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(54) **Flexible shield for protection against penetration.**

(57) A flexible shield for protection against penetration by a weapon such as a knife comprises three arrays (AY1,BY1, CY1 ; AX2,BX2,CX2 ; AY3,BY3,CY3,DY3) of protective plates arranged in separate layers (1,2,3) on flexible supports (22,23 etc). The first array (1) of plates provides protection over area covered by each of its plates but permits penetration along lines of weakness between the plates and particularly at intersections of such lines of weakness. The second array (2) of protective plates is coextensive with the first array and in a corresponding regular pattern to provide protection over area covered by each second plate. The first and second arrays are mutually offset such that an intersection between lines of weakness in the first array coincides with plates of the second array to provide protection at said intersections. The plates of the third array (3) are arranged at intersections between lines of weakness of the first array with lines of weakness of the second array.

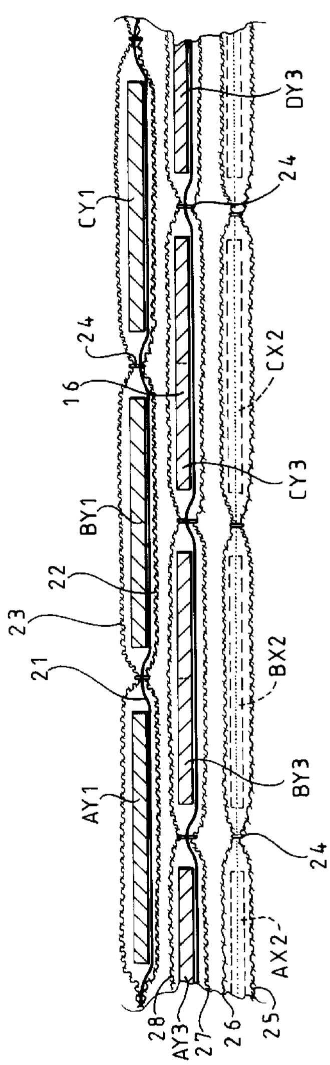

FIG 4

EP 0 611 943 A1

The invention relates to a flexible shield for protection against penetration. A typical application for the protective shield is in protective clothing to guard the wearer against a knife attack.

Conventional body armour intended primarily to protect against gun-shot wounds is not effective against a knife attack because the sharpness of a knife tends to cut its way through the body armour. Chain mail is effective against knife attacks but tends to be very heavy and its complex structure makes it very costly. Of course, a rigid metal plate can be effective against such an attack but it is very cumbersome and inconvenient to wear.

It is already known to provide flexible body armour in which primary protection is provided by metal plates arranged in a matrix. It is also known, for example from Lonza GB A 915345, to provide body armour constituted by layers of plates offset from one another to cover gaps in one layer with plates in another layer. It is also known from Fritch US A 4660223, to make flexible body armour from plates of a range of different sizes with a variety of overlap patterns.

An object of the invention is to provide an improved flexible shield for protection against penetration, for example from a knife or other sharp pointed object.

The invention is concerned with a flexible shield for protection against penetration comprising an arrangement of overlapping protective plates carried on a flexible support. The invention is characterised by an arrangement of plates and support as follows:

a first array of protective first plates carried by a flexible support in a regular pattern to provide protection over area covered by each first plate, but permitting penetration along lines of weakness between the first plates and particularly at intersections of such lines of weakness;

a second array of second protective plates carried by a flexible support generally coextensive with the first array and in a corresponding regular pattern to provide protection over area covered by each second plate;

the first and second arrays being mutually offset such that intersections between lines of weakness in the first array coincide with plates of the second array to provide protection at said intersections;

and a third array of third protective plates carried by a flexible support and coextensive with the first and second arrays, the third protective plates being arranged at intersections between lines of weakness of the first array with lines of weakness of the second array.

In this way a flexible shield can be built up from rigid plates without establishing easily penetrable weak points between the plates.

