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54 **Extrusion die.**

57 An extrusion die and process for the extrusion of extrudates, particularly from ceramic pastes, having relatively small, closely spaced, through passages has a core support plate (18) extending across the inlet region of the die housing (10), and a plurality of flexible core members (32) extending from the plate to the outlet region (22) of the housing (10). The cross section of the flexible members (32), at least at the ends remote from the plate, corresponds to the desired passage cross section. The plate has feed channels (28) therethrough for the passage of the material being extruded to the downstream side of the plate. In the process the flexible members (32) approximately follow the lines of material flow so that they assume the desired disposition at the die outlet.

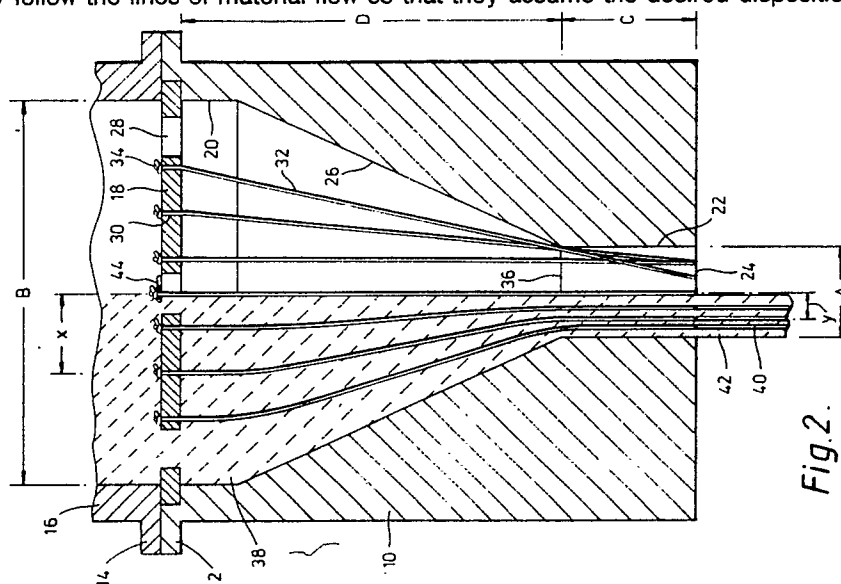


Fig. 2.

Extrusion die

This invention relates to an extrusion die and in particular to a form of die construction that is suitable for producing extrudates having a plurality of passages extending through the length thereof.

Heretofore dies for such extrudates have included a plurality of rigid core rods extending from a spider or die member, herein termed a core support plate, positioned upstream of the die exit with means to supply the material being extruded to the downstream side of the core support plate: such supply means commonly comprise holes, or channels, through the core support plate at locations between the core rods. An arrangement of this type is disclosed in FR-A-2582981.

Such a construction has been proposed or used for a variety of extrusions, including the extrusion of airbricks and ceramic honeycombs, but presents problems where it is desired that the maximum cross-sectional dimension of the passages is small, eg less than about 2 mm, since the cores then lack rigidity and mechanical difficulties are encountered where it is desired that the passages are closely spaced: eg where the minimum distance between the centres of adjacent passages is less than about 5 mm. While, with certain extrudable materials, eg thermoplastics (including glass), it is possible to employ a die having rigid core rods of greater dimensions and spacing than is required in the extrudate and to draw-down the extrudate after it has left the die, such a technique is not suitable for many extrudable compositions, particularly many plastic compositions such as ceramic pastes.

We have devised a die construction that overcomes these difficulties.

Accordingly the present invention provides an extrusion die for the production of an extrudate having a plurality of through passages of maximum cross-sectional dimension 2 mm with a spacing between the centres of adjacent passages of less than 5 mm, comprising:

- a) a die housing having an inlet region and an outlet region terminating in an orifice through which the extrudable composition is to be extruded;
- b) a core support plate extending across the inlet region of said housing and having a plurality of feed channels therethrough for the passage of the extrudable material from upstream of the core support plate to the inlet region of the housing downstream of the core support plate; and
- c) a plurality of elongated flexible members extending from said core support plate to said outlet region, the distance between the longitudinal axes of adjacent flexible members at said core support plate being greater than the desired spacing between the centres of the passages in the extrudate, said flexible members having cross section dimensions, at least at the ends thereof remote from said core support plate, corresponding to the cross sectional dimensions of said through passages.

The invention also provides a process for the production of an extrudate comprising feeding an extrudable material to the inlet region of the housing of a die as aforesaid, said material being fed to said inlet region at such a rate that the material flows through said channels to the downstream side of the core support plate and thence, in plug flow fashion, out of said orifice, whereby the flow of said material causes said flexible members substantially to follow the lines of material flow and to assume a configuration at said outlet region corresponding to the desired disposition of said passages in the extrudate.

In the present invention advantage is thus taken of the streamline flow of the extrudable composition to cause the cores formed by the flexible members to adopt the relative positions appropriate to the desired spacing of the passages in the extrudate.

While as mentioned hereinafter, in some cases each flexible member may have an enlarged portion at the end remote from the core support plate, it is preferred that the flexible members have a uniform cross section which is preferably circular, although other shapes, eg polygons such as triangles, squares, or hexagons, or re-entrant shapes eg clover leaf, may be employed if desired. Also, as mentioned hereinafter, the flexible members may be hollow, ie tubes.

