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(54) Static mixers.

(57) A static mixer comprises a conduit for transporting flowable material, and a plurality of stationary mixer elements which so deflect the flow of material that a thorough mixing is effected. Each mixer element comprises seven plate members: a diamond-shaped plate (34); two triangular plates (48,50), co-planar and perpendicular to the diamond-shaped plate, the base of one triangular plate providing a leading edge to divide material flow into the conduit into two separate flows; and four deflector plates (66,68,70,72), which join the diamond-shaped and triangular plates and conform to the contours of inner walls of the conduit to provide two separate flow paths. The flow paths are substantially helical and rotate through substantially 180 degrees from the leading edge to trailing edge of each mixer element to rotate and thoroughly mix individual flows through the element. The leading edge of each succeeding mixer element is angled relative to the trailing edge of the immediately preceding mixer element to obtain successive division, mixing and recombination of flows.

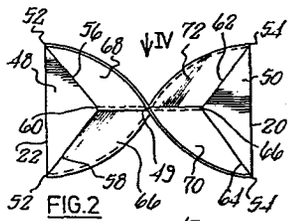

FIG.2

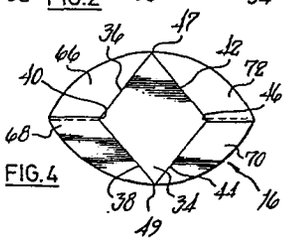

FIG.4

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TITLE: STATIC MIXERS

The invention relates to static or in-line mixers which incorporate a plurality of stationary baffles to deflect the flow of materials through a conduit thereby effecting a mixing or dispersion of the materials during transport through the conduit.

The function and construction of static mixers incorporating a plurality of baffles is described in the following U.S. patents: No. Re28072 issued to R. Sluitjters on July 9, 1974; No. 3,239,197 issued to J.E. Tollar on March 8, 1966; No. 3,643,927 issued to P.A. Crouch on February 22, 1972; No. 3,893,654 issued to H. Miura et al on July 8, 1975; No. 3,923,288 to L.T. King on December 2, 1975; No. 4,019,719 issued to Schuster et al on April 26, 1977; No. 4,034,965 issued to L.T. King on July 12, 1977; No. 4,164,375 issued to D.J. Allen on August 14, 1979; No. 4,179,222 issued Strom et al on December 18, 1979; and No. 4,208,136 issued to L.T. King on June 17, 1980.

An embodiment of the invention described below provides a static mixer element constructed in a plurality of plate-shaped members that can approximate the function of a helical mixing element. A smooth helical structure formed by twisting a sheet or plate of metal to provide 180 degrees of rotation between leading and trailing edges of the sheet or plate is a particularly effective mixing element for circular conduits. These helical structures can be constructed as left or right hand elements ("left" or "right" being determined by whether the flow pathways

defined by such an element curve counter-clockwise or clockwise respectively in the direction of material flow). Such left and right hand elements can be connected in series with leading edges substantially perpendicular to trailing edges to provide a very effective flow dividing and recombining arrangement. Additionally, such mixer elements provide effective radial mixing of flowable materials, eliminating radial gradients in composition, temperature and velocity, and can be readily dimensioned to provide flows of varying degrees of turbulence.

Helical mixer elements are presently manufactured from sheet or plate materials by a simple twisting process when practical. Unfortunately, they can be costly to manufacture with a diameter in the 5-10 inch range, and can be very difficult if not impossible to manufacture by a twisting process in sizes exceeding 10 inches in diameter. With larger diameter sizes, edge cracking tends to occur more frequently, and the process scrap rate tends to increase. Additionally, considerable stress is induced in the sheet or plate materials of large diameter mixer elements, which stress conduces to early corrosion and may require compensation by heat treatment. Furthermore, it is impractical to incur the cost of machinery necessary to twist large diameter elements for which there may be very limited demand.

A strip fabrication process is sometimes employed where a twisting process is thought to be impractical. A series of narrow strips of sheet or plate material are welded together to provide the required helical shape, and the weld joints mechanically ground to provide a smoother

flow surface, if necessary. The process is very labour intensive, and consequently costly.

