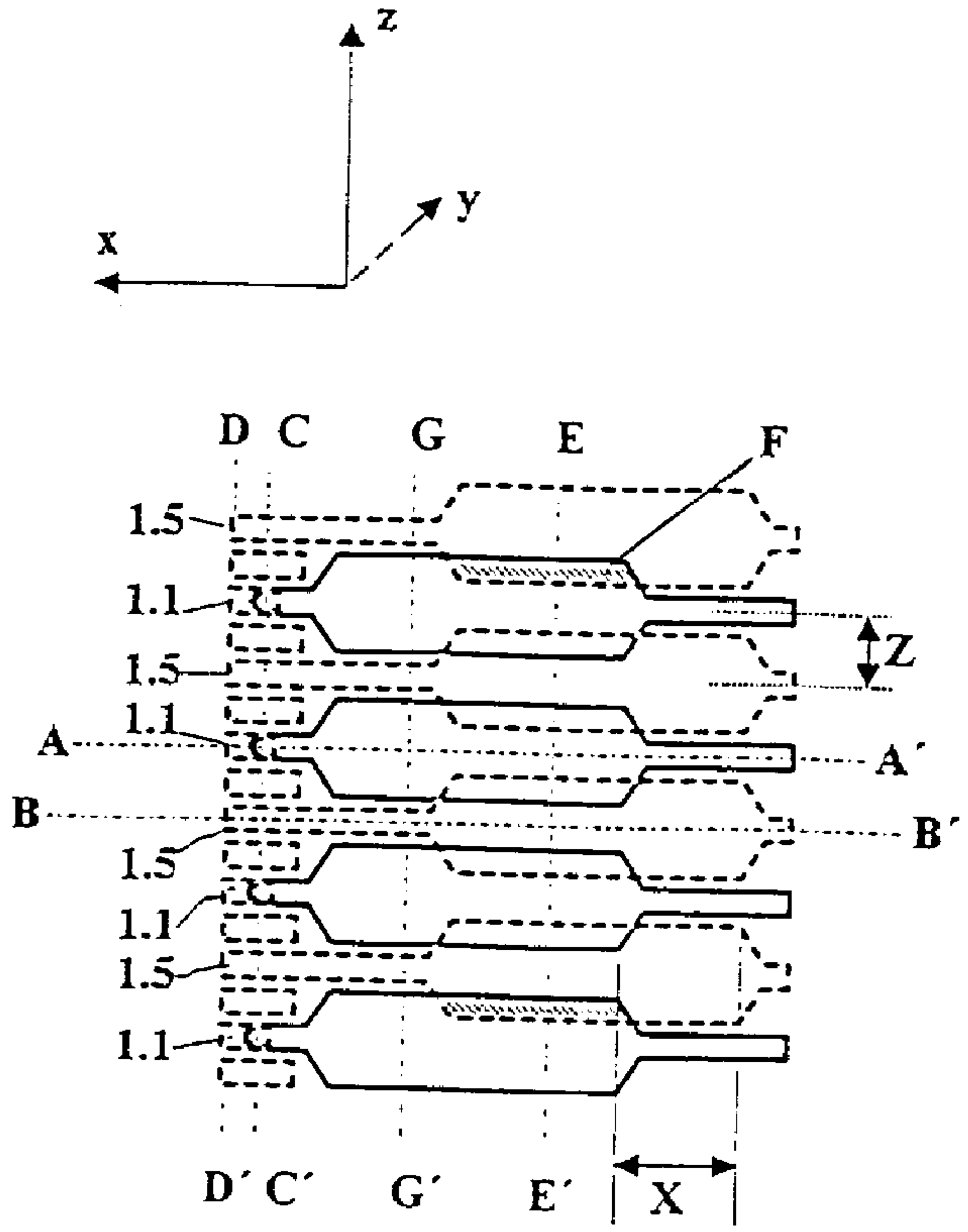
(54) **TETE D'IMPRESSION A JET D'ENCRE TRANSVERSAL ET METHODE DE FABRICATION DE CETTE TETE**

(54) **AN EDGE-SHOOTER INK-JET PRINT HEAD AND A PROCEDURE FOR MANUFACTURING THIS**



(57) An edge-shooter ink-jet print head that incorporates a nozzle row in the z direction on the edge of a module and which makes it possible to expel an ink jet in the x direction, with a plurality of plates that are arranged in the y direction, incorporates equal ink path lengths for at least one module. According to the present invention, the nozzle row lies in a part and which has chamber forming parts that are additionally incorporated. After the production of various module plates by parallel processing of a glass plate, including the formation of cavities of a defined depth by etching and fine grinding, this is followed by separation and joining of the individual parts to form a module that is provided with conductor tracks and PZT elements. The modules can be connected through an adhesive layer as part of an assembly process.

ABSTRACT

An edge-shooter ink-jet print head that incorporates a nozzle row in the z direction on the edge of a module and which makes it possible to expel an ink jet in the x direction, with a plurality of plates that are arranged in the y direction, incorporates equal ink path lengths for at least one module. According to the present invention, the nozzle row lies in a part and which has chamber forming parts that are additionally incorporated. After the production of various module plates by parallel processing of a glass plate, including the formation of cavities of a defined depth by etching and fine grinding, this is followed by separation and joining of the individual parts to form a module that is provided with conductor tracks and PZT elements. The modules can be connected through an adhesive layer as part of an assembly process.

Description

The present invention relates to an edge-shooter ink-jet print head, that incorporates nozzles in a nozzle row in the z direction on the face edge of a part of a module that forms chambers, which is provided with means to supply and expel ink from a chamber that is associated in each instance with a nozzle and which permits the expulsion of an ink-jet in the x direction, with a plurality of plates arranged in the y direction, a group of chambers being arranged on that side of twe part that forms the chambers that faces a middle part.

An ink-jet print head of this kind can be used in small, high-speed printers. Printers such as these are used, for example, for franking machines that are used to frank mail.

It is known that ink-jet print heads are constructed according to the edge-shooter or according to the face-shooter principle (First Annual Ink-Jet Printing Workshop, March 26-27, 1992, Royal Sonesta Hotel, Cambridge, Mass.). Up to the present time, efforts have been made to minimize the dimensions of the chambers in order to increase nozzle density. The measures proposed therein are however only useful in the case of ink-jet modules with a few nozzles in a row, and fail if a large number of nozzles is used.

Ink-jet print heads that have been further developed according to the face-shooting principle, as are described, for example, in US 47 30 197, US 47 03 333, US 46 95 854, US 46 35 079, US 46 41 153 and US 46 80 595, consist of ink chambers that are arranged to the right and left of a line of nozzle outlet openings, orthogonally to the longitudinal axes of the ink chambers. The ink chambers lie with all their longitudinal axes in one plane. In this arrangement, too, the density that can be achieved in the arrangement of the nozzles is determined by the width of the chambers and by the thickness of the partition walls that lie between two chambers which, because of the cross-talk effect, cannot fall below a specific minimum. The arrangement on both sides of and symmetrical to the line of nozzles, only brings about a two-fold increase in the jet density. Up to the present time, geometrical resolutions of 64 dpi have been achieved with arrangements of this kind. This solution is inadequate for printing graphic symbols of the kind required, for example, for label printers or franking machines. In the case of known arrangements, the chamber size beneath the PZT-elements (lead-zirconate-titanate elements) is restricted by width and no high level of nozzle density can be achieved.

US 46 80 595, in particular, describes a manufacturing process for a face-shooter ink-jet print head with a line of nozzles between two groups of ink chambers, which has a doubled nozzle density. A chamber plate that forms the chambers in a symmetrical arrangement relative to the jet line is produced and it is intended that subsequently a membrane plate is to be positioned on this. A single PZT layer is secured above the membrane plate, and subsequently separated into discrete PZT elements by the removal of material. Next, the membrane plate is positioned and secured over the chamber plate, beneath which there are a number of additional working plates.

Each rectangular chamber has an associated supply channel and a nozzle as well as an oscillator plate with a piezo-ceramic element. However, a disadvantage in this is that the pressure waves that occur in the ink feed and in each chamber can cause cross-talk in other pressure chambers. This cross-talk can only be eliminated subsequently by applying very costly measures so that ultimately these ink-jet print heads consist of a large number of individual plates that have to be produced in a costly production process.

Similarly, DE 34 45 761 A1 describes a process for producing a transducer arrangement from a number of individual plates of a transducer material. After the lower plate surfaces have been coated with a membrane layer, material is removed from the upper plate surface of the transducer material in order to create separate areas that are arranged on the membrane above each pressure chamber (area 25.4 mm x 2.54 mm). This eliminates the need to produce an adhesive connection between the individual transducer elements and the membrane by using an adhesive, and the uniformity of all the spaces is improved. However, in a print head produced in this way, the resulting spacing between the jets continues to be relatively great.

US 47 03 333 also describes the production of an ink-jet print heads for an arrangement that is inclined relative to the surface of a recording medium, with the ink-jet print heads being built up from face-shooter modules that are arranged obliquely above each other. Ink-jet print heads that are arranged so as to be inclined to the surface of a recording medium generate a more even image, even if the thickness of the recording medium varies. However, the production of such print heads involves a large number of production steps. It is difficult to guarantee the required precision, given such a complex overall structure of each print head. The electrical triggering of such print heads that have rows of nozzles that are offset relative to each other, which is required during their operation is similarly costly to configure. Even with an arrangement of two rows of chambers with nozzles that are offset relative to each other with, in each instance, a lower nozzle density in each row of nozzles, the minimum distance between the nozzles cannot be further reduced because of a required minimum size of the ink chambers.

A doubled nozzle density in a row is achieved in the face-shooter ink-jet module by means of two groups of ink chambers that are arranged symmetrically to the line of nozzles. In the edge-shooter ink-jet print module, an increase in nozzle density has to be achieved in another way. In the solution proposed in US 4,525,728, an edge-shooter ink-jet print module with one row of nozzles per chamber plate is proposed. The dimensions of the chambers and the channels can be further reduced under certain circumstances. Here, the longitudinal axes of the relatively long ink chambers lie in the direction of the ink jet, whereas the width of the ink chambers is greatly reduced. However, the production step required to apply the PZT elements is problematic, for the tolerances that have to be observed are extremely small.

In order to achieve greater imaging density, our Canadian patent application Serial No. 2,101,683, Laid open for public inspection on February 1, 1994, proposes that a plurality of chambers be offset horizontally and vertically relative to each other. A single row of nozzles for the whole of the module is formed in a part that forms chambers. However, in this, the channels that lead to the nozzles from the lowest plane, which is some distance away, are longer than the channels from the upper, closer plane, and this leads to a phase shift of the individual ink jets, which has to be balanced out electronically. In addition, because of the very long channels, greater forces have to be applied by the piezo crystals so that these fail earlier than other piezo crystals. A higher nozzle density in the rows of nozzles is the result of a multi-layer construction.

On the other hand, the triggering energy that is then required for the PZT elements, which moves ink from chambers with a very long ink path to the nozzles or ink reservoir, respectively, can no longer be applied using standard driver components.

The problem is to create a compact ink-jet print head for a printing at high resolution, which does not have the disadvantages of the prior art, and to describe an associated production process that involves low production costs.

This problem has been solved with an additional part, respectively, that forms chambers is arranged between the middle part and the first part that forms chambers, or the middle part and an additional part that forms chambers; in that the nozzle row is arranged in a part of the additionally arranged parts that form chambers; and in that the chamber groups, respectively, are so offset relative to each other in the x, y, and z direction that the ink path from the suction chamber, respectively, in the first part that forms chambers or the other part that forms chambers to the nozzles of the nozzle group, respectively, in the nozzle row is configured to be of equal length, at least within a module, respectively.

While retaining the advantages of the invention of Canadian patent application Serial No. 2,101,683, it is intended to make additional improvements in order to reduce problems that occur when a plurality of planes are to be set up one above the other. It is true that a cross-talk effect between the planes could be reduced by arranging a sufficiently thick spacer layer between the planes. On the one hand, however it is not possible to stack any large number of planes in this way, because triggering energy which could not be applied by conventional driver circuits would be required for the additional planes. On the other hand, the resistance that the flow of ink would have to overcome on its path to the nozzles cannot be reduced by simple changes in geometry. In this connection, the problem of gas generation becomes troublesome. Pressure differences, and sometimes air bubbles, would be formed between the topmost and the lowest groups of chambers, i.e., planes that are spaced relatively far apart vertically, in the case of increased triggering energy, and ultimately these prevent clean printing. This problem has been overcome by the arrangement according to the present invention. This makes provision for an arrangement in which at least one module is so configured with ink channels that run in a number of planes that ink paths of almost identical length are formed. Beneath a first plane, in which a first group of ink chambers lies in a first part that forms chambers, a part that forms additional chambers is arranged in a second plane with an additional group of ink chambers such that the ink chambers of the second plane are offset from the first plane both vertically and horizontally, relative to the nozzle line. Provision is made such that in at least one additional plane between the middle part and the first part that forms the chambers, or between the middle part and a part that forms additional chambers, there is a part that forms additional chambers according to the present invention, the nozzle row being formed only in some of the parts that form the chambers that are additionally incorporated. The chamber groups are so displaced relative to each other in the x, y and z directions that the ink path from the suction chamber in the part that forms the first chambers or from the part that forms the additional chambers the nozzles of the nozzle group in the nozzle row is configured to be of equal length, at least within a module.

The ink path lengths, which are configured differently because of the vertical space between the planes in the y direction, are thus balanced out by a defined ink-channel length in the planes. In particular, the chambers to the nozzle row on the one hand, and to a suction chamber on the other, are so arranged that, in each plane there are ink channels of different lengths, in particular, nozzle channels and inlet channels and, in the parts that form the additional chambers, there are transit channels, and the sum of all the ink-channel lengths associated with each chamber remains almost constant.

The present invention proceeds from the fact that because of this solution, according to the present invention, with ink chambers offset horizontally and vertically, it is possible to achieve a greater nozzle density, relatively independently of the dimensions of the ink chambers, for an edge-shooter ink-jet print head. Provision is made such that in the nozzle row, the nozzles that belong to different nozzle groups alternate in such a manner that the overlap of chamber groups of one plane is effective with those of the other planes only at the edges of the chambers.

In a manner comparable to Canadian patent application Serial No. 2,101,683, the ink chambers of additional planes can be connected with the associated nozzle groups through transit channels. Thus, nozzles are supplied with ink from the ink chambers of other planes which are, in their turn, arranged between those nozzles which are supplied from the ink chambers of the first plane, and form a dense line of equidistant nozzles in the x direction with these. On the other hand, differences in the lengths of the ink paths, which would lead to a distorted print image, are evened out.

A preferred variation provides that the ink-jet print head is made up of only one module that contains chambers arranged in at least two chamber plates, the distance to the nozzle line being bridged over by channels that lie within the volume of the module and in part between the chambers.

In each instance, the nozzle channels from the chambers to the nozzles, on the one hand, display a defined and equal first flow resistance and, in each instance, the inlet channels from the suction chamber to the chambers, on the other hand, display a defined equal second flow resistance. This can be achieved in that the channels pass through more planes in the vertical direction to the chambers or to the nozzles, respectively, with all the channels of one type being of equal length, with an equal cross-section. Each of the nozzle channels has a defined lower first flow resistance than each inlet channel. This can also be achieved additionally by selective cross-sectional changes and/or turns in the horizontal direction.

