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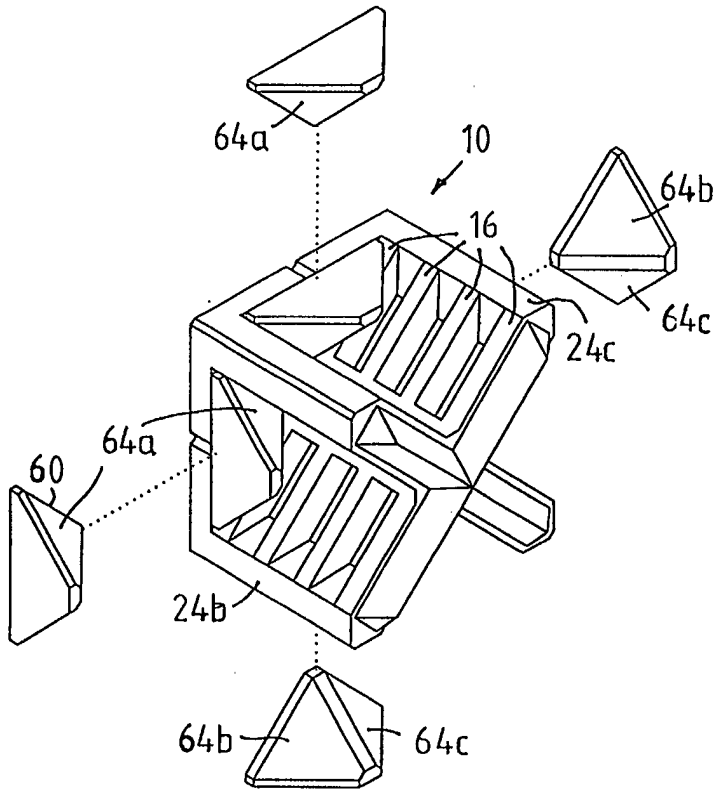
(54) Title: MEANS FOR DISSIPATING WAVE ENERGY

(57) Abstract

An element of cast cementitious material is disclosed for dissipating the energy of waves in the sea. The element comprises a base and vanes arranged in rows. There are typically four of such rows. The successive vanes in each row are located at increasing distances from the base. The vanes are mutually identical in shape. Open ended passages which are advantageously of venturi shape are defined between the side faces of each two adjacent vanes in a row. The passages are disposed transversely to the direction in which the rows extend. The rows are disposed symmetrically about the base either in a cruciform pattern or in a diamond pattern. A number of the elements can be erected to form a structure in which the bases of the elements collectively form a barrier to waves impinging on the structure. The bases may be located adjacent the face of a vertical seawall or other revetment. In the structure, the vanes of each element are inclined at an angle, typically 45°, to the vertical, and the rows of vanes are horizontally disposed so that the rows define a series of cavities each of which is open at one end and closed at an opposite end. Pyramid shaped members may be located in the cavities, each member typically comprising four triangular surfaces. Water which is carried into a cavity by waves is reflected by the surfaces into the passages between the vanes in the four rows of vanes defining the cavity.



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TITLE: MEANS FOR DISSIPATING WAVE ENERGY

This invention relates to means for dissipating the energy of waves in the sea or other body of water. It has particular but not necessarily exclusive application to a structure which is erected adjacent a natural or artificial sea wall, breakwater or other solid body for the dissipation of the energy of waves which, in the absence of the structure, would impinge on the body. For convenience any such solid body will be referred to herein as a revetment.

BACKGROUND OF THE INVENTION

A discussion of some prior art which is relevant to the present invention appears in the specification of the applicant's international patent application #PCT/NZ93/00008, the entire contents of which are incorporated herein by reference. However, the applicant considers that the prior art which is most relevant to the present invention is that disclosed in the application #PCT/NZ93/00008 itself. That application discloses a structure comprising a series of modules which are positioned adjacent a shore. Each module is cast from a cementitious material and incorporates rows of vanes whose side faces define a series of venturi passages. The fronts of the vanes and passages are positioned to face the general direction of waves which impinge on the shore. The rows of vanes are carried on a horizontally disposed hub, a first row of the vanes projecting angularly upwardly from the hub and a second row projecting angularly downwardly from the hub so that as a wave moves in the general direction of the shore, the flow is divided about the hub. Part of the flow is diverted upwardly to pass through the vanes in the first, upper, row and another part is diverted downwardly to pass through the vanes in the second, lower, row.

The structure allows water to pass therethrough to the shore and also to return from the shore to the sea. The structure thus presents an energy dissipating, permeable barrier to the waves which minimises reflection and generates turbulent flow in the water, predominantly towards the surface. As the water flows through the structure, vortices are formed at the rear sides of the vanes and hub which introduces aeration into the water, assisting with energy dissipation. However, entrapment of air in the structure is substantially precluded thus preventing pressurisation.

It is an object of the present invention to provide a structure, and modules for the erection of such a structure, which also incorporate energy dissipating passages. However, it is believed that the structure and the modules of the present invention are better suited for location adjacent to, or for use instead of, a sea wall, natural escarpment or other revetment for providing both ground retention and wave energy abatement.

SUMMARY OF THE INVENTION

According to the invention there is provided an element for dissipating the energy of waves in the sea or other body of water, characterised in that the element comprises a base and a number of vanes arranged in at least one row with successive vanes in the row being located at increasing distances from the base, at least one passage being defined between two adjacent vanes in the row which passage is disposed transversely to the direction in which the row extends.

In one form of the invention the element is constructed of cementitious material. Advantageously, the base and the vanes are constructed as a one piece casting.

According to one aspect of the invention, the adjacent vanes have side faces which define the passage, each side face having a first boundary located adjacent one end of the passage and a second boundary located adjacent an opposite end of the passage. Advantageously, the boundaries of the side faces which are located adjacent the one end of the passage lie in a first imaginary plane and the boundaries of the side faces which are located adjacent the opposite end of the passage lie in a second imaginary plane. Furthermore, the first imaginary plane is advantageously substantially parallel to the second imaginary plane.

In one form of the invention, the side faces are shaped so that the passage tapers inwardly from its ends to an intermediate position at which the width of the passage is at a minimum. Advantageously, the width of the passage at the one end is equal to the width of the passage at the opposite end and the intermediate position is located midway between the ends of the passage. According to one aspect of the invention, the two side faces of the vanes which define the passage are symmetrical about a third imaginary plane located between the two side faces and about a fourth plane in which

the intermediate position lies and which is perpendicular to the third imaginary plane. In this way the passage presents a venturi to water flowing in either direction therethrough.

In one form of the invention, the element comprises four rows of the vanes, the rows being disposed symmetrically two on either side of a fifth imaginary plane which is substantially perpendicular to the base and two on either side of a sixth imaginary plane which is substantially perpendicular to the base and perpendicular to the fifth imaginary plane.

In one form of the invention, the rows are disposed in a cruciform pattern having an axis coincident with an imaginary line coincident with the intersection of the fifth and sixth imaginary planes.