Accordingly, one aspect of the invention seeks to provide a mixer element constructed in a plurality of plates, which approximates the function of a smooth helical mixer element, but can be constructed more easily at relatively large diameters.

A described embodiment of the invention provides a mixer element comprising seven plate elements (some of which may be integrally formed by bending from an appropriate blank). These plate elements include a central plate preferably in the form of a substantially parallelogram-shaped plate having a first pair of diagonally opposite vertices, and a second pair of diagonally opposite vertices spaced to contact the walls of a conduit.

The mixer element also includes two substantially triangular in form. These end plates are preferably substantially co-planar and disposed perpendicular to the plane of the parallelogram-shaped plate. A vertex of each triangular plate is substantially co-incident with one of the first pair of diagonally opposite vertices of the parallelogram-shaped plate. The base of each triangular plate (the base being opposite the triangle vertex just mentioned) provides either a leading edge for dividing fluid flows into two parts or trailing edge where a succeeding element can be located. The two remaining vertices of each triangular plate are spaced to contact walls of the conduit when installed.

Four deflector plates are provided to rotate (and

keep separate) the two fluid flows over the mixer element. Preferably the deflector plates extend one from each side of the parallelogram-shaped central plate to a side of the triangular end plates (except the bases of the triangular plates which provide the leading and trailing edges) so that two separate flow paths are defined. To this end each deflector plate has a sealing edge which conforms to the contours of the inner walls of the conduit.

The deflector plates are so connected to the end and central plates that each flow path spirals substantially helically through about 180 of rotation, between the leading and trailing edges of a mixer element. These spiralling flow paths provide the desired rotation and mixing of materials in use.

It should be noted that the term "sealing" as used in this specification contemplates the possibility of some fluid chanelling between fluid flow paths. In the U.S.A., a clearance of one percent of the internal diameter of a conduit is commonly tolerated about a mixer element in the conduit. In applications where a fluid-tight seal is required, it is usually provided by welding, soldering or otherwise, after installation of mixer elements.

Description of the Drawings

In the drawings:

Fig. 1 is a perspective view, partially fragmented, illustrating a circular-section conduit housing a plurality of left and right hand mixing elements arranged so that the trailing edge of one element is at 90° to the leading edge of

the next element;

Fig. 2 is a side elevational view of a right hand mixing element;

Fig. 3 is an end view of the right hand mixing element (along Arrow III of Fig. 2);

Fig. 4 is a plan view of the right hand mixing element (along Arrow IV of Fig. 2); and,

Fig. 5 is a plan view of a blank for use in forming the right hand mixing element (and also suitable for forming a left hand mixing element).

Description of a Preferred Embodiment

A preferred embodiment of a static mixer 10 is illustrated in the perspective view of Fig. 1. The static mixer 10 comprises a circular-section steel conduit 12 containing a plurality of steel left and right hand mixer elements of substantially identical structure. The conduit 12 is broken away at 14 to better illustrate two mixer elements 16, 18.

The contemplated direction of material flow is indicated by arrows F in the view of Fig. 1. The materials can be liquids, gases, solids (granular or powder) or combinations thereof, as contemplated by the prior art. The flows can be effected under vacuum, positive pumping pressure, or gravity feed.

With the direction of flow as selected above, it will be seen that the mixer element 16 is a right hand element, and the succeeding mixer element 18 is a left hand element. The mixer element 16 has leading and trailing edges 20, 22

which are substantially parallel to one another and perpendicular to inner walls 24 of the conduit 12. It is not critical to the function of mixer elements that the trailing and leading edges be so oriented: the leading edge need only divide the flow of material entering the mixer element into two streams, and the trailing edge should be shaped to permit a succeeding mixer element to be abutted in series with the particular mixer element.

Mixer element 16 provides two separate, substantially helical flow paths indicated by arrows 30, 32 in Fig. 1. The leading edge 20 is positioned to divide the flow in conduit 12 evenly between the flow paths 30, 32 (assuming that the full cross-sectional area of the conduit 12 is being used in the transport of materials). The rotation and deflection of the materials along the surfaces defining the helical paths 30, 32 provides a thorough mixing of the materials.