Preferably the third array is interposed between the first and second arrays. This helps to make the shield effective against penetration from either side.

Preferably the first and second arrays are rectangular arrays with the same regular pattern for both arrays.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic representation of a first array of plates for use in a protective shield;

Figure 2 corresponds to Figure 1 but also shows the second array in chain dashed outline;

Figure 3 corresponds to Figures 1 and 2 but with the addition of a third array of plates as indicated in short dash outline;

Figure 4 is a diagrammatic side elevation on a larger scale through part of an assembled protective shield; and

Figure 5 is a view corresponding to Figure 3 showing plates of an alternative shape.

In this example, the protective shield is a section of flexible material intended to be incorporated in anti-stab personal body armour. The purpose of the armour is to resist a powerful lunge with a sharp pointed heavy knife which also has a sharp cutting edge. A feature of such a weapon is that once the point has penetrated a target the sharp edge cuts the opening formed by the point and facilitates further penetration. Individual flat metal plates can be made to withstand a knife thrust but when a flexible member is made up of such plates it is also necessary to provide protection at the joins or gaps between adjacent plates.

Figure 1 shows a first rectangular array of generally rectangular plates. Each plate is cut from titanium sheet and is square apart from rounded corners to remove sharpness. The section of array shown is made up of nine plates shown in three columns A1 B1 and C1 and three rows X1 Y1 and Z1. The numeral 1 indicates that the plates are in a first array. Individual plates will be referred to by their row, column and array; for example the central plate will be referred to as plate BY1.

In practice the plates are sewn into pockets between two layers of flexible woven fabric. Aramid or high performance polyethylene are suitable materials. The relatively large spacing between plates is shown for convenience of illustration and in practice the plates are placed as close together as possible subject to allowing flexibility after assembly and sewing by machine between the plates to form the pockets. Although the individual plates can each resist a knife thrust, there are lines of weakness such as line 11 between columns B1 and C1 and 12 between rows X1 and Y1. Intersections such as 13 provide even more significant points of weakness.

Figure 2 shows the same nine plates of array 1 as are shown in Figure 1 in full and also shows in chain dotted outline three further rows and columns of plates A2 B2 C2 and X2 Y2 Z2. The size of the plates in the second array and also their shape and mutual spacing corresponds exactly with that of Figure 1. However, as shown, the plates of array 2 are offset downward and to the left by dimensions equivalent to half the pitch between two plates of an array. The result of this is that the centre of each plate in array 2 is positioned at an intersection between lines of weakness in array 1. For example, plate XC2 has its centre coincident with intersection 13 between lines of weakness 11 and 12. Of course array 2 has lines of weakness and intersections between such lines and these intersections in array 2 coincide with centres of plates from array 1.

The arrangement thus far described still leaves an array of points of weakness such as at point 14 which is at the intersection between line of weakness 11 in array 1 and a line of weakness 15 in array 2.

Figure 3 shows the arrangement of Figure 2 but with a further array of plates arranged to cover the remaining points of weakness such as 14. This third array is placed between the first and second arrays. With the arrangement of mutually offset rectangular arrays 1 and 2, there are twice as many points of intersection such as 14 as there are plates in each array, ignoring effects at the edges of the arrays. It follows that plates of array 3 have to be smaller than plates of arrays 1 and 2. The plates of array 3 are also arranged as a rectangular array but the axes of the array are offset diagonally compared with those of arrays 1 and 2. With this arrangement, the centres of the plates of array 3 each coincide with a point of weakness such as 14 at the intersection of a line of weakness in array 1 with a line of weakness in array 2. For example plate 16 (or CY3) covers point of weakness 14. Other plates in array 3 are identified for example as AY3, BZ3 and DY3.

