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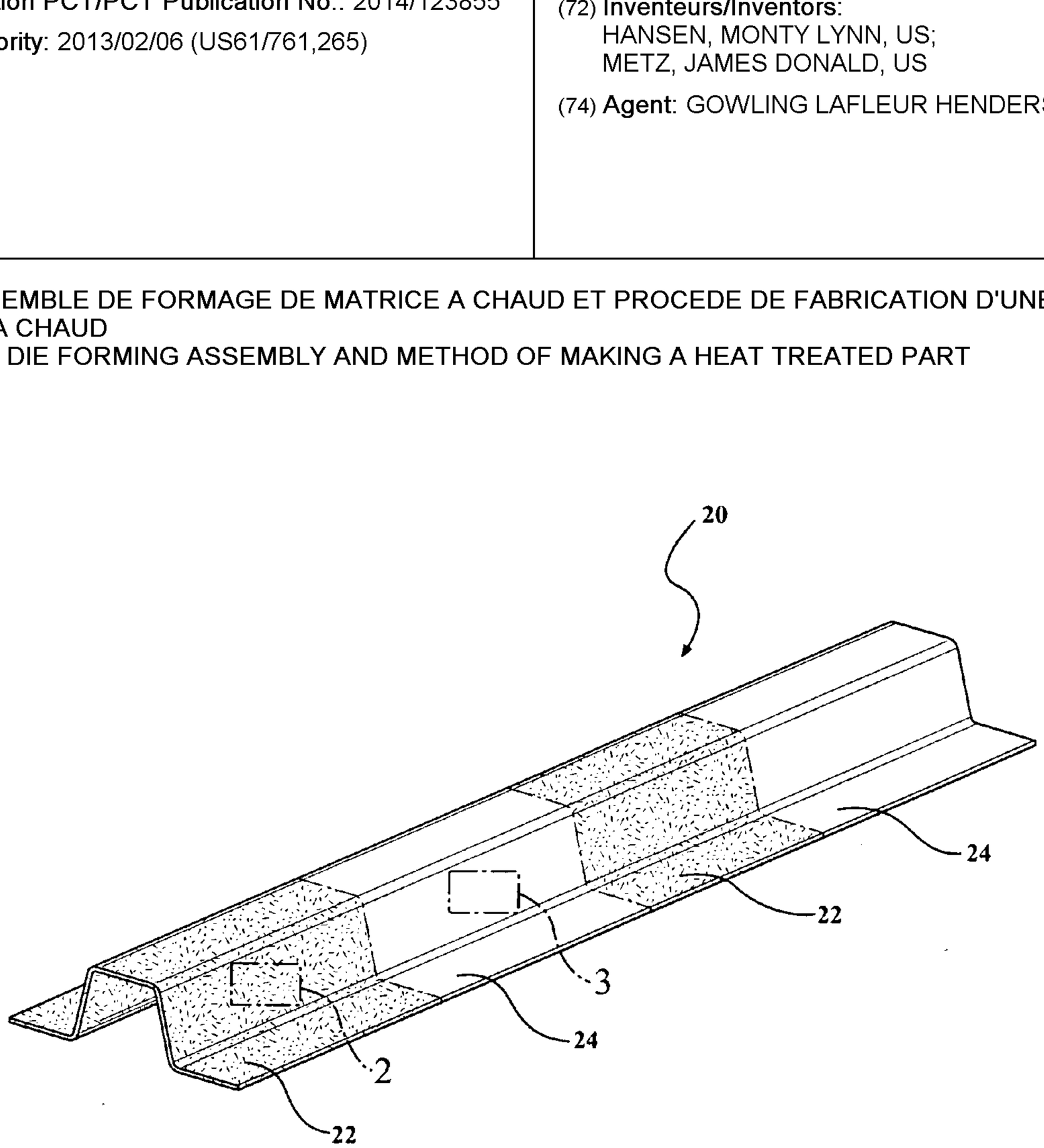
(71) Demandeurs/Applicants:
MAGNA INTERNATIONAL INC., CA;
HANSEN, MONTY LYNN, US;
METZ, JAMES DONALD, US

