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(54) **METHOD OF MANUFACTURING HAIRPIN CONFIGURED TUBES.**

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DE-A-2 952 736
DE-C-816 688
FR-A-733 037
FR-A-1 086 881
GB-A-2 055 064
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Description

Field of the invention

The present invention relates to a method of manufacturing metallic tubes having two parallel leg portions of oval cross-section, which are connected together by a U-shaped bent portion integrally formed with said tube.

This invention relates more particularly to a method of manufacturing metallic hairpin tubes provided with secondary heat exchanger elements or fins fixed to the tubes normally by brazing/soldering, crimping, expansion or gluing.

Background of the invention

The large number of connections between the tubes of a heat exchanger core and the terminating end plates of fluid tanks (headers) and/or U-shaped bends represent the main manufacturing and operating problems for these heat exchangers. The mechanical strength of the soldered or brazed connections between the tubes and the end plates is poor. These connections are vulnerable to damages causing leaks as a result of mechanical vibrations and due to changes in pressure and temperature to which these parts are subjected.

The tube end plate connections, realized by means of resilient joints where the tubes are expanded into a direct, tight engagement with the end plates, are known from prior art. This expansion operation is not an easy task in mass production manufacturing and therefore tubes commonly used in heat exchangers with this type of connection have a circular cross-section which facilitates the assembly of the tube ends, e.g. with U-shaped bends, as disclosed in DE-A-2 952 736.

Use of tubes with oblong or flat oval cross-section in order to improve the heat exchanging efficiency (performance) by increasing their surface area without increasing the aerodynamic resistance and/or size of the heat exchangers, is also known. The drawback of the heat exchangers provided with oval tubes is the necessity to conform the ends of the oval tubes to a circular cross-section of the connecting U-shaped bends or openings in the end plates. The conformation of the tube ends is an additional operation in assembling of the heat exchangers, which requires narrow dimensional tolerances in order to achieve satisfactorily tight connection between the tubes and the apertures in the perforated end plates. GB-A-2.055.064 and 2.056.330 disclose one of the known methods of conforming the end of an oblong metallic tube to a circular cross-section.

The FR-A-1 086 881 discloses a process of altering tubes with circular cross-section into tubes with an oval cross-section before bending. But there, the problems related to bending flat oval, especially thin-walled metallic tubes, namely a reduction of the cross-section area of the bends and formation of wrinkles on the inner tube walls are not overcome. Both phenomena have an adverse effect on the flow pattern of the circulating fluidum-increase of pressure drop in the heat exchanging systems and erosion of the bent tube parts.

Object of the invention

It is therefore an object of the present invention to provide a simple and low cost method of manufacturing oblong hairpin tubes where the above stated problems connected to the bending operation of oval tubes are avoided, where the heat rejection performance is better and where the tubing is easy.

The object of the present ivention will become apparent upon reading the following specification with accompanying drawings and patent claims.

Summary of the invention

The object of the present invention is accomplished by providing a tubular member of substantially circular cross-section, bending said tubular member to a U-shaped hairpin tube including two parallel leg portions, exposing the leg portions to a radial deformation resulting in an oblong cross-section of the entire length or parts of the leg portions.

The present invention proposes to bend a circular tube and then to deform only the leg portions to an oblong cross-section. This oval configuration is advantageous with relation to the direction of flow of the exterior heat exchange fluid providing an increased heat exchanger surface.

The bent portion has a circular cross-section resulting in an improved heat exchanging efficiency at a minimal pressure drop.

According to the inventive process, the largest diameter of the leg portions always is substantially coplanar with the main stream of the outer heat exchanging medium regardless connection pattern of the tubes applied in a heat exchanger core.

Description of the drawings

Embodiments of the invention are shown by way of nonrestrictive examples in the accompanying drawings, Fig. 1 - 10, where

Fig. 1 is a plan view of a hairpin configured tube.

Fig. 2 is a sectional view of the hairpin tube taken along line I-I of Fig. 1.

Fig. 3 is another sectional view taken on line II-II of Fig. 1.

Fig. 4 is a sectional view of a tool for accomplishing the step of radial deformation according to the present invention.

Fig. 5 is a sectional view of the tool from Fig. 4 after performance of the deformation step.

Fig. 6 is a planar view of the hairpin tube in a die after accomplished deformation step.

