

July 6, 1948.

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2,444,590

CRYSTAL PLATE AND METHOD OF FABRICATING SAME

Filed Sept. 7, 1944

2 Sheets-Sheet 1

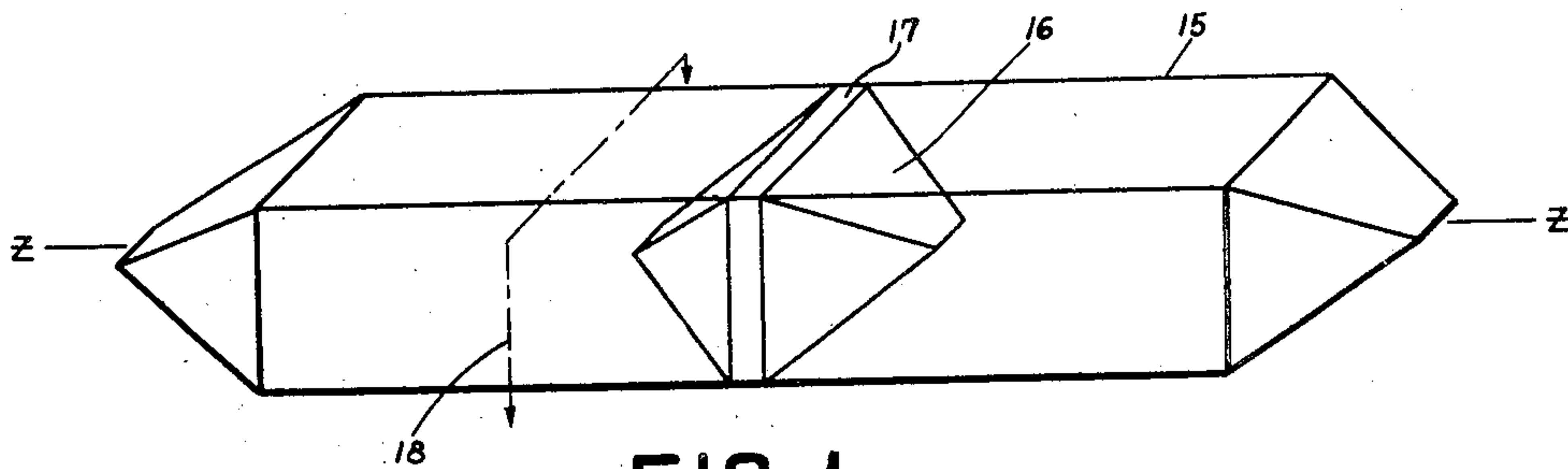


FIG. 1

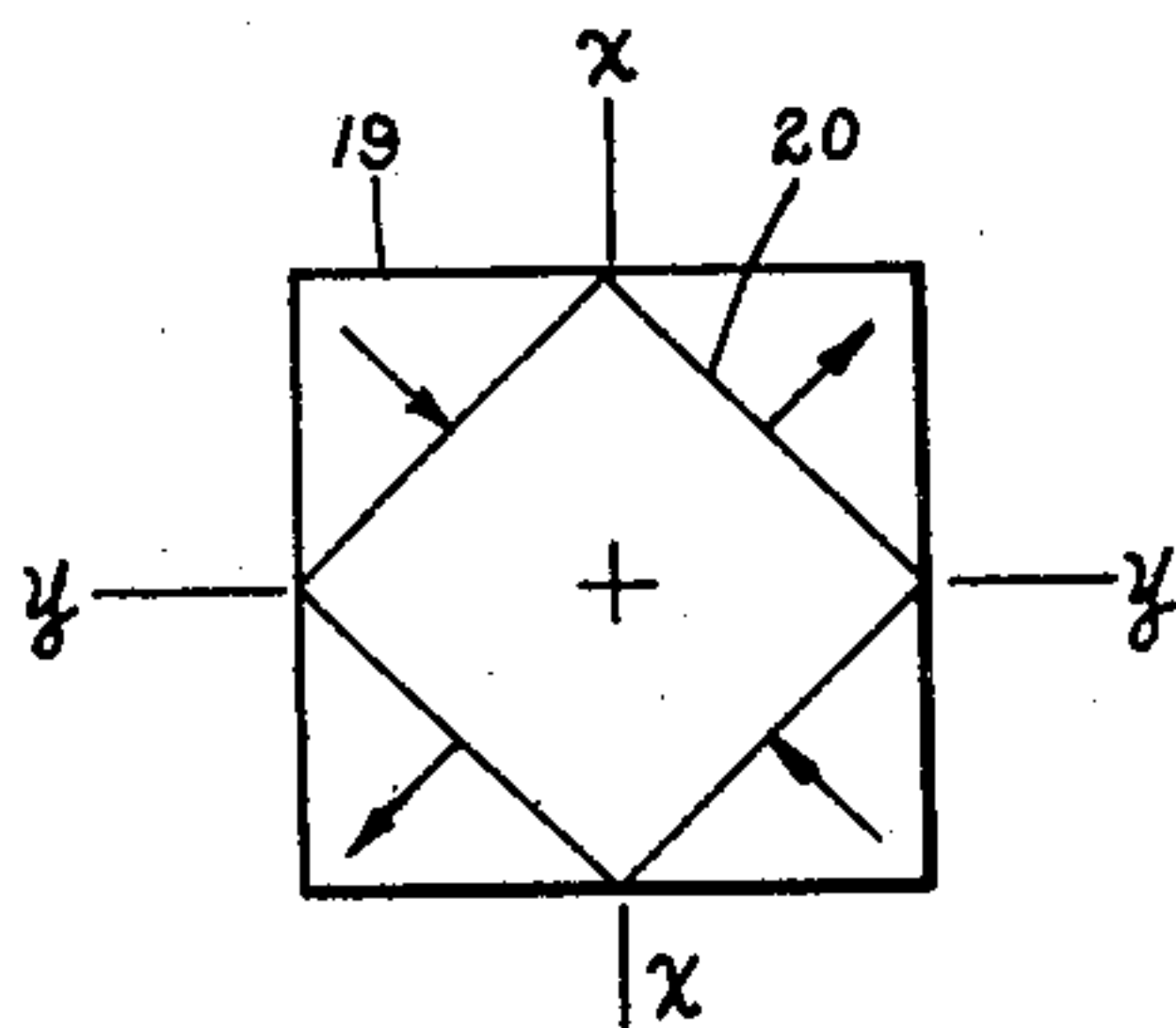


FIG. 2

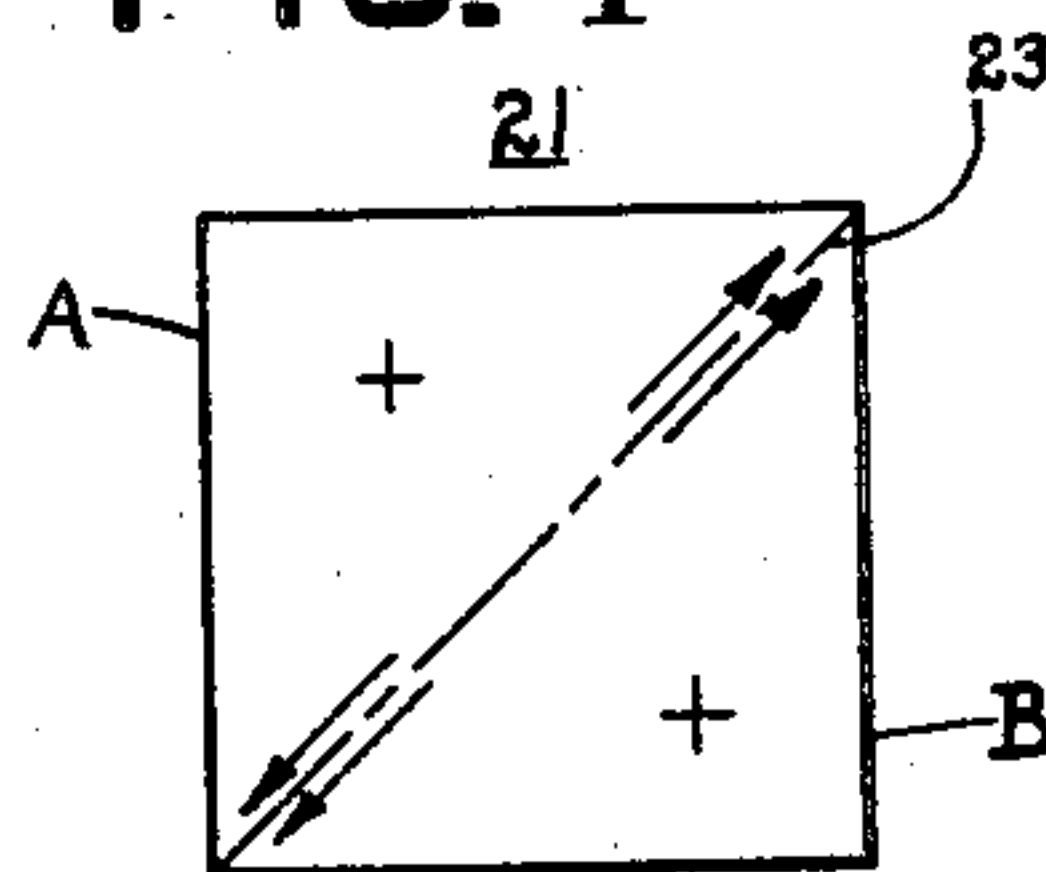


FIG. 3

