(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 538 846 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **92118049.3**

(51) Int. Cl.^{5}: **B21D 53/08**

(22) Date of filing: **22.10.92**

(30) Priority: **24.10.91 IT TO910802**

(43) Date of publication of application:
28.04.93 Bulletin 93/17

(84) Designated Contracting States:
DE ES FR GB IT SE

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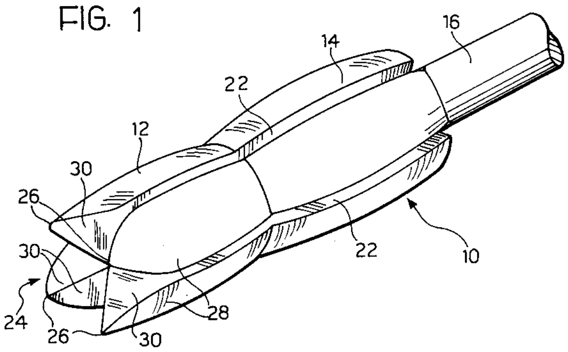
(54) A method for manufacturing a heat - exchange system.

(57) The process provides for the fixing of cooling fins to the tubes of a heat exchanger by tube expansion. Each tube has a plurality of internal ribs projecting from the inner wall of the tube to an extent greater than the thickness of the tube wall. The radial deformation of each tube is achieved by the exertion of a radial force on portions of the inner wall of the tube between two adjacent ribs by means of a tube-expander tool (10) inserted forcibly into the tube and having a plurality of grooves (22) for receiving respective ribs.

FIG. 1



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The present invention relates to processes for the manufacture of a heat-exchange system according to the introduction to Claim 1.

In heat-exchangers of the so-called 'mechanical expansion' type, the connection between the tubes and the external cooling fins which extent perpendicular to the tubes is achieved by tube expansion which creates a permanent radial deformation of each tube and an elastic deformation of the corresponding hole in the fin through which the tube passes without the need for further welding or adhesive processes. In the tube expansion of round tubes with smooth interiors, a suitable enlarging tool or mandrel of ogive shape plastically deforms the tube and elastically deforms the fins so as to create a firm mechanical contact between the two parts.

Tube expansion processes are known from the documents US-A4,706,355 and FR-A-2,647,375 which use a mandrel having a ridged surface which enables the radial expansion of the tube to be achieved simultaneously with scoring of the inner surface. The object of the scoring of the inner wall of the tube is to increase the heat-exchange efficiency by means of an increase in the surface contact between the tube and the fluid circulating therethrough.

The scored lines in the tubes formed during the tube expansion process have a very small radial dimension in relation to the thickness of the tube wall and can in no case reach a dimension close to the thickness of the tube wall. Because of the small dimensions of the scored lines such tubes may be used only in heat-exchangers traversed by fluids with a low dirt content, such as, for example, FREON, and they cannot be used in the presence of fluids containing anti-freeze additives of the type used in the radiators of cooling circuits of motor-vehicle engines nor with like fluids with a high dirt content. Indeed, given that anti-freeze fluids and the like tend to deposit crystals, the scored lines would become completely obstructed in time and the advantages resulting from the scoring of the inner surface of the tube would be annulled. Moreover, scored tubes are generally made from copper while aluminium (which is preferred for its lower cost) cannot be used because of its different mechanical characteristics and behaviour during the tube expansion process. Aluminium in fact tends to soil the tools used during the tube expansion process and make them stick rendering the process itself difficult.

A process for the manufacture of a heat-exchange system is known from FR-A-2,369,033 in which the tubes are fixed to the outer fins by tube expansion. FR-A-2,369,033 proposes the use of electro-welded tubes obtained by the rolling of a metal strip and the welding of its edges which are brought together. The welding process produces a longitudinal bead which projects both from the outer wall and from the inner wall of the tube. In order to expand tubes having an inner welding bead, FR-A-2,369,033 proposes the use of a tube expansion tool provided with a plurality of grooves, one of which is intended to receive the bead during the insertion of the tool into the tube. Use has also been proposed of a tube expansion tool which removes the welding bead during expansion of the tube.

The current tendency of heat-exchange manufacturers is to improve the heat-exchange efficiency by using tubes with oval or flattened sections which, for the same flow section, have larger heat-exchange surfaces than circular-section tubes.

It is known that tubes with internal longitudinal ribs can provide larger heat-exchange surfaces and create more turbulence in the fluid. However, up till now, the use of tubes with internal ribs has not been proposed for the manufacture of heat exchangers of the type with external fins in which the fins are attached to the tubes by mechanical expansion of the tubes.