Figure 4 shows diagrammatically the structure of the assembled arrays complete with flexible fabric by which the arrays are held in position. Figure 4 is a cross section along line 15 of Figure 3 through point of weakness 14. Three plates AY1, BY1 and CY1 are shown in cross section. In order to arrange the elements into the array they are secured by adhesive to a lightweight backing 21 which may be formed from paper or similar material. Backing 21 is provided solely to co-ordinate the positions of the plates during assembly and has no effect on the resulting structure. The plates and their backing are placed between a lower flexible support fabric 22 and an upper flexible support fabric 23. The fabric layers are then sewn together in a rectangular matrix along the lines of weakness such as 11 by stitching such as shown at 24 to provide an individual pocket for each plate. A high performance thread such as Aramid should be employed. In this way, one array of plates is united with its flexible backing into a flexible protective layer. The second array is assembled in exactly the same way as the first array between fabric layers 25 and 26. Plates AX2, BX2 and CX2 are shown in dotted outline, the section line 15 (Figure 2) coinciding with a line of stitching.

Plate 16 (or CY3) and other plates AY3, BY3 and DY3 in the third array are assembled with flexible backing, fabric 27,28 and stitching into a third layer as shown in Figure 4 and this layer is placed between the first and second layers. These plates of array 3 appear in Figure 4 to be the same size as the plates in arrays 1 and 2 because they are shown diagonally in Figure 4. The three layers are normally in use held close together but are spaced apart in the drawing for ease of illustration.

The structure of array 2 corresponds exactly with that of array 1. Array 3 is also constructed in the same way but with the different sizes of plates.

In practice a garment such as a waist coat is built up of three layers as shown in Figure 4, with the three layers being sewn or bonded or otherwise secured to each other around their edges to maintain the register relationship particularly as shown in Figure 3. It is strongly preferable that the third layer which is covering the intersections between the lines of weakness in the first two layers is placed between the first two layers. This helps to give improved protection against a diagonal knife attack because there is less possibility of a knife passing diagonally through a series of points of weakness in the adjacent layers. The symmetrical arrangement makes the complete shield equally effective against attack from either side. A protective garment made of such a shield should normally be worn close to the body and relatively tight around the body, holding the layers close together and thus reducing the risk of diagonal penetration. Any such diagonal penetration as does occur will meet the target at an acute angle and so is most unlikely to penetrate deeply and effect serious damage. When Aramid is used for the flexible support and for the stitching, its high resistance to cutting further increases the resistance to diagonal penetration.

The structure based on arrays of plates in separate layers effectively sewn into pockets formed between the two fabric layers is very important in providing effective flexibility and making it easily wearable.

A typical pitch between adjacent plates in arrays 1 and 2 is from 30 to 60 mm, depending on the flexibility required. A smaller pitch provides greater flexibility while a larger pitch simplifies construction and decreases the number of weak points in each layer. A garment may be made up from sections of different pitches when different degrees of flexibility are required for different parts of the garment.

The thickness of each plate must depend on the material from which it is constructed and the severity of an attack which it is required to withstand. Titanium sheet approximately 0.8 mm in thickness may be a satisfactory material. It may be possible to use thinner material with a high grade titanium alloy. Thicker aluminium alloy may also be suitable and because of its lower density may not carry a significant weight penalty compared with titanium. Other materials may also be suitable provided they do not shatter under a knife attack and have suitable properties to avoid being cut in a knife attack. It is envisaged that structural metals are likely to be the most suitable materials and although steel may provide a cost advantage, it may be unacceptably heavy. Other possible materials include reinforced ceramics, for example ceramic plates with fibrous layers bonded to both sides. Another possible material is a fibre reinforced polymer. The polymer could be chosen to have the property of gripping a blade which has penetrated a short distance, thereby reducing the risk of a repeat attack.

It is necessary for each plate to have a good degree of rigidity to guard against the possibility that a plate could fold up on impact allowing a knife to pass it or allowing the folded plate to be driven into the target by the knife.