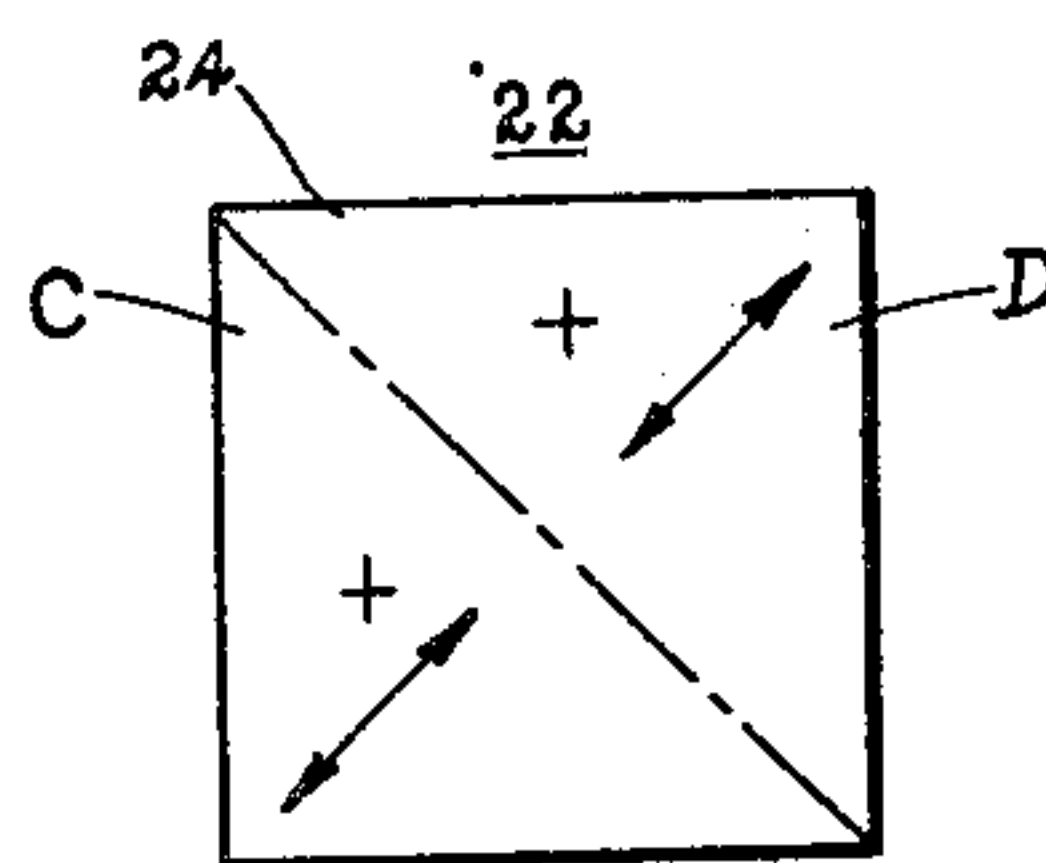


FIG. 4

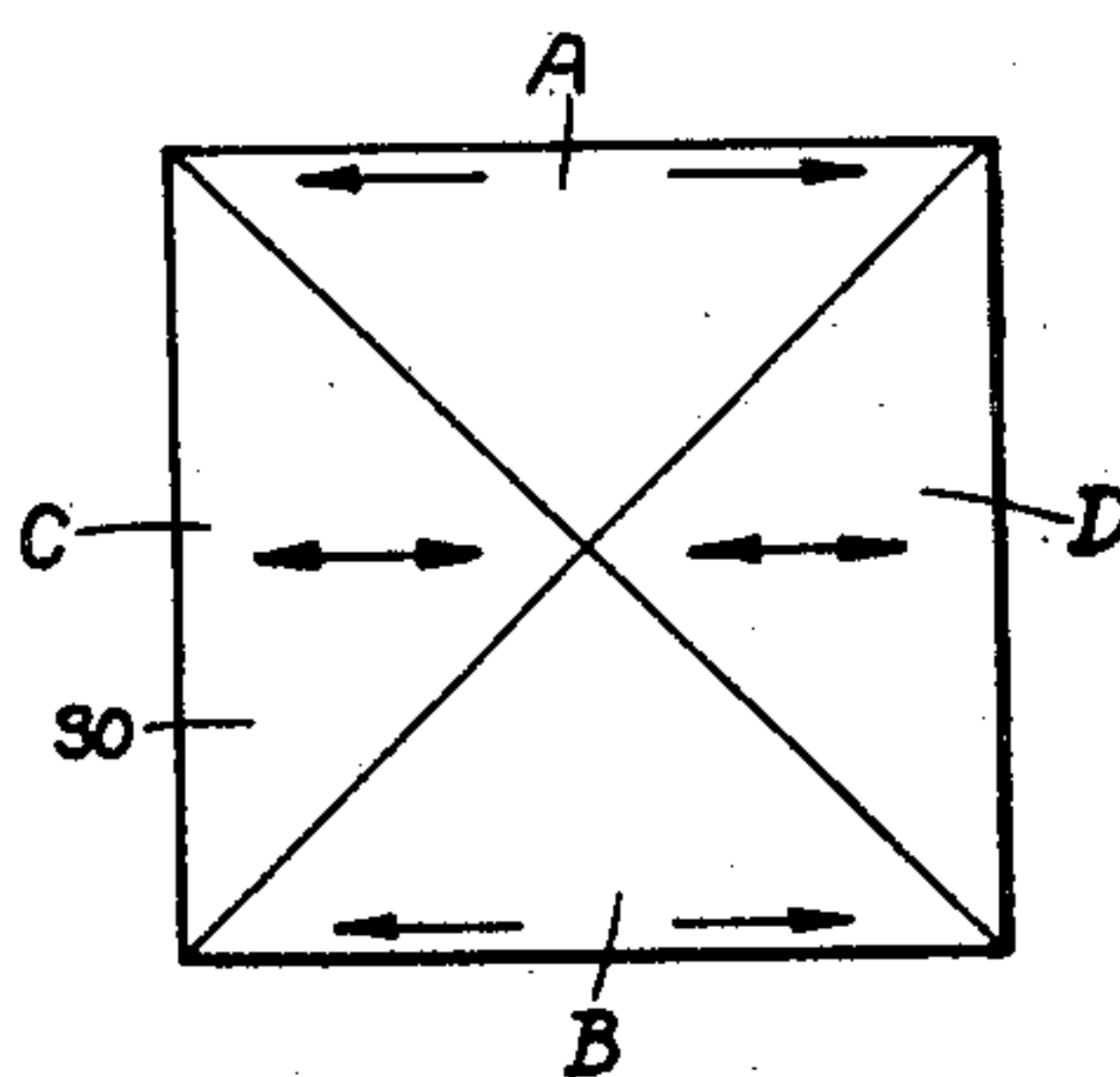


FIG. 5

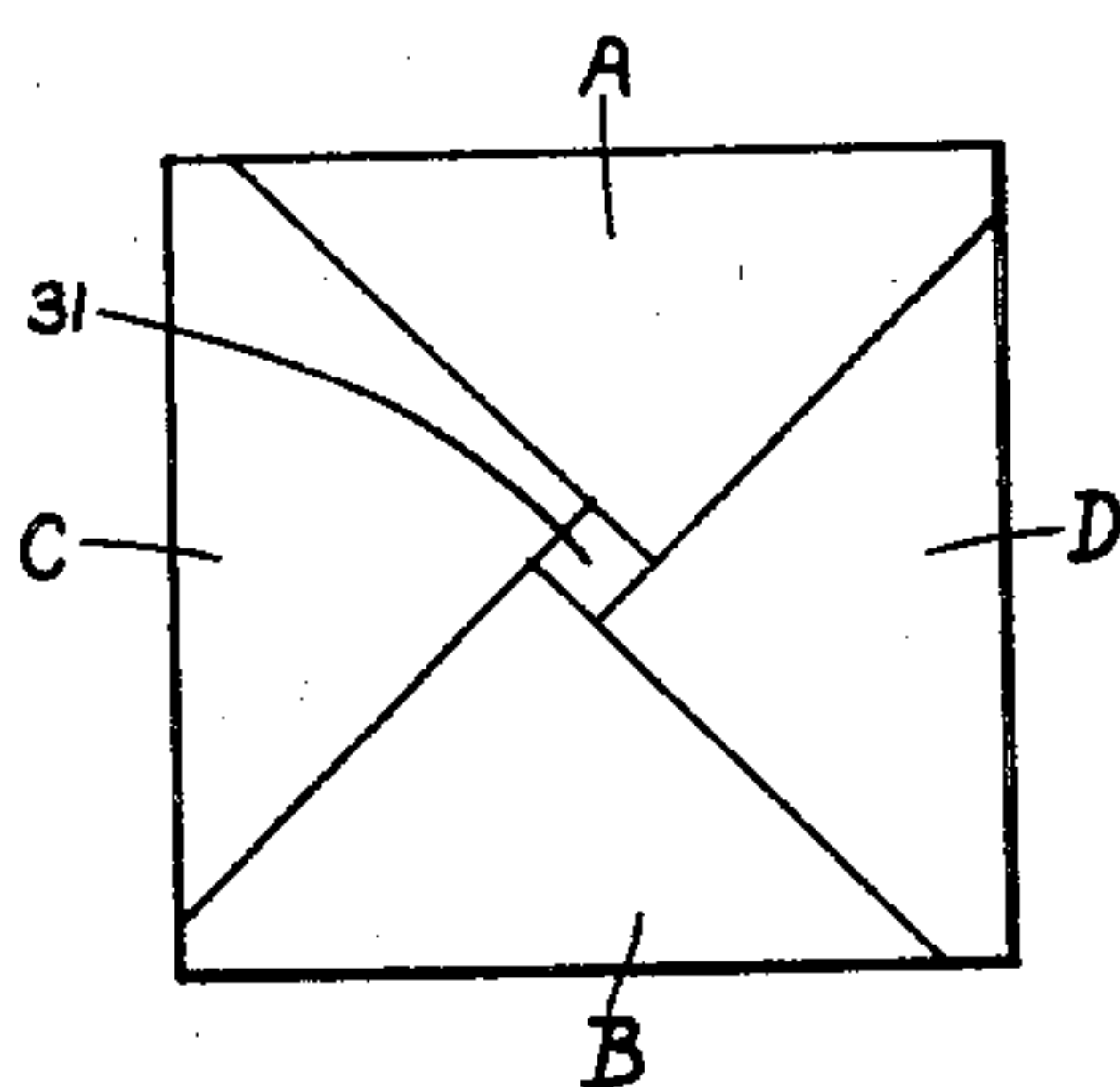


FIG. 6

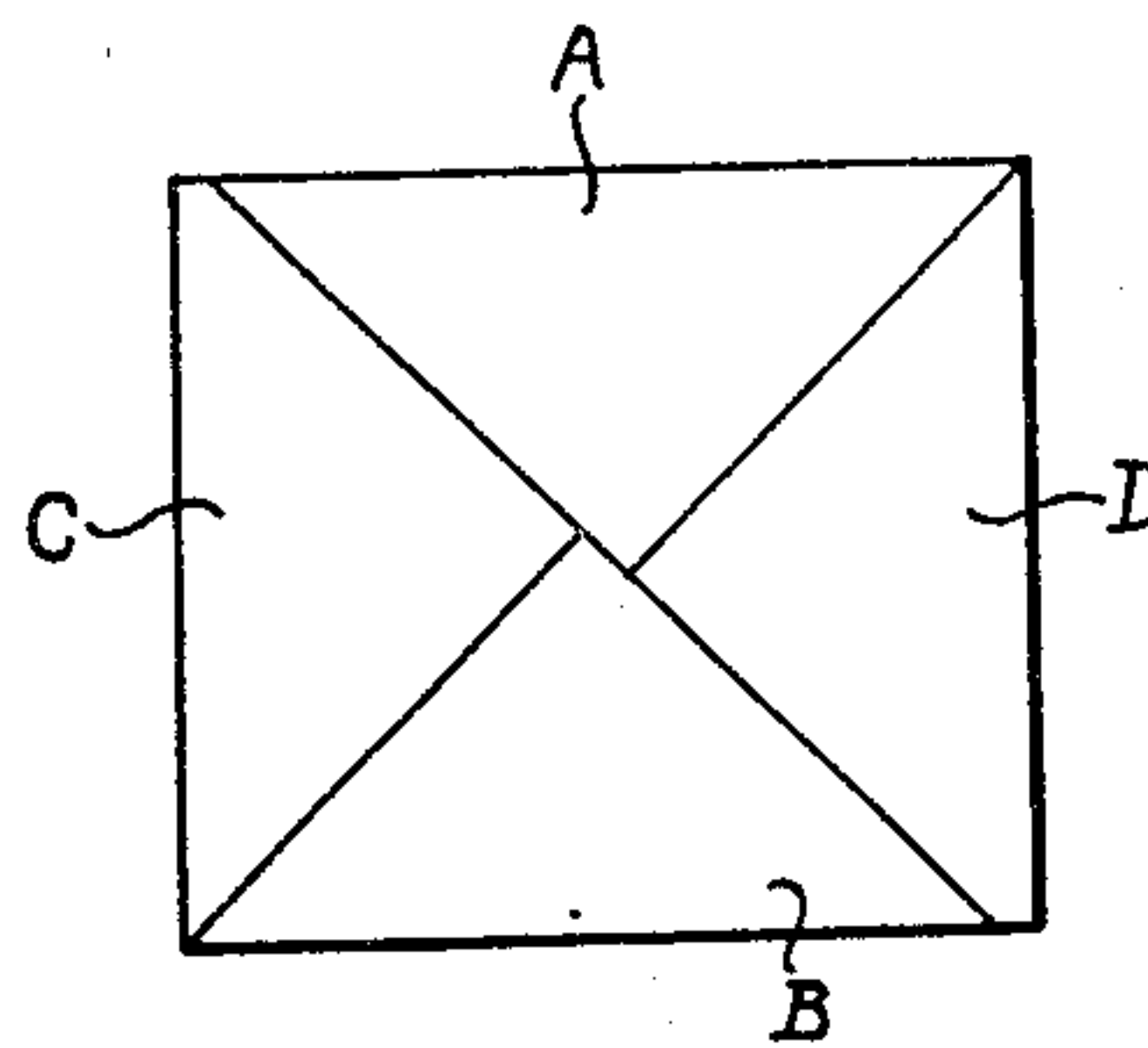


FIG. 7

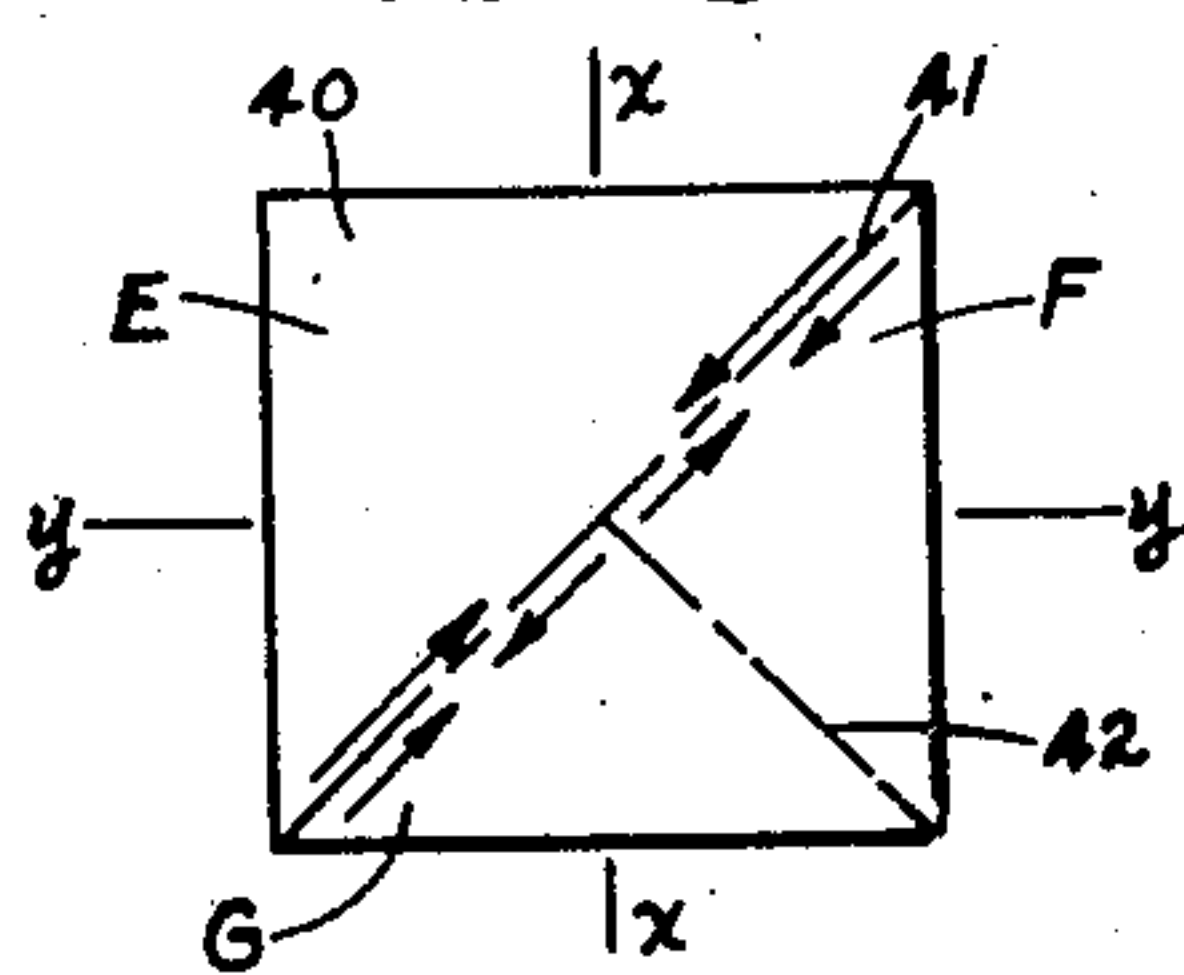


FIG. 8

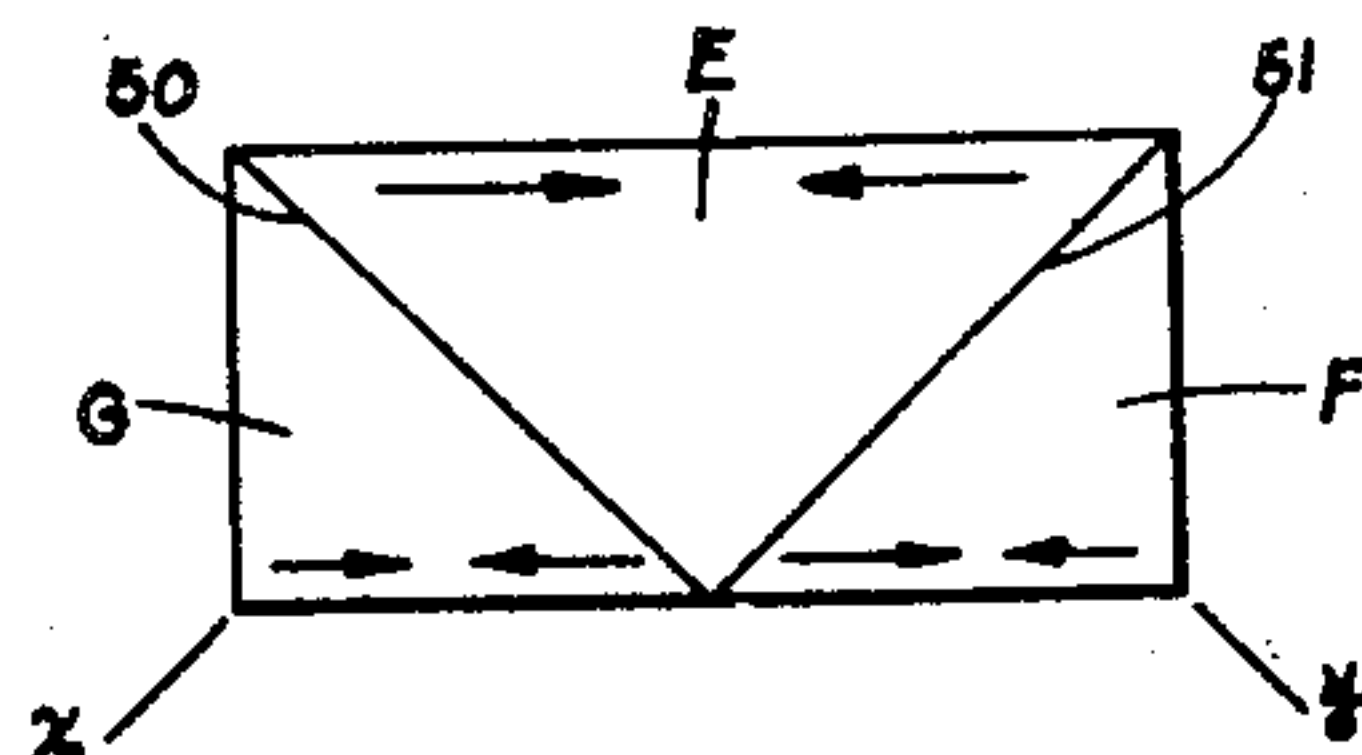


FIG. 9

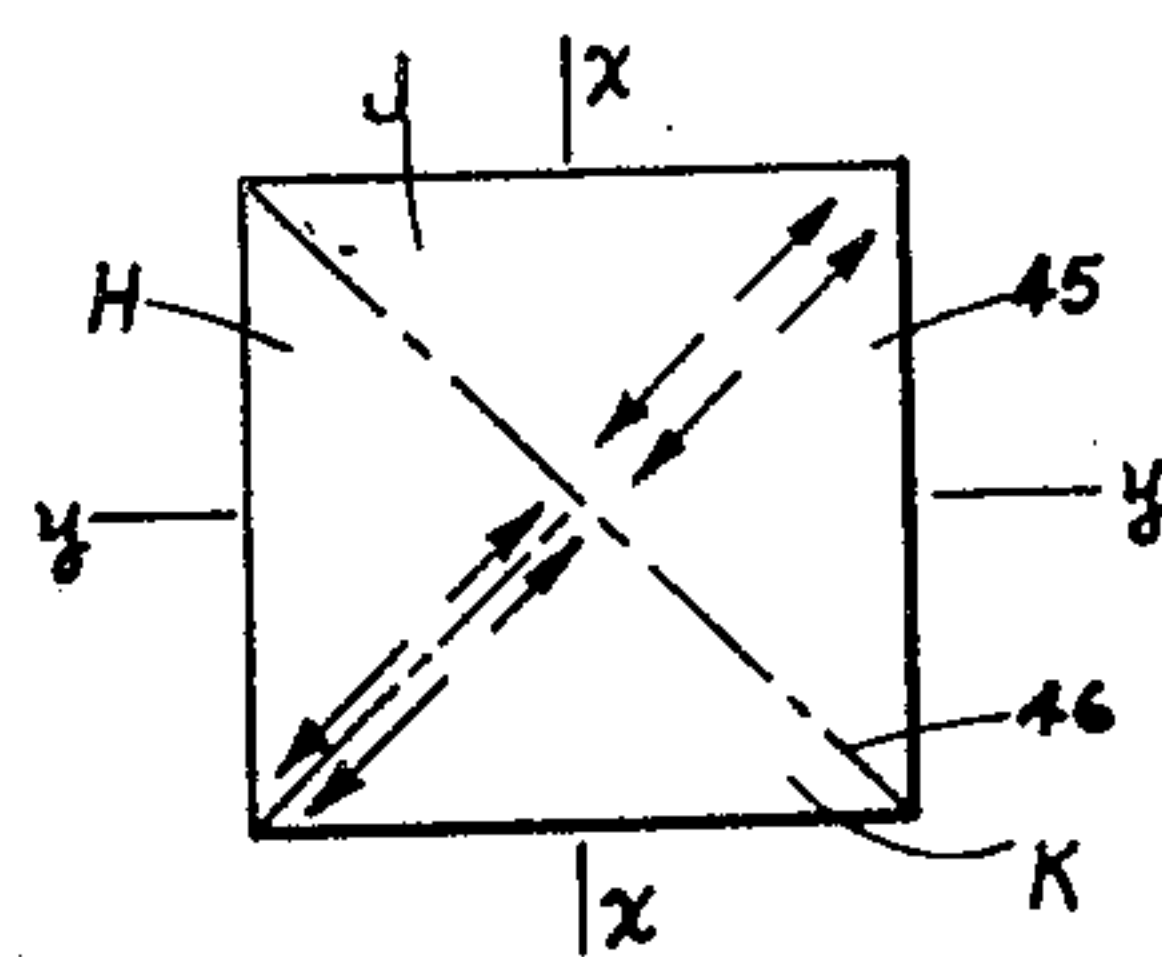