Mixing of materials is effected substantially in three ways: division and recombination of flows in succeeding mixer elements; radial mixing; and turbulence in the individual elements. Turbulence effects depend largely on geometry and pitch (herein defined as the ratio of the axial length of a mixer element to conduit diameter, which diameter may be some appropriate average cross-sectional diameter in the case of non-circular conduit), and are disclosed in the prior art. An angle of 0 to 90 degrees can be provided between the trailing edge of one mixer element and the leading edge of a succeeding mixer element, but 90 degrees is considered optimal for mixing by division and

recombination of flows. An angle of 0 degrees may be suitable in applications where the flows through individual mixer elements are designed to be particularly turbulent.

The right hand mixer element 16 is better illustrated in the view of Figs. 2-4, where it will be seen to be constructed in seven substantially plate members. These members include a substantially rhombus parallelogram-shaped central plate 34 with sides of equal length (best illustrated in the view of Fig. 4). A first pair of sides 36, 38 intersect to define a first central plate vertex 40, and a second pair of sides 42, 44 intersect to define a second central plate vertex 46, diagonally opposite to the first vertex 40. The remaining pair of diagonally opposite vertices 47, 49 of the plate 34 are spaced to contact the inner walls 24 of the conduit 12.

The mixer element 16 also includes a pair of end triangular plates 48, 50 (best illustrated in the view of Fig. 2). These end plates 48, 50 are substantially co-planar and perpendicular to the plane of central plate. 34. The bases of the end plates 48, 50 define the leading and trailing edges 20, 22 respectively.

The end plate 48 has a pair of lateral edge vertices 52, and the end plate 50, a pair of lateral edge vertices 54, which vertices are in contact with the inner walls 24 of the conduit 12. The end plate 48 has two equal sides 56, 58 which intersect to define an inner vertex 60, substantially co-incident with the vertex 40 of central plate 34. The end plate 50 has two equal sides 62, 64 which sides intersect to define an inner vertex 66 co-incident

with the vertex 40 of the central plate 34.

Four deflector plates 66, 68, 70, 72 are also provided. One deflector plate extends from each side of central plate 34 continuously to one of the sides of the two end plates 48, 50. Each deflector plate has a sealing edge 74 which extends from one of the vertices 47, 49 (contacting the inner walls 24 of the conduit 12) of central plate 34 to one of the pair of third and fourth vertices 52, 54 (contacting the inner walls 24 of the conduit 12) of the end plates 48, 50. These sealing edges 74 are shaped to conform to the contours of the inner walls 24 of conduit 12, whereby the flow paths 30, 32 are kept separate (not in fluid communication through substantially the full length of the mixer element 16). As mentioned above, a measure of fluid channeling between flow paths is acceptable in most applications. The orientation of the deflector plates is such that the paths 30, 32 spiral in a substantially helical fashion through about 180 degrees of rotation (as mentioned above). It is not critical to the operation of the mixer elements that exactly 180 degrees of rotation be achieved.

If desired, seven plates can be individually cut, then welded, soldered or otherwise fastened, to form the mixer element 16. Individual forming of the plates may in fact be preferred if the diameter of the mixer element is in the order of several feet. Alternatively, several

plates can be integrally formed from a single sheet or plate of metal and then appropriately bent. Sharp edges between the plates are clearly not necessary, and smooth curved surface at plate jointures may in fact be preferred. Additionally, it is not critical that the plates be "planar", although this may be preferable when forming the elements from blanks.

Fig. 5 illustrates a blank 76 which together with the two end plates 48, 50 can be used to form the mixer elements 16. In Fig. 5 the following parameters are indicated:

1) L is the axial length of the mixer element 16,

2) D is the inside diameter of the conduit 12,

3) A is the distance between each vertex 47, or 49 of the central plate 34 and the corresponding vertex 52 or 54 of the triangular plates 48, 50 intended to contact the inner surface or wall 24 of the conduit 12,

4) B is the length of the equal sides 56, 58 and 62, 64 of the end plates 48, and 50, respectively;

5) R is a radius of curvature for each of the sealing edges 74 of the deflector plates.

Bend lines 78 indicate, of course, where the blank 76 is to be bent, to a fixed bend angle. The direction of bending to obtain the required helical flow paths 30, 32 will be obvious from the views of Figs. 2-4.