The object of the present invention is to provide a process for the manufacture of a heat-exchange system which enables use to be made of tubes with internal ribs.

According to the invention, this object is achieved by virtue of a process having the characteristics defined in Claim 1.

In the process of the invention, tubes are used which have internal ribs with a thickness greater than the thickness of the tube wall, which increases the heat-exchange surface considerably. In view of the considerable dimensions of the internal ribs, these tubes may be operated with fluids with high dirt contents without loss of efficiency over time. Moreover, the tubes may be produced in aluminium, copper or any other material without compromising the tube expansion process. As regards the dynamics of the fluid flow, the tubes with internal ribs, in addition to increasing the heat-exchange surface noticeably, increase the speed and level of turbulence in the fluid traversing them, especially if the ribs extend helically relative to the tube axis. All this results in an overall increase in the efficiency of the heat-exchanger compared with that of an exchanger with internally smooth tubes of the same dimensions.

Further characteristics and advantages of the invention will become clear during the course of the detailed description which follows, given purely by a way of non-limiting example, with reference to the appended drawings, in which:

Fig. 1 is a perspective view of a tube expander tool utilised in the process of the invention,

Fig. 2 is an assembled view of a liquid/air heat-exchanger utilising the process of the invention,

Fig. 3 illustrates the process of tube expansion with the tool illustrated in Fig. 1,

Fig. 4 is a sectional view taken on the line IV-IV of Fig 3,

Fig. 5 is a section similar to Fig. 4 illustrating an alternative form of the ribs of the tubes,

Fig. 6 is a longitudinal section of a tube with helically extending internal ribs,

Fig. 7 is a section taken on the line VII-VII of Fig 6,

Fig. 8 is a side view illustrating a component used in the process of the invention, particularly suitable for the tube expansion of a tube according to Figures 6 and 7,

Fig. 9 is a schematic transverse section illustrating the tube expansion of a tube with the use of the tool of Fig. 1, and

Fig. 10 is a schematic transverse section illustrating the use of a tool expansion tube of alternative shape.

With reference to Fig. 1, a tube expander tool is generally indicated 10 and has a first end portion 12 of barrel shape and a second portion 14 also of barrel shape and having a maximum diameter greater than the maximum diameter of the first portion 12. The second portion 14 is connected to a movable shaft 16 operated in known manner by an actuator unit operable to drive its longitudinal translational movement.

As seen in Figures 3 and 4, the tool 10 is used to expand a tube 18 having a plurality of internal ribs 20. The ribs 20 are formed integrally with the outer wall of the tube during an extrusion process. Tests carried out by the Applicant have established that a significant increase in the heat-exchange efficiency is achieved with a number of ribs equal to or greater than 2 and with a radial thickness of the ribs (indicated H in Fig. 4) equal to or greater than 10% of the outer diameter of the tube (indicated D in Fig. 4). The tubes with internal radial ribs used in the process of the invention differ substantially from the tubes with internally scored surfaces in that the radial thickness H of the ribs 20 is greater than the thickness S of the tube wall. Moreover, the ratio between the transverse surface occupied by each rib and the inner surface of the tube if considered smooth is equal to or greater than 2%.

The tube expander tool 10 has the same number of longitudinal grooves 22 in its outer surface as the number of internal ribs 20 of the tube 18. The grooves 22 are spaced angularly from each other like the internal ribs 20 and have a width and a depth greater than the height and the width of the ribs 20 (Fig. 4).

The first portion 12 of the tool 10 has a shaped end 24 (Fig. 1) with four triangular cusps 26 each defining an outer surface 28 and two inner surfaces 30 connected to the grooves 22 to enable the self-centring of the tube 18 relative to the tool 10 without the need for pre-centring of the tool and the tube.

In Fig. 2 a heat-exchange system is indicated at 32 and is constituted by a pack of metal cooling fins 34 extending perpendicular to the axes of the tubes 18. The tubes 18 are inserted with clearance within respective series of aligned holes in the fins before the final assembly effected by means of the expansion of the tubes.

Fig. 3 illustrates the tube expansion phase of a tube 18 against collars 35 of the fins 34. In Fig. 3, the enlarging tool 10 is illustrated in broken outline and the function of the portion 12, adapted to effect a preliminary deformation of the tube 18, and of the portion 14, adapted to follow the initial deformation, is clear and is such as to ensure interference between the collars 35 of the fins 34 and the tube 18 of the order of a tenth of a millimetre. It is possible to use an enlarging tool of a type different from that illustrated in the drawings, for example without the division into two portions (in essence, the enlarging tool may be constituted solely by the end portion 12 of a diameter suitably enlarged, connected directly to the movable shaft 16).