FIG. 10

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2 Sheets-Sheet 2

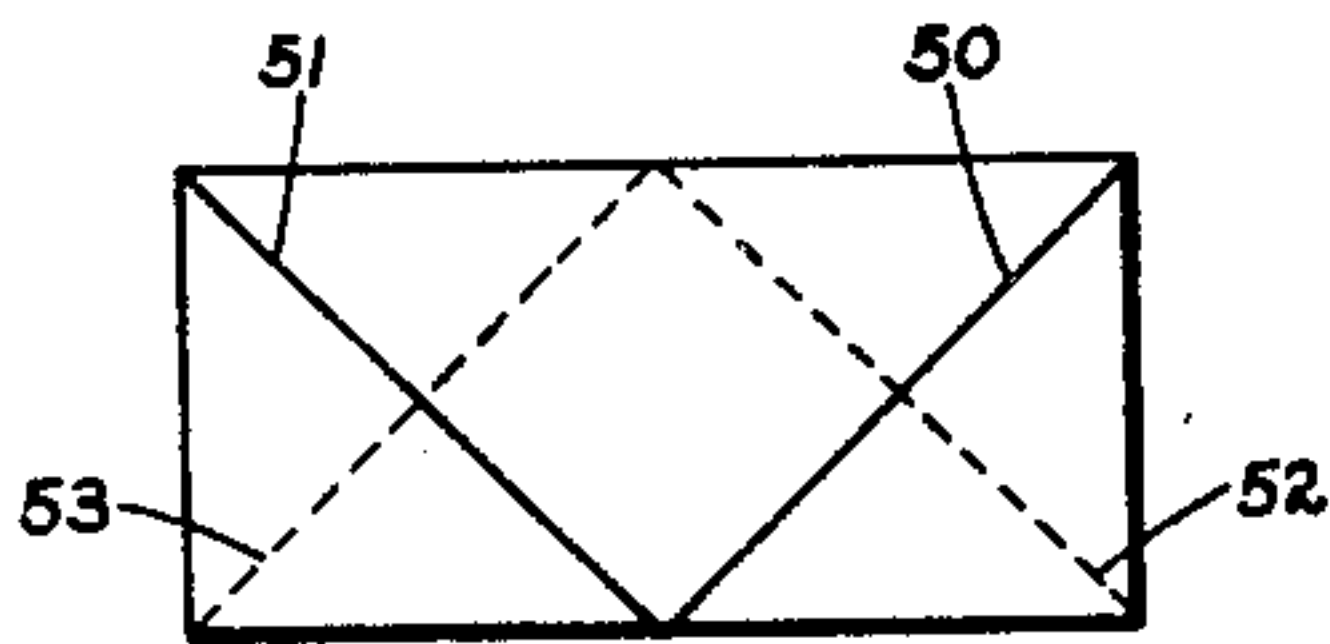


FIG. 11

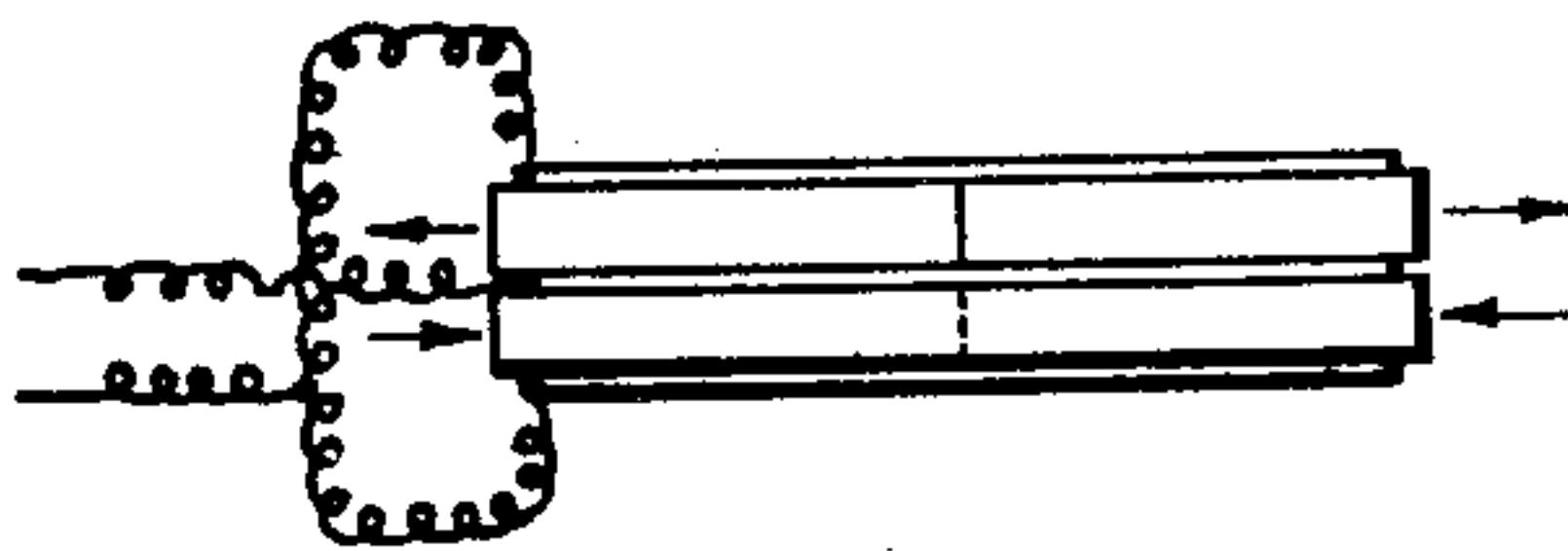


FIG. 12

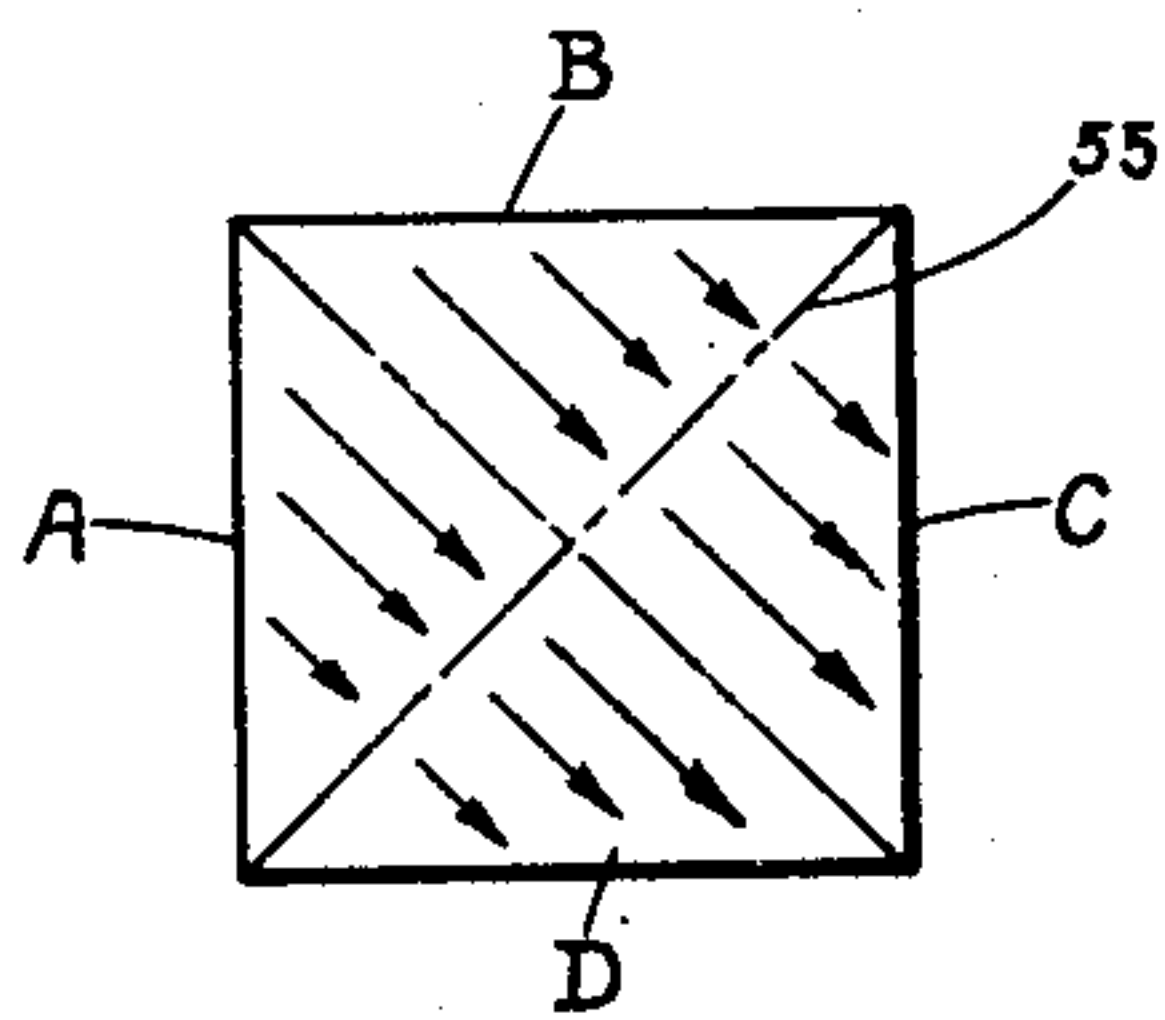


FIG. 13

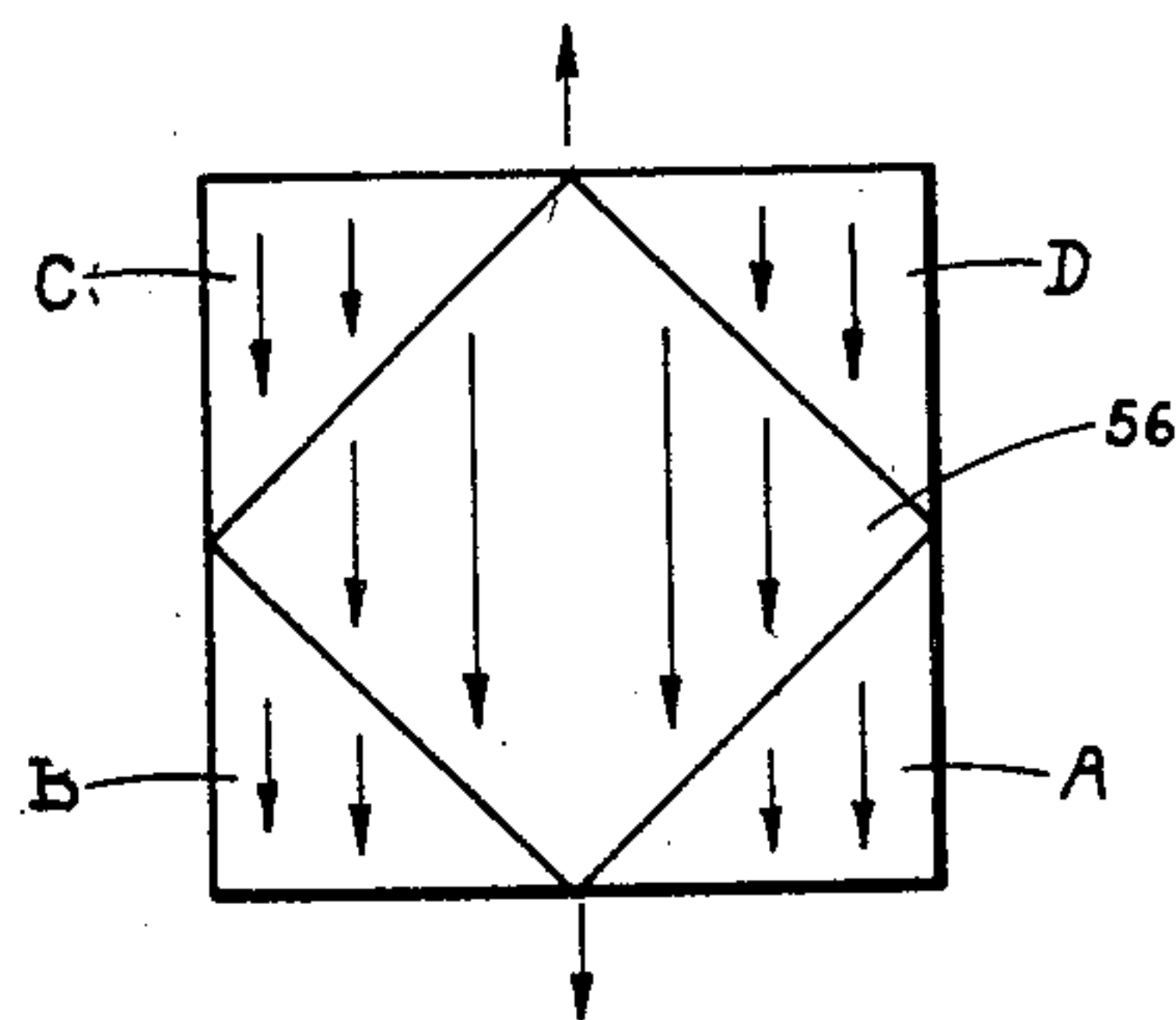


FIG. 14

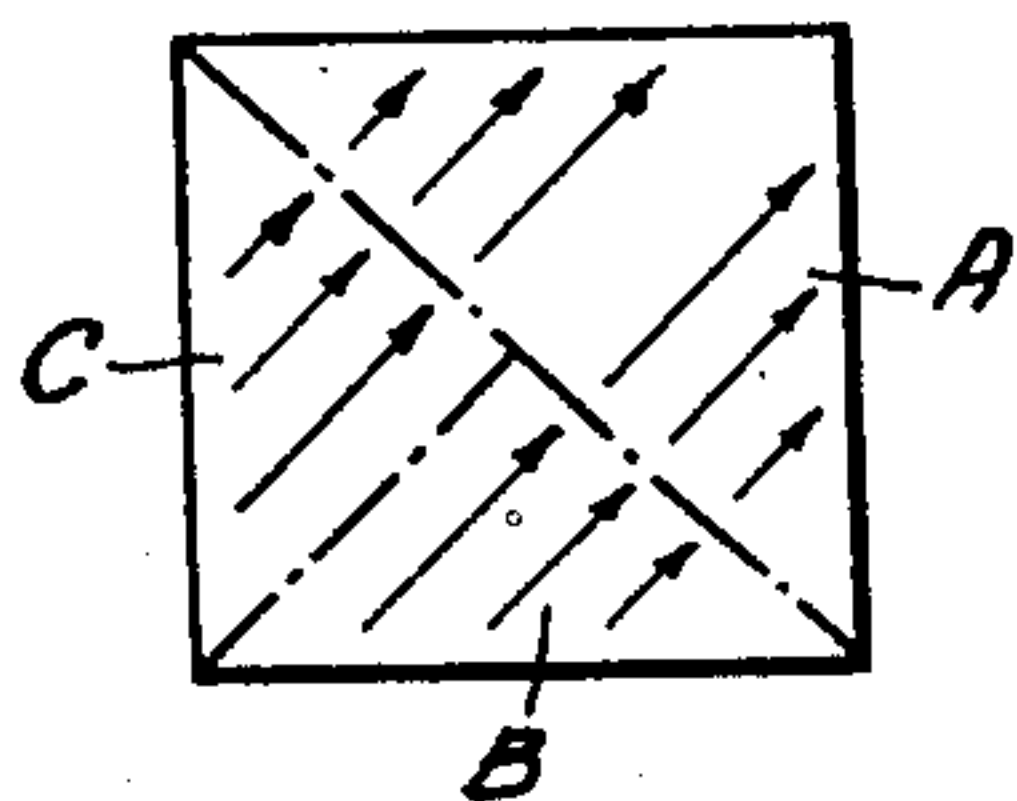


FIG. 15