In addition to the greater nozzle density, a further advantage of the solution according to the present invention, is the smaller effect of tolerance as a result of the design according to the present invention, since the individual planes of the multi-level construction do not have to be off-set relative to each other.

Parallel production process steps are followed for all module plates in order to produce the ink chambers, openings, bores, and, if necessary, the nozzle channels. The procedure for manufacturing the ink-jet print head proceeds from the CAD development of a print head design. A mask is produced in order to cover a photo-sensitive glass plate. First, there is a pre-treatment of those parts that are subsequently to be removed by an etching agent. Next, the masked glass plate is exposed at least once to irradiation with ultraviolet light of an appropriate wavelength, with subsequent thermal treatment; this brings about a phase change in the irradiated areas, which can be better etched than the non-irradiated areas because of this.

In a subsequent process, the areas that are to be removed are etched out of each plate in order to form cavities. The duration of the etching bath determines the thickness of the layer of material removed. The layer thickness of the membrane that remains during etching is monitored. When a specified layer thickness is reached, the surface is processed by means of fine grinding, or a defined membrane thickness is set up, respectively.

After production of the different module plates by parallel processing of glass plates, including the formation of cavities of a defined depth by etching and fine grinding, separation is carried out and the individual parts are joined to form a module that is provided with printed conductor tracks and PZT elements.

In each instance, three individual parts, consisting of two chamber parts and consisting of at least one additional plate, which simultaneously serves as a separator, are oriented and cemented to each other, and then finally tempered or passed through the diffusion-bond process. The plates are provided with conductor tracks for the PZT elements that are to be installed next. Finally, there is a special processing of the nozzle channels and the cavities (chambers) and of the nozzle plate of the module before the print head, together with the driver circuits, is provided with contacts, finished and installed.

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Finished modules can be connected through an adhesive layer as part of an assembly process. A print module can be completely assembled to form a print head either individually, or with a second print module that is built up, in principle, as a mirror image.

According to one aspect, the invention provides an ink jet print head of the edge-shooter type, comprising: a first chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof; a second chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof; said first chamber-carrying member having nozzles formed therein each assigned to a respective one of said ink chambers; means for supplying ink to said ink chambers and for ejecting ink from said ink chambers through said nozzles; said nozzles formed in said first chamber-carrying member forming a single nozzle row having k nozzle groups and extending in a first direction, said ink chambers having $k \geq 2$ chamber groups with each of said nozzle groups associated with a respective one of said chamber groups; said ink chambers formed in said first chamber-carrying member being a first chamber group and said ink chambers formed in said second chamber-carrying member being a k^{th} chamber group, a first nozzle group of said k nozzle groups communicating with said first chamber group, and a k^{th} nozzle group of said k nozzle groups communicating with said k^{th} chamber group; and said nozzle openings extending and ejecting ink droplets in a second direction substantially orthogonal to said first direction, said K chamber groups being disposed in a third direction relative to one another, said third direction being substantially orthogonal to said first and second direction.

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According to another aspect, the invention provides an edge-shooter ink jet print head, comprising a head module defining mutually orthogonal directions including an x-direction, a y-direction, and a z-direction and having nozzles formed in an end face thereof for expelling ink in the x-direction, said head module being formed of a plurality of plates stacked one upon another in the y-direction, said plates including a first ink chamber carrying part having ink chambers formed therein for receiving ink; a middle part disposed on said ink chamber carrying part; a second ink chamber carrying part having ink chambers formed therein for receiving ink and being disposed on said middle part; a further ink chamber carrying part having ink chambers formed therein for receiving ink and being disposed between said first ink chamber carrying part and said middle part; said nozzles communicating with said ink chambers in said first ink chamber carrying part, said second ink chamber carrying part, and said further ink chamber carrying part through conduits and said nozzles being mutually aligned on said end face in a nozzle row extending in the z-direction; said nozzle row being formed in said further ink chamber carrying part; said ink chambers formed in said first ink chamber carrying part and in said second ink chamber carrying part forming groups of ink chambers; said groups of ink chambers being offset relative to one another in the x-direction, the y-direction, and the z-direction for forming ink paths from said suction chambers to respectively associated ones of said nozzles having a substantially uniform length within each of said modules; and means for supplying ink through said chambers and for expelling ink from said nozzles.

According to another aspect, the invention provides an ink jet print head of the edge-shooter type, comprising: a first chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof; a second chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof; a center member disposed between the flat surface of said first chamber-carrying member and the flat surface of said second chamber-carrying member; one of said first chamber-carrying member and said center member having nozzles formed therein each assigned to a respective one of said ink chambers; means for supplying ink to said ink chambers and for ejecting ink from said ink chambers through said nozzles; said nozzles formed in said first chamber-carrying member forming a single nozzle row having $k \geq 2$ nozzle groups and extending in a first direction, said ink chambers having k chamber groups with each of said nozzle groups being associated with a respective one of said chamber groups; said ink chambers formed in said first chamber-carrying member being a first chamber group and said ink chambers formed in said second chamber-carrying member being k^{th} chamber group, a first nozzle group of said k nozzle groups communicating with said first chamber group, and a k^{th} nozzle group of said k nozzle groups communicating with said k^{th} chamber group; said nozzle openings extending and ejecting ink droplets in a second direction being substantially orthogonal to said first direction, said k chamber groups being disposed in a third direction relative to one another, said third direction being substantially orthogonal to said first and second directions; and said center member having communication openings formed therein, said communication openings being associated and cooperating with said ink supplying means for supplying said k^{th} nozzle group in said nozzle row with ink.

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According to another aspect, the invention provides a method of manufacturing an ink jet print head, which comprises: processing plate material in parallel and forming through openings in all members to be equipped with through openings; forming chamber-carrying members; connecting the members and forming at least one print head module, and subsequently annealing the at least one print head module; applying piezo-electrical elements to the at least one module and connecting the piezo-electrical elements with conductor paths applied to the module; and assembling the at least one module to form an ink jet print head.

According to another aspect, the invention provides a method of manufacturing an edge-shooter ink jet print head, which comprises: a) parallel processing of a glass plate for forming different module plates of an ink jet print head and forming cavities of defined depth in the glass plate; b) subsequently separating individual parts for the ink jet print head from the glass plate; c) joining the individual parts by diffusion bonding and forming a module of the ink jet print head; d) depositing conductor tracks on the glass plate and installing PZT elements or a PZT layer; e) assembling the print head module to form a print head, cleaning nozzles formed in the print head by means of compressed air, applying a hydrophilic inner coating on nozzle channels, applying a hydrophobic outer coating on a face edge of the module, providing driver circuits for the print head, providing supply means necessary for a functionality of the print head, placing the print head into a housing, and testing the print head for proper operation.

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The invention will now be described in greater detail with references to the accompanying drawings, in which:

Figure 1a: a cross-section on the line A-A′ of an ESIJIL print head as in version 1;

Figure 1b: a view of the nozzle side with the nozzle line of the ESIJIL print head as in version 1;

Figure 1c: the position of the chambers in the first two planes according to a version 1 of an ESIJIL print head, in plan view, on the first chamber plate (component side);

Figure 2a: a cross-section on the line A-A′ for the upper part with the first two planes of the ESIJIL print head as in version 1, shown in figure 1;

Figure 2b: a cross-section on the line B-B′ of the part of the ESIJIL print head as in version 1;

Figure 2c: a cross-section through the line C-C′ of the part;

Figure 2d: a cross-section on the line G-G' of the part;

Figure 2e: a cross-section on the line E-E' of the part in a combined representation with the illustration shown in figure 1c;

Figure 3: a cross-section on the line A-A' of a part of the ESIJIL print head according to the third version;

Figure 4: a cross-section on the line A-A' of a part of the ESIJIL print head as in the fourth version;

Figure 5: the ink feed in a perspective view of a detail of the ESIJIL print head according to the fifth version;

Figure 6: a cross-section on the line A-A' of the ESIJIL print head according to the sixth version;

Figure 7: a cross-section on the line A-A' of a part of the ESIJIL print head according to the seventh version;

Figure 8: a cross-section through an ESIJIL print head with a combination of various modules;

Figure 9: a manufacturing process for the ESIJIL print head according to the present invention as in figure 6;

Figure 10: a production process for the ESIJIL print head according to the present invention as shown in figures 1, 8.

Figures 1a to 1c show a first version, according to which the ESIJIL print head according to the present invention can be made as a development of the ESIJIL print head described in Canadian patent application Serial No. 2,101,683.

Figure 1a shows a cross-section through the edge-shooter ink-jet inline print head (ESIJIL print head) on the line A-A'. A chamber forming part 2 is arranged in a first plane, as in Canadian patent application Serial No. 2,101,683. The openings, channels, a suction chamber 151, and chambers face a middle part that consists of two layer-like separators. Beneath this, in the y direction, there is an additional chamber forming part 29 arranged in a second plane, and this has chamber openings in the same direction as in the first plane, the additional part 29 having the single nozzle row for all nozzles.

In the third plane, there is a first separator 33 which has comparable openings corresponding to the middle part, as in the main patent. The second separator 35 is arranged in the fourth plane, with openings that are comparable to the middle part, as in the main patent, and this is formed to the first separator 33 through an adhesive layer 34. Beneath the separators that form the middle part there are in each of the fifth and sixth plane a part 36, 4 that each form a chamber. The sixth part 4 that forms the chamber has openings, channels, a suction chamber 152 and the chambers of a chamber group 102. The open sides of the chambers and openings of the parts in the fifth and sixth planes face the middle part, discussed above, that is formed from the separators.

The ink passes through channels (not shown herein) into a suction chamber 151 that is connected through channels 110 with the ink chambers of the first and second planes. The ink chambers are connected through channels 111 and ink transit openings 112 through the second plane with the nozzles, which are arranged in the second plane. Each ink chamber has an associated membrane and a PZT element that, when acted upon by an electrical pulse, deforms the membrane and thus changes the volume of the chamber. When the chamber volume expands ink is delivered from the suction chamber 151. On compression of the chamber volume of a chamber that belongs to chamber group 101 in the x direction, the ink droplets will be expelled through a nozzle that is part of nozzle group 1.1. This part, which is also shown in figure 2a, forms an upper half of the ESIJIL print head.

The feed channels between the suction chamber 151 in the first plane and the ink chambers in the second plane or the transit openings, respectively, the ink chambers in the second plane and the feed channels between the ink chambers in the second plane and the nozzles in the second plane, cannot be seen in the cross-section A-A′ as in figures 1a or 2a and for this reason are shown in the cross-section B-B′ at figure 2b.

In the same way, additional channels, openings, chambers, and the like (not shown in figure 1a) are arranged in the lower half of the ESIJIL print head in order to supply link to the nozzles in the second plane of the upper half of the print head.

The nozzles that are associated with the nozzle groups 1.1, 1.5, 1.2, and 1.6 are arranged in one row in the z direction. In order to clarify this, figure 1b shows a section of an edge of the complete ESIJIL print head as in the first version, with a corresponding nozzle arrangement in one nozzle row 1, in cross-section D-D'. It can be seen that the nozzle dimensions alone determine the maximum number of nozzles on the row. The nozzle diameter amounts to approximately one-quarter of the interval between two adjacent nozzles that are arranged on one nozzle line in a single nozzle row 1. Provision is made such that within the nozzle row, the nozzles of the nozzle group alternate with the nozzles of the other nozzle groups. In each instance, nozzles of nozzle group 1.1 and 1.5 and of 1.2 and 1.6 belong to an associated chamber of the chamber groups 101 and 105, or 102 and 106, respectively. The associated chamber groups 101, 105 of the upper half and the chamber groups 102, 106 of the lower half of the print head are arranged so as to be offset vertically in the y direction and, in addition, horizontally in the x and z directions.

Figure 1c shows the position of the chambers in the first planes of the ESIJIL print head, in plan view as viewed from the component side according to the arrangement in the first version. The chambers of the second chamber plate according to the present invention, which lie below, are indicated by dashed lines in order to make their position relative to the first chamber plate clear. Both chamber groups 101, 105 are offset by the value X in the x direction and by the value Z in the z direction.

The nozzle row 1 comprises nozzles that belong to the different nozzle groups 1.1, 1.2, 1.5, 1.6, that alternate in an advantageous manner such that the overlap of the chamber groups of the one plane with those of the other plane is only effective at the chamber edges. Also possible is another nozzle arrangement (not shown in figures 1a to 1c) in the nozzle line 1 according to another version of the ESIJIL print head with a larger overlap area F. The overlap area F of one chamber of the chamber group 105 in the second chamber plate 29 with a chamber of the chamber group 101 in the first chamber plate 2 is shaded. The overlap area F of each chamber of the chamber group 101 or 102, respectively, in the first or fourth chamber plate, respectively, relative to the chambers of the chamber group 105 or 106, respectively, in the second or third chamber plate, respectively, can be minimized by the offset in the x and z direction.

The sectional drawings in figures 2a to 2e show the layered structure of the print head and the path of the ink flow as in a preferred embodiment of the present invention (first version as in figures 1a to 1c).

Figure 2a shows the section A-A' with ink channel routing from a suction chamber 151 to an ink chamber 101 of the first plane and from there to the associated nozzle in the second plane 29. The first chamber plate 2 that forms ink chambers, lying in a first plane, is fitted with feed means 151, 110 and PZT elements 31 as activators for expelling ink from one of the chambers associated to the nozzle belonging to the nozzle group 1.1.

The chamber plate 2 contains the structures of the ink chambers and horizontal ink channels 111 that run in the direction to the nozzles, as well as at least one suction chamber 151 and horizontal connecting channels 110 (suction inlet channels) from the suction chamber 151. In addition, it can also be seen that the chamber plate 29 incorporates vertical connecting channels 112 from the ink chambers of the first chamber plate 2 to their associated nozzles in the second chamber plate 29. The nozzle groups 1.1, 1.5 are connected to the associated chamber groups 101, 105 that are located in the chamber plate 2 or 29, respectively, through the ink channels.

Figure 2b shows a corresponding cross-section B-B′ with ink channel routing from the suction chamber 151, which shows the suction channel 110, 113, 114 to an ink chamber of the second plane that belongs to the ink chamber group 105 and from there through the nozzle channel 115 to the associated nozzle of the nozzle group 1.5. In the first version, the upper print head half consists of three plates. In each chamber plate 2, 29 there is a group 101, 105 of ink chambers that is open on the side that faces the middle of the print head and which is covered by the part of the next plane that forms the chambers. Each separator includes machined-in areas 20 that are formed as a membrane on which PZT elements 31 are arranged as means to expel ink.

The section C-C′ that is shown in figure 2c is located in the connecting planes in the x/y direction, at a short distance from the edge with the nozzle row. It makes clear how, according to the present invention, a particularly high density is achieved in the arrangement of the nozzles in each print-head half.

Figure 2d shows a cross-section through the line G-G' of the plan view shown as in figure 1c for the upper half, the section passing on the one hand through the chambers of the first plane and, on the other, through the horizontal nozzle channels 115.

In figure 2e, a cross-section on the line E-E' has been imposed on the left-hand half of the plan view shown in figure 1c, the cross-section E-E' passing through all the chambers of the planes of the upper half of the print head.

Photo-sensitive glass is used as the material for all the plates of the print head. Structuring, including the formation of the nozzles, is effected by means of a photo-lithographic process and by etching out the parts that have been exposed.

The transit openings 112, 113 can be produced in various ways. They can be etched, burned out with a laser beam, or stamped out using special tools. The selection of the process will depend, amongst other things, on the material that is used.