In the variant illustrated in Fig. 5, the fins 20 have a dimension which varies radially from a minimum value L_1 to a maximum value L_2. The ribs 20 have a smaller width close to the inner wall of the tube 18. The grooves 22 of the tube expander tool 10 have an undercut profile with a minimum width in correspondence with the outer surface of the tool. This solution enables the width of the zones in which there is no contact between the expander tool 10 and the inner wall of the tube 18 to be reduced so as to enable a more regular profile to be achieved on the tube at the end of the tube expansion operation.

Fig. 9 illustrates schematically the deformation of a tube as a result of tube expansion carried out with a tool 10 whose outer surfaces have a radius of curvature R of several tenths of a millimetre more than the radius of the inner wall of the tube 18. The outer surface of the tube 18 is deformed to a lesser extent in correspondence with the zones in which the ribs 20 are located. Consequently, zones 36 may be formed in which the contact between the outer wall of the tube 18 and the collar 35 of the fin 34 is less firm.

The solution which has been described with reference to Fig. 5 tends to limit this problem by reducing the zones in which there is no contact between the expansion tool and the inner wall of the tube 18.

Fig. 10 illustrates a solution which tends to overcome this same problem by causing a differential plastic deformation of the tube. In this case, the surfaces of the expander tool 10 between two adjacent grooves 22 have a radius of curvature R_1 less than the radius of the inner wall of the tube 18. The curved portions of radius R_1 are connected to flat surfaces spaced from the axis of the tool by a distance slightly greater than the radius R of the inner wall of the tube 18. The grooves 22 open into the surfaces which join two adjacent curved portions.

The expander tool illustrated in Fig. 10 causes plastic deformation of the tube to a maximum extent along the radial directions intermediate the ribs 20 and to a minimum extent along the radial directions in correspondence with the ribs 20. Consequently, the deformed tube assumes a generally polygonal configuration with the same number of sides as the number of ribs 20. This type of expansion causes the collar 35 of the fin 34 to deform elastically in such a manner that, in the zones of maximum expansion, the tube 18 is brought against the collar and, by reaction, in the zones of minimum expansion the collar is brought against the tube 18.

Figures 6 and 7 illustrate a tube provided with helical internal ribs 20. In order to expand these tubes, the tool illustrated schematically in Fig. 8 is used, this tool providing thrust bearings 38 between the movable drive shafts 16 of the expander tools 10 and a pressurised fluid actuator 37 in order to allow the tools 10 to rotate within the respective tubes 18 during the tube expansion process. The rotation of the tools 10 is caused by the contact of the ribs 20 with the side walls of the grooves 22.

As illustrated in Figures 11 and 12, the expansion process of the invention also provides for the use of flared tools 40 also provided with longitudinal grooves 42 of a shape and dimensions corresponding to those of the ribs 20 of the tubes 18. The flared tools 40 are inserted in the ends of the tubes 18 so as to provide a firm mechanical connection between the tubes 18 and the manifold plate 44 with the interposition of a seal 46 of elastomeric material.

Claims

1. A process for the manufacture of a heat-exchange system comprising a plurality of tubes (18) with parallel axes fixed to a pack of fins (34) which are superposed in the direction of the axes of the tubes (18), in which each tube (18) is inserted with clearance within a series of aligned holes formed in the fins (34) and is deformed plastically in a radial sense by the forced insertion of a tube-expander tool (10), characterised in that each tube (18) has a plurality of internal ribs (20) which, in a section on a plane perpendicular to the axis of the tube (18) project from the inner wall of the tube (18), by a distance (H) greater than the thickness (S) of the wall of the tube (18), and in that the radial deformation of each tube (18) is achieved by the exertion of a radial force on portions of the inner wall of the tube (18) between adjacent ribs (20) by means of a tube-expander tool (10) having a plurality of grooves (22) for receiving the respective ribs (20).

2. A process according to Claim 1, characterised in that the inner ribs (20) of each tube (18) extend helically along the axis of the tube (18) and in that the said tube-expander tool (10) can be rotated about the axis of the tube (18) during its insertion into the tube, the rotation of the tube-expander tool (10) being caused by its contact with the helical ribs (20).

3. A process according to Claim 1, characterised in that, between two adjacent grooves (22), the mandrel (10) has a curved connecting portion having a radius of curvature (R_1) less than the radius of the inner wall of the tube (18) in its undeformed condition.