Fig. 7 illustrates the step of conforming of a predeterminated part of an oblong tube to a circular cross-section in a modified method of manufacturing the hairpin tubes.

Fig. 8 is a sectional view of a tool for accomplishing the conforming operation taken on line I-I of Fig. 7.

Figs. 9 and 10 represent modifications in the manner of configuration of the leg portions of the hairpin tubes with regard to the U-bend portion.

Referring to Figs. 1-3, it has been established that it is possible to obtain a hairpin configured tube (1) retaining the body of the oblong cross-section and to accomplish a bending operation without encountering the above mentioned difficulties/drawbacks known from the prior art. The new one-piece hairpin tube (1) provided according to the present invention comprises two parallel leg portions (2,2') of the oblong cross-section connected together by an U-shaped bend portion (3) having a substantially circular cross-section - see Fig. 2.

The new and unique configuration of the hairpin tubes is thus provided based upon a new inventive approach to solve the problem connected to bending thin-walled oblong tubes.

It has been empirically established that a certain relation between the wall thickness, the central distance of the leg portions (bend-radius) and the largest diameter of the oblong tubes must be respected in order to avoid surface defects on the tube walls during the bending operation. An empirically derived factor $f = \frac{Dm^2}{c \cdot d}$, where

Dm = largest diameter of the tube,

c = central distance between the leg portions and

d = wall thickness

should be < 10 to ensure smooth quality tubes. At f in a range from 11-14 problems can arise and at f > 14 the problems with formation of wrinkles are unavoidable.

Example

A typical A1-tube to be used in a motor vehicle radiator or heater core will have a wall thickness of 0.4 mm, central tube distance 22.0 mm and largest diameter of the oblong cross-section 13.0 mm (short diameter 6.0 mm)

The empiric factor in this case is: $f = \frac{13^2}{22 \cdot 0,4} =$ 19.2 so that the bending operation of such tubes in order to achieve the above central distance between the leg portions of the hairpin tube cannot be conducted without adverse effects on the U-bend surface quality.

According to the present invention the tubes are subjected to a bending operation while retaining a substantially circular cross-section over the deformed part of the tubes. In a preferred embodiment or the invention a circular tube with a diameter of 10 mm is provided and then by means of commercially available apparatuses, e.g. hydraulically powered tube benders, a bend of 180° is formed as the first step in the manufacture of oblong hairpin tubes.

Figs. 4 and 5 show schematically the subsequent step of radial deformation of the just provided hairpin tube from the circular cross-section to an oblong/elliptical cross-section along the parallel leg portions of the tube. The hairpin tube of circular cross-section (1) is inserted between the open jaws (51, 52) of a pressure die (5) so that a predetermined part or the whole leg portions (2, 2') of the hairpin tube being conformed to an oblong cross-section having diameters of 13.0 and 5.7 mm respectively, see Fig. 5, showing a sectional view of the pressure die from Fig. 4 after performance of the deformation step.

The hairpin tube provided in the above example exhibits no surface irregularities in the U-bend portion (3) and transition curves of intermediate portions of the tube between the oblong parts and the circular U-bend being smooth without sharp edges. Furthermore, the circular cross-section of the U-bend portion is larger than the cross-section of the leg portions so that the result is a hairpin tube of substantially oblong cross-section body ensuring improved heat exchanging efficiency at a minimal pressure drop in the heat exchanger.

Fig. 6 illustrates in planar view the hairpin tube in the pressure die (5) comprising an U-bend portion (3) of the substantially circular cross-section outside the pressure die and the leg portions (2, 2') of the oblong cross-section having free ends (21, 21') retaining the original, circular cross-section. This configuration of the hairpin tube offers a special advantage allowing direct connection to a terminating plate of headers provided with circular apertures.

Other types of conforming apparatus than the pressure die shown and described in connection with the above example can be used for the conforming operations, e.g. drawing dies. The apparent advantage of the described pressure forming operation is that it ensures by simple means a controlled fixation of the desired angle between the leg portions (2, 2') and the U-bend (3) of the hairpin tubes. Figs. 3, 9 and 10 represent the most usual patterns of the hairpin tube configuration with regard to the assembling of the heat exchanger cores - so-called parallel, staggered parallel or series connection, respectively.