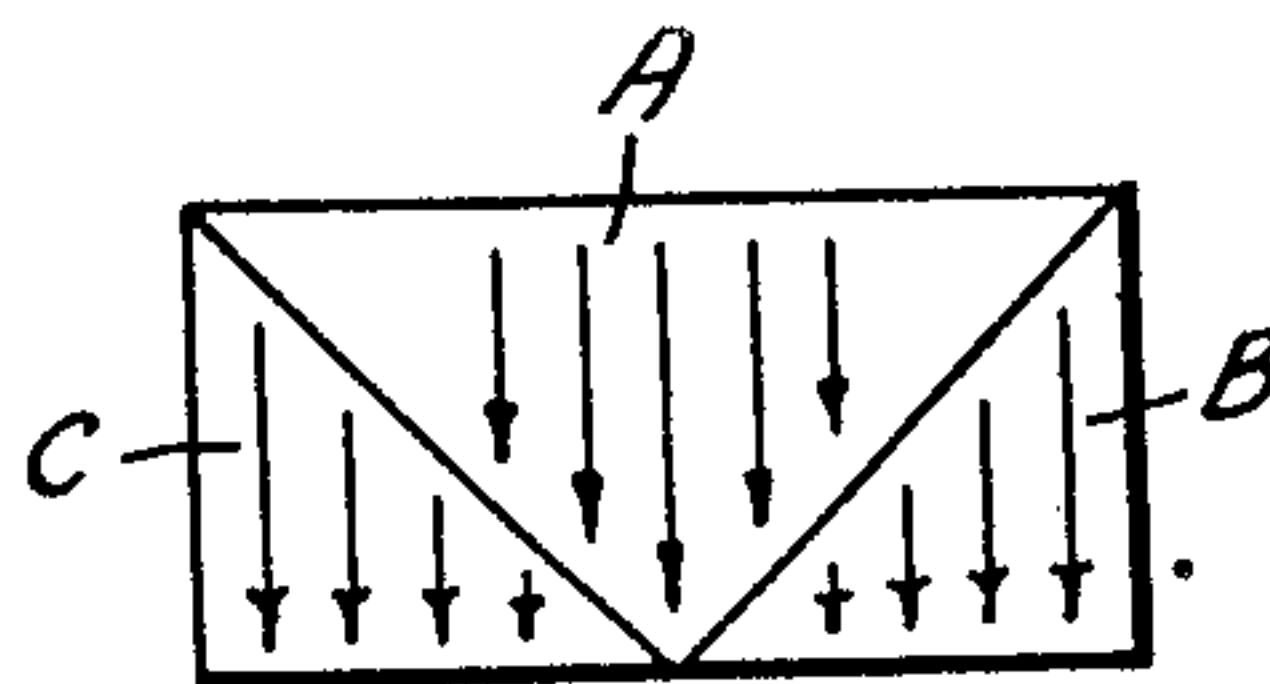


FIG. 16

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CRYSTAL PLATE AND METHOD OF FABRICATING SAME

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Application September 7, 1944, Serial No. 553,096

15 Claims. (Cl. 171—327)

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This invention pertains to a fabricated piezoelectric crystal element and a method of fabricating it.

More particularly this application relates to the fabrication of expander plates and multi-plate flexing elements of P-type piezoelectric crystalline material.

An object of my invention is to provide an expander piezoelectric plate of an unusually large size.

Another object of my invention is to provide a method of fabricating large expander plates of P-type piezoelectric crystalline material.

Another object of my invention is to efficiently use substantially all of the clear unflawed crystalline material in a P-type crystal bar for making expander plates.