In an alternative form of the invention, the rows are disposed in a diamond pattern having a longitudinal axis of symmetry which is coincident with an imaginary line coincident with the intersection of the fifth and sixth imaginary planes.

In one form of the invention, the vanes in each row define a number of the passages mutually substantially similar shape.

Further according to the invention there is provided a structure for dissipating the energy of waves in the sea or other body of water, characterised in that the structure comprises a number of the aforementioned elements erected so that their bases collectively form a substantial barrier to waves impinging on the structure.

In one form of the invention, the bases are located adjacent a revetment as herein defined. Advantageously the bases are substantially in mutual alignment. Furthermore, the bases are advantageously substantially vertically disposed.

According to one aspect of the invention the first and second imaginary planes in which the boundaries of the vanes of each element lie are inclined from the vertical. Advantageously, the first and second imaginary planes are disposed at substantially 45° to the vertical.

According to one aspect of the invention, the rows of vanes are substantially horizontally disposed. Advantageously, the passages between the adjacent vanes are substantially vertically disposed.

In one form of the invention, the rows of vanes define a series of cavities each of which is open at one end and closed at an opposite end by the base of one of the elements or portions of the bases of two or more of the elements.

The vanes are advantageously of substantially similar shape and the respective imaginary planes in which the boundaries lie are disposed at substantially 45° to the horizontal and intersect each other in an equal sided diamond pattern. Advantageously, the vanes in one row adjoin the vanes in the adjacent rows so that, together, four of the rows surround a diamond-shaped cavity bounded at one end by the wave impermeable barrier formed by the bases of the elements.

Typically the erected structure comprises a multiplicity of the rows of vanes defining a series of such diamond shaped cavities. Such a structure can be achieved by erecting a series of the elements in the form of precast modules each incorporating four rows of the vanes formed integrally with a square base which, when the module is erected will form part of the wave impermeable barrier.

The diamond shaped cavities can be achieved in at least two ways. In the case in which, as noted above, each element has four rows of vanes disposed around its longitudinal axis, the adjacent rows may intersect each other along lines passing through the centre points of each side of the base. The four rows of each element define a first of the diamond shaped cavity whose axis coincides with the longitudinal axis. After erection of the structure, the respective rows of vanes form sides of four further diamond shaped cavities whose other sides are formed by the rows of vanes in adjacent elements and whose respective longitudinal axes lie along lines passing through the corners of the base.

In a second case in which the four rows of vanes of an element radiate outwardly towards the corners of the base of the element from a central hub projecting from the base, each pair of adjacent rows form two sides of a diamond shaped cavity whose other two sides are formed by a pair of adjacent rows of vanes in a neighbouring

element.

In both of the above cases the diamond shaped cavities are closed at one end by portions of the bases of the element. According to the invention, the cavities are open at their opposite ends to allow water carried by the waves to flow into the cavities.

The purpose of the structure is to dissipate the energy in the water which is carried by the waves towards the revetment. This is achieved by the rows of vanes which present energy dissipating passages which are advantageously of venturi shape through which the water can flow, minimising reflection and generating turbulent flow in the water, predominantly towards the surface. As the water flows through the passages, vortices are formed which introduce aeration into the water, assisting with energy dissipation.

The water can be assumed to flow generally in an axial direction into the cavities from seaward. Since the passages between the vanes are disposed transversely to the direction of this flow, it is beneficial and in many cases perhaps essential, according to the invention, to provide in the passages means to divert the flow of water into the passages. In one form of the invention this means comprises reflection members located in the cavities, each reflection member comprising at least one reflection surface which is so positioned and disposed that the flow of water which passes through the open end of the cavity in which the reflection member is located and impinges on such reflection member is reflected by the reflection surface into at least one of the passages between adjacent vanes in one of the rows of vanes defining the cavity. Advantageously, each reflection member has the shape of a pyramid having a bottom face located adjacent the barrier and a number of said reflection surfaces of triangular shape, the reflection surfaces arising from the bottom face and meeting at a vertex of the pyramid which projects towards the open end of the cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention are further discussed with reference to the accompanying drawings and in which

Figure 1 is a side view of a module for use in a wave energy dissipating structure;

Figure 2 is a perspective view of the module with wave reflecting elements shown separately and also mounted in a working position thereon;

Figure 3 is an end view (on Arrow C in Figure 1) of the module;

Figure 4 is a cross-sectional view on Arrows A-A in Figure 1;

Figure 5 is a partial cross-sectional view on Arrows B-B in Figure 3;

Figure 6 is a side view, similar to Figure 1, of the module with the wave reflecting elements shown in Figure 2 in their working position;

Figure 7 is an illustration of a wave energy dissipating structure made up of the modules shown in Figures 1 to 6;

Figure 8 is a typical frontal view of four of the modules in place in the structure shown in Figure 7;

Figure 9 is view, similar to Figure 8 but slightly from one side, of the same four modules; and

Figure 10 is a view, similar to Figure 8, of four modified modules in place in a wave energy dissipating structure similar to that shown in Figure 7.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

In Figures 1 to 6 inclusive there is shown a module 10 constructed of high strength cast cement or concrete. Typically, the module is approximately of one meter length, breadth and height, although each of these dimensions can vary according to wave design height. The module comprises a base 12 with which four rows 14 of vanes 16 are integrally cast.

The base 12 is square and in use is usually vertically disposed with two sides 18a, 18b vertical and two sides 18c, 18d horizontal. Semicircular recesses 22 are cast into each side at its centre point.

Four arms 24a,b,c,d are cast integrally with the base. The respective arms are located at each corner of the base, projecting at right angles to the flat face 26 of the base. The base and the arms define the boundaries of the approximately cubic space occupied by the module. Each arm 24 has two outer sides 27', 27" of equal width and two inner sides 29', 29" also of equal width. The outer sides are at right angles to each other but the inner sides subtend something less than a right angle, typically about 70°.

Also integrally cast with the base is a central hub 28. The hub is located at the centre of the base and projects at right angles to the flat face 26. The hub has an imaginary central longitudinal axis 30 which is coincident with a line which passes through the centre of the base, normal to the face 26.

The hub has a substantially square cross-sectional shape, having four orthogonally disposed sides 42a,b,c,d of equal length. The sides 42 face the inner sides 29', 29" of the respective arms 24a, b, c, d and are at a constant distance therefrom.

The four rows 14a, b, c, d of vanes 16 are disposed between the respective sides 42 of the hub 28 and the sides 29', 29" of the respective arms 24a, b, c, d. The vanes are cast integrally with the hub and arms.

The module is symmetrical about each side of an imaginary vertical plane and also an imaginary horizontal plane which intersect at a line which is coincident with the axis 30. Further discussion of the module can thus be limited to a single row 14a of the vanes 16 and a single arm 24a. The vanes 16a in the row 14a are equally spaced apart so that three passages 32 are defined between the side faces 34 of each pair of adjacent vanes. The side faces 34 are substantially similar to one another. Each side face 34 extends between the lower edge 36 and the upper edge 38 of a vane. The side face comprises portions 34a, 34b which are angularly disposed to one another and extend from the respective edges 36, 38, intersecting at a location 40 located halfway therebetween. At the location 40 the width of the passage is at a minimum so that the passage has the cross sectional shape of a venturi.