An alternative manufacturing method to the one described with reference to the above example is illustrated in Figs. 7 and 8. A tube (11)

of the required oblong cross-section and dimensions is provided by extrusion, extrusion followed by a drawing operation or by welding. The thus provided tube (11) is then subjected to a local radial deformation over a predeterminated part (3') of the tube. The cross-section of this part (3') being conformed to a circular shape in a pressure die (5) - see Fig. 8 showing the die (5) in a vertical sectional view taken along line I-I of Fig. 7, facilitates the subsequent bending operation conducted by means of adapted commercial benders. The bending operation in this case is a final step in the manufacture of oblong hairpin configurated tubes.

The cross-section of the U-bend parts (3) can also exhibit other shapes deviating from the circular one shown in the drawings without departing from the scope of the present invention. Even if the circular cross-section offers advantages such as direct use of commercially available benders without any need for adaptation of the apparatuses or special accessories (mandrels), tubes with other cross-sectional shapes in the bending area can be used. It is, however, important that such cross-sectional shapes comply with the requirements to a cross-section of the U-bend being larger than or equal to a cross-section of the leg portions, and furthermore that the relation between the wall thickness, the bend radius and the largest diameter of the tube according to the above empiric formula ensures avoidance of surface defects on the tube wall.

Claims

1. Method of manufacturing metallic tubes having two parallel leg portions of oval cross-section, which are connected together by a U-shaped bent portion integrally formed with said tube, characterized by providing a tubular member of substantially circular cross-section, bending said tubular member to a U-shaped hairpin tube including two parallel leg portions, exposing the leg portions to a radial deformation resulting in an oblong cross-section of the entire length or parts of the leg portions, where the substantially circular cross-section of the U-shaped bent portion is larger than or equal to the cross-section of the parallel leg portions.

2. Method according to claim 1, characterized in that the radial deformation is carried out with respect to only part of the leg portions, resulting in free ends (21, 21') having circular cross-sections.

3. Method according to claim 2, characterized in that the radial deformation of said leg portions is carried out as a cold pressure forming operation in a die.

Patentansprüche

1. Verfahren zur Herstellung von Metallrohren mit zwei parallelen Schenkelteilen ovalen Querschnittes, die miteinander durch einen U-förmig gebogenen Teil verbunden sind, der in einem Stück mit dem Rohr ausgebildet ist, dadurch gekennzeichnet, daß von einem rohrförmigen Element mit im wesentlichen kreisförmigen Querschnitt ausgegangen wird, das rohrförmige Element in ein U-förmiges haarnadelförmiges Rohr mit zwei parallelen Schenkelteilen gebogen wird, die Schenkelteile einer radialen Verformung unterworfen werden, die zu einem länglichen Querschnitt der gesamten Länge oder von Teilen der Schenkelteile führt, wobei der im wesentlichen kreisförmige Querschnitt des U-förmig gebogenen Teils größer als der oder gleich dem Querschnitt der parallelen Schenkelteile ist.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die radiale Verformung nur bezüglich eines Teils der Schenkelteile durchgeführt wird, was zu freien Enden (21, 21') mit kreisförmigen Querschnitten führt.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die radiale Verformung der Schenkelteile als Kaltpressformen in einem Preßwerkzeug durchgeführt wird.

Revendications

1. Procédé de fabrication de tubes métalliques ayant deux parties parallèles ou branches de section ovale, raccordées l'une à l'autre par une partie coudée en U réalisée sous forme solidaire du tube, caractérisé par la disposition d'un organe tubulaire de section sensiblement tubulaire, le cintrage de l'organe tubulaire afin qu'il forme un tube en épingle à cheveux en U comprenant deux parties parallèles de branches, et l'exposition des parties de branches à une déformation radiale donnant une section oblongue à toute la longueur ou à des parties de la longueur des parties de branches, la section sensiblement circulaire de la partie coudée en U étant supérieure ou égale à la section des parties parallèles des branches.

2. Procédé selon la revendication 1, caractérisé en ce que la déformation radiale est réalisée uniquement dans une portion des parties de branches, si bien que les extrémités libres (21, 21') ont une section circulaire.

3. Procédé selon la revendication 2, caractérisé en ce que la déformation radiale des parties de branches est réalisée dans une opération de mise en forme par compression à froid dans un moule.