Still another object of my invention is to so cut and reassemble one or more crystal shear bars or shear plates of P-type crystalline material that expander bars or expander plates of maximum size are obtained.

Other objects and a fuller understanding of my invention may be had by referring to the following description and drawings in which:

Figure 1 is an isometric view of a P-type crystal bar.

Figure 2 is a plan view of a shear plate and showing the relationship of an expander plate to a shear plate.

Figures 3 and 4 are end views of severed crystal bars or plates looking in a direction parallel to the Z-axis of the crystalline material.

Figures 5 and 6 illustrate expander bars or plates fabricated by reassembling the portions of the bars or plates shown in Figures 3 and 4.

Figure 7 illustrates still another method of assembling cut portions of a shear bar or shear plate to form a large expander bar or plate.

Figure 8 illustrates another method of cutting a shear bar or plate.

Figure 9 illustrates how the portions cut from the bar or plate in Figure 8 may be reassembled to form an expander bar or an expander plate.

Figure 10 illustrates still another method of cutting a shear bar or shear plate.

Figures 11 and 12 illustrate by plan and side views a multi-plate flexing element comprised of two or more built up expander plates such as the plate shown in Figure 9.

Figures 13 and 14 illustrate still another form of my invention.

Figures 15 and 16 illustrate another form of my invention.

In the production of expander plates and of

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multiplate flexing elements it is often desirable to obtain plates having large areas which cannot readily be cut from crystal bars of the size which are easily grown at present.

In the process of growing crystals, a large number of crystal bars will have an average cross-sectional area; a small percentage of the bars will have smaller cross-sectional area and a small percentage will have a cross-sectional area somewhat larger than the average. In order to obtain large expander plates and large multi-plate flexing elements it has been necessary to cut plates from the select few crystal bars which have the largest cross-sectional area, and often these bars are not large enough to yield the required large plates.

In Figure 1 there is illustrated a crystal bar 15 which has been grown from a seed crystal 16; the seed crystal having been grown from a seed plate 17. This crystal bar 15 illustrates a P-type crystal. This type is to be understood as comprising primary ammonium phosphate ($\text{NH}_4\text{H}_2\text{PO}_4$), primary potassium phosphate, primary rubidium phosphate, the primary arsenates of ammonium, potassium and rubidium, isomorphous mixtures of any of these named compounds and all other piezoelectrically active crystalline material isomorphous therewith.

In Wyckoff's Structures of Crystals (2nd edition, N. Y. 1931) this crystal type is introduced as the KH_2PO_4 type. In the Strukturbericht (Supplement to Zietschrift fuer Kristallography) this type is designated as type H-2-2.

The habit of this P-type crystal is a combination of the secondary prism and the secondary by-pyramid. (See Figure 2.) It is characteristic for the P-type crystals that they are elongated parallel to the axis of the prism, which is the optic axis of these crystals and designated as Z-axis in this patent.

All the crystals enumerated above as members of the P-type group belong to the crystallographic symmetry class designated commonly by the symbol V_d . This class is also known as the di-tetragonal alternating crystal class or as the tetragonal sphenoidal class, the latter name being the one used in Dana-Ford, Textbook of Mineralogy, 4th ed., N. Y., 1932. This crystal class is characterized by the presence of three two-fold axes of symmetry perpendicular to each other and two planes of symmetry at right angles to each other and intersecting in one of the two-fold axes. The planes cut the other two two-fold axes under angles of 45° . This combination of symmetry elements makes that axis which is par-

allel to the two planes of symmetry a four-fold alternating symmetry axis which is also the optic axis of the crystal.

Shear plates are obtained from the crystal bar 15 by slicing or cutting in a plane parallel to the plane indicated by the line 18. These plates may be of any desirable thickness.

Figure 2 illustrates a shear plate 19 and also illustrates an expander plate 20 which may be cut from the shear plate 19. It will be noted that the major edges of the expander plate 20 lies at angles of 45° to the X, Y axes of the crystalline material, and that the major face areas thereof are substantially normal to the Z-axis of the crystalline material. In the past in the fabrication of expander plates the corner pieces of the shear plate 19 have been wasted, and an expander plate obtained from a sheer plate has been considerably smaller in area than the shear plate from which it was obtained.

According to my invention two shear plates or shear bars 21, 22 are utilized for obtaining a large expander plate or bar whose cross-sectional area is substantially equal to the sum of the cross-sectional areas of the two plates or bars 21, 22.

I speak of shear plates or shear bars 21, 22. This is for the reason that my invention includes cutting the crystal bar 15 of Figure 1 into a number of shear plates and then cutting the shear plates and reassembling the sections in accordance with my invention, and it also includes cutting the crystal bar 15 into two clear substantially unflawed shear bar portions, such as by cutting the seed crystal 16 out of the center thereof and thereafter cutting those two shear bar portions and reassembling them in accordance with my invention.

I shall describe my invention in connection with assembling plates, but it is to be understood that it is also applicable to assembling bars; substantially the only difference being that the expander bars are somewhat more easily assembled. Once assembled, however, they must be cut perpendicular to the Z-axis to obtain expander plates. This slicing operation is sometimes apt to disturb the adhesive which holds the portions together. This disadvantage is not met when the plates are first sliced to their proper thickness and then connected together.

After a pair of shear plates 21, 22 has been obtained each is polarized to determine its direction of expansion under the influence of a given electrostatic field. These directions of expansion for a given field are illustrated by the arrows on the surface of the plates. The plates are ground or milled until their edge faces are planar and form a rectangle. The plate 21 is then cut along line 23 which is parallel to the direction of expansion for the given electrostatic field thereby establishing two triangularly shaped crystal portions A and B. The crystal plate 22 is cut along line 24 which is substantially normal to the direction of expansion of the crystal under the influence of the given electrostatic field to establish two triangularly shaped crystal portions C and B. The four triangularly shaped crystal portions A, B, C, and D are then rearranged as is shown by Figure 5 so that the direction of expansion in each crystal portion under the influence of the given electrostatic field is parallel to the direction of expansion of the other crystal portions. This is shown by the relationship of the arrows in Figure 5. The direction of contraction in each of the four crystal por-

tions A, B, C, D for the given field is perpendicular to the direction of expansion. The triangularly shaped crystal portions A, B, C and D are then connected together by their edge faces. Suitable adhesives such as "Vinylite" or "Bakelite" cements may be used. By this process there is obtained an expander plate which is twice as large as either of two shear plates from which it is obtained, and which is four times as large as the largest square expander plate that could be cut from one of the shear plates.

While in the description of this invention I have illustrated an expander plate formed from two shear plates, it is to be understood that any number of shear plates may be cut and the triangularly shaped portions obtained therefrom reassembled to form a large expander plate so long as the proper attention is paid to the directions of expansion of the several pieces which form the expander plate. The large expander plate 30 which is shown in Figure 5 may be sold in the form illustrated, or it may have an electrode put on each of its major faces to form an expander unit which may be used in a variety of devices such as microphones, loudspeakers, phonograph pickups and pen recorders, and it may first be cut to the required shape, and then sold. Particular care should be exercised if the plate is to be used in a motor device which converts electrical energy into vibrational mechanical energy, to assure that the adhesive utilized for securing the plates together be a sufficiently good insulator that electrical breakdown along the connection lines does not occur.

I have found that "Bakelite" adhesive will bond portions of crystal together much more firmly than "Vinylite" cement. However, it is a very hard, brittle, and unyielding engagement compared to a "Vinylite" adhesive joint. Occasionally when "Bakelite" cement has been utilized to connect the several bar portions together to form an expander bar, subsequent slicing by an abrasive wheel or by a thin saw has set up sufficient vibration to crack the brittle "Bakelite" cement. The "Vinylite" cement, however, has a slight amount of yield or give to it, and when expander bars are made with it they can be sliced into thin plates without splitting along the adhesive lines. Thus, I prefer "Vinylite" cement for securing the expander bars. "Bakelite" cement, however, is a stronger adhesive so I prefer it for securing expander plates if no further machining is to be done.

Figure 6 illustrates another way in which the four plates A, B, C, and D may be put together to obtain a large expander plate. This method leaves a hole 31 at the center of the four plates and it is contemplated that the hole 31 be filled with an insulating material such as a "Bakelite" peg or the like or by adhesive material prior to electroding the expander plate. In this construction it is necessary to either grind or mill away one corner of each of the triangularly shaped portions in order to form a rectangular plate.

Figure 7 illustrates still another way of positioning the four triangularly shaped crystal portions A, B, C, D, when they are cemented together. By thus positioning the four portions, the four apexes do not come together at one point and thus the plate is somewhat stronger mechanically than the plate shown in Figure 5.