The flexibility of the flexible members and the tension created therein by the extrudable composition flowing past the flexible members will affect the disposition they adopt in the outlet region in relation to their disposition at the core support plate. Also the size of the feed channels in the core support plate, and their disposition relative to the flexible members, will also affect the disposition adopted by the flexible members at the die outlet.

Where the extrusion is of a ceramics paste composition, the extrusion may be effected at temperatures ranging from 10 to 100°C and in some cases the flexible members may be monofilaments of plastics material, eg nylon. The flexible members preferably have a substantially circular cross-section of diameter in the range 0.05 to 2, particularly 0.2 to 1.0, mm. Nylon monofilament, eg fishing line, or metal wire, eg stainless steel wire, is a suitable material for the flexible members in many cases.

The dies of the invention are of particular utility in the production of extrudates having a relatively large number of passages per unit cross section area of the extrudate. To this end it is preferred that the number of core members is at least 20, particularly at least 25, per square cm of the orifice cross-section.

5 The cross-sectional area of the inlet region of the housing is preferably 4 to 100 times the cross sectional area of the orifice.

Since the extrudable composition may be somewhat abrasive, the core support plate is preferably constructed so that the flexible members can readily be replaced after a period of extrusion. To this end the core support plate may be provided with a plurality of small holes sized to permit passage of the flexible members therethrough and the flexible members are simply passed through these holes with means, eg, in
10 the case of flexible members in the form of monofilaments, knots or globules formed by heating the end of the flexible member, on the upstream side of the core support plate to prevent the flexible member from being pulled through its associated hole during extrusion. Alternatively the ends of a length of flexible core member material may be passed through adjacent holes in the core support plate so that a single length of core member material forms two adjacent core members, the loop of core member material between
15 adjacent holes thus serving to prevent the core members from being pulled through the holes during extrusion.

The invention also provides extrusion die components for use in a die as described above, comprising

a) a die housing having an inlet region and an outlet region terminating in an orifice through which the extrudable composition is to be extruded; and

20 b) a core support plate for extending across the inlet region of said housing, said core support plate having

a plurality of feed channels therethrough for the passage of the extrudable material from upstream of the core support plate to the inlet region of the housing downstream of the core support plate, and

25 a plurality of holes therethrough, each hole being for the receipt of an elongated flexible member passing through the hole and extending to the outlet region of said housing, the distance between the centres of adjacent holes being greater than the desired spacing between the centres of the passages in the extrudate.

The outlet region of the housing preferably has a die land of substantially uniform cross-section: the flexible members preferably extend into such a uniform cross-sectional area die land and, in particular, at least to the downstream end of the die land.

30 The die land preferably has a length of 1 to 5 times the minimum cross-sectional dimension of the orifice.

The core support plate is preferably disposed at a distance from the orifice at least equal to one third of the minimum cross-sectional dimension of the inlet region of the housing at the location of the core support plate. In particular the core support plate is preferably disposed at a distance from the orifice equal to the
35 die land length plus one third to three times, particularly one to two times, the minimum cross-sectional dimension of the inlet region of the housing at the location of the core support plate.

In some cases it may be desirable to provide a multiplicity of extrudates from a single extruder. To this end the housing has a multiplicity of inlet regions, each of which has its associated outlet region, terminating in an orifice, and core support plate provided with the feed channels and the core members.

40 Alternatively a single core support plate may be provided having an array of feed channels, and core members, for each inlet region in the housing.

While, as mentioned above, the flexible members preferably have a uniform cross section, in some cases it may be desirable to provide enlarged portions at the ends of the flexible members remote from the support plate, ie in the die outlet region. This enables passages of a given cross section to be made using
45 flexible members that, for a substantial, eg major, portion of their length, have a thinner cross section and hence a greater flexibility and consequent more complete alignment with the laminar flow lines. Such enlargements may have a cross sectional shape dissimilar to that of the flexible members: thus the latter may be of circular cross section with enlargements of triangular, square, or hexagonal cross section. It is preferred that, where there are such enlargements, the flexible member has a tapered transition region
50 between the thinner cross section portion and the enlarged portion. By the use of flexible members having enlargements, it is possible to produce extrudates having a honeycomb cross sectional configuration.

As mentioned above, in some cases, it may be desirable to employ hollow flexible members so that a fluid can be passed through the flexible members and hence into the passages created thereby, or by enlargements thereon, in the extrudate. Such a flow of fluid may be advantageous where:

55 a) it is desired to apply a coating to the interior surfaces of the passages: in that case the fluid may be the coating material in liquid or gaseous form or a solution thereof;

b) there is a risk of the passages collapsing or deforming, eg when cutting the extrudate into lengths: in this case the fluid may be a liquid or gas such as air;

c) such a fluid can assist setting of the extrudable composition: in this case the fluid may react with the extrudable composition and/or may assist drying, heating or cooling of the latter as appropriate: in many such cases air is a suitable fluid.

The die may be constructed with a plurality of orifices in order to provide a plurality of extrudates using a single core support plate.