4. A process according to Claim 1, characterised in that the ribs (22) have a width which varies radially, with the smallest width (L_1) close to the inner wall of the tube (18), the grooves (22) in the tube-expander tool (10) having an undercut profile with a minimum width in correspondence with the outer surface of the tool (10).

5. A process according to Claim 1, characterised in that it includes the operation of fixing the end of each tube (18) within a respective hole formed in a manifold plate (44) by the enlargement of the end of the tube (18) by a flared tool with longitudinal grooves (42) for receiving respective ribs (20).

FIG. 1

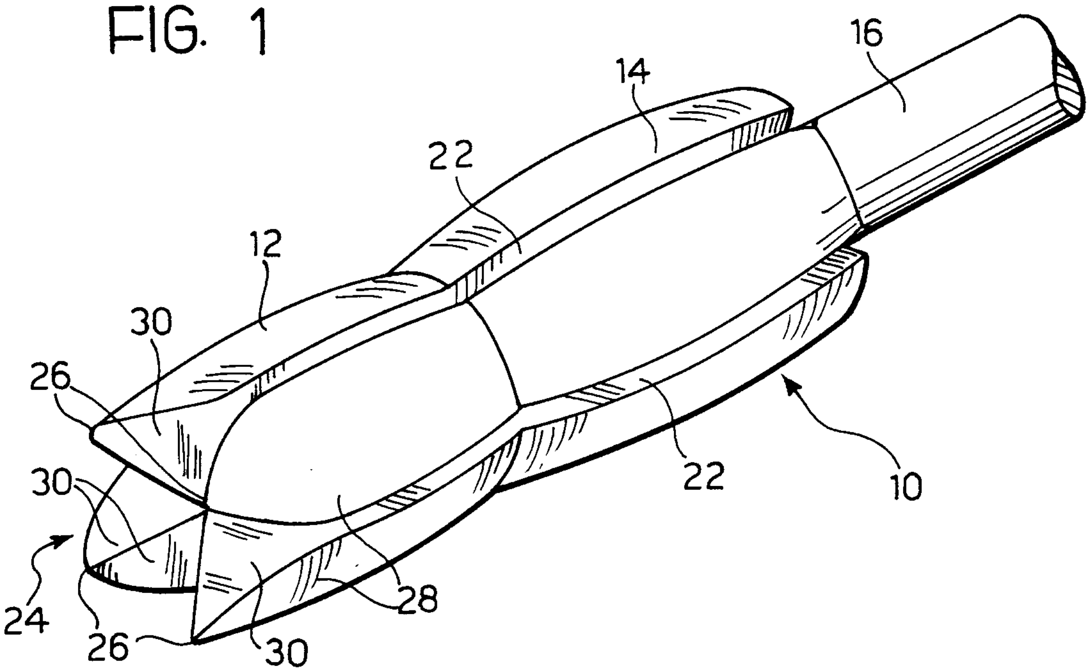


FIG. 2

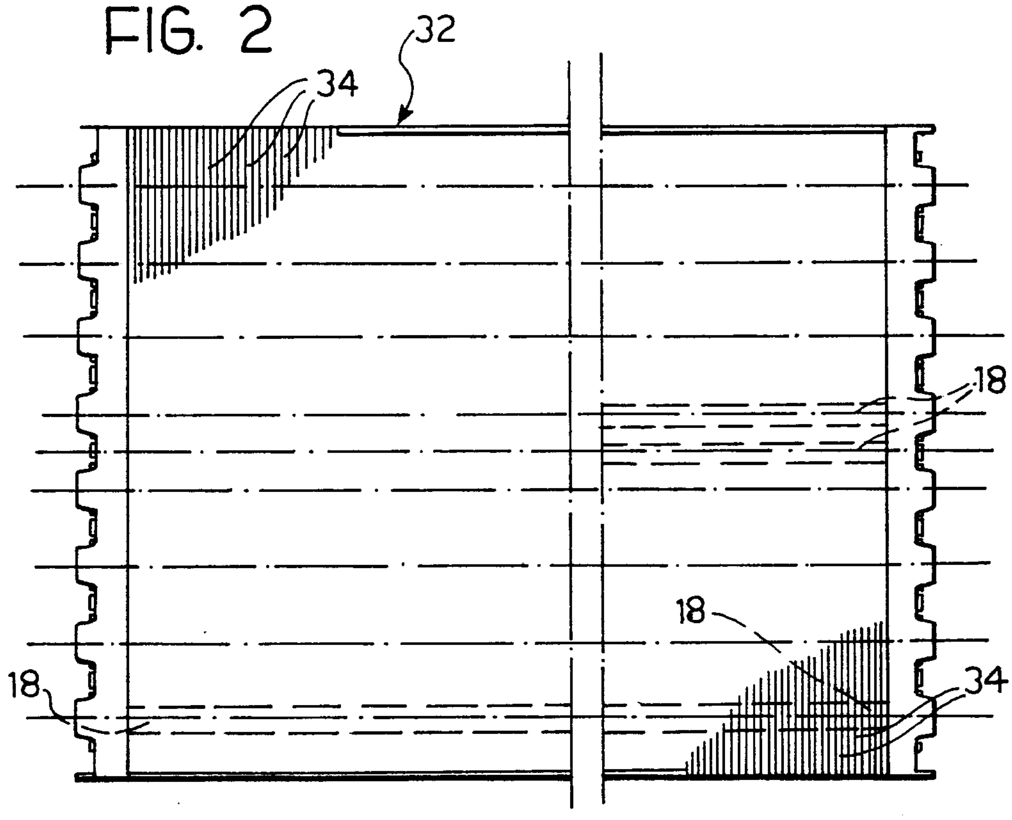


FIG. 3

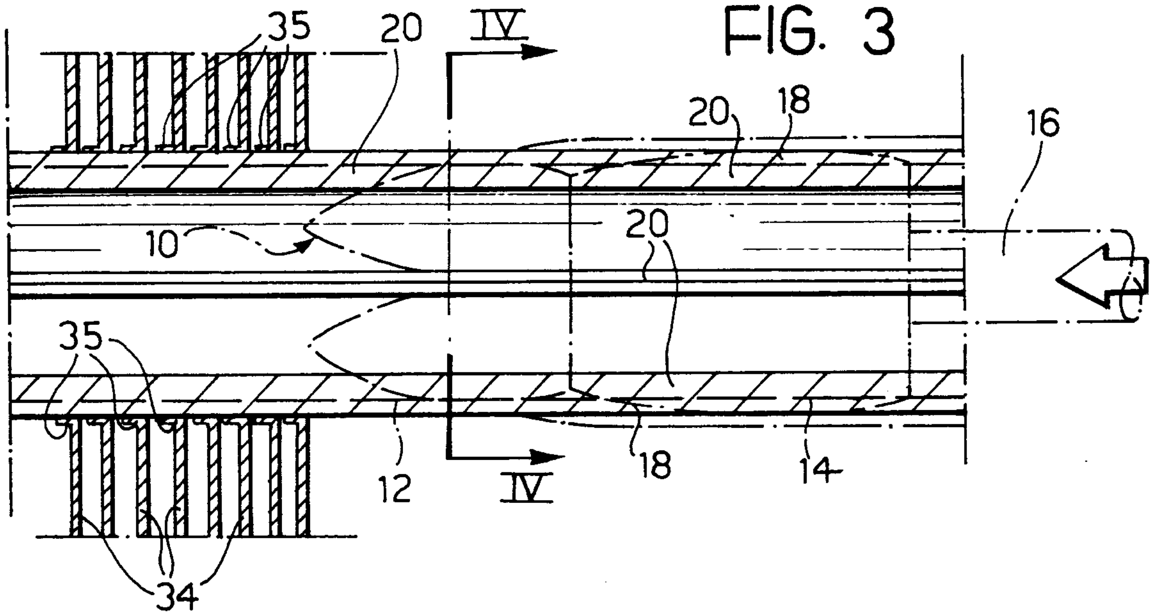


FIG. 4

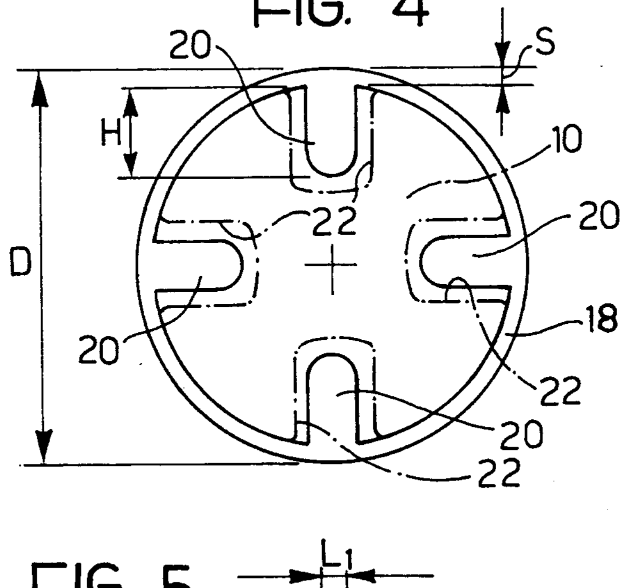


FIG. 5