(72) Inventeurs/Inventors:
HANSEN, MONTY LYNN, US;
METZ, JAMES DONALD, US

(74) Agent: GOWLING LAFLEUR HENDERSON LLP

(54) Titre : ENSEMBLE DE FORMAGE DE MATRICE A CHAUD ET PROCEDE DE FABRICATION D'UNE PIECE TRAITEE A CHAUD

(54) Title: HOT DIE FORMING ASSEMBLY AND METHOD OF MAKING A HEAT TREATED PART



(57) Abrégé/Abstract:
A method of making a part is provided. A blank is loaded into a die assembly having a pair of shoes with forming pieces attached thereto and compressible members sandwiched between the shoes and the forming pieces. The die is closed about the blank to deform the blank into a part. The die is then opened by a predetermined distance while at least one of the compressible members deforms elastically to maintain contact between at least one of the forming pieces and the part. Less than the entire surface of the part is then conductively cooled through the at least one forming piece to provide a predetermined portion of the part with a predetermined micro structure.

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(71) Applicant: **MAGNA INTERNATIONAL INC.** [CA/CA]; 337 Magna Drive, Aurora, Ontario, L4G 7K1 (CA).

(72) Inventors; and
(71) Applicants : **HANSEN, Monty, Lynn** [US/US]; 36358 Almont Drive, Sterling Heights, MI 48310 (US). **METZ, James, Donald** [US/US]; 1629 N. Maplewood, Chicago, IL 60647 (US).

(74) Agents: **HURLES, Steven, C.** et al.; Dickinson Wright PLLC, 2600 West Big Beaver Road, Suite 300, Troy, MI 48084 (US).

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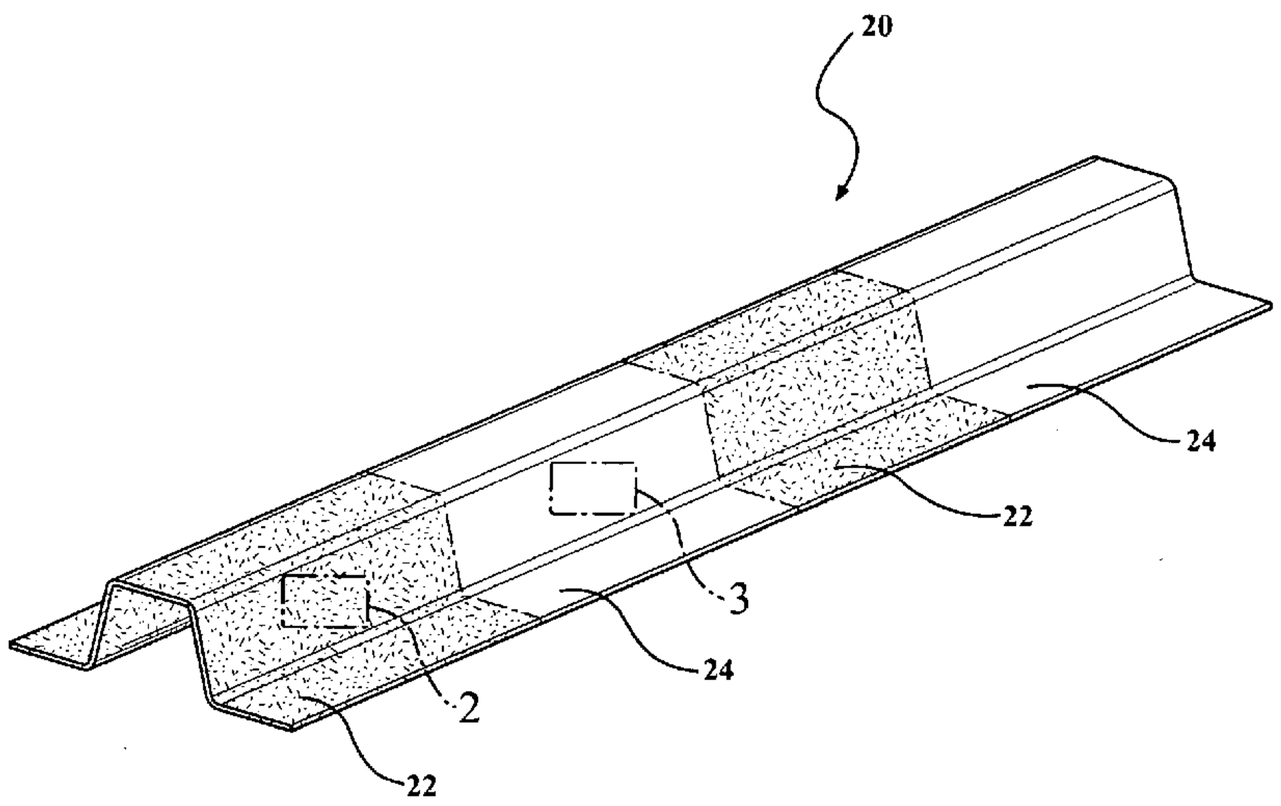