Since, in use, the flexible members assume a disposition approximately corresponding to the laminar flow pattern of the material undergoing extrusion, in order to obtain a uniform spacing of passages in the extrudate, it may be thought that the flexible members should be positioned at the core support plate in accordance with a square law. However, in addition to the spacing of the core members at the core support plate, various other factors have an effect on the disposition adopted by the flexible members in the outlet region of the die. These other factors include:

the degree of flexibility of the flexible members coupled with the tension therein caused by the frictional drag of the extrudable composition as it flows past the flexible members;
the shape and size of the feed channels through the core support plate and their disposition relative to the flexible members;
the nature of the extrudable composition and the extrusion conditions, eg extrusion rate.

The core support plate configuration, ie the shape and size of the feed channels and the disposition of the flexible members in relation to the feed channels, required to achieve any desired disposition of passages in the extrudate formed from any given material under given extrusion conditions may be determined by experiment. In some cases it may be desirable to modify the thickness of the core support plate across its width. For example it may have a "convex lens" configuration: such a configuration will affect the flow of material through the feed channels.

In preferred configurations the flexible members are positioned at the core support plate such that, under design extrusion conditions, the extrudate has passages evenly spaced with their centres at the apices of equilateral triangles.

If desired, locating members, eg spiders, through which the flexible members or enlargements thereof pass, or projections on some or all of the flexible members, especially those carrying enlargements, round which the extrudable composition can flow, may be provided to locate the passage defining members, ie the flexible members or enlargements thereon, in spatial relationship to one another. In this way spatial arrangement of the passages can be determined by such locating members and the portions of the flexible members upstream of the locating members merely serve to provide the longitudinal connection for the passage defining members to the core support plate. In this case, the flexible members need not be arranged at the core support plate such that they follow the lines of laminar flow upstream of the locating members.

The invention is of particular utility for the production of multiholed ceramic units eg for use as tower packings or as catalysts or catalyst supports. Examples of ceramic compositions that can be extruded using dies in accordance with the invention are described in EP-A-134138.

One embodiment of the invention is illustrated by reference to the accompanying drawings wherein:

Figure 1 is a plan view of a die in accordance with the invention with the core members removed;

Figure 2 is a diagrammatic longitudinal section along the line X-X of Figure 1 with the core members inserted: the right hand half of Figure 2 shows an empty die, ie with no material being extruded while the left hand half shows the die in use;

Figure 3 is a section of a typical extrudate produced using a die of the type shown in Figures 1 and 2;

Figure 4 is a plan of a die providing for four extrudates: for clarity the flexible members, and the holes therefor in the core support plate, are omitted and the core plate is part cut away;

Figure 5 is a cross section along the line IV-IV of the die of Figure 4;

Figure 6 is a diagrammatic section of a die wherein the flexible members have enlarge portions at the ends thereof remote from the core support plate; and

Figure 7 is a cross section along the line VI-VI of Figure 6.

The die of Figures 1 and 2 comprises a housing 10 having a flange 12 abutting a flange 14 of an extruder barrel 16: a circular core plate 18 is clamped between the barrel and housing 10. The housing 10 has an inlet cylindrical region 20 and a cylindrical outlet region 22 forming the die land terminating in an orifice 24. Intermediate the inlet and outlet regions is a frusto-conical region 26. This region need not be of frusto-conical configuration - thus a cylindrical section could be employed although this will give rise to a stagnant region of the extrudable material during extrusion. Core support plate 18 has a plurality of circular

cross section feed channels 28 therethrough for the passage of extrudable material from the extruder barrel 16 and a plurality of small holes 30 through each of which a flexible core defining member 32, eg a nylon monofilament, passes. Each core member has a stopper knot 34 upstream of the core support plate 18 to retain the core member 32.

5 In the die of Figures 1 and 2 there are fifty cores 32 arranged with one central core, a first circle of seven cores, an intermediate circle of fourteen cores, and an outer circle of twenty eight cores. There are thirty six feed channels arranged as a central channel, a first circle of seven intermediate channels, a second circle of fourteen intermediate channels, and an outer circle of fourteen channels.

The central core member is supported by a member 44 bridging the central channel.

10 A typical extrudate produced from the die of Figures 1 and 2 is shown in Figure 3.

In the arrangement shown in Figures 4 and 5 the die has four orifices 24 each fed via a frusto-conical region 26 from feed channels 28 in a core support plate 18.

As in the embodiment of Figures 1 and 2, the core support plate 18 is provided with a series of feed channels 28 and holes (not shown) through which the flexible members associated with the appropriate orifice pass. The core support plate 18 is supported as shown in Figure 2 in a recess in the housing 10 incorporating the outlet orifices 24. The central region 38 of the core support plate 18 is supported by the central part of housing 10.

In the embodiment shown in Figures 6 and 7 the flexible members 32 are provided with enlarged portions 46 at their ends remote from the core support plate 18. These enlarged portions 46 extend along at least the length of the die land 22. The enlarged portions 46 have a hexagonal cross section thereby defining passages of hexagonal cross section in the extrudate. In the arrangement shown in Figures 6 and 7 there are seven such core members. In order to locate the enlarged portions 46 of the flexible members 32 at the desired positions with respect to the interior of the die land 22 and with respect to one another, the enlarged portions 46 are provided, at a point upstream of the outlet end 24 of the die, with projections 48 which engage with the interior surface of die land 22 or with the enlarged portion 46 of an adjacent flexible member 32. These projections are shaped so that the extrudable material can flow between the projections and reunite on the downstream side thereof. At the upstream end of the enlarged portions 46 of the flexible members 32 there is provided a tapered transition section 50 to assist distribution of the extrudable material to the flow channels between the interior surface of the die land 22 and the enlarged portions 46 of the flexible members 32 or to between adjacent enlarged portions 46 of the flexible members 32.