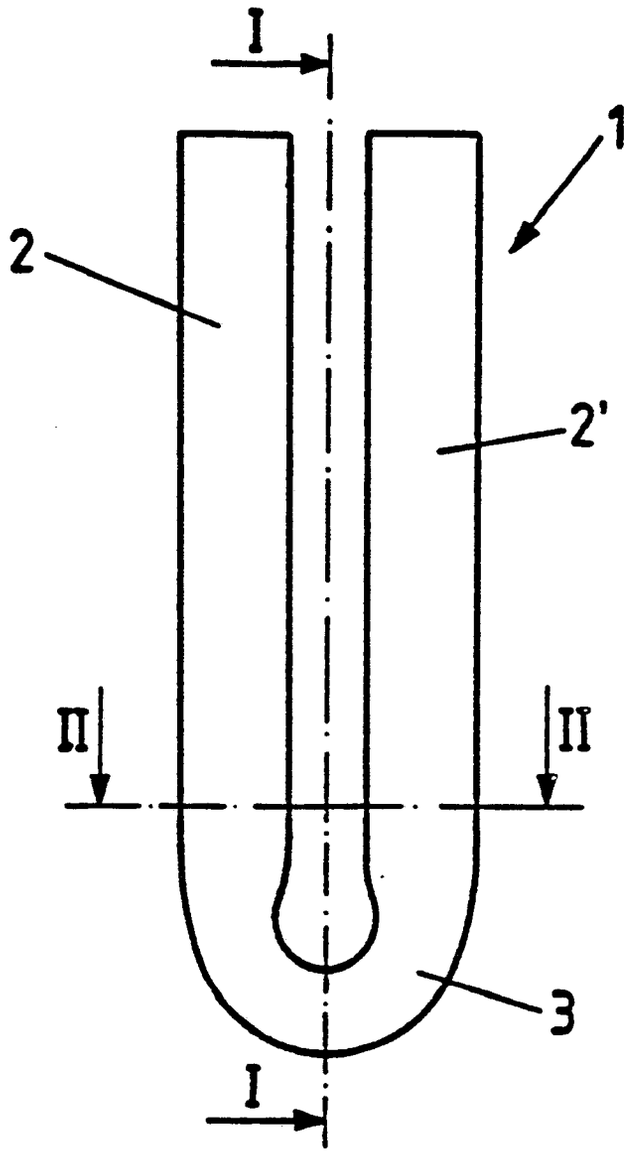


FIG. 1

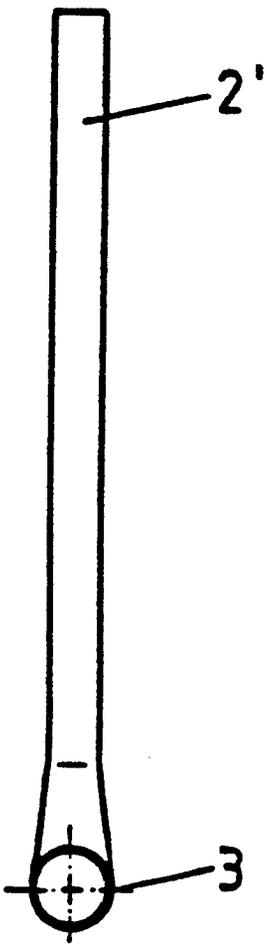


FIG. 2

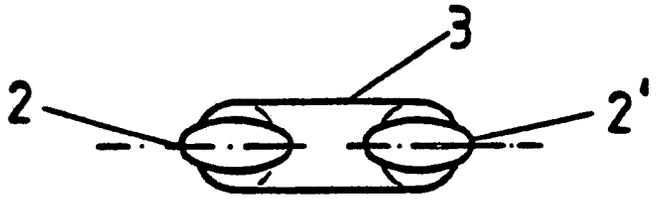


FIG. 3