The homogenous and tight connection between each three plates 2, 29, 33 or 4, 36, 35 is achieved by means of thermal diffusion bonding.

Figures 3 to 7 show other embodiments of the present invention (versions 3 to 7).

Figure 3 is a cross-section on the line A-A' of a part of the ESIJIL print head according to a third version. In order to reduce the overlap area between the chambers of different chamber groups, the interval between the chambers in the x-direction has been increased. According to the present invention, an additional separator 28 is arranged between the parts 2 and 29 that form the chambers. The offset in the x-direction can thus be increased by the value H. The corresponding section on the line B-B' and C-C', etc., for the corresponding parts of the ESIJIL print head do not have to be explained in detail, for they are similar to the cross-sections as in the first version.

Figure 4 shows a development of the present invention, namely a cross-section through the line A-A' of a part of the ESIJIL print head according to a fourth version. By interposing two separators 27 and 28 between the parts 2 and 29 that form the chambers, the offset in the x-direction can be increased by the value 2*H relative to that in the first version that is shown in figure 2a. This permits not only an additional reduction of the overlap of the chambers, rather, in a manner not shown herein, a second version can be created by combining a lower half of the ESIJIL print head with the parts 35, 36, and 4, produced according to the first version (set out in figure 1a) with an upper half of the ESIJIL print head with the parts 27, 28, 29, and 33, as used according to the first version, as set out in figure 4. This second version, with a common row of nozzles in the upper half of the ESIJIL print head and ink paths that are of equal length, can be used to advantage in print heads that are used to print at higher resolution.

Figure 5 shows the ink routing in a perspective view for a detail of the ESIJIL print head. Each ink channel 111, 115, respectively, incorporates sections for routing the ink in other planes, and the ink chambers of a group are arranged closer to the nozzle edge by a path length. In contrast to this, the ink chambers of the other group are arranged closer to the suction chamber 151, 152 (not shown). Each ink channel thus has sections of the ink routing in other planes.

Figure 6 shows a part of the ESIJIL print head according to the present invention, according to the first version, in section on the line A-A', the whole print head being used to print at lower resolution and consisting only of the parts 2, 29, and 33 of an upper half. The circuit 160 and the actuators 31 are protected against environmental effects by external moulded plastic parts 170, 171. The PZT elements are connected to the conductor tracks 190, 191 through bonded wires 131, 132, and these conductor tracks 190, 191 lead to the aforementioned driver circuit 160. A ribbon cable 185 provides a connection to the control electronics, for example, of a franking machine. A defined distance between the print head and the surface 100 of the mail is maintained by a spacer plate (not shown in greater detail herein).

The lines from the PZT elements of the second chamber plate are also on the circuit side. The conductor track routing on the circuit side of this module is described in greater detail in an application that is still pending. The type HV 04 or HV 06, HVCMOS technology, produced by Supertex Inc. can be used as the driver circuit. This includes a 64-bit series/parallel shift register with 64 subsequent latches that are connected through NAND and OR gates to 64 SEAMOS driver stages that can deliver an output of up to Vs = 80V. The suction chambers 151, 152 are connected on the periphery of the module by means of a passage 150, a further passage 153 leading to a damping element 154 on the surface (circuit side) of the module, this being connected through at least one feed channel 155 to an ink supply orifice. The complete module (not shown in greater detail herein) has, in the known manner, bores 177 for securing the module and grounding tracks 180 with connected electrode surfaces 181. Subsequently, the particular PZT crystal is arranged on the latter and contacts established with it. The other electrode on the surface of the PZT crystal is connected to the associated conductor track 190 which leads to the appropriate output of the driver circuit by way of a bonded wire.

Figure 7 shows a seventh version with equal ink path lengths for an upper half of the ESIJIL print head, which incorporates parts 2 and 29 that form chambers and an additional spacer 26 between the parts 2 and 29 that form the chambers, with which the chamber openings are covered over. In the seventh version, for building up an ink-jet print head, the ink chambers of the second chamber plate are structurally arranged in front of the opposite side. This means that no additional spacer is required as a membrane plate that closes off the ink chambers from below. In place of this, in order to seal the ink chambers tightly, the middle plate 26 is used. By displacing the chamber group in the x, y, and z direction in each part that forms chambers relative to the chamber group in an additional part that forms chambers, it is possible to achieve an equal ink path length, in contrast to the construction selected in Canadian patent application Serial No. 2,101,683.

The solution according to Canadian patent application Serial No. 2,101,683 can be improved for a preferred version in the way described in connection with the second version. By combining the seventh version with one of the previously described versions, which use middle plates as separators, and/or with measures according to the fifth version, it is possible to obtain ink paths of equal length to each nozzle.

An edge-shooter ink-jet print head can comprise modules that are built up differently. In this connection, provision is made such that the parts 29 or 36 that form chambers that are arranged additionally between the middle part 33, 35 and the first part 2 that forms chambers, or the middle part 33, 35 and an additional part 4 that forms chambers, are of the same or opposite orientation in the chamber configuration. For example, in one version--shown in figure 1--that uses opposite orientation of the chambers, the orientation relative to the middle part 33, 35 is then in the same direction. Both groups of chambers 105, 106 formed on the side of the additional part 29, 36 that forms the additional chambers and faces the one middle part 33, 35. On the other hand, in another version--shown in figure 8--for identical orientation in the chamber configuration, the orientation relative to the middle part 33, 35 is then in the opposite direction. Figure 8 shows a cross-section through an ESIJIL print head with a combination of different modules. In this version, the three parts 29, 36, and 4 are provided for orientation in the same direction within the chamber orientation. The reversed version--not shown in the figures--has a group of chambers 105 on a part 29 that forms the chambers that faces a middle part 33, whereas a group of chambers 106 on the side of the other part 36 that forms the additional chambers is formed on the side that faces away from a middle part 35.

In another version--not shown herein--for orientation in the same direction, both groups of chambers 105, 106 are formed on the side of the part 29, 36 that forms the chambers that faces away from a middle part 33, 35. This version results if an appropriate lower print head half is arranged with the print head half shown in figure 7.

For a combination of modules that are built up in the same way or differently in a print head, the middle parts consist of separators 33 and 35 that are joined to each other through an adhesive layer 34. In at least one additional plane between the parts 2 and 29 that form the chambers there is at least one additional spacer 27, 28 of thickness H which results, in the way described above, in an additional displacement of adjacent chamber-forming parts 2, 29 in the x and y direction. In this connection, it is also advantageous that the offset in the x, y, and z directions is so formed that the ink path within adjacent modules is of almost equal length, with openings for the transit channels 112 being formed in the adhesive layer 34, these then leading through the middle part 35, 33 to the nozzles of the nozzle groups 1.2 and 1.6 in the additional chamber-forming part 29.

In addition, by extending the ink chambers into a plurality of planes, the width of the ink chambers can be optimized so as to correspond to a lower triggering energy, and the nozzle density in the nozzle line 1 can be increased. Only if there is a requirement for even greater resolution would an additional print module have to be incorporated, as is described in DE 43 09 255, which describes a further solution for a modular ink-jet print head.

An additional increase in printing density can also be achieved by the usual inclined position of the module to the direction of print.

A preferred version of a procedure for manufacturing ink-jet print heads incorporates the following steps--as set out in the main patent:

- parallel processing of a glass plate for the production of variously structured module plates, fine grinding, and the application of conductor tracks;
- separation and joining of the individual parts to form at least one module, with subsequent tempering;
- the application, processing, and installation of contacts between the piezo electric elements and the conductor tracks that have been applied;

- assembling to form a print head.

The development of the above manufacturing process is shown in figure 9 with reference to the ESIJIL print head according to the present invention, which is shown in figure 6.

According to the present invention, in a first Step 200 the chamber parts for the lower planes are produced simultaneously for those of the upper planes, and simultaneously with the separators or the nozzle plate, respectively, from a common glass plate. When this is done, processing steps involving etching and fine grinding are used, as has been proposed with respect to manufacturing an ESIJIL print head as set out in Canadian patent application Serial No. 2,101,683. The thickness H of each plate is approximately equal and is adjusted precisely by fine grinding. The required offset between the chamber groups in one plane is ensured at the highest degree of accuracy by the lithographic process that proceeds the etching.

The production process for the ESIJIL print head according to the present invention is based on using a wafer of photo-sensitive glass, on which a mask is laid. After irradiation with ultraviolet light, a phase conversion of the amorphous material into its crystalline phase is brought about by thermal treatment of the areas that have been irradiated. Then, crystalline material is removed layer by layer by etching, as has already been proposed by IBM in US 4 092 166.

Etching agents at different concentrations and/or having different etching times are used for the three areas, in order that the appropriate areas can be removed to varying degrees of precision with respect to depth, the depth accuracy being less when etching areas for continuous bores than it is when etching very flat areas for the channels in the chamber parts, when first the continuous bores, then the chambers, and then the nozzle channels are etched. Provision is also made such that the thickness of the base layer is monitored when etching the chambers, and such that the thickness of the base layer (membrane) of the chambers that is required to conclude the production of the chambers is achieved by fine grinding each of the chamber parts.

Then, in Step 210, separation into individual chamber plates or spacers is carried out.

In Step 220, the individual parts are combined to form a module. When this is done, the individual parts are first aligned and the module that results from cementing the individual parts to each other is next tempered. During tempering, there is a phase transition from amorphous to crystalline within the glass material.

Then, in Step 230, the electrical conductor tracks are installed on the surface of the separators, including the membrane or on the chamber surface, respectively; the piezo crystals are installed and contacts are established in the usual way. The piezo crystals can be cemented into position individually and then the adhesives can be hardened subsequently. On the other hand, a layer of piezo electric material can be applied to the surface that has the conductor tracks and this is subsequently structured and contacts provided. Provision is made such that the PZT layer is first separated into individual PZT elements, preferably by using laser processing. After the application of additional conductor tracks, the contacts are established for the PZT elements.

Finally, it is also possible to metallize a pre-treated PZT plate and apply it to the first chamber plate or separator, respectively. Installation can be effected in an advantageous manner by adhesion. Next, a number of individual PZT elements are separated for each module. The PZT elements have contacts installed on them, if necessary, after the application of additional conductor tracks.

The installation of the PZT elements can be effected in the following manner:

- A first pre-treated PZT plate is metallized and applied to the chamber plate. Next, a number of individual PZT elements are separated for that side of the module.
- A second pre-treated PZT plate is metallized and installed on the membrane of the separator. Then, a number of individual PZT elements are separated for that side of the module.

The assembly in Step 240 to produce an arrangement for a print head as in figure 6 can be effected in an advantageous way during the production process, as follows:

- Nozzle cleaning by means of compressed air, in Step 241;
- Processing (cleaning and flushing) of the chambers and nozzles, in Step 242. A water-resistant inner coating

is formed by flushing with an initial and suitable commercially available liquid;

- A water-resistant outer coating is obtained by treating the nozzle plate on the printing side, in Step 243, with a second suitable liquid. The nozzles are finished after the upper layer has hardened;
- Provision of the module with the necessary driver circuits on the side of the module that is orthogonal to the printing side and optionally with a protective housing, in Step 244;
- In Step 245, the module is combined with the other additional means that are required to operate it (electrical, mechanical, and ink supply means);
- Then, in Step 251, the print head is installed in its own housing before it is tested for correct operation, in order to eliminate any faulty units;
- In conclusion, the finished print head is tested in Step 252.

Figure 10 shows a production procedure for the ESIJIL print head according to the present invention, as in figure 1 or figure 8, respectively. Initially, the Steps 200 to 230 described above are carried out, although for both halves of the print head.

Assembly to form an arrangement as shown in figures 1 and 8, and the arrangements as in figure 4 in combination, or arrangements as in figure 7 in combination with other arrangements to form a multi-level print head requires a modification to Step 240 of the production process. For the first print head half, assembly can be effected in the above-described manner by means of Steps 241 to 245:

- Nozzle cleaning by means of compressed air in Step 241;
- Processing (cleaning and flushing) of the chambers and nozzles to produce a water-resistant inner coating in Step 242;
- Processing of the nozzle edge on the printing side with a second suitable fluid in order to produce a water-resistant outer coating and to harden the upper layer on the nozzle edge, in Step 243;
- Provision of each module with the necessary driver circuits on the side of the module that is orthogonal to the printing side and with a protective housing, in Step 244;
- Combination of the module with other different means (electrical, mechanical, and ink supply means) that are required for its operation. This is followed by a test of one-half of the print head for the nozzles of nozzle groups 1.1 and 1.5 or chamber groups 101 and 105 in Step 245.

According to the present invention, this is followed by assembly Steps 246 to 250 for the second print head half:

- Preparation of the second print head half by cleaning, flushing by means of a cleaning agent, and with compressed air, in Step 246;

- Cementing the print head halves together in Step 247, using an adhesive layer 34. In one advantageous version, the adhesive layer 34 has an adhesive that can be dissolved by means of a solvent, as long as it has not hardened. This adhesive layer 34 can be applied, for example, as a self-adhesive foil on one-half of the print head. Next, material is removed from the foil, for example, by means of a laser beam, in order to open up transit openings to the channels 112, that lead through the separators 33 and 35 to the nozzles of nozzle groups 102 and 106. The other half of the print head can be provided with an adhesive layer in the manner described above, and treated similarly. After the two print head halves are positioned one above the other, and after they have been joined, the adhesive layer 34 is hardened by the application of energy. Provision is also made such that the supply of energy be so controlled with respect to time and position in a special manner that the channels 112 that lead to the nozzles are not plugged by the adhesive of the adhesive layer, or such that blocked places do not harden so rapidly, so that any possible blockage can be eliminated;
- Cleaning the channels in Step 248 by means of an appropriate solvent for the adhesive, in which connection the ink solvent agent is not one of these solvents;

- Cleaning the channels in Step 249 by means of a cleaning agent and with compressed air;
- Combination of the module with other different means (electrical, mechanical, and ink supply means) that are required for its operation, in Step 250;
- Then, once again, the print head is installed in a housing, in Step 251 before it is tested for correct operation in Step 252, in order to eliminate any faulty units.

The present invention is not restricted to the embodiments described heretofore. Rather, a number of versions is possible which make use of the solution described above, even in embodiments that are fundamentally different.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An ink jet print head of the edge-shooter type, comprising:

a first chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof:

a second chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof:

said first chamber-carrying member having nozzles formed therein each assigned to a respective one of said ink chambers;

means for supplying ink to said ink chambers and for ejecting ink from said ink chambers through said nozzles;

said nozzles formed in said first chamber-carrying member forming a single nozzle row having k nozzle groups and extending in a first direction, said ink chambers having $k \geq 2$ chamber groups with each of said nozzle groups associated with a respective one of said chamber groups;

said ink chambers formed in said first chamber-carrying member being a first chamber group and said ink chambers formed in said second chamber-carrying member being a k^{th} chamber group, a first nozzle group of said k nozzle groups communicating with said first chamber group, and a k^{th} nozzle group of said k nozzle groups communicating with said k^{th} chamber group; and said nozzle openings extending and ejecting ink droplets in a second direction substantially orthogonal to said first direction, said K chamber groups being disposed in a third direction relative to one another, said third direction being substantially orthogonal to said first and second direction.

2. The ink jet print head according to claim 1, wherein said second chamber-carrying member is one of a plurality of chamber-carrying members having a respective one of said chamber groups formed therein.