Instead of having projections 48 on the enlarged portions 46 of the flexible members 32, a spider may be provided upstream of the enlarged portions 46 and having holes therein through which the flexible members 32 pass.

The invention is illustrated by the following examples.

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Example 1

Haematite was milled to a fine powder, having a median particle size of 3 μm , all the particles having a size below 10 μm .

31 parts by weight of alumina trihydrate, 11 parts by weight of calcium carbonate, and 10 parts by weight of magnesium aluminate spinel, all of which had been previously ground to a similar degree of fineness as the haematite, were then mixed with 958 parts by weight of the milled haematite powder.

45 To this mixture was then added 10 parts by weight of a high molecular weight polysaccharide, ("Zusoplast PS 1", available from Zschimmer und Schwarz, Lahnstein am Rhein, FRG), 40 parts by weight of corn starch ("Kordek", grade G08010 available from CPC UK Ltd, Industrial Division, Trafford Park, Manchester, UK) and about 130 parts by weight of an aqueous solution containing 96 g.l⁻¹ of potassium carbonate, and mixed into the form of a homogeneous paste.

50 The mixture was then extruded at room temperature through the fifty core die described above in relation to Figures 1 and 2 and which had an orifice of 9.5 mm diameter. The core members were nylon monofilaments of diameter 0.5 mm. The inlet region of the die at the core support plate had a diameter of 70 mm and the feed channels were of the following dimensions and disposition:

55

5	Channel Array	diameter (mm) of	
		channel	circle
10	central channel	6	-
	first intermediate circle	4	16
	second intermediate circle	4	29
	outer circle	6	44

The holes for the core support members were of 0.75 mm diameter and were disposed in circles of diameters 9.5, 22, and 35 mm.

The cylindrical extrudates, having 50 passages extending longitudinally through, were cut into lengths, dried at 30°C for 12 hours under a humidity controlled atmosphere, then heated to 400°C at a rate of 200°C per hour, and held at 400°C until the organic components were fully burnt out. The extruded articles were then sintered at 1300°C in an air atmosphere for 4 hours, and then cooled to ambient over 6 hours.

The sintered extrudates, which were cylinders of length 8.5 mm and diameter 8.5 mm with 50 passages of diameter about 0.48 mm extending therethrough, had a particle density, as determined by reference to their volume in mercury at atmospheric pressure, of about 4 g.cm⁻³, and, after reduction of the haematite to iron, were suitable for use as ammonia synthesis catalysts.

Similar extrudates were obtained using nylon or poly ether ether ketone monofilaments of 0.7, 0.55, 0.35, 0.3, 0.25, and 0.19 mm diameter, and stainless steel wires of 0.2 and 0.3 mm diameter, as the core members.

Similar extrudates were obtained when alumina, carbon, silica gel, zeolite, and marzipan compositions were used in place of the haematite composition as the extrudable material.

Example 2

The procedure of Example 1 was repeated using the haematite composition and a die of the type described in relation to Figures 1 and 2 having an orifice of hexagonal cross section with a maximum cross-section dimension of 18 mm. 200 cores of nylon monofilaments of 0.19 mm diameter were employed disposed such that, in the extrudate, the passages were approximately at the apices of equilateral triangles. The extrudate was cut into lengths of about 40 mm before drying.

Similar extrudates were obtained when a zeolite composition was used in place of the haematite composition.

Example 3

The procedure of Example 1 was repeated using a zeolite composition in place of the haematite composition and employing a die of the type shown in Figures 1 and 2 having an orifice of 3 mm diameter and having 37 cores of nylon monofilament of diameter 0.2 mm disposed so that the passages in the extrudate were at the apices of equilateral triangles. Similar extrudates were obtained using cores of nylon monofilament of diameter 0.25 mm.

Claims

1. An extrusion die for the production of an extrudate having a plurality of through passages of maximum cross-sectional dimension 2 mm with a spacing between the centres of adjacent passages of less than 5 mm, comprising:

a) a die housing having an inlet region and an outlet region terminating in an orifice through which the extrudable composition is to be extruded;

b) a core support plate extending across the inlet region of said housing and having a plurality of feed channels therethrough for the passage of the extrudable material from upstream of the core support plate to the inlet region of the housing downstream of the core support plate; and

c) a plurality of elongated flexible members extending from said core support plate to said outlet region, the distance between the longitudinal axes of adjacent flexible members at said core support plate being greater than the desired spacing between the centres of the passages in the extrudate, said flexible members having cross section dimensions, at least at the ends thereof remote from said core support plate, corresponding to the cross sectional dimensions of said through passages.

2. A die according to claim 1 wherein the core support plate has a plurality of holes, the distance between the centres of adjacent holes being greater than the desired spacing between the centres of the passages in the extrudate, and each elongated flexible member passes through one of said holes and is provided with means upstream of said core plate for preventing it from being pulled through its associated hole during extrusion of the extrudate.