Furthermore, the inner sides 29a', 29a" of the arm 24a intersect at a location 42 which is closer to the side 42a of the hub than either of the locations 44', 44" at which the outer sides 27a', 27a" intersect the respective inner sides 29a', 29a". The width of the

passage between the side 42a and the sides 29a', 29a" of the arm 24a is thus also at a minimum at the location 42, thereby increasing the venturi effect of the passage.

As will be clear from the drawings, the vanes in each row are aligned with each other and are substantially similar to one another so that their edges 36, 38 lie in planes which are perpendicular to the face 26 of the base.

It will also be noted that the edges of the vanes and the corners of the hub are chamfered. This is not essential but is useful because it facilitates casting of the module and also reduces the tendency of the edges and corners to fail in use.

The structure 50 shown in Figure 7 illustrates the typical manner of use of the modules 10. The structure comprises two rows 52, 52' of the modules mounted one above the other. The modules are positioned with their bases 12 face to face with the vertical face of a sea wall or other revetment along a foreshore 53. In the present case, the modules in the lower row 52 are mounted directly on the sea bed or on suitable foundations or plinths. However, where the sea is deeper, the modules in the lower row could be supported on columns or piles set in the sea bed 55. To make up the upper row, modules 10 are placed directly on top of each module in the lower row with the upper sides 27a', 27c' of the upper arms of each module in the lower row being face to face with the respective lower sides 27b', 27d' of the lower arms of the modules in the upper row.

When the modules are in place, their bases constitute a composite vertical barrier to the flow of water carried towards the sea wall by the waves. Furthermore the erected modules present to the sea a series of diamond shaped cavities 54 having what may be considered as side walls made up of the edges 36, 38 of the vanes in each row. At one end each of these cavities is closed by portions of the bases 12. At the opposite end the cavity is open to the sea so that water, carried by waves, can flow more or less unobstructed into the cavity.

Of course, the end face 56 of the vane at the end of each row facing the sea presents a certain obstruction around which the water must flow when entering the cavity. The flow of water past the end face can be smoothed by wedge-shaped formations 58 cast into the end face.

The modules are held in place where necessary by high strength adhesive applied to the interfacing parts of the modules and, if necessary, the sea wall. Anchor bolts, set into the sea wall and passing through suitable passages in the bases may also be used. Similar bolts may also be used to hold pyramid-shaped elements 60 in position against the faces 26 of the bases 12 at the closed ends of the cavities 54. These elements are not shown in Figure 7 but can be seen in Figures 2, 6 8 and 9. Each element 60 comprises a square, flat bottom face 62 from the four sides of which arise flat triangular sides 64a, b, c, d whose apices meet at the vertex 66 of the pyramid. The sides 64 are disposed at 45° to the bottom face 62. The vertex of each element lies on the central longitudinal axis of the cavity 54. The element 60 is positioned so that the four sides 64 face the respective side walls of the cavity.

In the present case an element 60 comprises two halves, as illustrated at 60', 60" in Figures 8 and 9, joined together. However, the element may be made in one piece or, for example, of four pieces.

The aforementioned composite barrier constituted by the bases of the modules is not water impermeable but it does act as a substantially complete barrier to the flow of water carried by the waves. However, ground water landward of the barrier is able to permeate through the barrier, particularly through the recesses 22 and through the joints between the edges 18 of the bases thus preventing back pressure being applied to the barrier by ground water behind the barrier.

The object of providing the structure is to protect land and infrastructure shore wards of the structure and at the same time minimise reflected wave energies arising on the seaward side of the structure which are known to cause considerable bottom scour and foreshore erosion. The water which is carried by incoming waves into the cavities 54 impinges on the triangular sides 64 of the elements 60 and is reflected into opposed streams which flow angularly upwardly and downwardly to both the left and right. These streams pass through the venturi passages 32. Because of the venturi effect, the flow through the passages is thus first accelerated and then decelerated. This has the beneficial effect of dissipating the energy of the water thereby reducing the impact of the water on the aforementioned composite barrier constituted by the bases of the modules. There is thus a reduced tendency for the modules to be dislodged by the water.

The energy in the water is dissipated by the venturi passages 32 through which the water flows, generating turbulent flow in the water directing the energy flow predominantly towards the surface. As the wavefield is redirected and accelerated through the passages, vortices are formed which introduce aeration into the water, assisting with rapid energy dissipation.

The elements 60 assist in reducing reflection of the energy back to seaward. It is known that such reflected energy can amplify the incident waves which are moving towards the shore, substantially increasing the destructiveness of the incident waves.

An important characteristic of the modules is the cavities 54 defined by the rows of vanes. The cavities help to entrap wave field energy water flowing into them thus forcing it to pass through the venturi passages rather than reflecting it back to seaward.

A further advantage of the design is that concrete plates as shown at 70 can be used in conjunction with the modules. A plate can be placed on top of each of the modules in the upper row to provide a walkway along the structure. This, and the ability to stack the modules, enables structures of the modules to be used for a variety of recreational and utilitarian purposes incidental to their primary use. For example, the structure may incorporate a deck, stairway, a multilayered promenade or a jetty. Alternatively the plates 70 can be placed underneath the modules to act as a permeable base. Tapered passages are cast into the plates to allow water to pass therethrough.

The modules can be used in ways other than that illustrated. In particular, the modules need not be placed with their bases only against the vertical faces of sea walls. The surface against which the bases are placed could be canted at substantial angles from the vertical; and, indeed, the modules could conceivably be useful in applications in which their bases are placed on a substantially horizontal surface.

Modules 110 of modified construction are shown in Figure 10. As in the case of the modules 10, each module comprises four rows of vanes 116 extending outwardly from a base 112. The vanes 116 are substantially similar to the vanes 16 but, instead of radiating outwardly from the hub 28 located at the centre of the base, the rows of vanes 116 are arrayed in a diamond configuration around the centre of the base. The vanes 116 meet at arms 24 which are located at the centres of the respective sides of the base.

The cross sectional shape of each arm is essentially similar to that of the hub 28 of a module 10 which has been divided in half along its axis. It is clear that, after the modules 110 have been erected, the resulting structure comprises a series of diamond shaped cavities which are substantially similar in shape, location and effect as the cavities 54 in the structure shown in Figure 7.

Figure 10 shows also that the elements 60 may be one piece units, as shown at 120, or four piece units, as shown at 122.

In all cases the elements 60 will typically be joined to the bases before the modules are erected.

It is not intended that the scope of a patent granted in pursuance of the application of which this specification forms a part should exclude modifications and/or improvements to any matter described and/or illustrated herein, or known equivalents of such matter which are within the scope of the invention as claimed or be limited by such matter further than is necessary to distinguish the invention from the prior art.

CLAIMS

1.