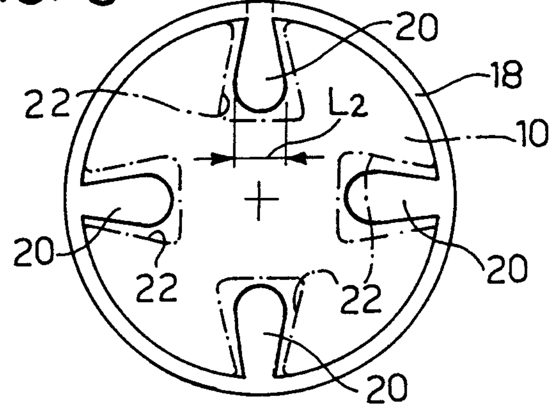


FIG. 6

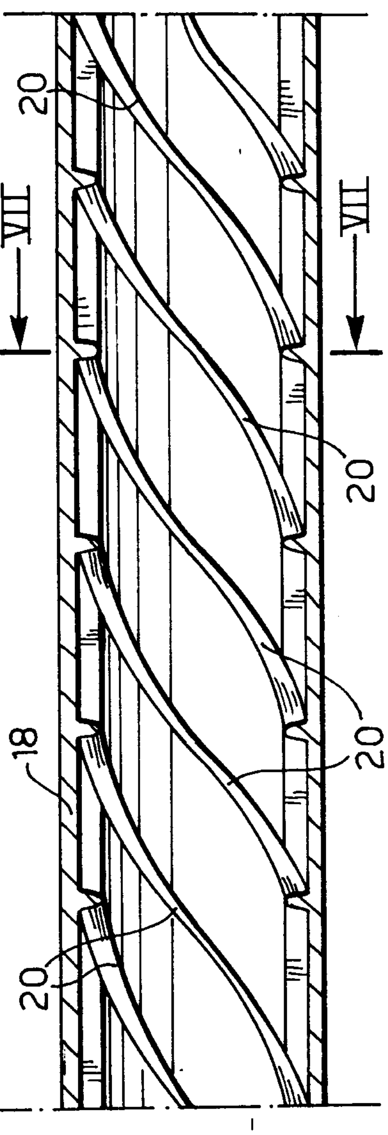


FIG. 7

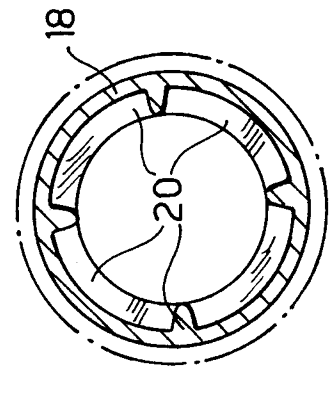


FIG. 8

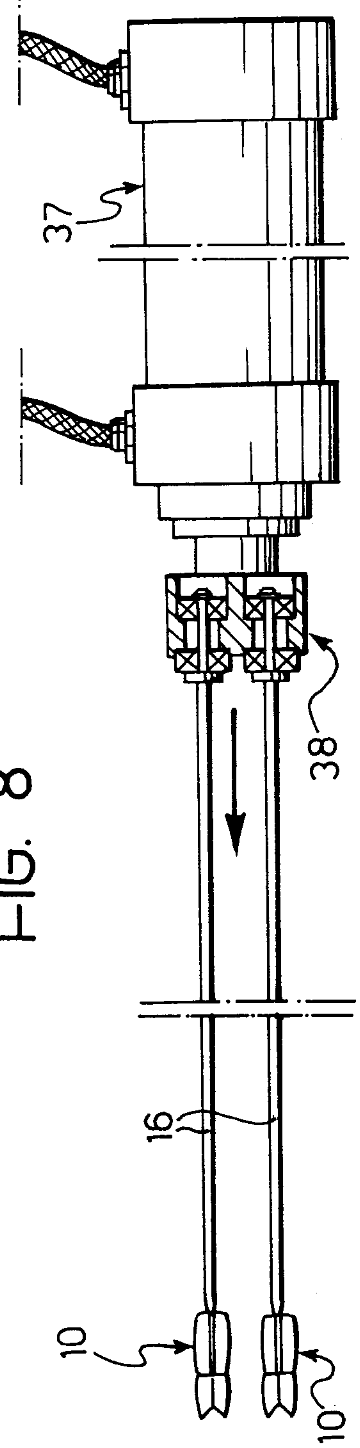


FIG. 9

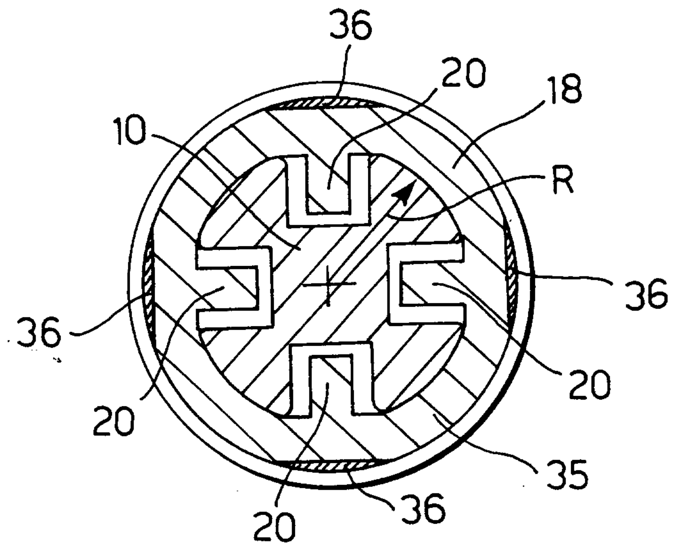

36
20
18
10
R
36
36
20
20
35
20
36

FIG. 10

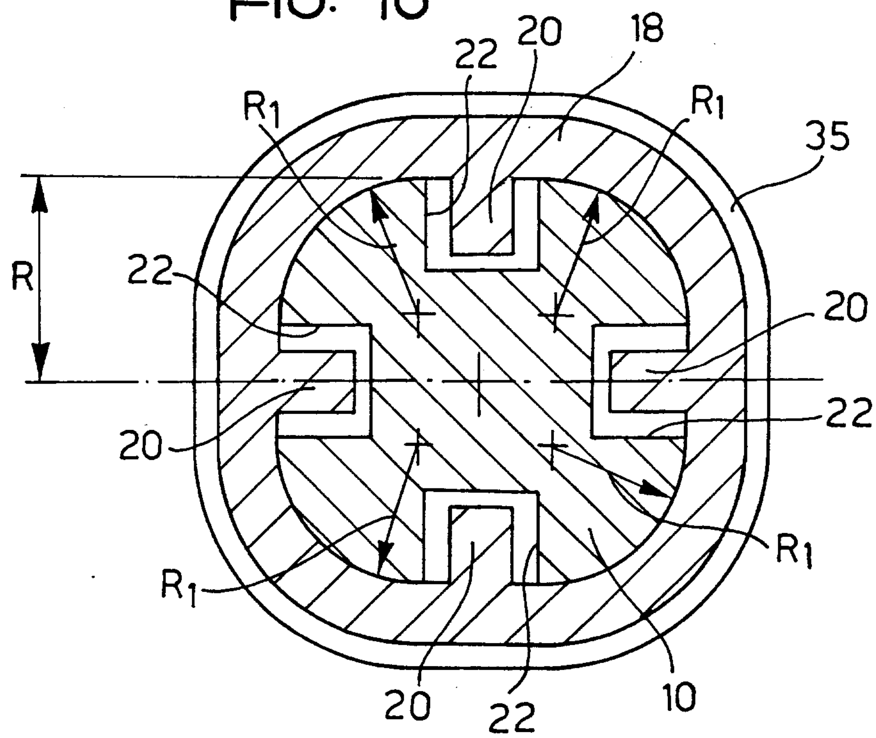

22
20
18
R_1
R_1
35
R
22
20
20
22
20
R_1
R_1
20
22
10

FIG. 12

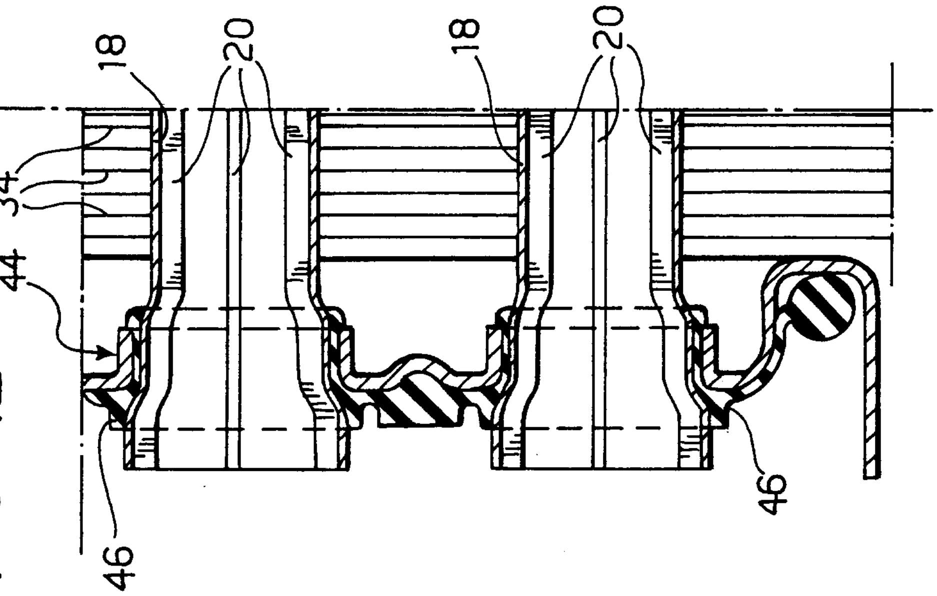