The plates do not need to be rectangular. Figure 3 shows that there are substantial areas of overlap from one array to another. It is possible to remove some material from the plates to save weight without any significant effect on performance.

Figure 5 corresponds to Figure 3 apart from the shapes of the plates. The cruciform shape of the plates in array 3 reduces weight but maintains good overlap with arrays 1 and 2.

An arrangement as shown in Figure 5 with plates in arrays 1 and 2 50mm x 50 mm has proved particularly satisfactory. The plates are cut form 0.8 mm Titanium. The woven fabric used is Aramid. Spacing between adjacent 50 mm plates is 5 mm.

It may be possible to use circular plates for some or all of the layers. It may be possible to pack circular plates more closely together than rectangular plates and still maintain the required degree of flexibility because circular plates would give notional point contact between plates in one array rather than notional line contact.

Also, it is not essential to arrange the plates of each array in a square matrix. The individual plates could be elongated in one direction in a rectangular matrix. A triangular matrix would theoretically be possible but results in large numbers of intersections of lines of weakness in the first layer with lines of weakness in the second layer, placing onerous requirements on the third layer.

A hexagonal pattern is also possible but may require different sizes of plates as between the first and second arrays as well as between the second and third arrays. It is even possible that with some patterns, it may be possible to leave out some plates from complete matrixes. Of course with hexagonal arrays and possibly with some other forms of array the associated lines of weakness will not be straight lines.

Where limited flexibility is acceptable, the shield may be made up of a first array of relatively large plates, a second array of smaller plates covering most or all of the gaps between the plates of the first array and a third array covering the areas of coincidence between gaps in the first array and the gaps in the second array. The second and third arrays should then be in front of the first array so that the first array supports the second and third arrays in the event of an attack. Such an arrangement can reduce the material required for second and third arrays and thus reduce weight and cost.

It is preferable in the interests of flexibility and resistance to cutting to employ a separate flexible support for each layer but it may be possible in some cases to use a common flexible support for two layers.

The shield described above may be combined with other means to give improved protection. For example a structure based on reinforced ceramics may be backed by a flexible Aramid fibre fabric to give protection against armour piercing ballistic projectiles.

Claims

1. A flexible shield for protection against penetration comprising an arrangement of overlapping protective plates carried on a flexible support characterised by an arrangement of plates and support as follows:

   a first array (1, i.e. AY1 etc) of protective first plates carried by a flexible support (23,24) in a regular pattern to provide protection over area covered by each first plate, but permitting penetration along lines of weakness (11,12) between the first plates and particularly at intersections (13) of such lines of weakness;

   a second array of second protective plates (2, i.e. AX2 etc) carried by a flexible support (25,26) generally coextensive with the first array and in a corresponding regular pattern to provide protection over area covered by each second plate;

   the first and second arrays being mutually offset such that intersections (e.g. 13) between lines of weakness in the first array coincide with plates (e.g. CX2) of the second array to provide protection at said intersections;

   and a third array of third protective plates (3, i.e. AY3 etc) carried by a flexible support (27,28) and coextensive with the first and second arrays, the third protective plates being arranged at intersections (14) between lines of weakness (11) of the first array with lines of weakness (15) of the second array.

2. A shield as claimed in Claim 1 wherein each array

is a rectangular array.

3. A shield as claimed in Claim 2 wherein each plate is generally rectangular.

4. A shield as claimed in any one of the preceding claims wherein each array is carried by its own respective flexible support which comprises two layers of flexible fabric united to form pockets to receive the elements.