An element for dissipating the energy of waves in the sea or other body of water, CHARACTERISED IN THAT the element comprises a base and a number of vanes arranged in at least one row with successive vanes in the row being located at increasing distances from the base, at least one passage being defined between two adjacent vanes in the row which passage is disposed transversely to the direction in which the row extends.

2.

An element according to claim 1, CHARACTERISED IN THAT it is constructed of cementitious material.

3.

An element according to claim 1 or claim 2, CHARACTERISED IN THAT the base and the vanes are constructed as a one piece casting.

4.

An element according to any one of claims 1 to 3, CHARACTERISED IN THAT the adjacent vanes have side faces which define the passage, each side face having a first boundary located adjacent one end of the passage and a second boundary located adjacent an opposite end of the passage.

5.

An element according to claim 4, CHARACTERISED IN THAT the boundaries of the side faces which are located adjacent the one end of the passage lie in a first imaginary plane and the boundaries of the side faces which are located adjacent the opposite end of the passage lie in a second imaginary plane.

6.

An element according to claim 5, CHARACTERISED IN THAT the first imaginary plane is substantially parallel to the second imaginary plane.

7.
An element according to any one of claims 4 to 6, CHARACTERISED IN THAT the side faces are shaped so that the passage tapers inwardly from its ends to an intermediate position at which the width of the passage is at a minimum.

8.
An element according to claim 7, CHARACTERISED IN THAT the width of the passage at the one end is equal to the width of the passage at the opposite end and the intermediate position is located midway between the ends of the passage.

9.
An element according to any one of claims 1 to 8, CHARACTERISED IN THAT the two side faces of the vanes which define the passage are symmetrical about a third imaginary plane located between the two side faces and about a fourth plane in which the intermediate position lies and which is perpendicular to the third imaginary plane.

10.
An element according to any one of claims 1 to 9, CHARACTERISED IN THAT the element comprises four rows of the vanes, the rows being disposed symmetrically two on either side of a fifth imaginary plane which is substantially perpendicular to the base and two on either side of a sixth imaginary plane which is substantially perpendicular to the base and perpendicular to the fifth imaginary plane.

11.
An element according to claim 10, CHARACTERISED IN THAT the rows are disposed in a cruciform pattern having an axis coincident with an imaginary line coincident with the intersection of the fifth and sixth imaginary planes.

12.
An element according to claim 10, CHARACTERISED IN THAT the rows are disposed in a diamond pattern having a longitudinal axis of symmetry which is coincident with an imaginary line coincident with the intersection of the fifth and sixth imaginary planes.

13.
An element according to any one of claims 10 to 12, CHARACTERISED IN THAT the vanes in each row define a number of the passages mutually substantially similar shape.

14.
A structure for dissipating the energy of waves in the sea or other body of water, CHARACTERISED IN THAT the structure comprises a number of elements according to any one of claims 1 to 13 erected so that their bases collectively form a substantial barrier to waves impinging on the structure.

15.
A structure according to claim 14, CHARACTERISED IN THAT the bases are located adjacent a revetment as herein defined.

16.
A structure according to claim 14 or claim 15, CHARACTERISED IN THAT the bases are substantially in mutual alignment.

17.
A structure according to any one of claims 14 to 16, CHARACTERISED IN THAT the bases are substantially vertically disposed.

18.
A structure according to any one of claims 14 to 17, CHARACTERISED IN THAT the first and second imaginary planes in which the boundaries of the vanes of each element lie are inclined from the vertical.

19.
A structure according to claim 18, CHARACTERISED IN THAT the first and second imaginary planes are disposed at substantially 45° to the vertical.

20.
A structure according to any one of claims 14 to 19, CHARACTERISED IN THAT the rows of vanes are substantially horizontally disposed.

21.
A structure according to any one of claims 14 to 20, CHARACTERISED IN THAT the the passages between the adjacent vanes are substantially vertically disposed.

22.
A structure according to any one of claims 14 to 22, CHARACTERISED IN THAT the rows of vanes define a series of cavities each of which is open at one end and closed at an opposite end by the base of one of the elements or portions of the bases of two or more of the elements.

23.
A structure according to claim 22, CHARACTERISED IN THAT the structure comprises reflection members located in the cavities, each reflection member comprising at least one reflection surface which is so positioned and disposed that the flow of water which passes through the open end of the cavity in which the reflection member is located and impinges on such reflection member is reflected by the reflection surface into at least one of the passages between adjacent vanes in one of the rows of vanes defining the cavity.

24.
A structure according to claim 23, CHARACTERISED IN THAT each reflection member has the shape of a pyramid having a bottom face located adjacent the barrier and a number of said reflection surfaces of triangular shape, the reflection surfaces arising from the bottom face and meeting at a vertex of the pyramid which projects towards the open end of the cavity.