(57) Abstract: A method of making a part is provided. A blank is loaded into a die assembly having a pair of shoes with forming pieces attached thereto and compressible members sandwiched between the shoes and the forming pieces. The die is closed about the blank to deform the blank into a part. The die is then opened by a predetermined distance while at least one of the compressible members deforms elastically to maintain contact between at least one of the forming pieces and the part. Less than the entire surface of the part is then conductively cooled through the at least one forming piece to provide a predetermined portion of the part with a predetermined micro structure.

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HOT DIE FORMING ASSEMBLY AND METHOD OF MAKING A HEAT TREATED PART

CROSS-REFERENCE TO PRIOR APPLICATIONS

[0001] This PCT Patent Application claims the benefit of U.S. Provisional Patent Application Serial No. 61/761,265 filed February 6, 2013, entitled "Hot Die Forming Assembly And Method Of Making A Heat Treated Part," the entire disclosure of the application being considered part of the disclosure of this application and hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention is related generally to shaping and heat treating parts.

2. Related Art

[0003] The manufacture of many metal parts, such as automotive parts, requires both shaping and heat treating operations. Various types of shaping operations include, for example, stamping, extruding, machining, roll forming, hydro forming, etc. Heat treating operations typically include heating the part to a predetermined temperature, such as an austenite transformation temperature, and cooling the part at a predetermined rate. The cooling rate chosen will affect the microstructure of the metal and thus the mechanical properties of the part.

[0004] One particular type of shaping operation includes placing a metal blank into a die assembly and closing a pair of dies having patterns around the blank to deform the blank into a workpiece having a predetermined shape. Next, the dies are separated from one another and the workpiece is removed from the die assembly. After removal from the die assembly, the workpiece is heat treated to provide it with a desired microstructure.

SUMMARY OF THE INVENTION

[0005] One aspect of the present invention includes a method of making a workpiece. The method includes the step of preparing a die assembly including a pair of dies, wherein at least one of the dies has a shoe, a plurality of forming pieces operably coupled with the shoe, and at least one compressible member which is sandwiched between the shoe and at least one of the forming pieces. The method proceeds with the step of positioning a blank in the die assembly between the pair of dies. The method continues with the step of moving at least one of the dies towards the other die. The method proceeds with the step of compressing the at least one compressible member to move at least one of the forming pieces relative to another of the forming piece. The method continues with the step of deforming the blank with the plurality of forming dies. The method proceeds with the step of separating the pair of dies by a predetermined distance such that at least one of the forming pieces disengages from the deformed blank while the at least one compressible member expands to maintain at least one of the forming pieces in engagement with the deformed blank. The method further includes the step of conductively cooling less than the entire surface of the deformed blank with the at least one forming piece in engagement with the deformed blank after separating the pair of dies by the predetermined distance.