5. A shield as claimed in claim 4 wherein the pockets are formed by stitching the two layers of fabric together.

6. A shield as claimed in claim 4 or claim 5 wherein the material of the flexible supports is Aramid or polyethylene.

7. A shield as claimed in any one of the preceding claims wherein each protective element is formed of metal.

8. A flexible shield as claimed in claim 7 wherein the metal is titanium or titanium alloy or aluminium alloy.

9. A protective garment constructed from a shield in accordance with any one of the preceding claims.

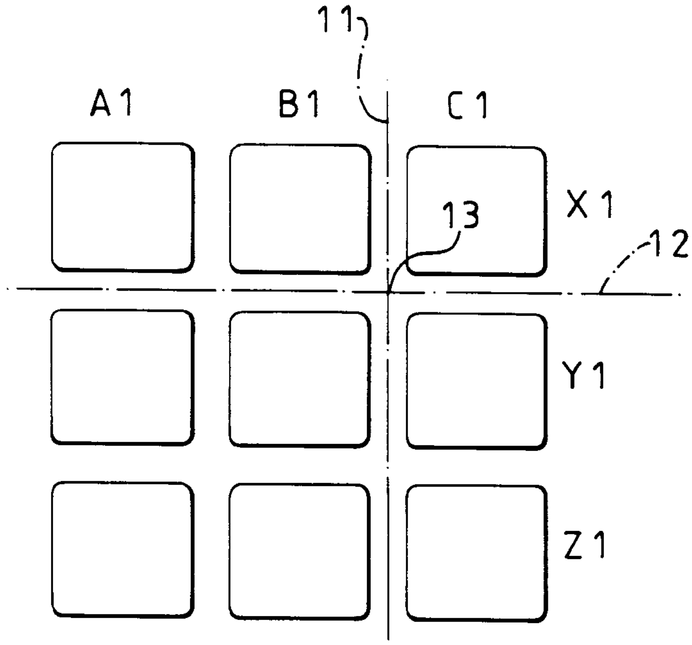
11
A1
B1
C1
X1
13
12
Y1
Z1

FIG 1

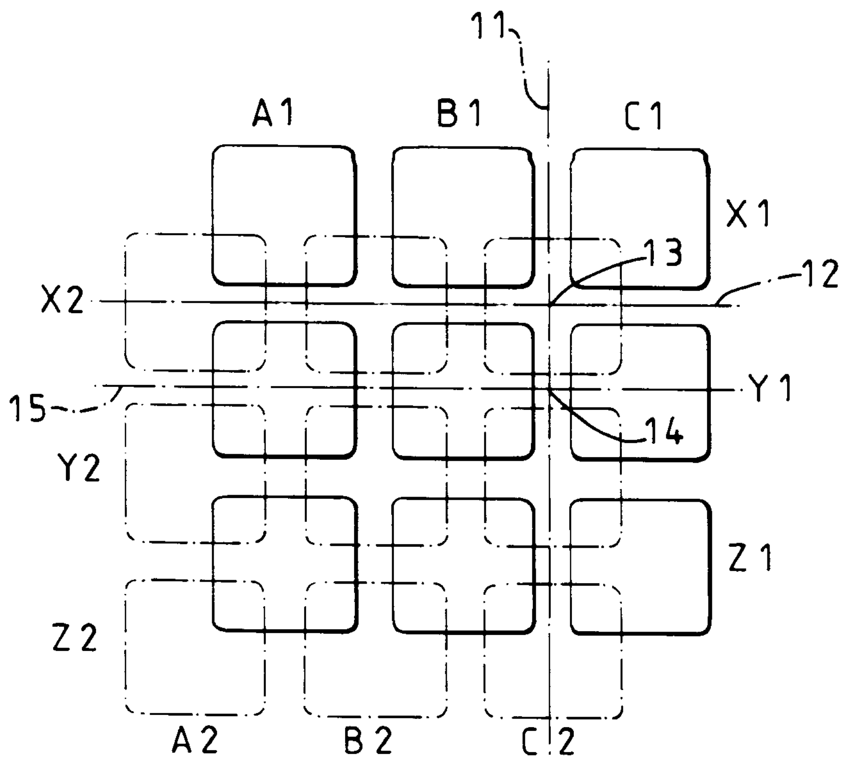
11
A1
B1
C1
X1
13
12
X2
Y1
15
14
Y2
Z1
Z2
A2
B2
C2