FIG. 1

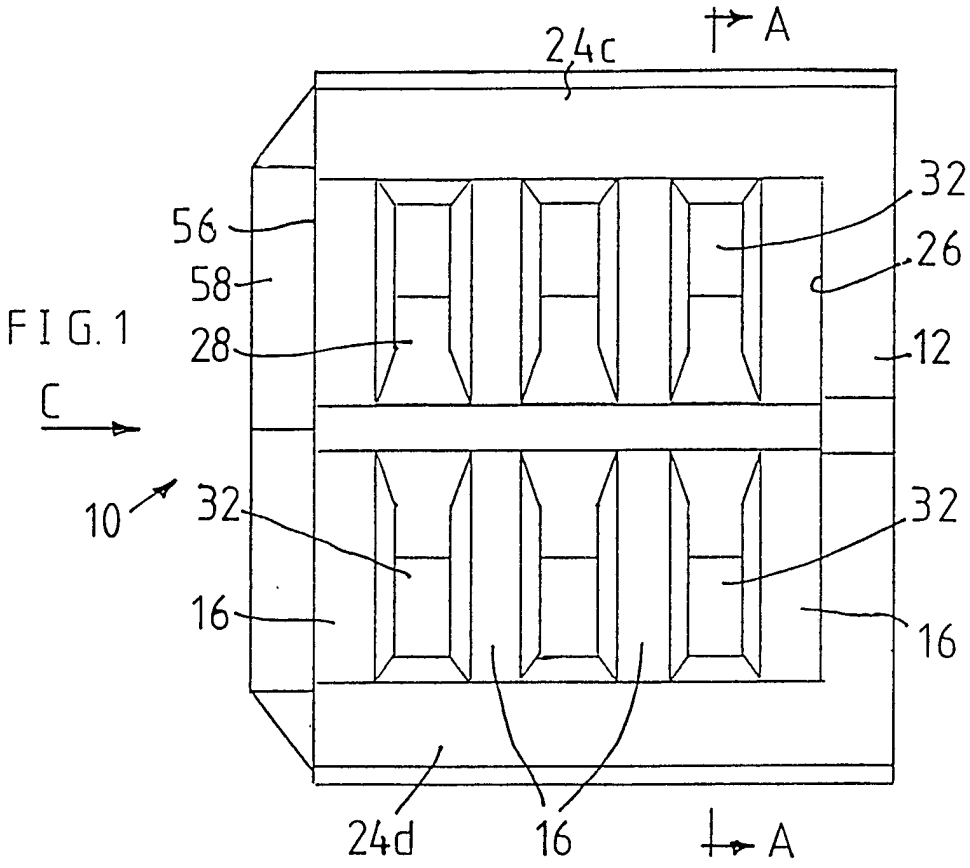


FIG. 2

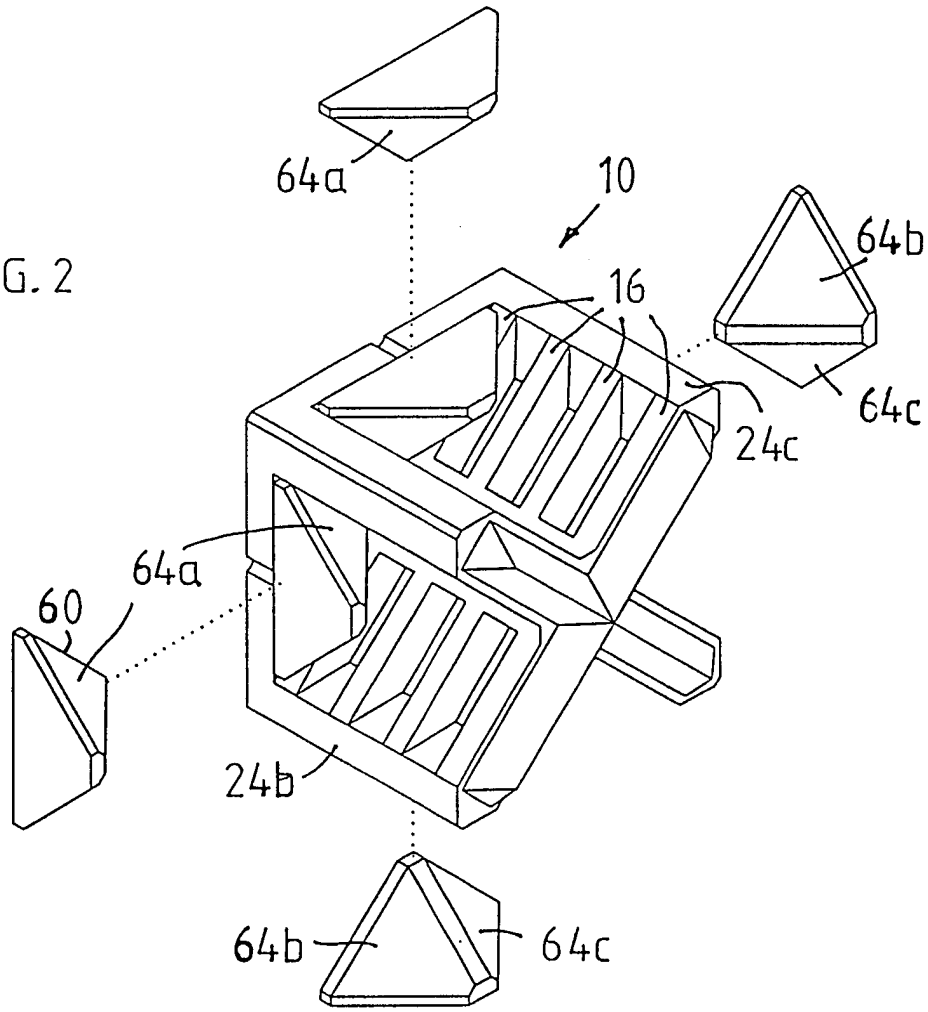


FIG. 3

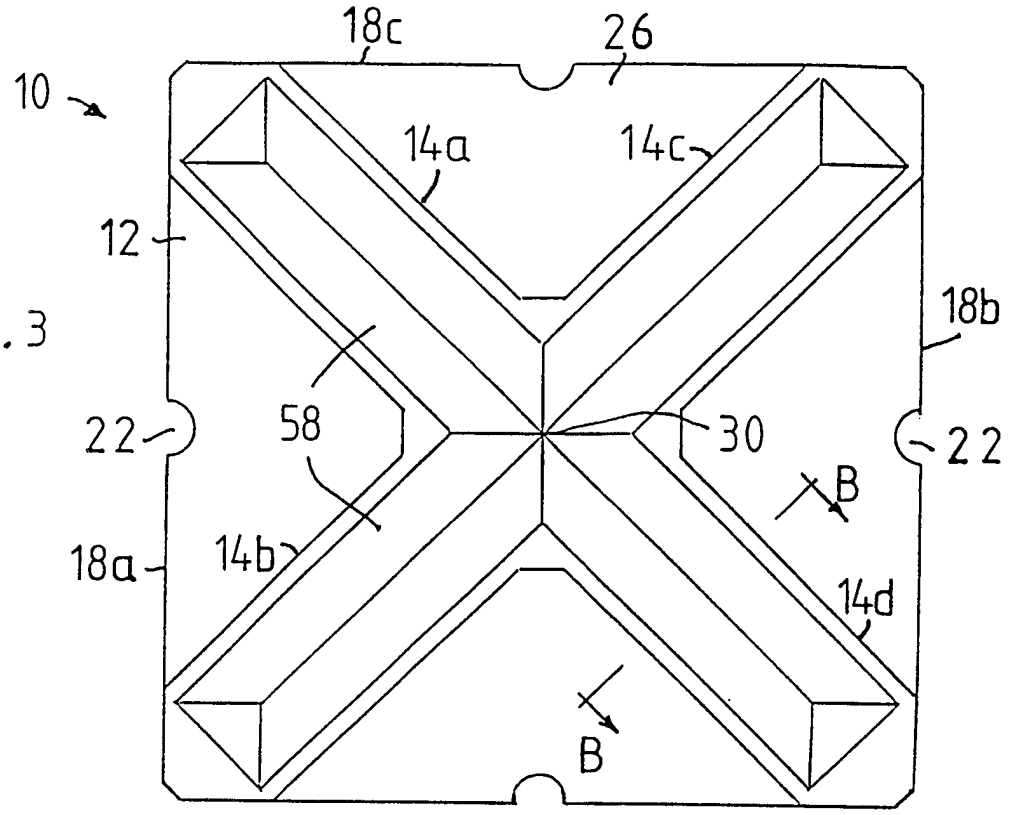

18c
26
10
14a
14c
12
18b
22
58
30
22
B
18a
14b
14d
B

FIG. 4