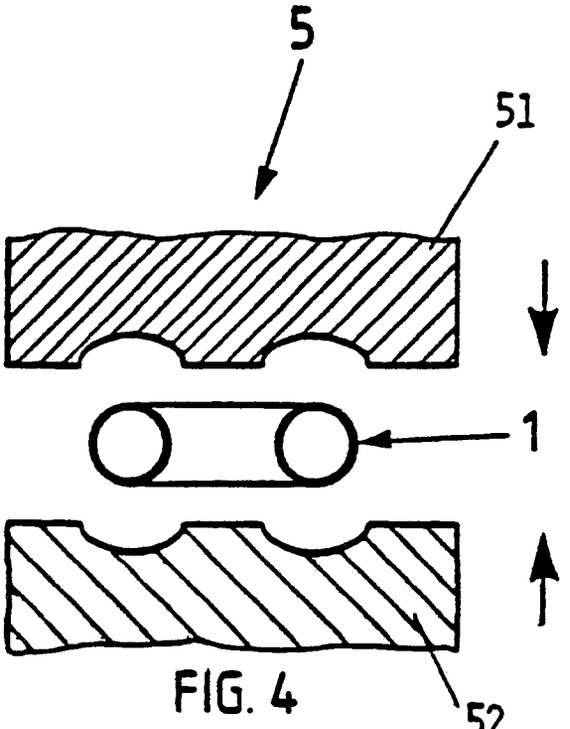


FIG. 4

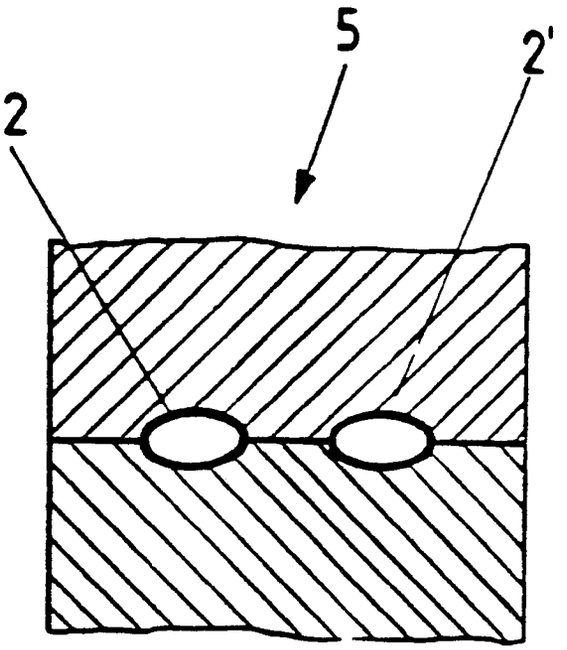


FIG. 5

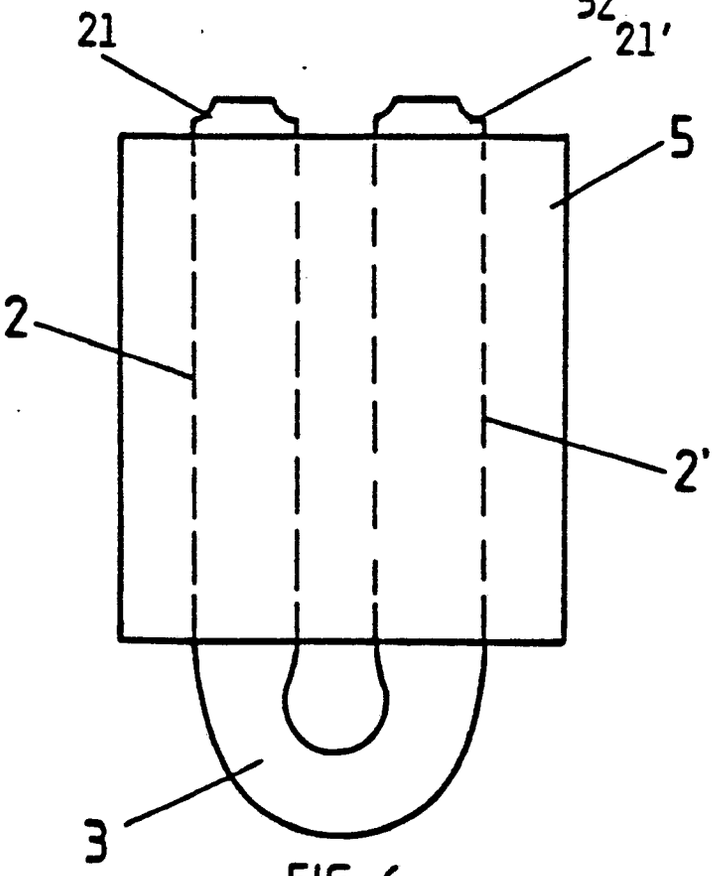


FIG. 6

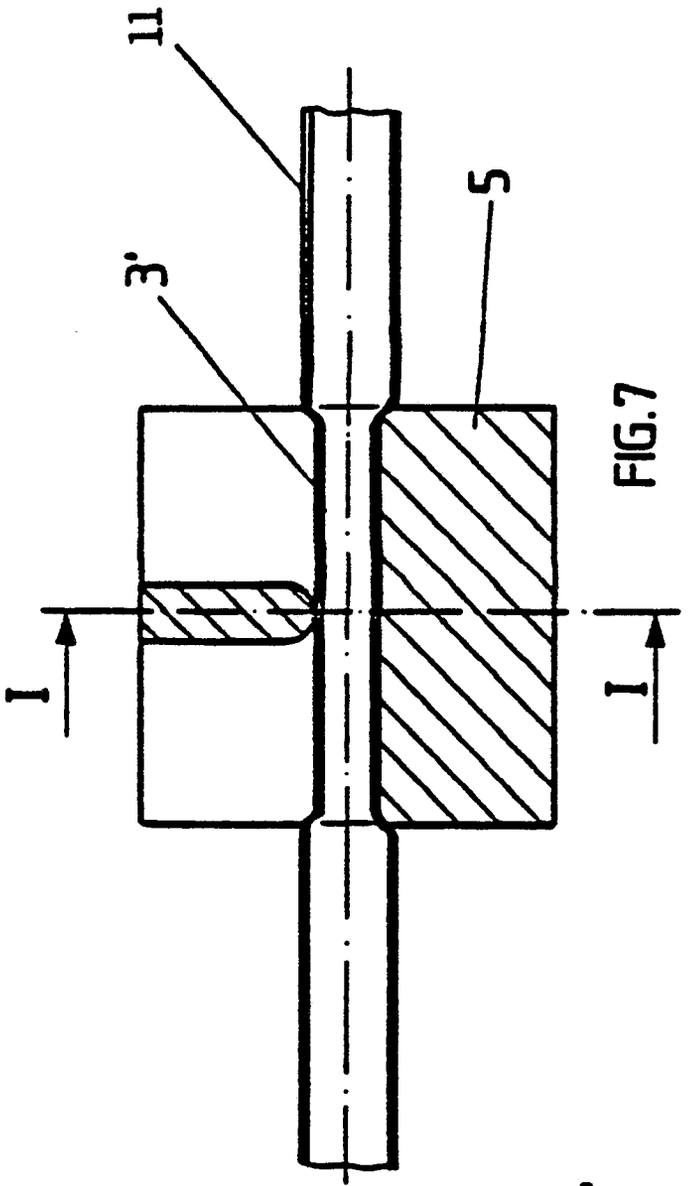