3. A die according to claim 2 wherein the core support plate has the feed channels disposed in concentric circles of channels and the holes for receiving the core members disposed in concentric circles of holes between each circle of feed channels.

4. A die according to any one of claims 1 to 3 wherein the number of core members is such that the number of core members per square cm of the orifice cross-sectional area is above 20.

5. A die according to any one of claims 1 to 4 wherein the core members are of uniform circular cross-section and have a diameter in the range 0.05 to 2mm.

6. A die according to claim 5 wherein the core members comprise monofilaments of a plastics material.

7. A die according to any one of claims 1 to 4 wherein the core members have enlarged portions at their ends remote from the core support plate.

8. A die according to any one of claims 1 to 7 for the extrusion of a multiplicity of extrudates wherein the housing has a multiplicity of inlet regions, each inlet region having its associated outlet region, terminating in an orifice, and core support plate provided with the feed channels and the core members, or

each inlet region having its associated outlet region, terminating in an orifice, and a single core support plate is provided, said single core plate having an array of feed channels and core members for each inlet region.

9. Extrusion die components for use in a die according to claim 2, or any claim dependent thereon, comprising

a) a die housing having an inlet region and an outlet region terminating in an orifice through which the extrudable composition is to be extruded; and

b) a core support plate for the extending across the inlet region of said housing, said core support plate having

a plurality of feed channels therethrough for the passage of the extrudable material from upstream of the core support plate to the inlet region of the housing downstream of the core support plate, and

a plurality of holes therethrough, each hole being for the receipt of an elongated flexible member passing through the hole and extending to the outlet region of said housing, the distance between the centres of adjacent holes being greater than the desired spacing between the centres of the passages in the extrudate.

10. A process for the production of an extrudate comprising feeding an extrudable material to the inlet region of the housing of a die according to any one of claims 1 to 8, said material being fed to said inlet region at such a rate that the material flows through said channels to the downstream side of the core support plate and thence, in plug flow fashion, out of said orifice,

whereby the flow of said material causes said flexible members substantially to follow the lines of material flow and to assume a configuration at said outlet region corresponding to the desired disposition of said passages in the extrudate.