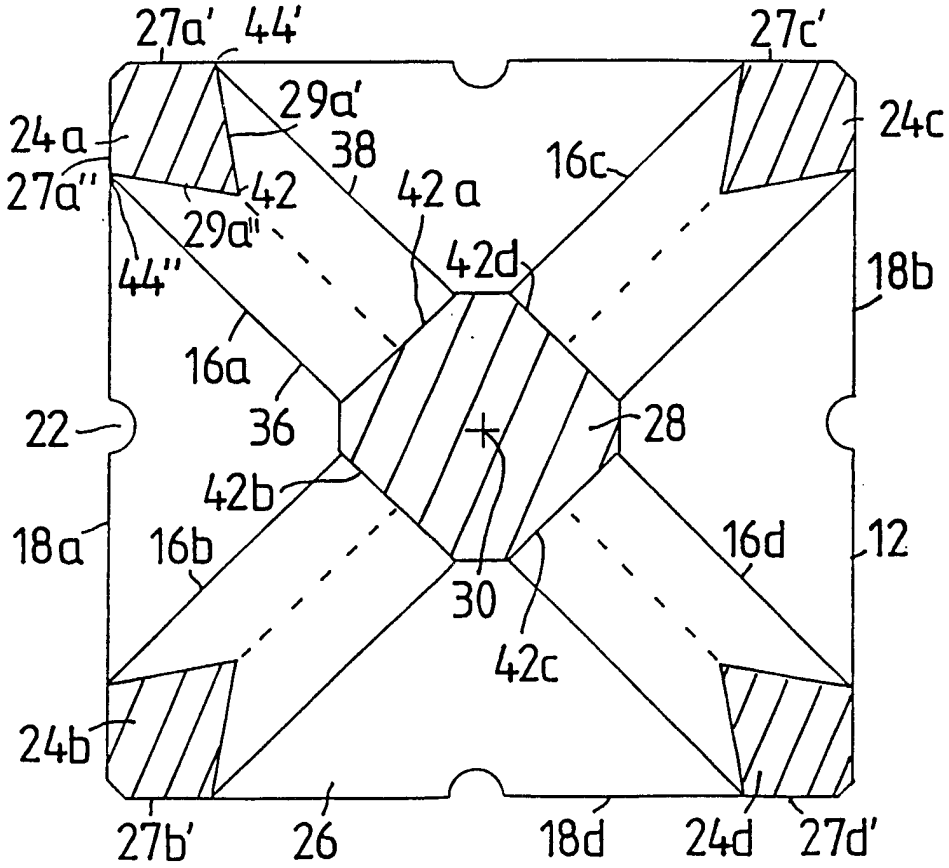
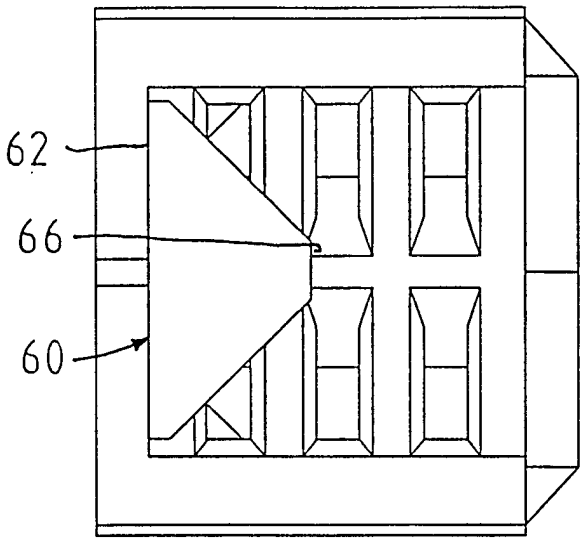

27a'
44'
27c'
29a'
24a
24c
38
16c
27a''
42
42a
29a''
42d
44''
18b
16a
22
36
28
42b
18a
16b
16d
12
30
42c
24b
27b'
26
18d
24d
27d'