FIG 2

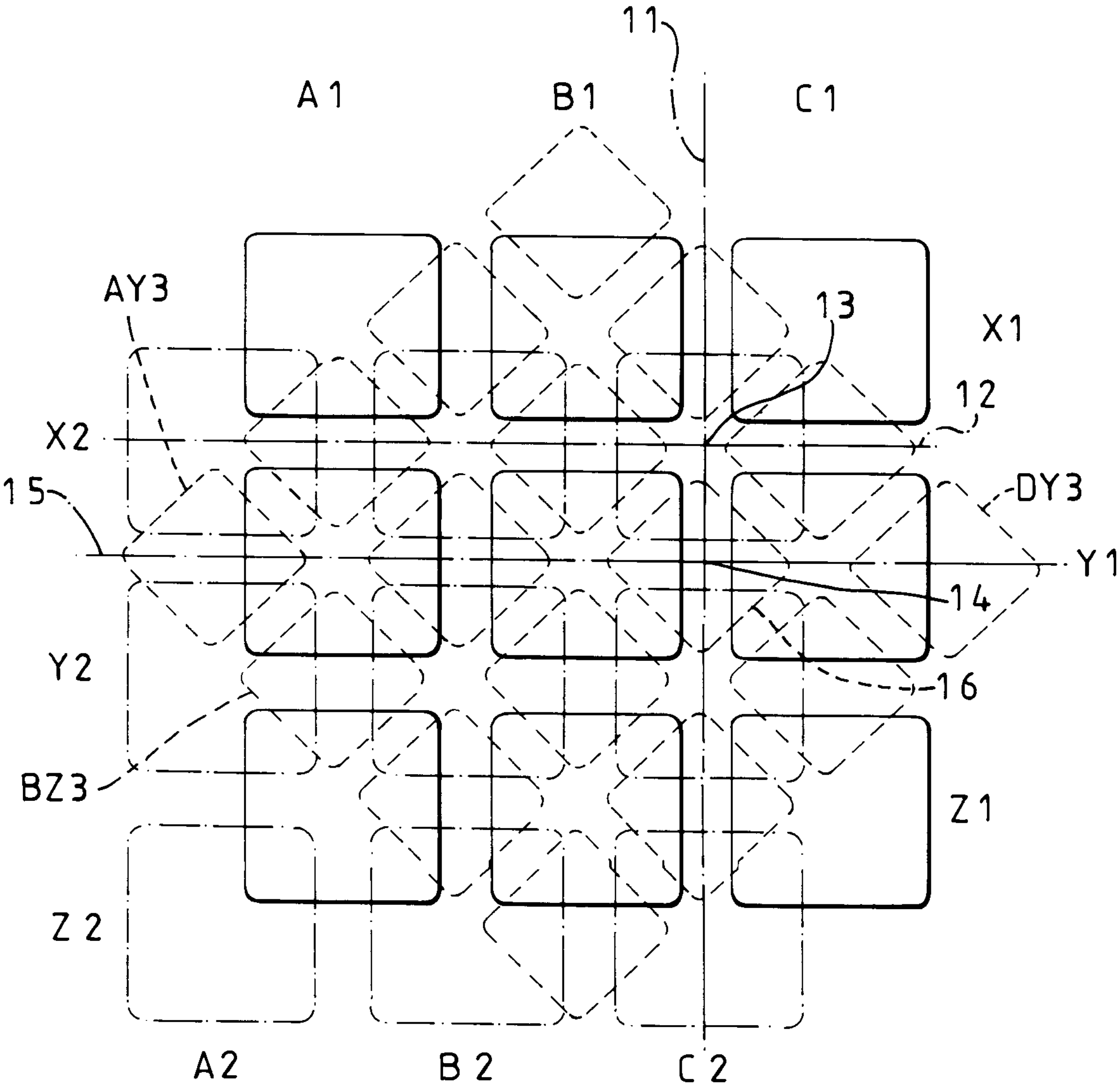

FIG 3

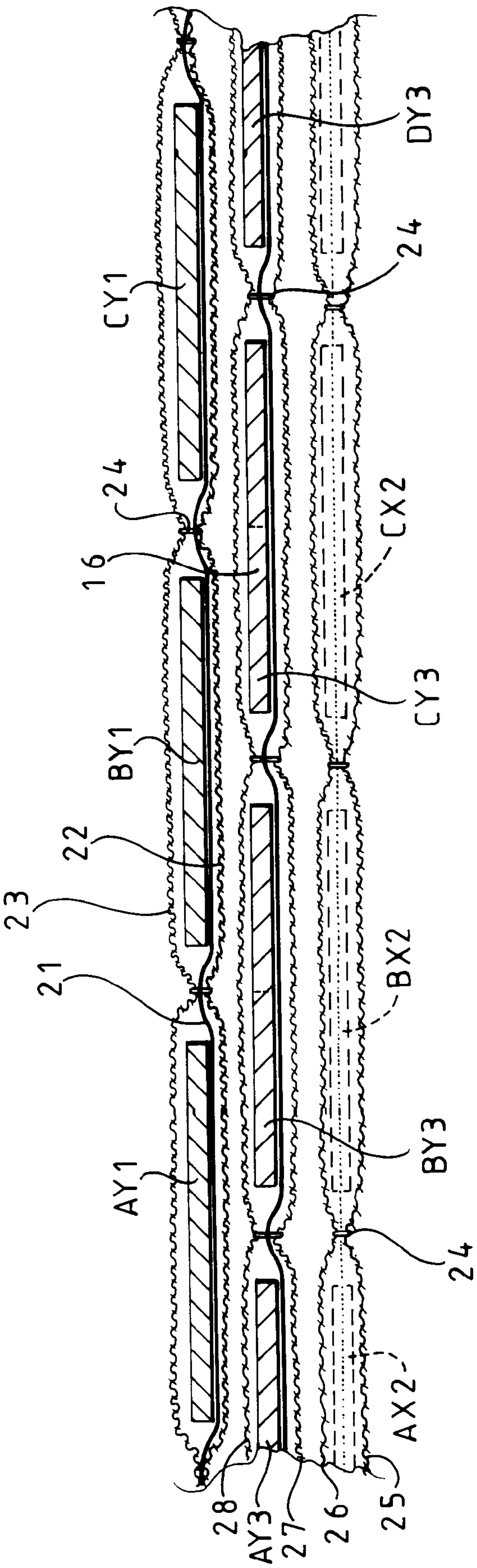
CY1
24
16
BY1
22
23
21
AY1
28
AY3
27
26
25
AX2
24
BY3
BX2
CY3
CX2
24
DY3