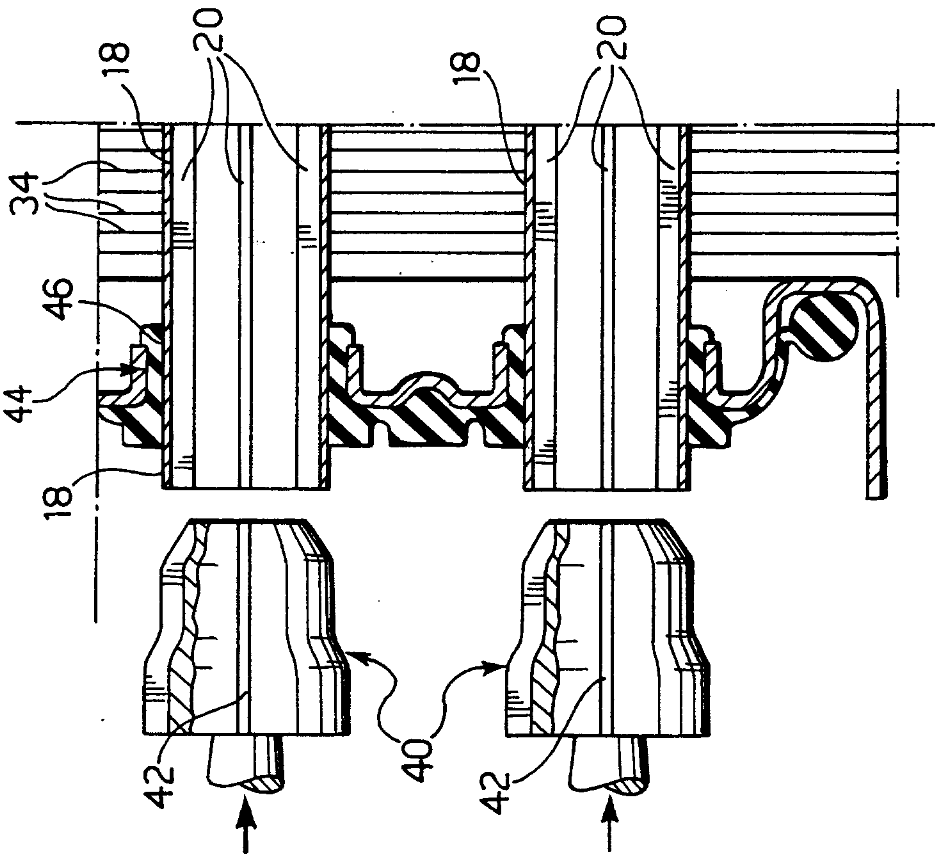


FIG. 11



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EUROPEAN SEARCH REPORT

Application Number

EP 92 11 8049

Category	DOCUMENTS CONSIDERED TO BE RELEVANT Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,A	FR-A-2 647 375 (ITALCOIL S.P.A.) * the whole document * ---	1	B21D53/08
D,A	FR-A-2 369 033 (S.A. DES USINES CHAUSSON) * page 6, line 9 - page 6, line 19; figures 1,7,8 * ---	1	
D,A	US-A-4 706 355 (KUHNS) * claims; figures 1-7 * ---	1	
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 299 (M-524)(2355) 11 October 1986 & JP-A-61 111 732 (HITACHI CABLE LTD) 29 May 1986 * abstract * -----	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B21D
B21C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 JANUARY 1993	PEETERS L.

CATEGORY OF CITED DOCUMENTS

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