FIG.6


62
66
60

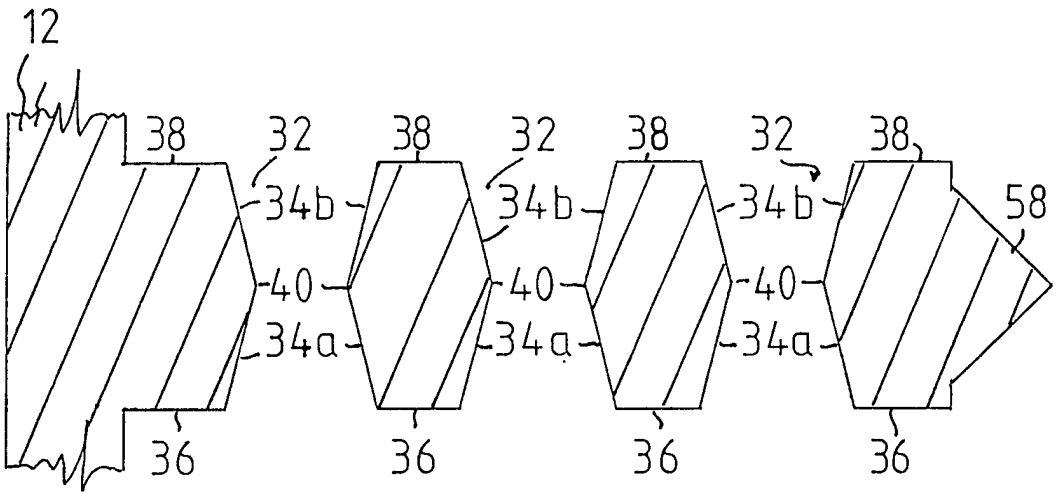

12
38
32
38
32
38
32
38
34b
34b
34b
58
40
40
40
34a
34a
34a
36
36
36
36

FIG. 5

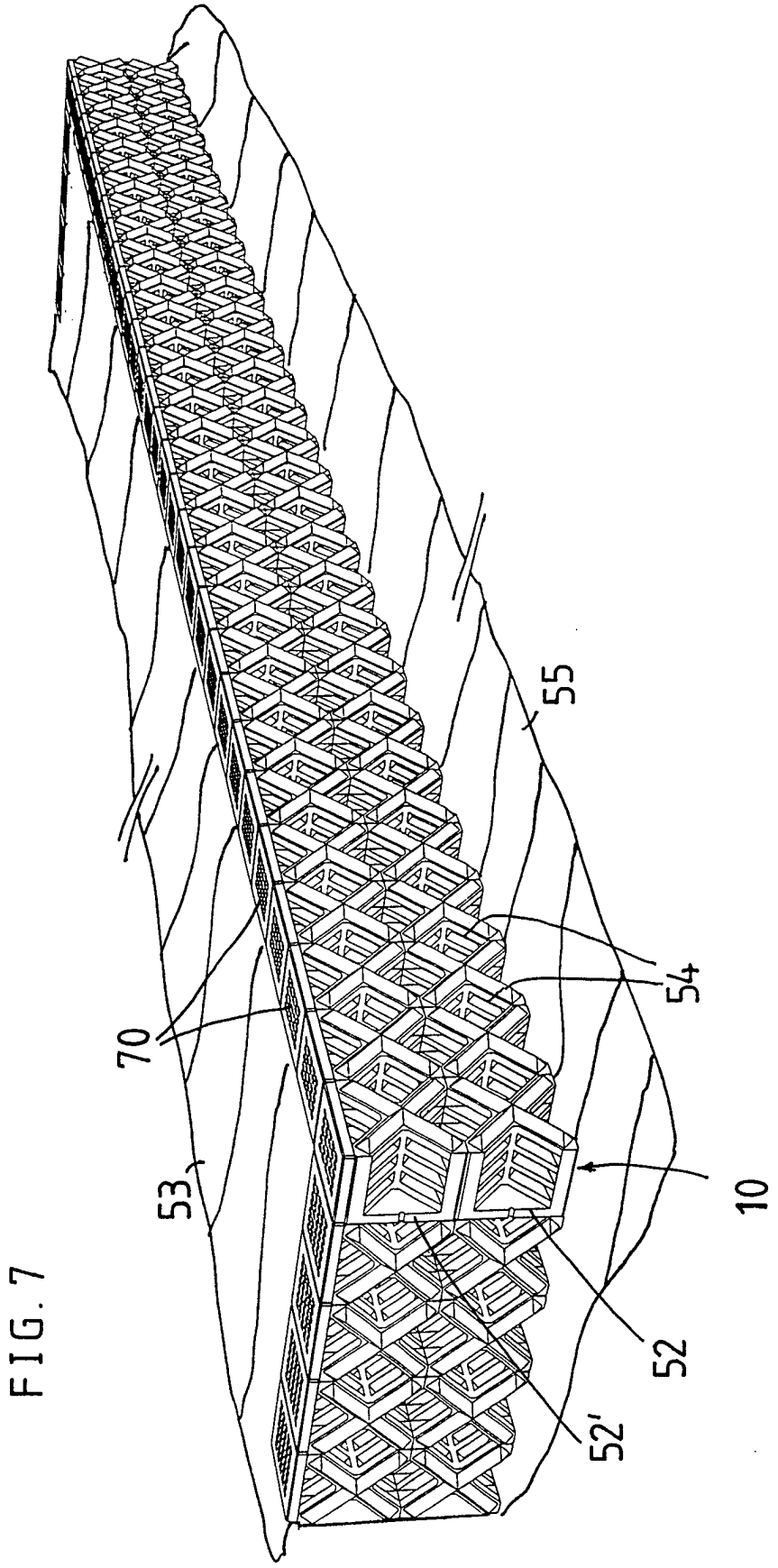