FIG 4

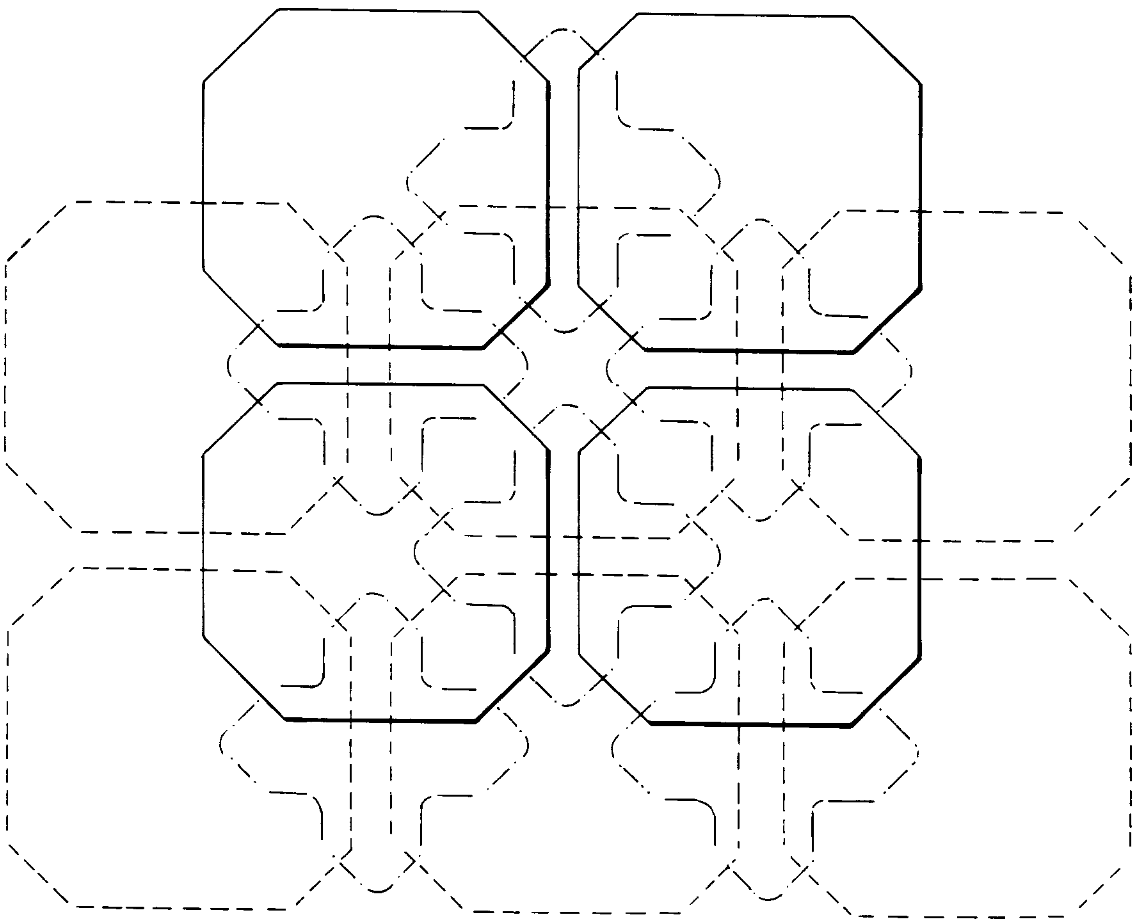

FIG 5

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EUROPEAN SEARCH REPORT

Application Number
EP 94 30 0864

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
D,X	GB-A-915 345 (LONZA) * page 2, line 95-98; figures 1-3,5,6 * * page 3, line 36 - line 78 * * page 4, line 19-41 *	1-3,7-9	F41H5/04
Y	---	4-6	
Y	US-A-4 316 286 (J. KLEIN) * column 3, line 32 - column 4, line 29; figures 1-7 * ---	4-6	
X	US-A-2 723 214 (E. MEYER) * column 2, line 2-66; figures 1-4,6-10 * * column 4, line 57-70 * * column 5, line 17 - column 6, line 41 *	1-3	
Y	---	4-9	
Y	WO-A-92 20520 (ALLIED-SIGNAL INC) * page 5, line 30-33 * * page 7, line 8 - page 9, line 8; figures 3-6 * * page 18, line 27-33 * * page 31, line 16 - page 32, line 21 * * page 37, line 6 - page 38, line 6; figures 10,11 * ---	4-9	TECHNICAL FIELDS SEARCHED (Int.Cl.5) F41H A41D
A	US-A-3 813 281 (L. BURGESS) ---		
A	US-A-3 563 836 (J. DUNBAR) ---		
A	US-A-3 684 631 (J. DUNBAR) ---		
D,A	US-A-4 660 223 (D. FRITCH) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 April 1994	Van der Plas, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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