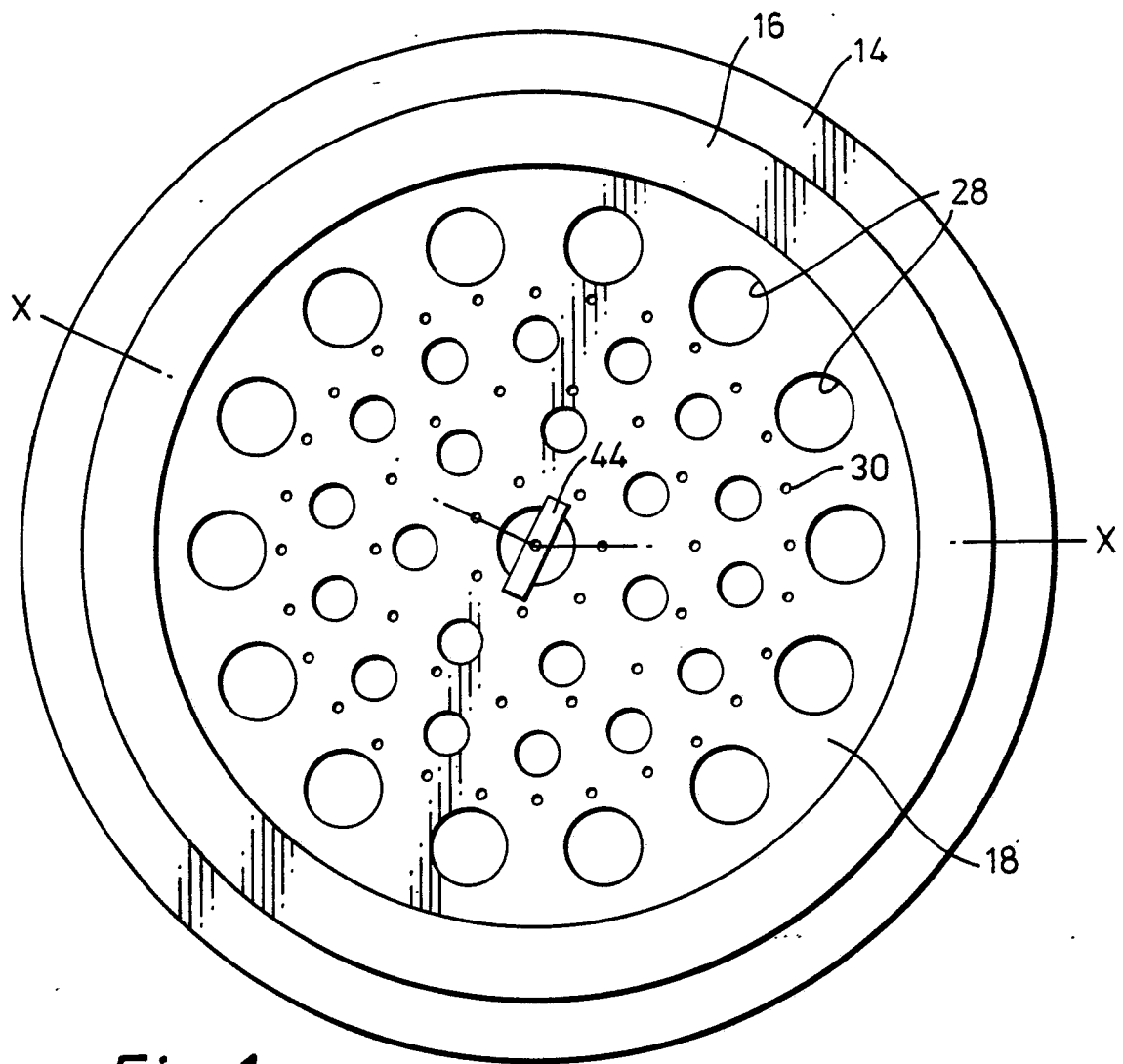


Fig. 1.