3. The ink jet print head according to claim 1, wherein said nozzles of said respective nozzle groups are disposed in an alternating fashion within said single nozzle row.

4. The ink jet print head according to claim 1, wherein said first chamber-carrying member and second chamber -carrying member together form a module, and including at least one further module comprising two mutually adjacent chamber-carrying members, said module and said at least one further module together forming the ink jet print head.

5. The ink jet print head according to claim 1, including further chamber-carrying members forming an ink jet print head module together with said first chamber-carrying member, and wherein only said first chamber-carrying member

has said nozzles formed therein.

6. The ink jet print head according to claim 1, including a spacer member, said first chamber-carrying member, said second chamber-carrying member and said spacer member forming a print head module, said print head module including an ink supply opening and having a suction chamber formed therein, said spacer member having an opening formed therein for connecting said ink supply opening to said suction chamber, said spacer member having second and third openings formed therein, said second openings supplying at least one of said k^{th} chamber groups with ink from said suction chamber, said k^{th} nozzle groups communicating with respective ones of said chamber groups through said third openings.

7. The ink jet print head according to claim 4, including a spacer member disposed between said modules, and wherein each of said modules has a suction chamber formed therein, said spacer member having ink supply and ink lead-through openings and a recess for receiving said ink ejection means formed therein, each of said suction chambers communicating with a respective one of said chamber groups through second ink supply openings, and each module having supply openings formed therein for supplying ink to said suction chambers.

8. The ink jet print head according to claim 4, wherein said ink supply openings are elongated openings being

one of rectangular, oval and longhole, respective ones of said elongated openings being disposed above one another and being rotated relative to one another by substantially 90°, said elongated openings extending along a first line near an edge face of said module, said first line being offset with regard to a second line of elongated openings disposed below said first line of elongated openings, an offset distance between said first and second lines and a longest lateral distance between said elongated openings being greater than said elongated openings disposed above or below and rotated by substantially 90°, respective ones of said elongated openings together with openings rotated by 90° together defining a cross-section being larger than a cross-section of said nozzles, wherein said second chamber-carrying member is a plurality of second chamber-carrying members each having a suction chamber formed therein, said ink ejecting means being in the form of piezo-electrical elements disposed at said ink chambers.

9. The ink jet print head according to claim 8, wherein said spacer members are formed of the same material as said first chamber-carrying member and said second chamber-carrying member or of the same material as said piezo-electrical elements.

10. An edge-shooter ink jet print head, comprising a head module defining mutually orthogonal directions including an x-direction, a y-direction, and a z-direction and having

nozzles formed in an end face thereof for expelling ink in the x-direction, said head module being formed of a plurality of plates stacked one upon another in the y-direction, said plates including

a first ink chamber carrying part having ink chambers formed therein for receiving ink;

a middle part disposed on said ink chamber carrying part;

a second ink chamber carrying part having ink chambers formed therein for receiving ink and being disposed on said middle part;

a further ink chamber carrying part having ink chambers formed therein for receiving ink and being disposed between said first ink chamber carrying part and said middle part;

said nozzles communicating with said ink chambers in said first ink chamber carrying part, said second ink chamber carrying part, and said further ink chamber carrying part through conduits and said nozzles being mutually aligned on said end face in a nozzle row extending in the z-direction;

said nozzle row being formed in said further ink chamber carrying part;

said ink chambers formed in said first ink chamber carrying part and in said second ink chamber carrying part forming groups of ink chambers; said groups of ink chambers being offset relative to one another in the x-direction, the y-direction, and the z-direction for forming ink paths from said suction chambers to respectively associated ones of said nozzles having a substantially uniform length within each of said modules; and

means for supplying ink through said chambers and for expelling ink from said nozzles.

11. A edge-shooter ink jet print head according to claim 10, wherein said nozzles in said nozzle row belong to given nozzle groups, said nozzles of different nozzle groups alternating with one another such that said ink chambers of one plate overlap said ink chambers of another plate in the y-direction only at chamber edges thereof.

12. An edge-shooter ink jet print head according to claim 10, wherein said plurality of plates defines a plurality of planes of said module, and wherein said ink chambers are disposed relative to said nozzle row and relative to said suction chamber for forming ink channels of varying lengths in each of said planes of said module, said conduits being formed of nozzle channels, inlet channels and transit channels in said second ink chamber carrying parts, a sum of the various lengths of ink channel for each chamber remaining substantially constant.

13. An edge-shooter ink jet print head according to claim 10, including another head module, said middle parts of each of said head modules being disposed on one another, said ink chamber carrying parts each defining a given ink chamber formation, said ink chamber formation in said second ink

chamber carrying part being oriented opposite said ink chamber orientation in said first ink chamber carrying part.

14. An edge-shooter ink jet print head according to claim 10, including another head module, said middle parts of each of said head modules being disposed on one another, said ink chamber carrying parts each defining a given ink chamber formation, said ink chamber formation in said second ink chamber carrying part being oriented in the same direction as said ink chamber orientation in said first ink chamber carrying part.

15. An edge-shooter ink-jet print head according to claim 10, including another head module, said middle parts of each of said head modules being spacers and being joined to one another with an adhesive layer; and at least one additional separator plate having a given thickness disposed between said first and second ink chamber carrying parts, said additional separator plate defining an offset in the x and y-directions between adjacent ones of said first and second ink chamber carrying parts.

16. An edge-shooter ink jet print head according to claim 15, wherein said offset in the x, y, and z-directions is so formed that an ink path length within adjacent head modules is substantially equal, said adhesive layer having openings formed therein defining transit channels through said middle part and to said nozzles of nozzle groups in said second ink

chamber carrying part.

17. An edge-shooter ink jet print head according to claim 10, wherein said ink chambers in various said planes of said module overlap one another and define an area of overlap, and including additional ink conduits formed in said head module for minimizing said area of overlap.

18. An ink jet print head of the edge-shooter type, comprising:

a first chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof;

a second chamber-carrying member having a plurality of ink chambers for receiving ink formed in a flat surface thereof;

a center member disposed between the flat surface of said first chamber-carrying member and the flat surface of said second chamber-carrying member;

one of said first chamber-carrying member and said center member having nozzles formed therein each assigned to a respective one of said ink chambers;

means for supplying ink to said ink chambers and for ejecting ink from said ink chambers through said nozzles;

said nozzles formed in said first chamber-carrying member forming a single nozzle row having $k \geq 2$ nozzle groups and extending in a first direction, said ink chambers having k chamber groups with each of said nozzle groups being associated with a respective one of said chamber groups;

said ink chambers formed in said first chamber-carrying member being a first chamber group and said ink chambers formed in said second chamber-carrying member being k^{th} chamber group, a first nozzle group of said k nozzle groups communicating with said first chamber group, and a k^{th} nozzle group of said k nozzle groups communicating with said k^{th} chamber group;

said nozzle openings extending and ejecting ink droplets in a second direction being substantially orthogonal to said first direction, said k chamber groups being disposed in a third direction relative to one another, said third direction being substantially orthogonal to said first and second directions; and

said center member having communication openings formed therein, said communication openings being associated and cooperating with said ink supplying means for supplying said k^{th} nozzle group in said nozzle row with ink.

19. The ink jet print head according to claim 18, wherein said second chamber-carrying member is one of a plurality of chamber-carrying members each having a respective one of said chamber groups formed therein.

20. The ink jet print head according to claim 18, wherein said nozzles of said respective nozzle groups are disposed in an alternating fashion within said single nozzle row.

21. The ink jet print head according to claim 18, wherein said first chamber-carrying member, said second chamber-carrying member, and said center member together form a module having a middle region and an edge region, said nozzles being formed in an edge surface of said first chamber-carrying member, and said edge surface being disposed in one of said middle and edge regions.

22. The ink jet print head according to claim 18, wherein said first chamber-carrying member, said second chamber-carrying member, and said center member together form a module, and including at least one further module comprising two chamber-carrying members and a center member disposed therebetween, said module and said at least one further module together forming the ink jet print head.

23. The ink jet print head according to claim 18, including further chamber-carrying members and at least one further center member disposed between respective ones of said further chamber-carrying members, said chamber-carrying members and said center members together forming an ink jet print head module with only said first chamber-carrying member having said nozzles formed therein.

24. The ink jet print head according to claim 18, including spacer members, said chamber-carrying members, said center member and said spacer members forming a print head module, said print head module including an ink supply opening

and having a suction chamber formed therein, at least one of said center member and said spacer members having an opening formed therein for connecting said ink supply opening to said suction chamber, at least one of said center member and said spacer members having second and third openings formed therein, said second openings supplying at least one of said k^{th} chamber groups with ink from said suction chamber, said k^{th} nozzle groups communicating with respective ones of said chamber groups through said third openings.

25. The ink jet print head according to claim 22, including a spacer member disposed between said modules, and wherein each of said modules has a suction chamber formed therein, said spacer member having ink supply and ink lead-through openings and a recess for receiving said ink ejection means formed therein, each of said suction chambers communicating with a respective one of said chamber groups through second ink supply openings, and each module having supply openings formed therein for supplying ink to said suction chambers.

26. The ink jet print head according to claim 22, wherein said ink supply openings are elongated openings being one of rectangular, oval and longhole, respective ones of said elongated openings being disposed above one another and being rotated relative to one another by substantially 90°, said elongated openings extending along a first line near an edge face of said module, said first line being offset with regard

to a second line of elongated openings disposed below said first line of elongated openings, an offset distance between said first and second lines and a longest lateral distance between said elongated openings being greater than said elongated openings disposed above or below and rotated by substantially 90°, respective ones of said elongated openings together with openings rotated by 90° together defining a cross-section being larger than a cross-section of said nozzles, wherein said second chamber-carrying member is a plurality of second chamber-carrying members each having a section chamber formed therein, said ink ejecting means being in the form of piezo-electrical elements disposed at said ink chambers, said center members and said chamber-carrying members being formed of the same material.

27. The ink jet print head according to claim 26, wherein said spacer members are formed of the same material as said center and chamber-carrying members or of the same material as said piezo-electrical elements.

28. A method of manufacturing an ink jet print head, which comprises:

processing plate material in parallel and forming through openings in all members to be equipped with through openings;

forming chamber-carrying members;

connecting the members and forming at least one print head module, and subsequently annealing the at least one print head module;

applying piezo-electrical elements to the at least one module and connecting the piezo-electrical elements with conductor paths applied to the module; and

assembling the at least one module to form an ink jet print head.

29. The method according to claim 28, which comprises, prior to the processing step, preparing masks and pretreating the plate material by removing from the plate material areas for ink chambers, nozzle openings and supply conduits, for suction chambers and for through openings, exposing the plate material to ultraviolet radiation and subsequently heat-treating, and etching areas of the plate from which material is to be removed.

30. The method according to claim 29 which comprises, in the pretreating step, exposing all areas from which material is to be removed to ultraviolet light of substantially identical wavelength and intensity, applying a first mask to the plate prior to etching photo-sensitized areas of the plate, etching first areas of the plate, subsequently removing the first mask, subsequently applying a second mask and etching second areas of the plate, subsequently removing the second mask and etching third areas of the plate.

31. The method according to claim 29, which comprises, in the pretreating step, applying different masks on the plate

material, exposing given areas of the plate to more frequent and more intense ultraviolet radiation of a given wavelength than other areas of the plate for creating areas of different sensitivity to the etchant, applying a mask with regard to areas where plate material is to be removed to different depths, and using an etchant of a certain concentration in the etching step.

32. The method according to claim 30, which comprises using etchant of respectively different concentrations in etching the first, second and third areas, for removing material from the areas with respectively different depth accuracy, and choosing a relatively lower depth accuracy for etching the through openings as compared to etching very flat areas for ink channels in the chamber-carrying members, and etching the through openings first, etching the chambers second, and etching the nozzle conduits third.

33. The method according to claim 28, which comprises, during the etching step, continuously observing a thickness of a floor layer of the chambers being etched, and subsequently precision smoothing the chamber-carrying parts for obtaining a final thickness of the floor layers of each of the etched-out chambers.

34. The method according to claim 28, which comprises, subsequently to the processing step, separating individual components from the plate and further processing the

individual components separately.

35. The method according to claim 34, which comprises, subsequently to etching through openings in all components, separating the components, precision smoothing surfaces of the chamber carrying members, masking given areas of the surfaces of the chamber-carrying members, and depth etching areas of the surfaces which are not masked, forming recesses and ink chambers in the chamber-carrying members, precision smoothing at one surface for obtaining a desired depth of the ink chambers, and precision smoothing at an opposite surface for exactly adjusting a desired thickness of a floor layer of the ink chamber, removing the mask used in the depth etching step by means of precision smoothing, and finally etching the ink nozzles.

36. The method according to claim 35, which comprises, in the etching of the ink nozzles, removing essentially only photo-sensitive plate material.

37. The method according to claim 35, which comprises applying a third mask prior to the etching of the ink nozzles.

38. The method according to claim 28, which comprises photo-sensitizing given areas of the plate material to respectively different degrees of etching sensitivity, subsequently forming recesses, chambers and through openings concurrently in one step at different etching speeds caused by

the different sensitivity of the respective areas, then separating the plate into components after a required depth of the recesses and chambers is obtained and subsequently etching ink nozzle openings into individual chamber members.

39. The method according to claim 38, which includes etching dividing lines into the plate for simplifying the separation of the plate into the components.

40. The method according to claim 38, which comprises etching nozzle openings into a chamber-carrying member, arranging individual plate parts including chamber-carrying members and center members into a module, aligning the components, durably affixing the components to one another, cutting an edge face of the module into which the nozzle openings formed and subsequently precision smoothing the edge face for creating an even surface along the edge face with the nozzle openings, applying a hydrophilic inner film on surfaces of cavities formed in the module by flushing the cavities with a first liquid, applying a hydrophobic outer film on even surfaces along the edge face with the nozzle openings, and subsequently hardening the inner and outer films.

41. The method according to claim 40, which comprises, subsequently to the applying steps, attaching piezo-electric crystals to at least one of a base of the chambers formed in the module and an outer surface of a bottom layer of the chambers formed in the module, and electrically connecting the

piezo-electric crystals.

42. The method according to claim 41, which comprises affixing the piezo-electric crystals with an adhesive and hardening the adhesive connection.

43. The method according to claim 40, which comprises providing a plate material for forming the components of amorphous, photo-sensitive glass, annealing the components in the durably affixing step and choosing a temperature in the annealing step which causes a phase transition in the glass from amorphous to crystalline.

44. The method according to claim 41, which comprises sputtering conductor tracks on the chamber carrying parts in the electrically connecting step.

45. The method according to claim 41, which comprises sputtering a piezo-electric layer onto the chamber-carrying part in the attaching step, and structuring the piezo-electric layer.

46. The method according to claim 28, which comprises assembling individual modules with at least one spacer member disposed therebetween to form an ink jet print head, mounting the ink jet print head in a casing and providing electrical connections to the ink jet print head.

47. The method according to claim 28, which comprises assembling an ink jet print head from a plurality of chamber-carrying members and center members, mounting the ink jet print head in a casing and providing electrical connections to the ink jet print head.

48. The method according to claim 46, which comprises producing the at least one spacer member from the plate material.

49. The method according to claim 46, which comprises producing the at least one spacer member by applying a layer of piezo-electric material on a surface of the plate, and structuring the layer of piezo-electric material by means of etching.