Figure 8 illustrates a method of cutting a single shear plate into three triangularly shaped portions, and Figure 9 illustrates how to reas-

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semble the three portions to obtain a rectangular expander plate. The shear plate 40 of Figure 8 first is polarized, as has been explained in connection with previous figures, to determine its direction of expansion for a given exciting electrical field. This direction is illustrated by the arrows on the plate. The plate is then cut along a first line 41 which is parallel to that direction of expansion to obtain two substantially similar triangularly shaped crystal pieces. Either one of these two pieces is then cut along a line such as line 42 to obtain two substantially similar triangularly shaped crystal portions F and G. Thus, the shear plate 40 is cut into 3 similar right triangles E, F, and G; F and G being of the same size and substantially half the size of the triangular portion E. These three crystal portions E, F, and G are rearranged as is illustrated by Figure 9 so that a rectangular expander plate is obtained and so that the direction of expansion of each triangularly shaped crystal piece for a given exciting electrical field is parallel to the direction of expansion of the other two pieces. The three pieces are then secured together such as by an adhesive. Thus it will be seen that the expander plate of Figure 9 has an area substantially equal to the area of the shear plate of Figure 8. Of course, the process of sawing or otherwise severing the shear plates causes the loss of some crystalline material but the amount is very small especially when compared with the previous process wherein large corner areas of a shear plate were unusable.

Figure 10 illustrates a shear plate 45 which has been polarized to determine its direction of expansion for a given electrostatic field, this direction being illustrated by the arrows on the surface of the crystal. It may be cut along line 46 in a direction perpendicular to its direction of expansion under the influence of the electrical field to establish two equal triangularly shaped crystal portions one of which is indicated by the reference letter J and the other of which is cut into two smaller triangularly shaped portions H and K. These three crystal portions H, J, and K may be reassembled to establish an expander plate having the same shape as the plate shown in Figure 9, the only difference being that the direction of expansion as indicated by the arrows will be perpendicular to the direction of expansion of the plate in Figure 9.

Multi-plate flexing elements may be made from any of these expander plates, such, for example, as the unit, illustrated in Figures 11 and 12. I have found that when a multi-plate flexing element is to be made from two or more plates of the type illustrated in Figure 9 it is desirable to have the connection lines such as the lines 50 and 51 of one plate lie substantially normal to the connection lines 52 and 53 of the other plate. The reason for this is that unless adhesives are utilized which have a greater mechanical strength than the crystalline material a weak line will be established in the multi-plate unit if one connection line is superposed on the other connection line. By fabricating composite plates and assembling them into a multi-plate unit with the fabrication or connection lines at right angles to each other this weakness is substantially avoided, and each plate strengthens the other plate.

Figures 13 and 14 illustrate another form of my invention where only one of two similarly shaped plates 55, 56 is cut along its diagonals, and the resulting triangularly shaped portions A,

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B, C, D are connected to the uncut plate 56 as shown by Figure 14. As has previously been explained, the polarities of the various plates connected must be such as to result in the composite plate becoming an expander plate.

While I have described my invention with a certain degree of particularity it is to be understood that modifications in the procedure and to a certain extent in the arrangement of parts may be made without departing from the spirit and scope of my invention.

I claim as my invention:

1. In the process of fabricating P-type expander plates, the steps of: providing at least two square Z-cut P-type crystal plates, determining the direction of expansion for each plate for a given exciting electrical field, cutting each of said plates diagonally in half, and connecting the four half plates together by their edge faces to form a single composite rectangular plate with the directions of expansion of the four half plates aligned.

2. In the process of fabricating P-type expander plates, the steps of: providing a pair of similar substantially square Z-cut P-type crystal plates, determining the direction of expansion of each plate for a given exciting electrical field, cutting one of said plates diagonally perpendicular to the direction of said expansion to form two substantially equal portions, cutting the other of said plates diagonally parallel to the direction of said expansion to form two substantially equal portions, and connecting edge faces of said four portions together to form a substantially square composite plate with the direction of expansion for each of the four portions of a given electrical field substantially parallel.

3. In the process of fabricating P-type expander plates, the steps of: providing a substantially square plate of Z-cut P-type crystalline material, determining the direction of expansion for said plate for a given exciting electrical field, cutting said plate diagonally into two substantially similar portions having triangularly shaped major face areas, cutting one of said two portions to form two similar portions having triangularly shaped major face areas, and connecting edges of said three triangularly shaped portions together with the direction of expansion for each of the three portions for a given electrical field substantially parallel to form a rectangularly shaped composite expander plate.

4. The process as set forth in claim 3, further characterized in this: that the said diagonal cut is in a direction parallel to the direction of expansion of said plate for the given exciting electrical field.

5. The process as set forth in claim 3, further characterized in this: that the said diagonal cut is in a direction perpendicular to the direction of expansion of said plate for the given exciting electrical field.

6. In the process of fabricating P-type expander plates, the steps of: providing substantially square Z-cut plate means of P-type crystalline material, polarizing said plate means to determine the direction of expansion for a given exciting electrical field, cutting said plate means into a plurality of triangular sections, and connecting edge faces of said plurality of triangular sections together to form a composite rectangular expander plate, the directions of expansion of the several triangular sections being parallel to each other and parallel to an edge of said rectangular composite plate.

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7. The process as set forth in claim 6, further characterized in this: that said plate means comprises only a single Z-cut plate, and it is cut into three triangular sections, and edge faces of said three triangular sections are connected together to form said rectangular composite plate.

8. The process as set forth in claim 6, further characterized in this: that said plate means comprises a pair of Z-cut plates and each of said pair of plates is cut into two triangular sections, and edge faces of said four triangular sections are connected together to form said rectangular composite plate.

9. In the process of fabricating a multi-plate flexing P-type piezoelectric unit, the steps of: providing two substantially square Z-cut plates of P-type crystalline material, polarizing the first of said two plates to determine its direction of expansion for a given exciting electrical field, cutting said first plate into at least three triangular sections, connecting edge faces of said plurality of triangular sections together to form a first composite rectangular expander plate having the direction of expansion of each of the several triangular sections lying parallel to a major edge of said rectangular composite plate, polarizing the second of said two plates to determine its direction of expansion for a given exciting electrical field, cutting said second plate into a plurality of triangular sections, connecting edge faces of said plurality of triangular sections together to form a second composite rectangular expander plate having the direction of expansion of each of the several triangular sections lying parallel to a major edge of said rectangular composite plate, connecting said first and said second composite plates together in face-to-face relationship with their respective directions of expansion for a given exciting electrical field opposite to each other, and with the connection lines of one composite plate at substantially right angles to the connection lines of the other composite plate.

10. As an article of manufacture a piezoelectric crystal unit of the multi-plate flexing type comprising, a first rectangular plate of piezoelectric crystalline material adapted to expand along its length dimension under the influence of a given electrical field and comprised of a plurality of triangularly shaped portions connected together at their edges with the connection lines extending in directions at 45 degrees to the directions of the major edges of said first rectangular plate, and a second rectangular plate of piezoelectric crystalline material adapted to contract along its length dimension under the influence of the given electrical field and comprised of a plurality of triangularly shaped portions connected together at their edges with the connection lines extending in directions at 45 degrees to the direction of the major edges of said second rectangular plate, said first and second rectangular plates having substantially the same length and width dimensions and being connected together in face-to-face relationship with the said connection lines of one plate extending at substantially a 90-degree angle to the said connection lines of the other plate.

11. As an article of manufacture a piezoelectric crystal unit of the type which expands and/or contracts in a direction substantially parallel to the direction of one of its major dimensions

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comprising, a plurality of triangularly shaped plate-like fragments of piezoelectric crystalline material connected together by their edge faces, said plurality of triangularly shaped portions being so oriented that their direction of expansion for a given exciting electrical field are mutually parallel.

12. As an article of manufacture, a composite plate-like crystal unit of the type which expands and/or contracts in a direction substantially parallel to the direction of one of its major dimensions, comprising, a plurality of plate-like fragments of piezoelectric crystalline material, cement means connecting said fragments together at their edge faces with each of said plurality of fragments so oriented with respect to the crystallographic axes of the crystalline material that at least one of its directions of expansion under the influence of a given exciting electrical field is parallel to the direction of expansion of each of the other fragments under the influence of the said given electrical field, each of the said connected edge faces lying at an angle of substantially 45 degrees to the direction of expansion of said unit.

13. The invention as set forth in claim 12, further characterized in this: that said article of manufacture comprises a square plate adapted to expand and/or contract in a direction parallel to its diagonals and four right angle equilateral triangularly shaped plates, the length of the hypotenuse side of each of said triangularly shaped plates being substantially equal to the length of one of the sides of said square plate, said hypotenuse faces of said four triangularly shaped plates being connected to the edge faces of said square plate.

14. As an article of manufacture, a rectangular composite plate-like piezoelectric unit of the type which expands and/or contracts in a direction substantially parallel to the direction of its major dimension, comprising, three right angle equilateral triangularly shaped plates of piezoelectric material, the length of the hypotenuse side of two of said three plates being equal to the length of the leg side of the other plate, and cement means connecting said three plates together at their edge faces to form a rectangularly shaped composite plate and said three triangularly shaped plates being so oriented that a direction of expansion and/or contraction is parallel to the major dimension of said composite rectangular plate.

15. As an article of manufacture, a composite piezoelectric unit comprising, four similar right angle equilateral triangularly shaped plates of piezoelectric material, and cement means connecting said four plates together at their edge faces with said plates oriented to form a square composite expander plate.

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