It should be noted that the height of the end plates 48, 50 (as measured perpendicular to the leading and

trailing edges) has been selected to be L/4 units, and diagonals of the central plate 34 have been selected to be L/2 units. The pitch of a mixer element will typically be 1:1 to 1.5:1, but is not limited to such ranges. Additionally, the relative axial widths of the central and end plates can be varied significantly.

Accordingly, with the above definitions and specifications, the various parameters are governed by the following relationships:

$$(1)\quad A = \left(\frac{D}{2}^2 + \frac{L}{4}^2\right)^{\frac{1}{2}}$$

$$(2)\quad B = \left(\frac{D}{4}^2 + \frac{L}{16}^2\right)^{\frac{1}{2}}$$

$$(3)\quad R = \frac{.21339\ L^2}{D} + \frac{D}{2}$$

$$(4)\quad \text{Bend Angle} = 180^\circ - \tan^{-1}\left[\frac{2D}{\sin\left[\tan^{-1}\frac{2D}{L}\right] L}\right]$$

The blank 76 dimensioned and bent as indicated, with the end plates 48, 50 secured by welding to the remaining plates, should fit in a substantially sealing fashion into a circular-section (ie cylindrical) conduit of inner diameter D.

The left hand mixer element 18 can be formed as well from the blank 76 together with the end plates 48, 50. The deflector plates will be bent through the same bend angle calculated, but in opposite directions relative to the central plate 34.

The mixer elements 16, 18 described above are adapted for use in a cylindrical conduit. It will be appreciated that the

sealing edges of the deflector plates can be shaped for sealing engagement with the inner walls of conduits of rectangular or eliptical or other cross-sectional shapes. The relative spacing of the vertices of the triangular plates and the vertices of the rhomboid central plate that must contact the walls of the conduit will be readily apparent in any particular application, being dictated by the internal dimensions of the conduit. The dimensions for the deflector plate edges can be accurately calculated for best fit in any given conduit.

Preferred embodiments of a static mixer and mixing elements have been described. It will be appreciated that variations of a workshop nature can be effected in the static mixer and elements without departing from the scope and spirit of the invention. In particular, mixer elements constructed according to the invention and having different pitches and different angles between leading and trailing edges of succeeding stages can be combined in a single in-line mixer to obtain various mixing and dispersion effects.

Among other modifications which could be made in the above embodiment without departing from the scope of the invention are:

1 Central plate 34 need not necessarily be in the form of a rhombus. Other forms of parallelogram may be employed such as a square or a rectangle with two unequal pairs of opposite sides, or the parallelogram resulting from changing the angles of such rectangles. Indeed, though for

simplicity of production the plates of the mixer element are preferably symmetrical, it will be appreciated that some deviation from symmetry will not unduly affect the performance of the mixer element and quadrilateral plates of such form may be acceptable for certain types of production;

2 The end plates 48,50 need not be triangular. For example, the end plates may each be in the form of a pentagon such as is obtained by providing a rectangular extension of the end plates by joining a rectangle onto the leading and trailing edges 20, 22. Obviously, such a plate would be manufactured as an integral unitary item. The provision of such an extended end plate would allow the provision of inter-fitting slots formed in the end plates of adjacent mixer elements in a static mixer, whereby the strength of the mixer assembly can be increased;

3 The end plates 48, 50 need not be coplanar and could be inclined with respect to each other by as much as ninety degrees. This affects the total angular movement of fluids passing over the mixer element and allows the provision of more or less than one hundred and eighty degrees of angular movement per mixer element;

4 The end plates 48, 50 need not be perpendicular to the plane of the central plate, the inclination is

preferably at a substantial angle of from forty five degrees with respect thereto, and better results are achieved with inclinations of from sixty to ninety degrees with respect to the central plate;

The arrangement of mixer elements is preferably such that successive mixer elements have their adjacent leading and trailing edges at ninety degrees to each other, but this inclination may be varied by up to 22.5 degrees in either direction.