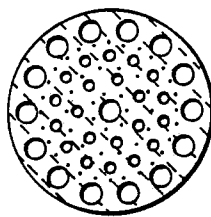
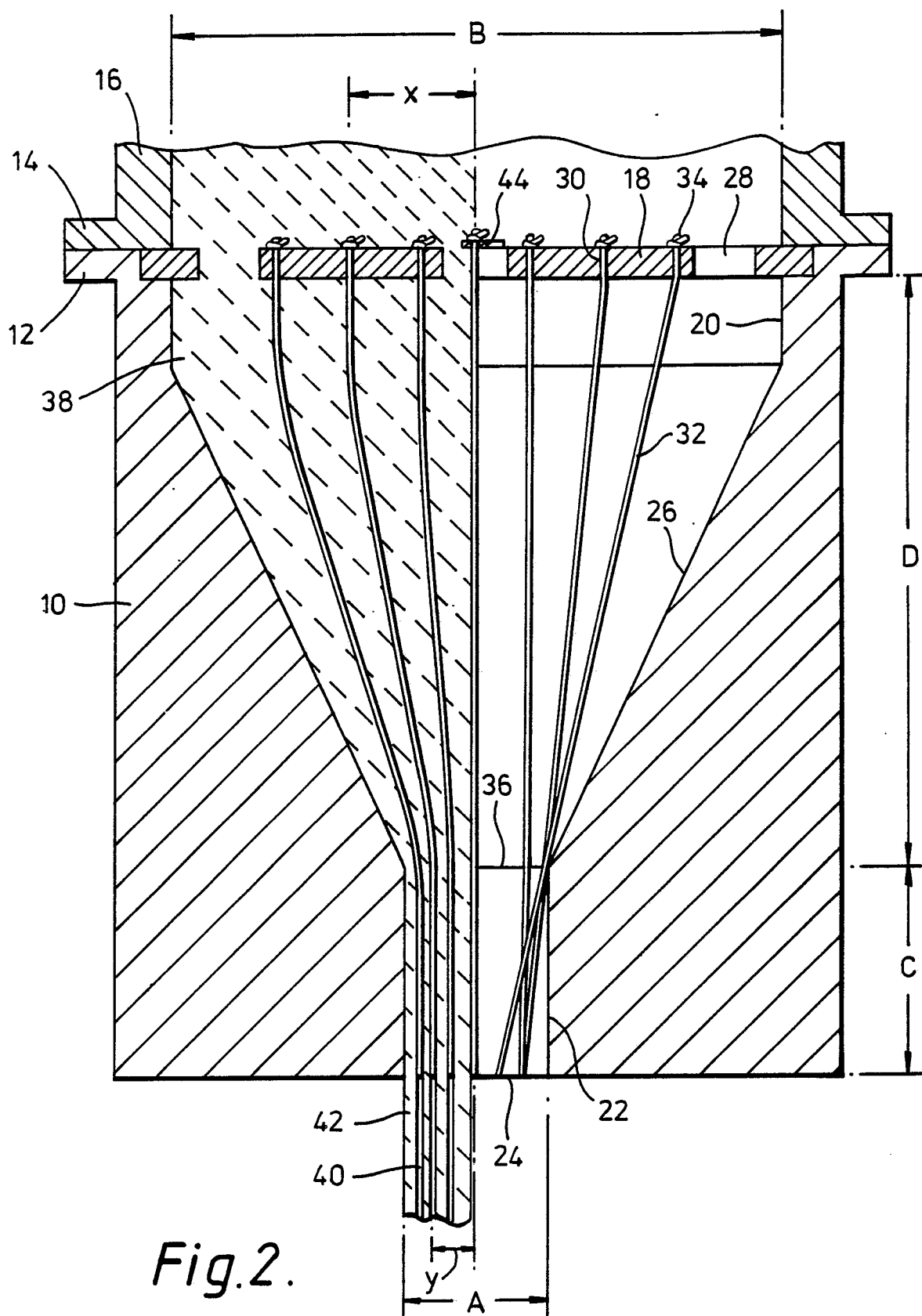
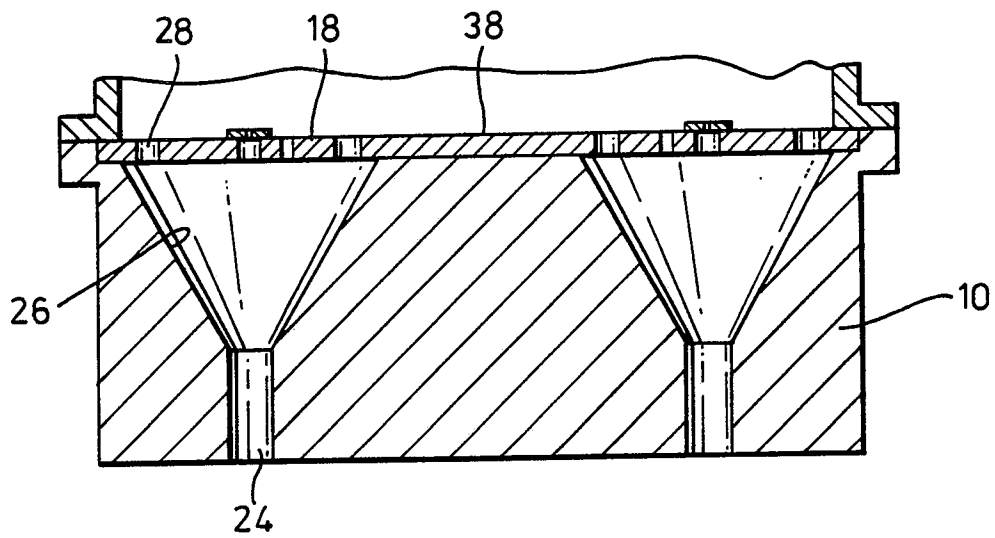
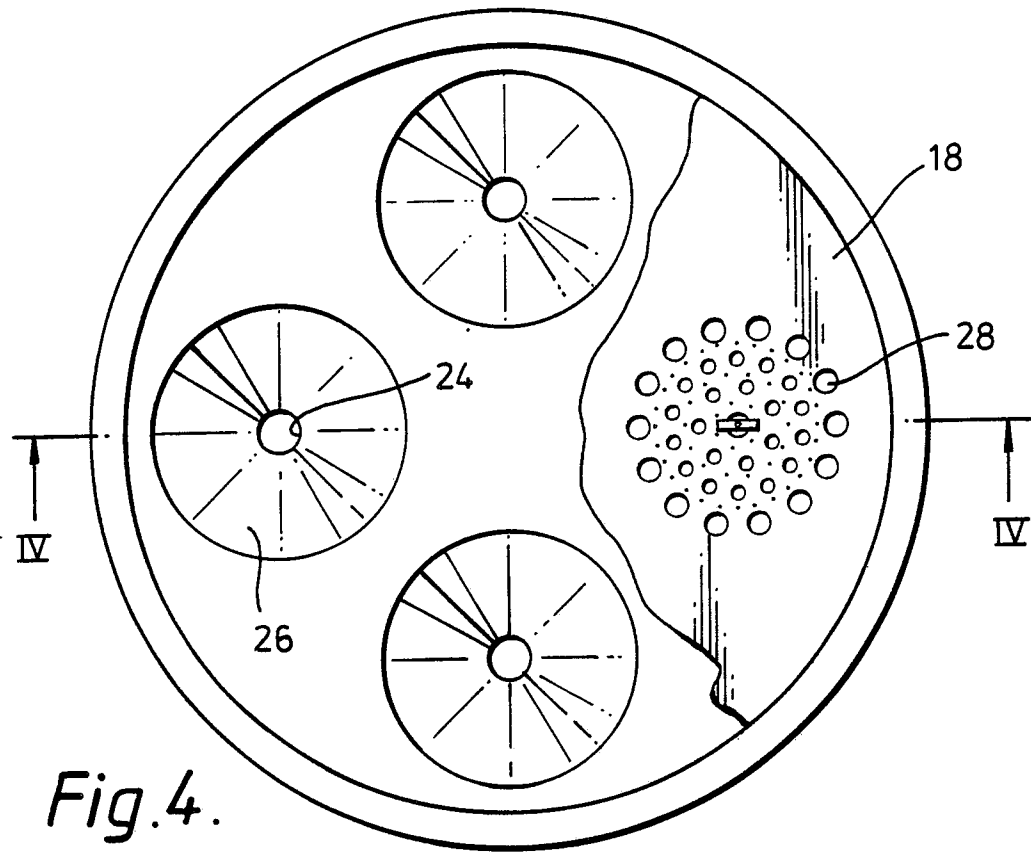
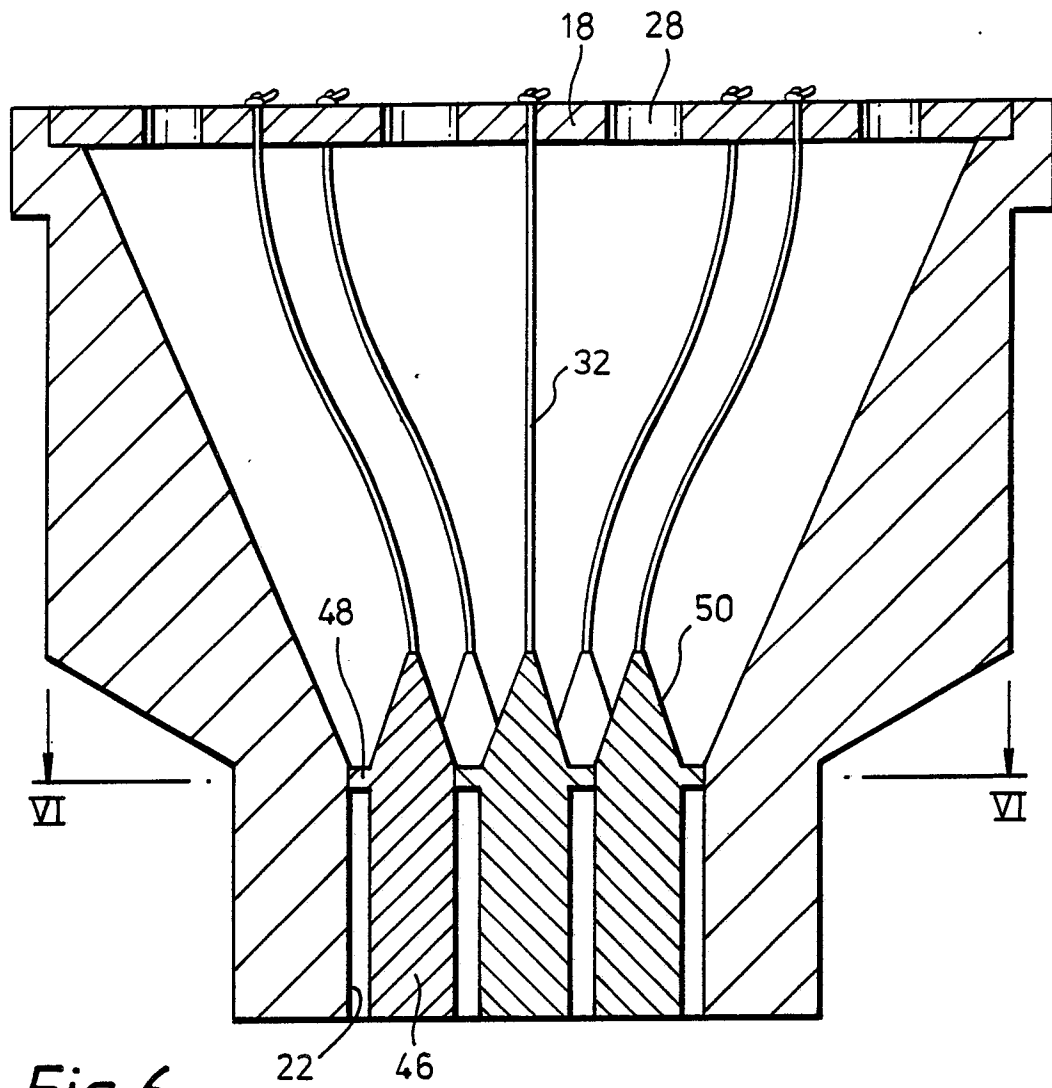
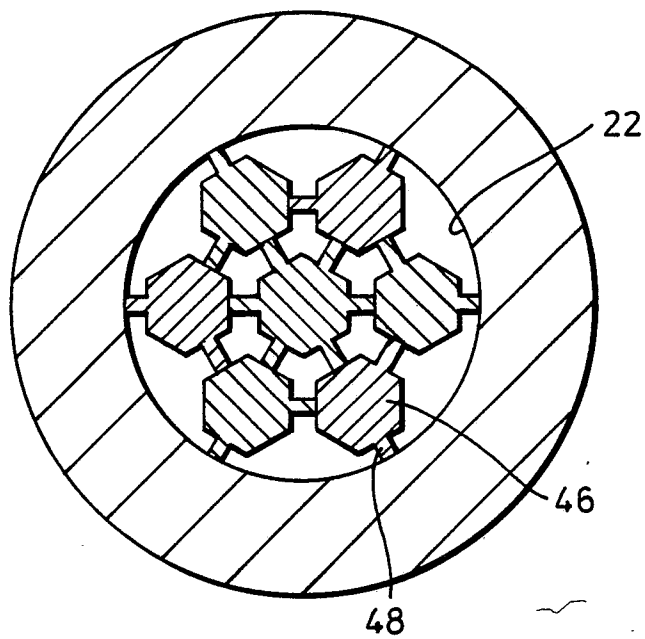


Fig. 3.





*Fig.6.**Fig.7.*



DOCUMENTS CONSIDERED TO BE RELEVANT			EP 87304404.4
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	DE - B - 1 069 052 (EISEN- UND HARTGUSSWERK) * Fig. 1,2 *	1,2,3,7	B 28 B 3/26

Y	GB - A - 1 207 952 (MINISTER) * Fig. 1 *	1,2,3,7	

A	DE - C - 588 556 (KORBACHER) * Fig. 1 *	1,10	

A	DE - C - 675 280 (KOIDL) * Fig. 2 *	1,10	

			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 28 B
			B 29 B
			B 29 C
			B 30 B
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 16-09-1987	Examiner GLAUNACH
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone		T : theory or principle underlying the invention	
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A : technological background		D : document cited in the application	
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P : intermediate document		& : member of the same patent family, corresponding document	