50. The method according to claim 48, which comprises producing the at least one spacer member from the plate material during the parallel processing step and prior to separating the components.

51. The method according to claim 28, which comprises forming nozzle openings in one of the chamber-carrying members, and cleansing the nozzle openings with compressed air subsequently to forming the print head module.

52. The method according to claim 47, which comprises forming nozzle openings in one of the chamber-carrying

members, and cleansing the nozzle openings with compressed air subsequently to assembling the ink jet print head.

53. The method according to claim 47, which comprises operatively testing the assembled ink jet print head and separating out defective ink jet print heads.

54. The method according to claim 41, which comprises applying electric conductor paths onto the center members for obtaining crossover-free conductor paths.

55. The method according to claim 28, which comprises performing the processing step with a photo-sensitive ceramic material and providing a second plate material of photo-sensitive amorphous glass, forming at least one component of the module of the glass material and connecting the components with adhesive.

56. The method according to claim 28, which comprises performing the processing step with a photo-sensitive ceramic material and providing a second plate material of photo-sensitive, amorphous glass, forming at least one component of the module of the ceramic material, and connecting the components with adhesive.

57. A method of manufacturing an edge-shooter ink jet print head, which comprises:

a) parallel processing of a glass plate for forming different module plates of an ink jet print head and forming cavities of defined depth in the glass plate;

b) subsequently separating individual parts for the ink jet print head from the glass plate;

c) joining the individual parts by diffusion bonding and forming a module of the ink jet print head;

d) depositing conductor tracks on the glass plate and installing PZT elements or a PZT layer;

e) assembling the print head module to form a print head, cleaning nozzles formed in the print head by means of compressed air, applying a hydrophilic inner coating on nozzle channels, applying a hydrophobic outer coating on a face edge of the module, providing driver circuits for the print head, providing supply means necessary for a functionality of the print head, placing the print head into a housing, and testing the print head for proper operation.

58. The manufacturing method according to claim 57, which further comprises: performing steps a) through d) simultaneously for two mutually associated print head halves; assembling each of the print head halves, cementing the print head halves together with an adhesive layer, cleaning channels of the print head of adhesive in a liquid cleaning process and utilizing a solvent which is not a solvent for a print head ink; and cleaning the channels by means of compressed air prior to the step of providing supply means.

59. The manufacturing method according to claim 58,

which further comprises forming the adhesive layer from an adhesive which can be dissolved with a solvent prior to hardening thereof.

60. The manufacturing method according to claim 58, which further comprises: applying the adhesive layer to at least one half of the print head as a self-adhesive foil, removing adhesive material from the foil by means of a laser beam forming opening transit openings to the channels, the channels leading through separators to the ink jet nozzles; and, after joining the two print head halves together, hardening the adhesive layer by supplying energy thereto.

61. The manufacturing method according to claim 60, which further comprises adjusting the hardening step by controlling the energy supply with regard to time and location such that channels leading to the print head nozzles are not blocked off by adhesive from the adhesive layer and that any possible stoppage cannot harden so quickly as to disallow a removal thereof with an adhesive solvent.

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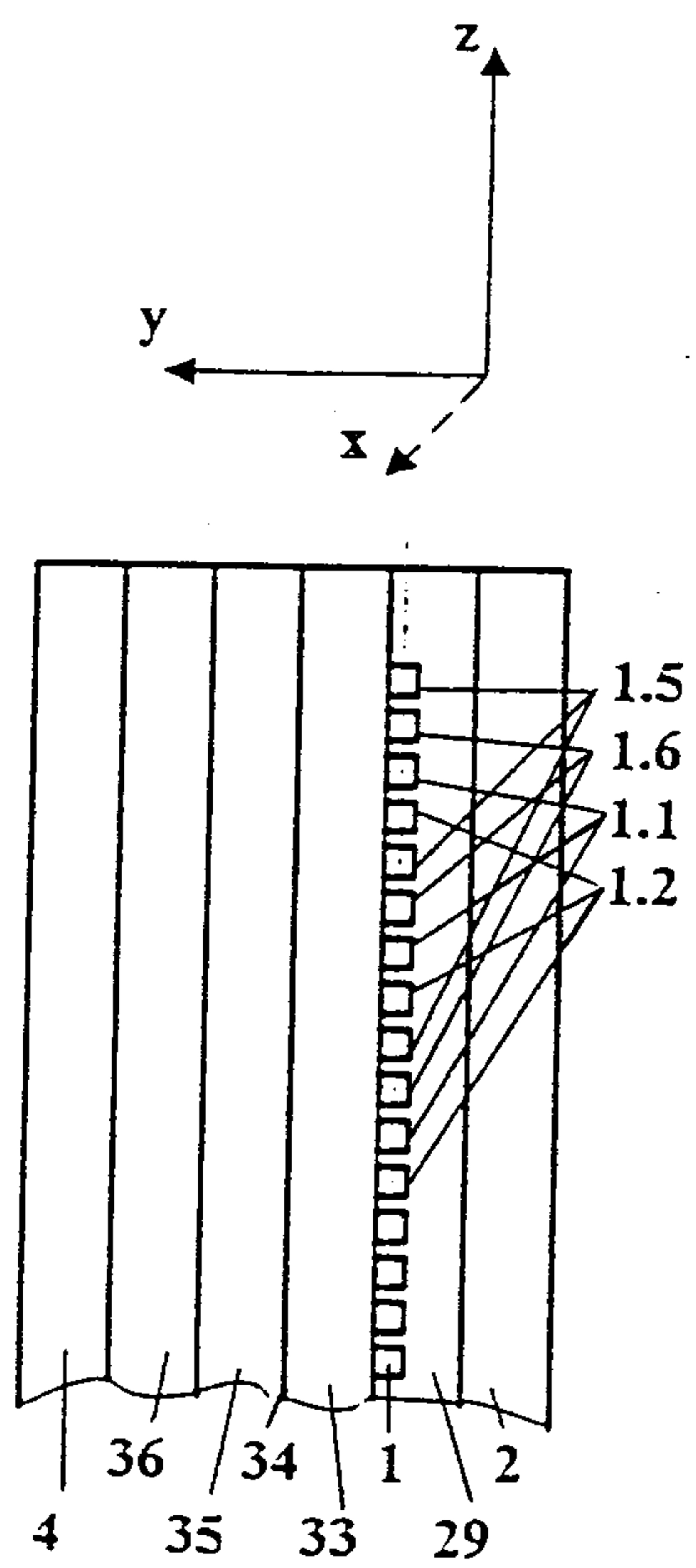

Fig. 1b

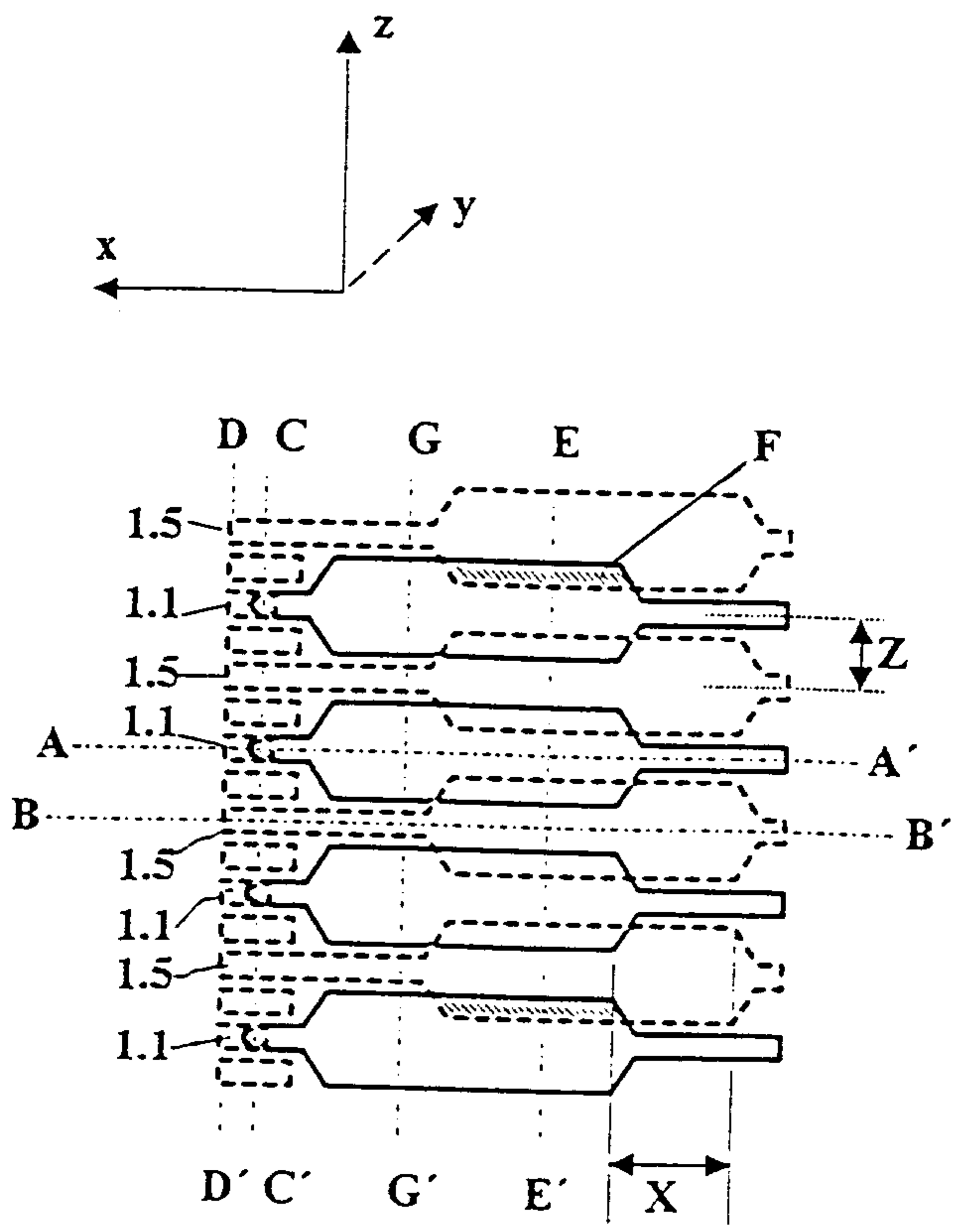

Fig. 1c

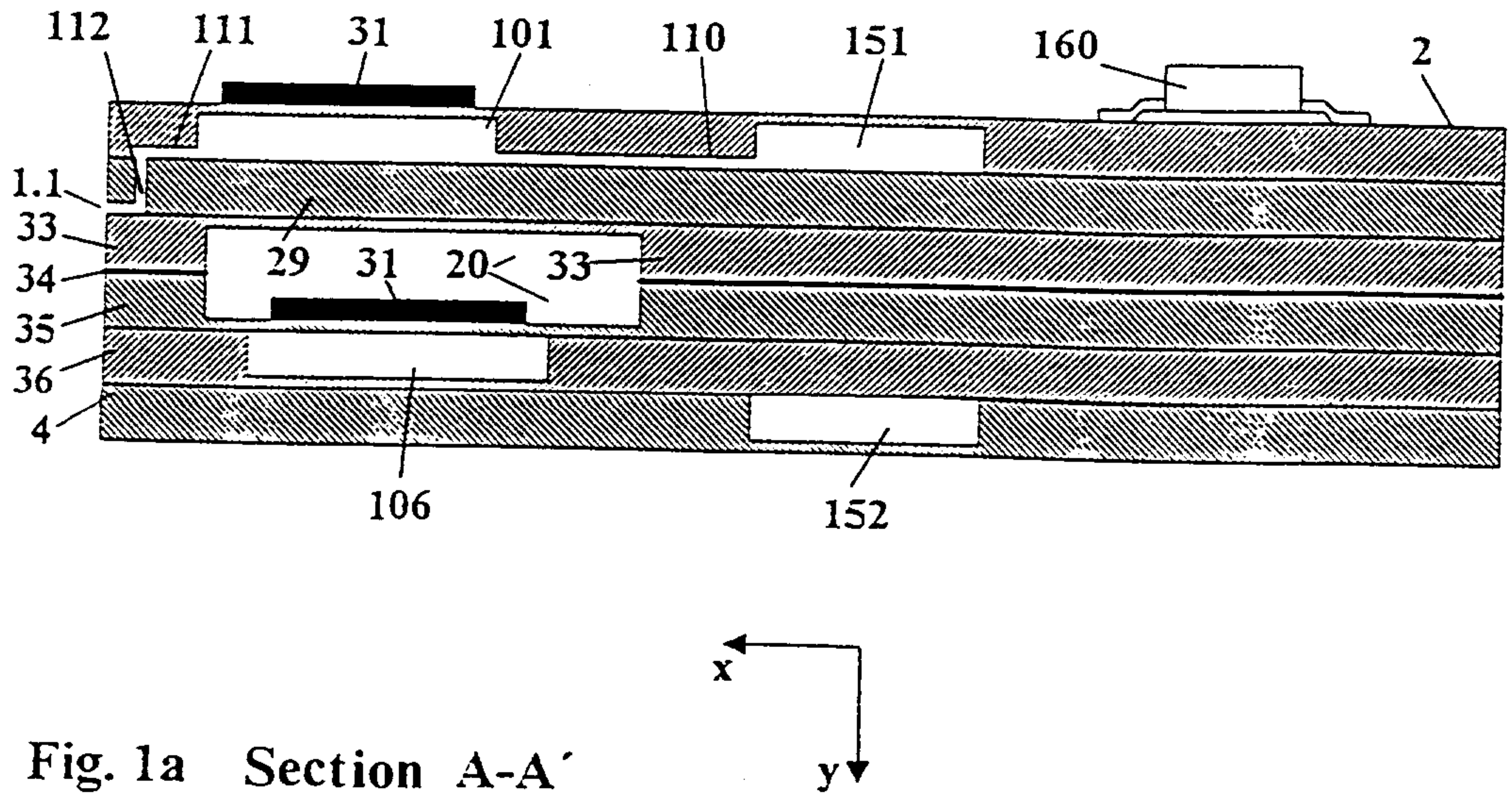

Fig. 1a Section A-A´

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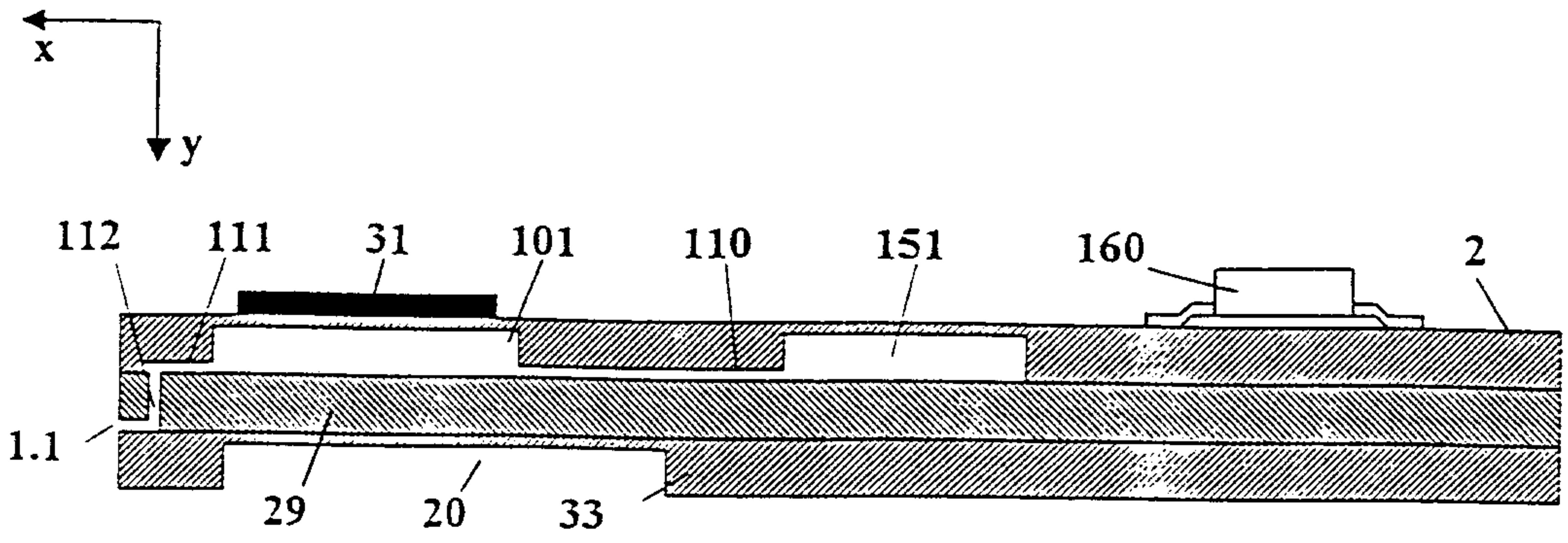