CLAIMS:

1 A static mixer element (16) locatable in a conduit (12);

characterised in that the mixer element comprises:

a central plate (34) in the form of a quadrilateral having first and second pairs of sides (36, 38) and (42, 44) the sides of each pair intersecting to define first and second central plate vertices (40 and 46) respectively, and the first and second pairs of sides of the central plate intersecting to define third and fourth central plate vertices (52 and 54) spaced to contact the inner surface of the conduit when the mixer element is located in the conduit;

first and second end plates (48, 50) disposed at substantial inclinations with respect to the plane of the central plate (34), the end plates each having a pair of sides (56, 58 and 62, 64) intersecting to define an end plate vertex (60, 66) and said end plate vertices being secured one adjacent each of the first and second central plate vertices (40, 46), and each end plate having lateral edges spaced to contact the inner surface of the conduit when the mixer element (16) is located therein;

first and second pairs of deflector plates (66, 68, 70, 72), one pair for each end plate, and each deflector plate interconnecting a vertex-defining side of its end plate and an adjacent side of the central plate, each of

the deflector plates having an edge (74) shaped to conform substantially to the profile of the inner surface of the conduit, when the mixer element (16) is located in the conduit, whereby, first and second separate flow paths are defined along the length of the mixer element, the deflector plates being so connected between the central and end plates (34 and 48, 50) that the flow paths extend helically around the mixer element.

2 A static mixer element according to claim 1 characterised in that said central plate (34) is in the form of a parallelogram.

3 A static mixer element according to claim 2 characterised in that said central plate (34) is in the form of a rhombus.

4 A static mixer element according to any one of the preceding claims characterised in that said end plates (48, 50) are inclined at from sixty degrees to ninety degrees with respect to the plane of the central plate.

5 A static mixer element according to claim 4 characterised in that said end plates (48, 50) are coplanar and mounted at ninety degrees with respect to the central plate (34).

6 A static mixer element according to any one of the preceding claims characterised in that said end plates

(48, 50) are substantially triangular in form.

7 A static mixer element according to any one of the preceding claims characterised in that the central plate (34) and the end plates (48, 50) and the deflector plates (66, 68, 70, 72) are mounted in attitudes such that when the mixer element (16) is located in the conduit (12) the flow paths defined thereby have substantially equal cross-sectional areas in any plane perpendicular to the flow axis of the conduit and intersecting the flow paths, throughout substantially the full length of the flow paths.

8 A static mixer element according to claim 6 characterised in that the four sides of said triangular plates defining the vertices (60, 66) adjacent the first and second central plate vertices, are all of substantially equal length.

9 A static mixer element according to any one of the preceding claims characterised in that the outer edge (74) of each deflector plate is shaped to conform with the circular profile of the inner surface of a cylindrical conduit (12).

10 A static mixer comprising a conduit (12) housing a plurality of stationary mixer elements (16) as claimed in any one of the preceding claims.

11 A static mixer according to claim 10 characterised by successive mixer elements (16) being of left hand and right hand construction.

12 A static mixer according to claim 10 or claim 11 characterised in that successive mixer elements (16) have their adjacent leading and trailing edges arranged at substantially ninety degrees with respect to each other.