[0006] The same equipment to be used to both shape and heat treat predetermined portions of the blank. This allows for reduced manufacturing time and improved cost effectiveness in the manufacturing of the part.

[0007] According to another aspect of the present invention, the method further includes the steps of moving at least one of the dies towards the other die to engage all of the forming pieces with the deformed workpiece after the step of conductively cooling less than the entire surface of the deformed workpiece and conductively cooling substantially the entire surface of the deformed workpiece. This is advantageous because it allows for

heat treating of substantially the entire part within the die assembly. Additionally, closing the die assembly has the effect of compensating for any deformations in the workpiece that may arise from uneven cooling.

[0008] Another aspect of the present invention provides for a forming assembly for shaping a blank into a workpiece. The forming assembly includes a pair of dies that are moveable towards and away from one another. At least one of the dies has a shoe and a plurality of forming pieces operably coupled with the shoe and at least one compressible member that is sandwiched between the shoe and at least one of the forming pieces. The at least one compressible member is of a material that is elastically deformable for allowing at least one of the forming pieces to move relative to an adjacent forming piece. The at least one die with the forming piece further includes a cooling system for extracting heat from the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] These and other features and advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0010] Figure 1 is a perspective elevation view of an exemplary part;

[0011] Figure 2 is an enlarged view showing the microstructure of a portion of the part shown in Figure 1;

[0012] Figure 3 is an enlarged view showing the microstructure of a different portion of the part shown in Figure 1;

[0013] Figure 4 is a perspective view of an exemplary die assembly having a pair of dies that are in open positions;

[0014] Figure 5 is a cross-sectional view of one of the dies of the die assembly shown in Figure 4;

[0015] Figure 6 is a cross-sectional view of the dies of Figure 4 in closed positions; and

[0016] Figure 7 is a cross-sectional view of the dies of Figure 4 in intermediate positions.

DETAILED DESCRIPTION OF THE ENABLING EMBODIMENTS

[0017] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, an exemplary embodiment of a one-piece, stamped automotive part **20** (or workpiece) made of steel or a steel alloy is generally shown in Figure 1. As shown in Figures 1-3, the exemplary automotive part **20** is broken into a plurality of portions **22, 24** or areas with differing metallurgical microstructures. Specifically, the exemplary part **20** includes two portions **22** (hereinafter referred to as "untempered portions") which are spaced from one another and have a first microstructure and two portions **24** (hereinafter referred to as "tempered portions") which are spaced from one another and have a second microstructure that is different than the first microstructure. In the exemplary automotive part **20**, the first microstructure of the untempered portions **22** is untempered martensite (shown in Figure 2) and the second microstructure of the tempered portions **24** is tempered martensite (shown in Figure 3). The different microstructures provide the untempered and tempered portions **22, 24** with differing mechanical properties or characteristics, thereby allowing the part **20** to be optimized for a particular application. The locations, geometries, and specific microstructures of the different portions **22, 24** on the part **20** may be chosen based on the intended application of the part **20**. For example, the tempered portions **24** may be located in areas of the part **20** where increased toughness is desired, and the untempered portions **22** may be located in

areas of the part **20** where increased hardness is desired. As discussed in further detail below, the part **20** could also be provided with any desirable number of differing microstructures, and the specific microstructures could be any combination of, for example, martensite, tempered martensite, bainite, pearlite, etc. The part **20** could be, for example, an A-pillar, a B-pillar, or a C-pillar of an automobile body or a control arm of a suspension system or a range of other automotive or non-automotive components.