FIG.7

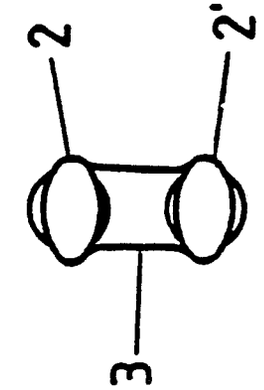


FIG.10

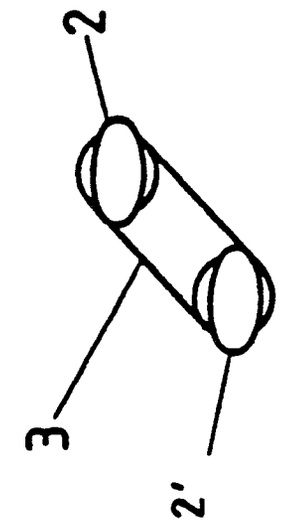


FIG.9

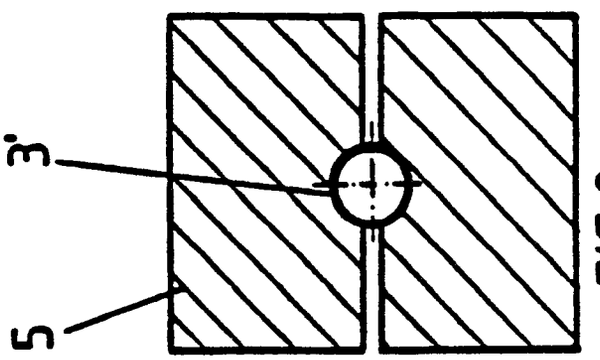


FIG.8