FIG. 7

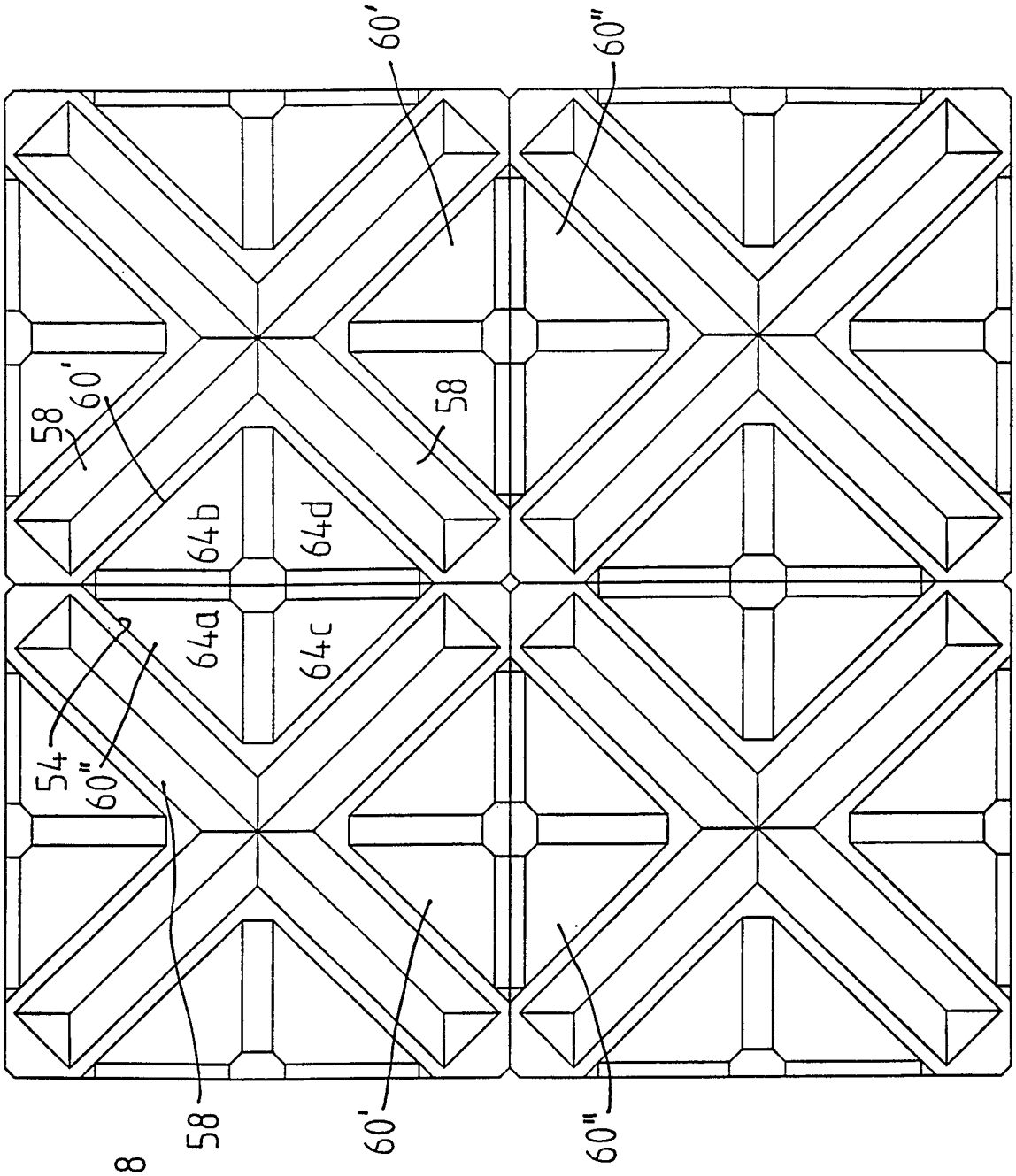


FIG. 8

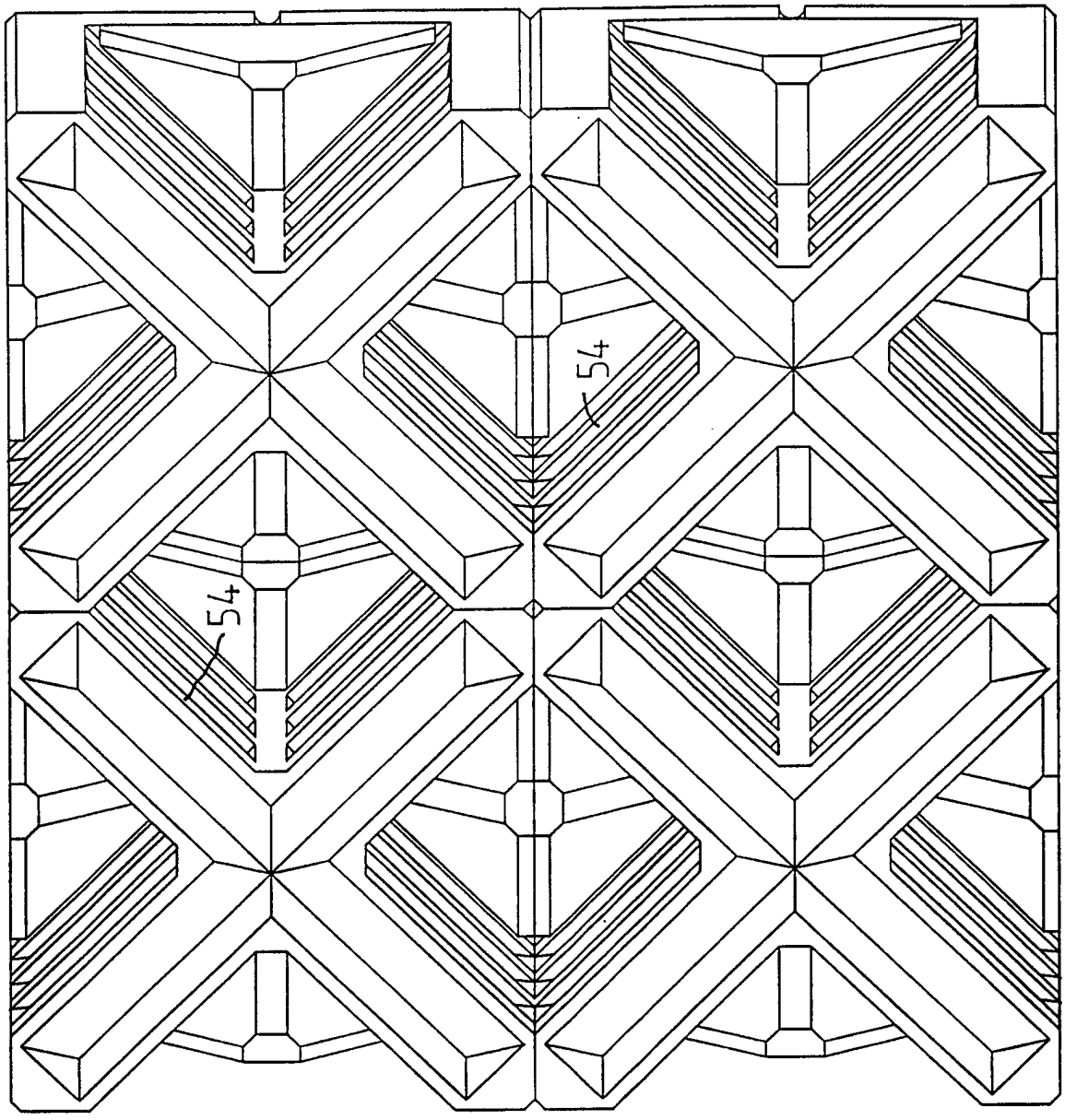


FIG.9

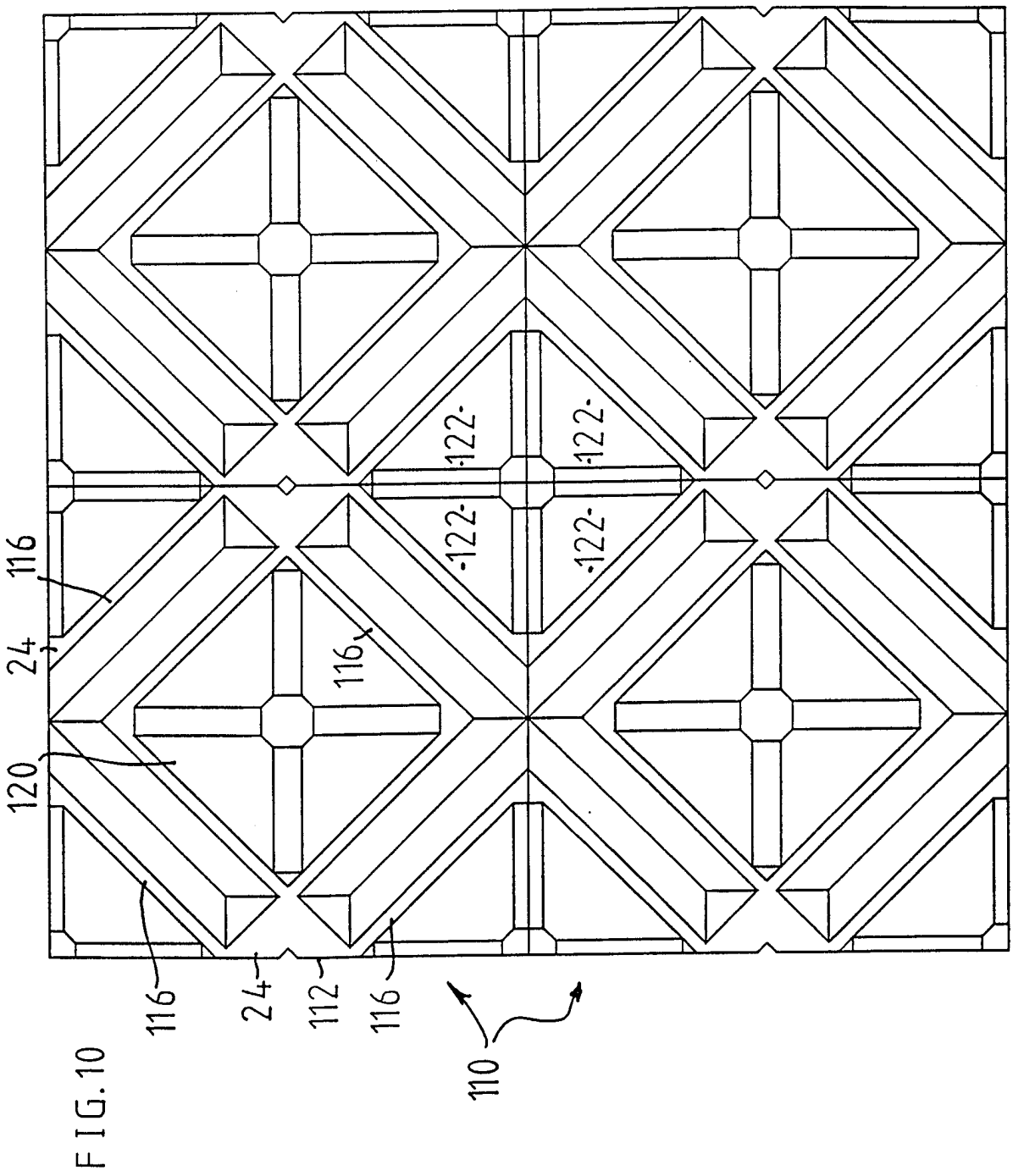


FIG. 10