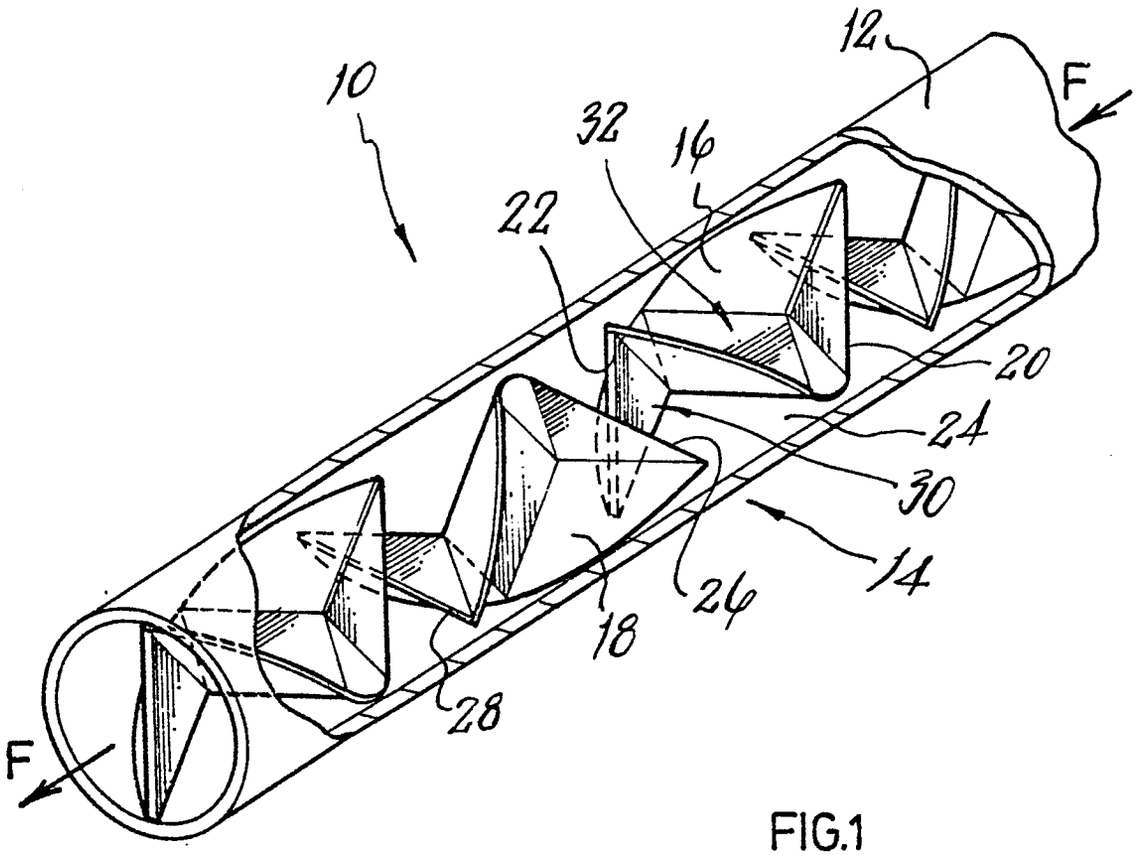


FIG.1

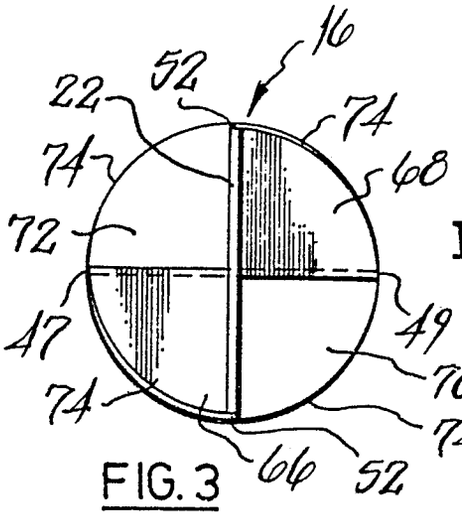


FIG. 3

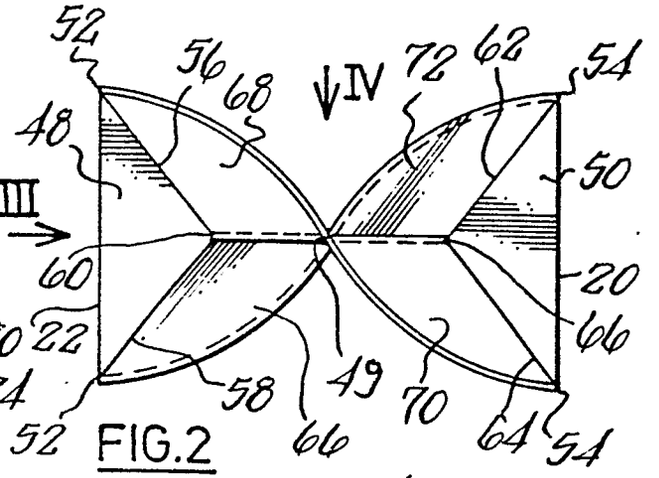


FIG. 2

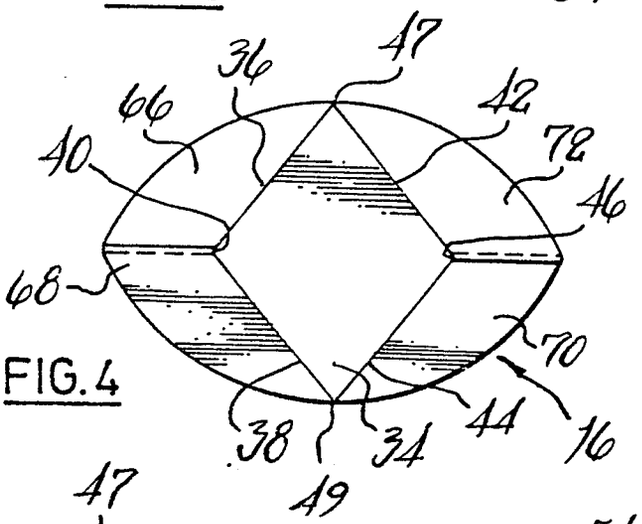
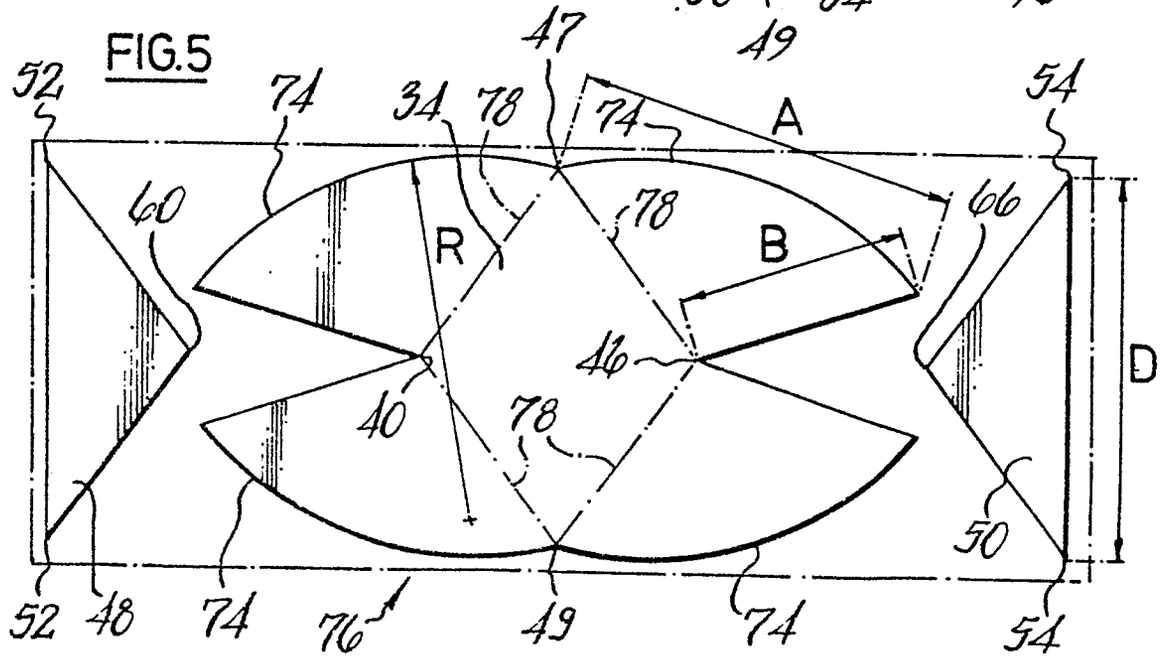


FIG. 4

FIG. 5



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EUROPEAN SEARCH REPORT

Application number
EP 82 30 3951.6

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
D,A	US - A - 3 643 927 (R.A. CROUCH) * fig. 1, 2 *	
D,A	US - A - 3 923 288 (L.T. KING) * fig. 1 to 12 *	
D,A	US - A - 4 034 965 (L.T. KING) * fig. 1 to 8 *	
D,A	US - A - 4 179 222 (J.R. STROM et al.) * fig. 1, 2 *	
D,A	US - A - 4 208 136 (L.T. KING) * fig. 2 to 5 *	

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

B 01 F 5/06

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

B 01 F 5/06

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
Y: particularly relevant if combined with another document of the same category
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: earlier patent document, but published on, or after the filing date
D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	10-09-1982	KÜHN