Fig. 2a Section A-A′

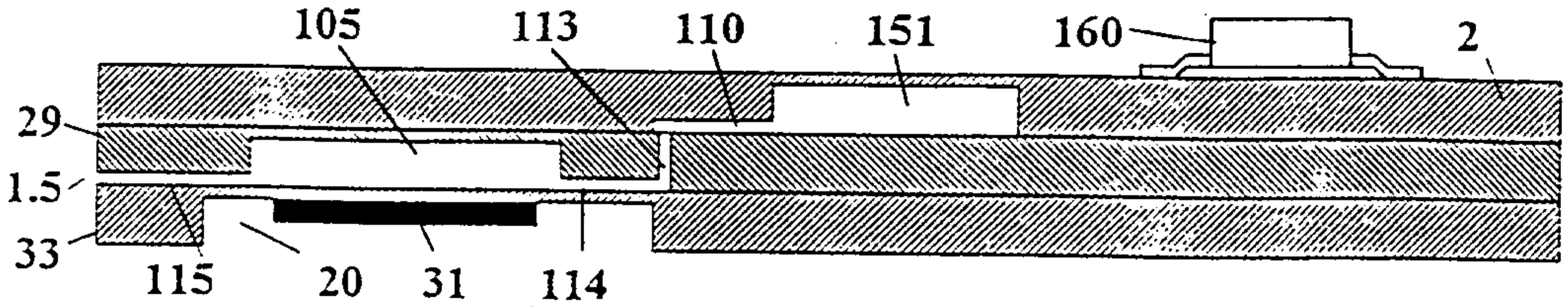
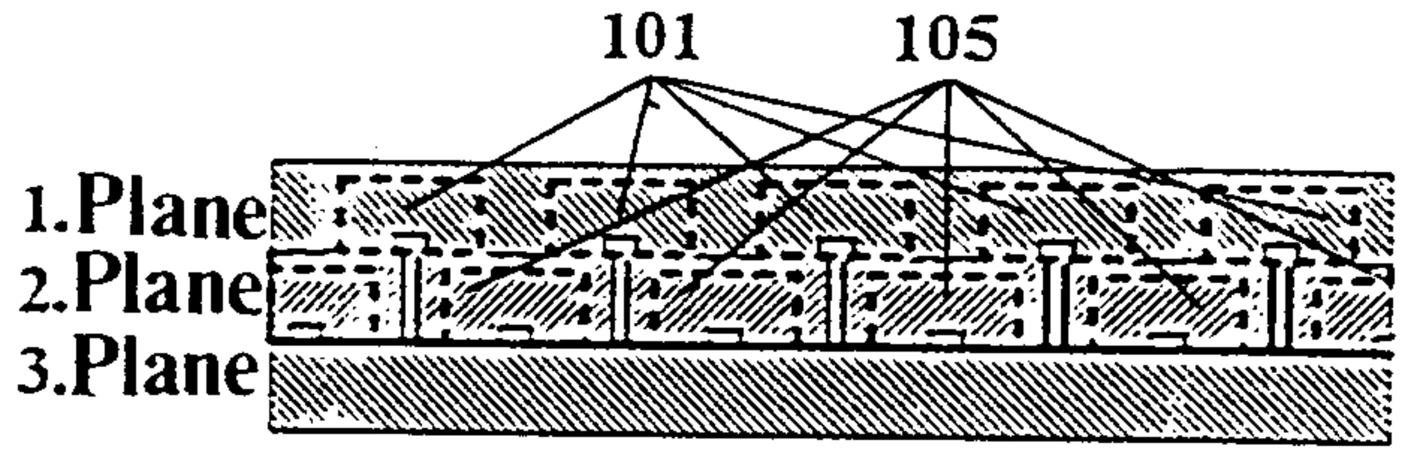


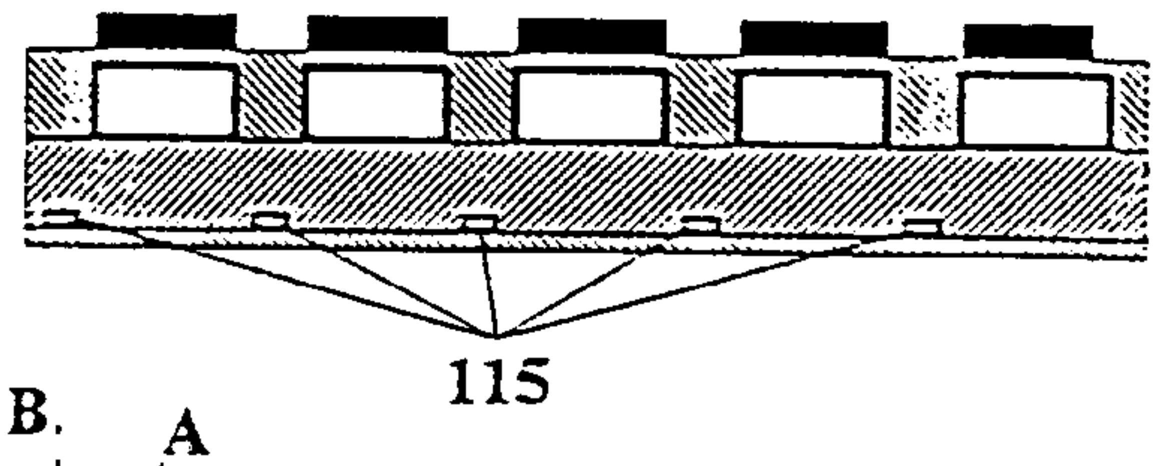
Fig. 2b Section B-B′

Fig. 2c



Section C-C′

Fig. 2d



Section G-G′

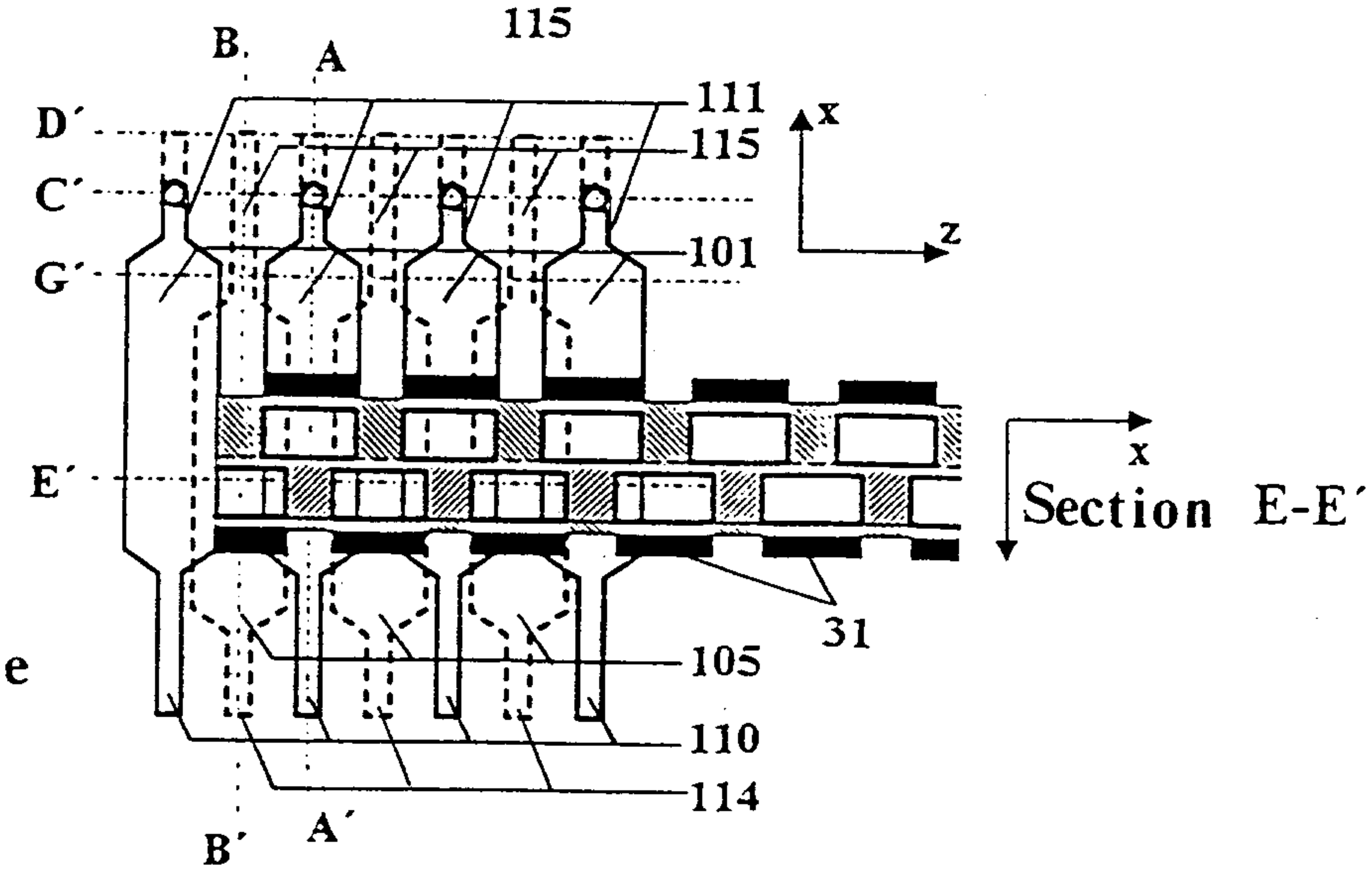


Fig. 2e

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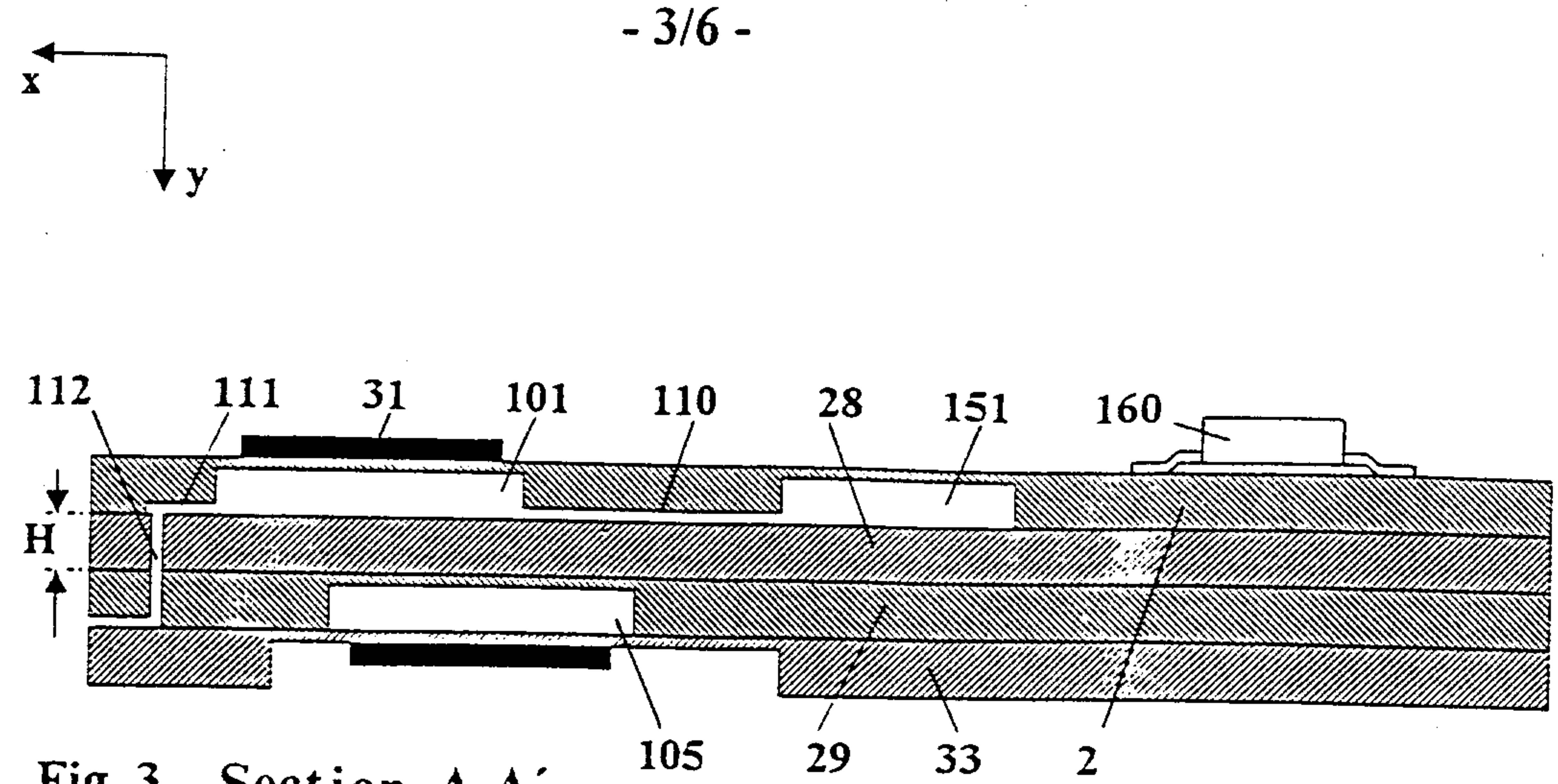

Fig. 3 Section A-A´

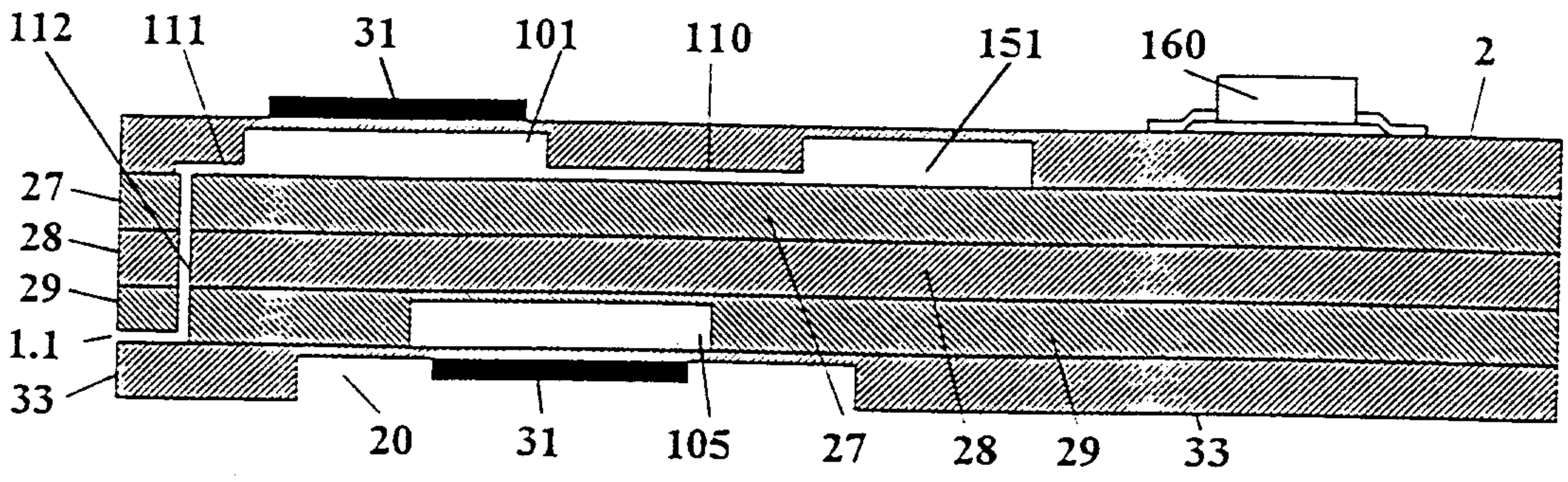

Fig. 4 Section A-A´

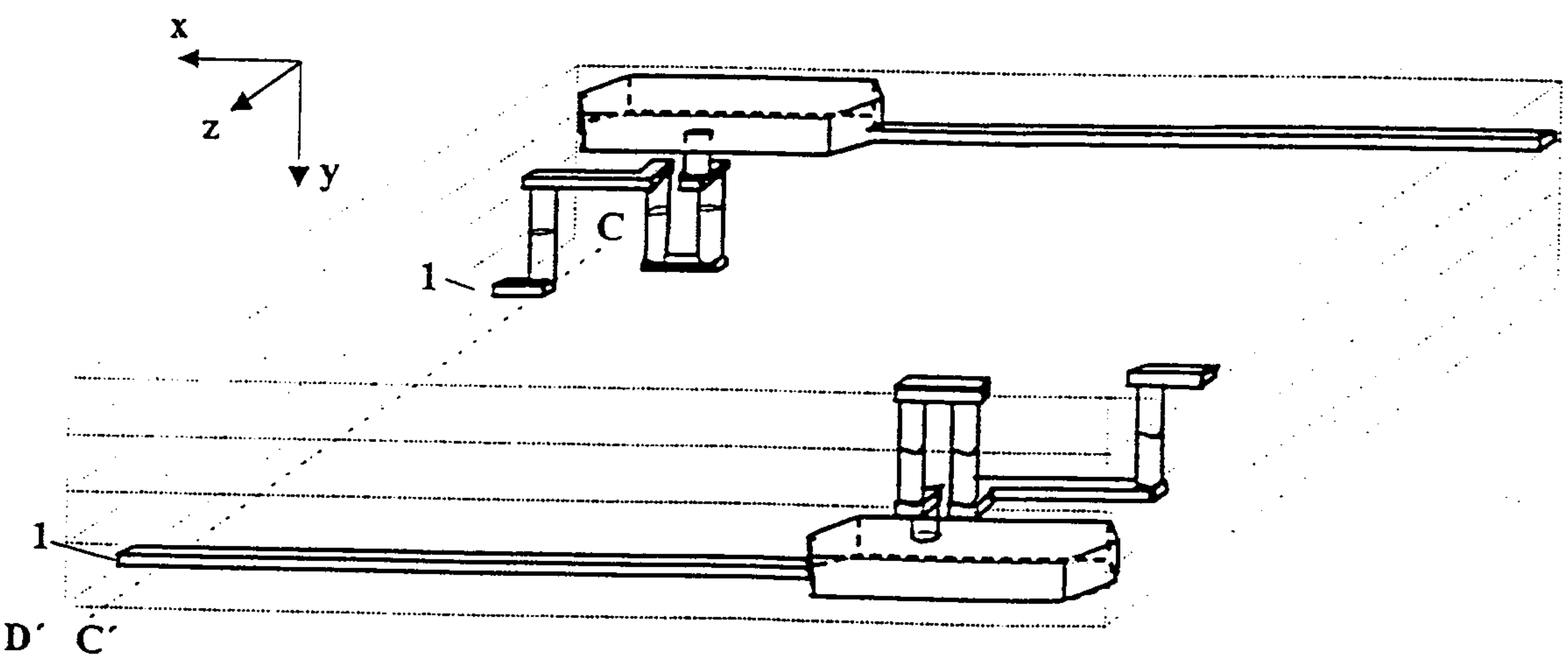

Fig. 5

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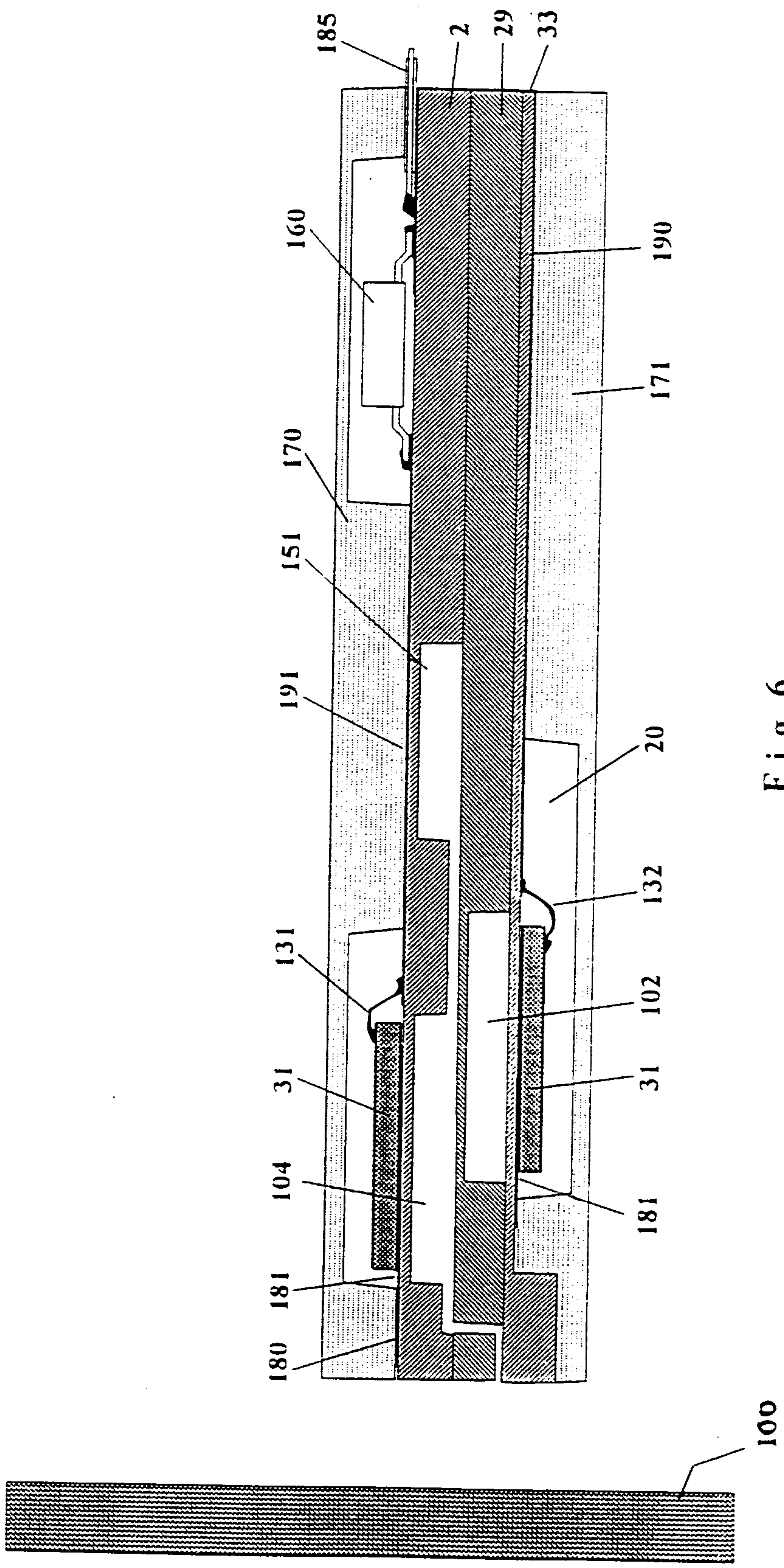

Fig. 6

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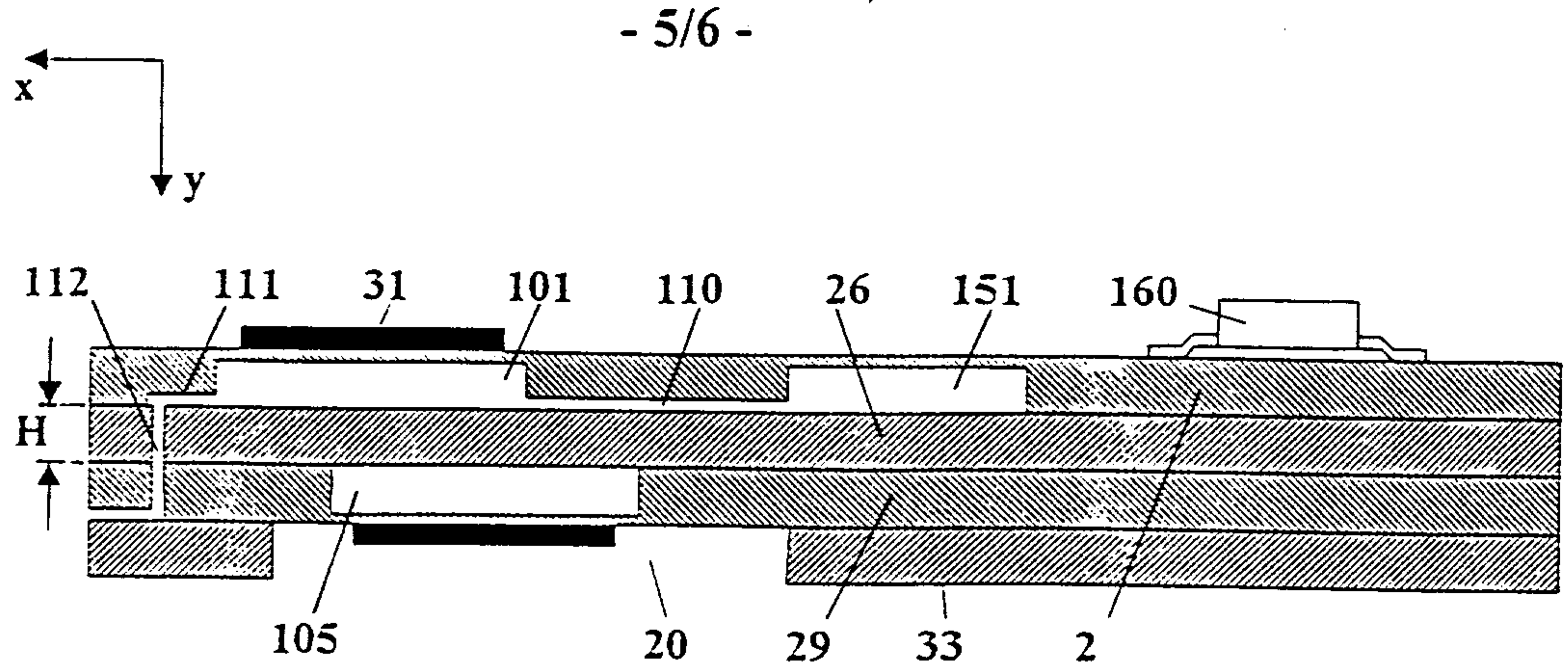


Fig. 7 Section A-A´

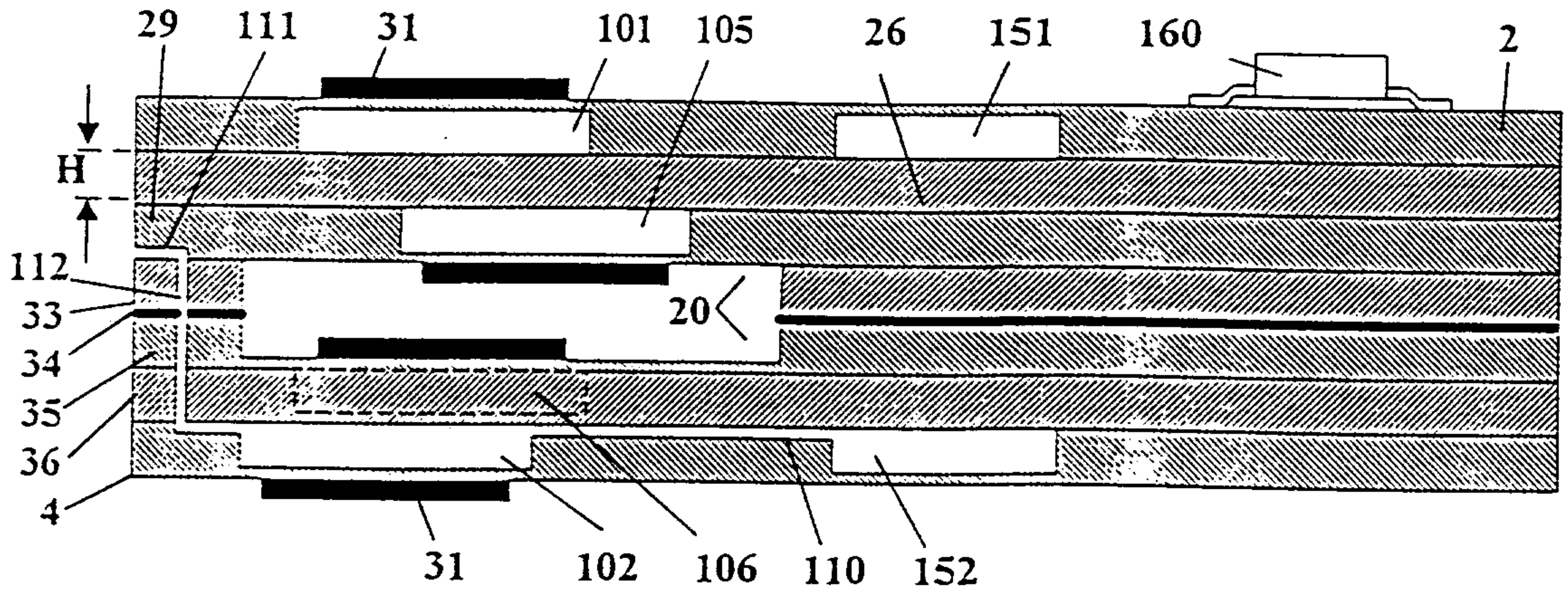


Fig. 8

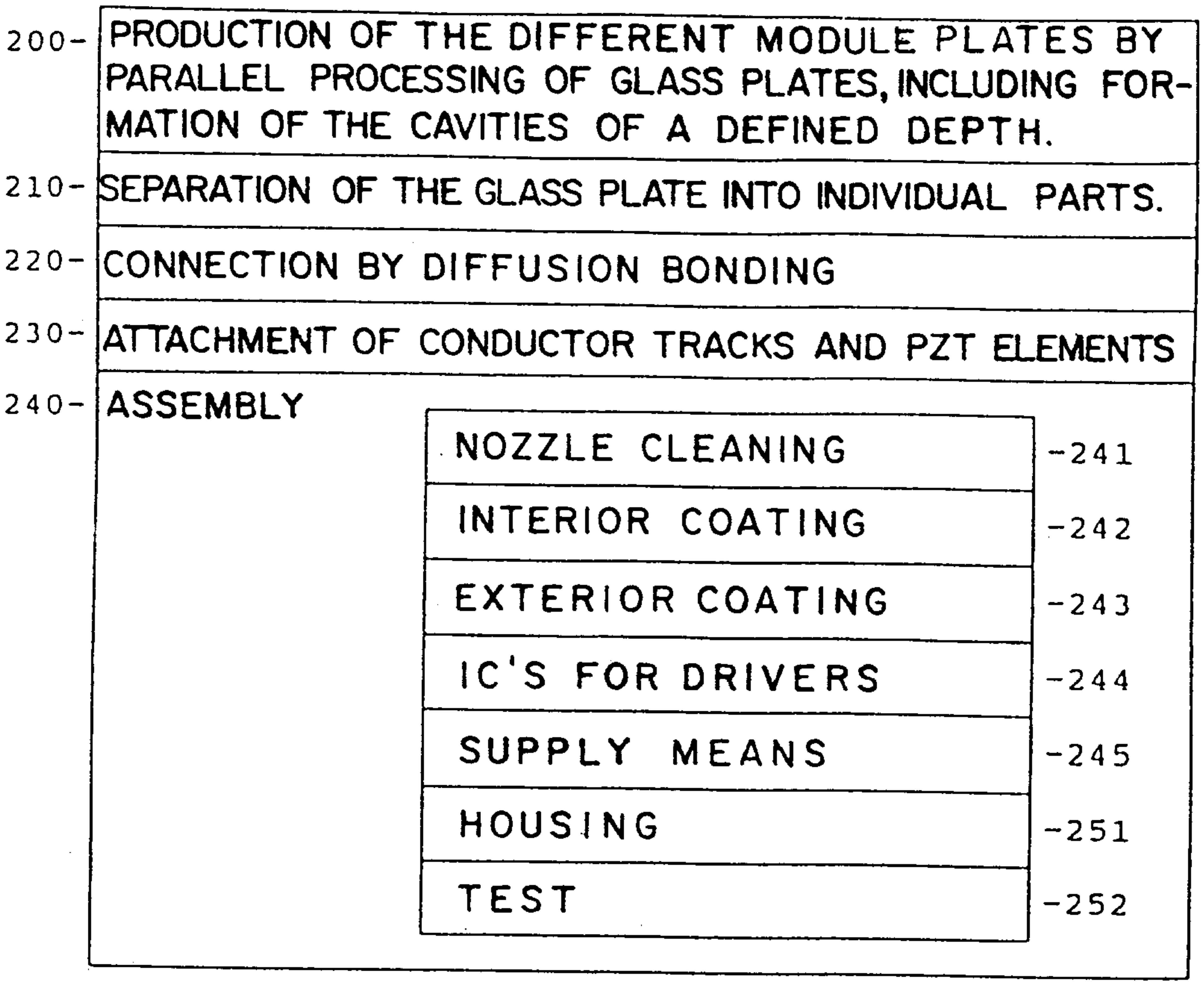

200- PRODUCTION OF THE DIFFERENT MODULE PLATES BY PARALLEL PROCESSING OF GLASS PLATES, INCLUDING FORMATION OF THE CAVITIES OF A DEFINED DEPTH.
210- SEPARATION OF THE GLASS PLATE INTO INDIVIDUAL PARTS.
220- CONNECTION BY DIFFUSION BONDING
230- ATTACHMENT OF CONDUCTOR TRACKS AND PZT ELEMENTS
240- ASSEMBLY
NOZZLE CLEANING -241
INTERIOR COATING -242
EXTERIOR COATING -243
IC'S FOR DRIVERS -244
SUPPLY MEANS -245
HOUSING -251
TEST -252

Fig. 9

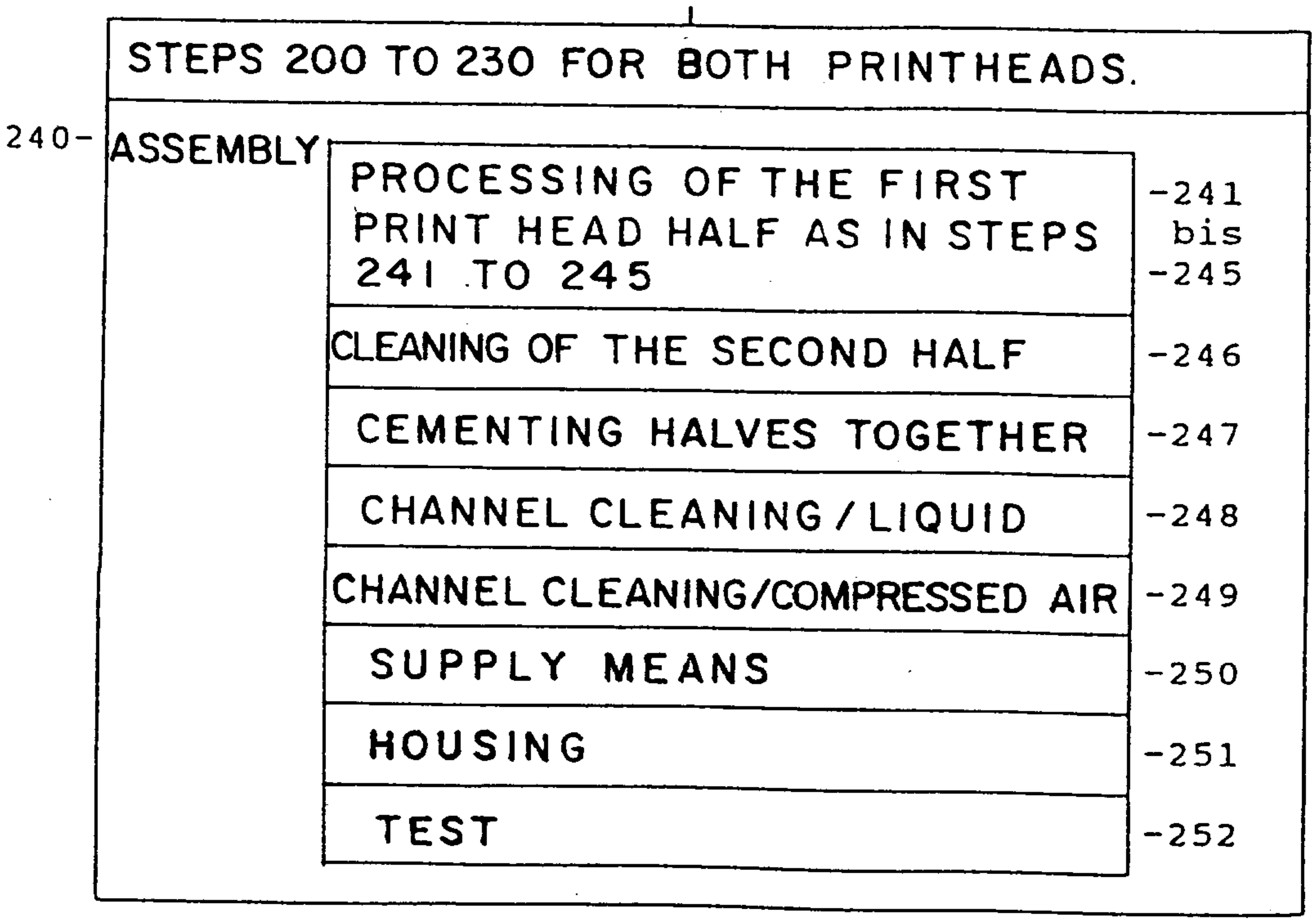
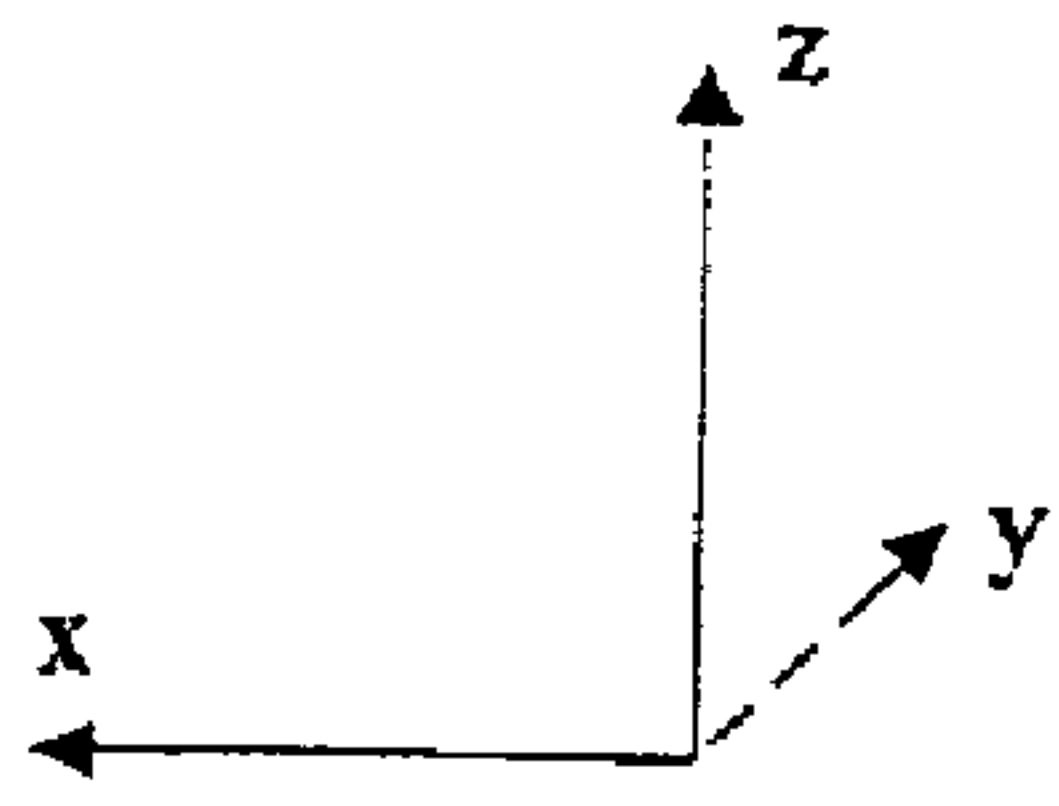
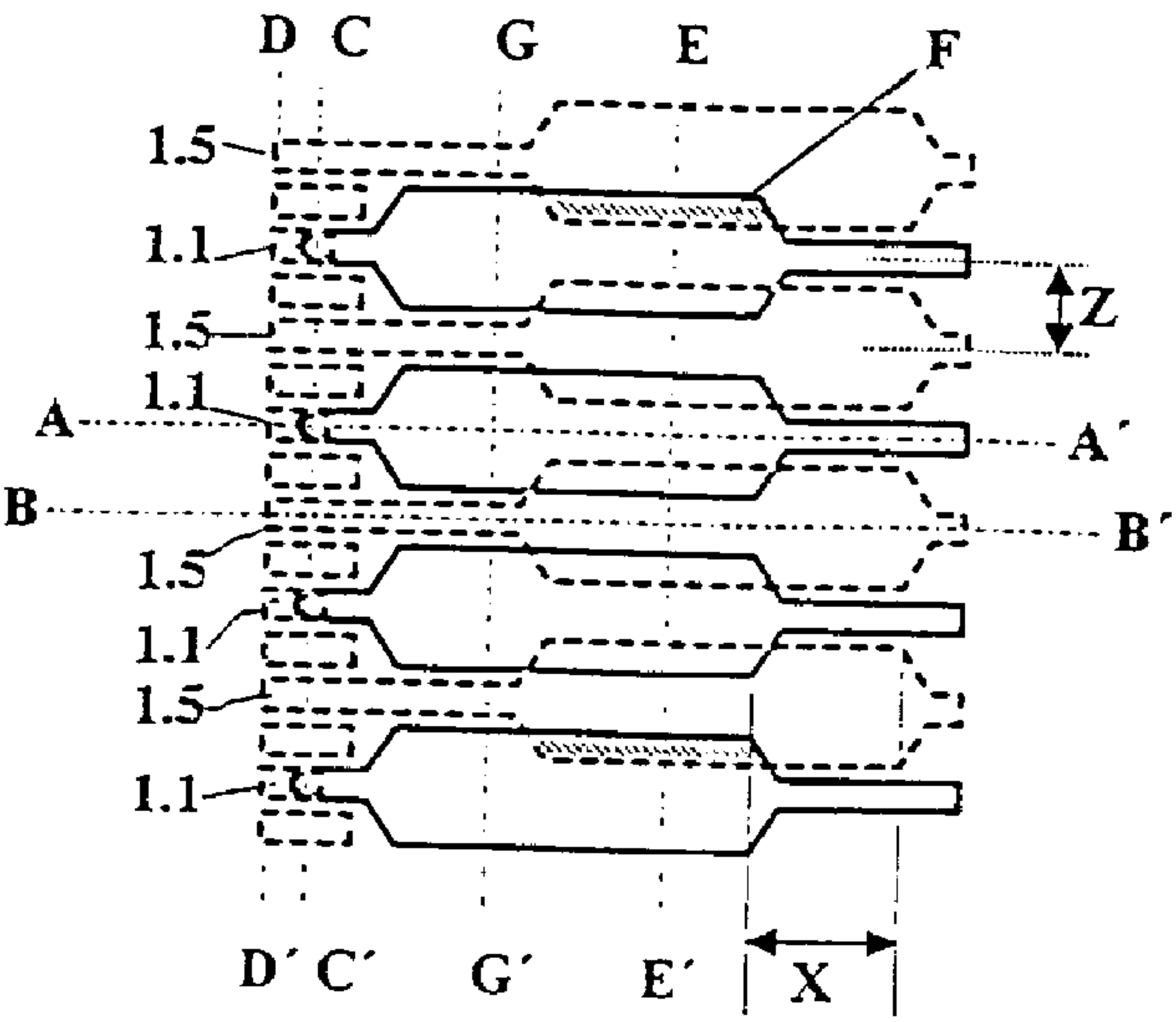

STEPS 200 TO 230 FOR BOTH PRINTHEADS.
240- ASSEMBLY
PROCESSING OF THE FIRST PRINT HEAD HALF AS IN STEPS 241 TO 245 -241 bis -245
CLEANING OF THE SECOND HALF -246
CEMENTING HALVES TOGETHER -247
CHANNEL CLEANING / LIQUID -248
CHANNEL CLEANING/COMPRESSED AIR -249
SUPPLY MEANS -250
HOUSING -251
TEST -252

Fig 10


z
y
x


D
C
G
E
F
1.5
1.1
1.5
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A
A´
B
B´
1.5
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Z
D´
C´
G´
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X