[0018] The untempered and tempered portions **22, 24** are formed into the one-piece part **20** during and immediately following a stamping process on a die assembly **26**, and using the same die assembly **26** as is used for the stamping process. Referring now to Figure 4, the exemplary embodiment of the die assembly **26** includes an upper die **28** and a lower die **30** which are moveable relative to one another between open positions (shown in Figure 4), closed positions (shown in Figure 6) and intermediate positions (shown in Figure 7). Each of the dies **28, 30** has a shoe **32, 34** and a plurality of forming pieces **36, 38**, and each of the forming pieces **36, 38** has a forming surface which faces away from the respective shoe **32, 34**. As shown, the forming surfaces cooperate with one another to present a cavity **40** for shaping a blank into the part **20**. In the exemplary embodiment, the forming pieces **36, 38** of each die **28, 30** have similar heights. However, it should be appreciated that forming pieces with differing heights could alternately be employed.

[0019] A plurality of compressible members **42, 44** or discs made of an elastically compressible material (such as neoprene) or hydraulic or pneumatic cylinders are sandwiched between the shoes **32, 34** and the respective forming pieces **36, 38** for allowing movement of the forming pieces **36, 38** relative to one another during operation of the die assembly **26**, as discussed in further detail below. Referring now to Figure 5, when the lower die **30** is in the open position, two of the compressible members **42a** (hereinafter "thin compressible members **42a**") have a first thickness $\mathbf{t_1}$ and two of the compressible members

42b (hereinafter "thick compressible members **42b**") have a second thickness $\mathbf{t_2}$ which is greater than the first thickness $\mathbf{t_1}$. As such, because the forming pieces **36** have similar heights, when the lower die **30** is in the open position, the forming surfaces of the forming pieces **36** joined with the thin compressible members **42a** are relatively lower than or recessed relative to the forming surfaces of the forming pieces **36** joined with the thick compressible members **42b**. In other words, there are steps between adjacent forming surfaces, and the heights of the steps correspond with the difference in the thicknesses of the thin and thick compressible members **42a, 42b**. It should also be appreciated that one or more (but not all) of the forming pieces could be directly attached to either of the shoes or attached thereto without a compressible member sandwiched therebetween.

[0020] In the exemplary embodiment, the compressible members **42, 44** are formed of a rubber material with a high thermal conductivity. However, it should be appreciated that the compressible members **42, 44** could alternately be formed of any suitably elastically compressible material. The compressible members **42, 44** could also be formed of different materials.

[0021] Referring back to Figure 4, each of the shoes **32, 34** has an inlet **44, 46** for receiving a coolant, an outlet **48, 50** for dispensing the coolant out of the respective shoe **32, 34**, and a coolant passage extending therebetween. As will be discussed in further detail below, during operation of the die assembly **26,** a coolant, such as water, therethrough to selectively cool or heat treat the part **20** after a shaping process is completed.

[0022] The process of shaping and heat treating a metal blank to form a part, such as the part **20** shown in Figures 1-3, begins with heating the blank to a predetermined temperature, such as for example, greater than five hundred degrees Celsius (500 °C) or the austenite temperature of the material, which is approximately 730 °C for steel. Next, as shown in Figure 6, the upper and lower dies **28, 30** are moved together to sandwich the

blank **20** between the forming surfaces of the forming pieces **36, 38** and deform the blank **20** until it conforms to the shape of the cavity **40** (shown in Figure 4). As shown, during the deformation process, the thick compressible members **42b, 44b** deflect or compress by a greater distance than the thin compressible members **42a, 44a**, thereby negating the steps between the forming surfaces of the adjacent forming pieces **36, 38** and allows for a generally smooth part **20** without steps to be formed. In the exemplary embodiment, all four of the forming pieces **36, 38** are in abutting engagement with the blank **20** during the deforming process.

[0023] During or immediately following the deformation of the blank **20** in the cavity **40** of the die assembly **26**, the part **20** is heat treated between the upper and lower dies **28, 30** to provide the material of the part **20** with predetermined microstructures and mechanical properties. The heat treating process includes separating the upper and lower dies **28, 30** from one another by a predetermined distance such that the thick compressible members **42b, 44b** elastically expand by a greater distance than the thin compressible members **42a, 44a** to maintain the forming pieces **36, 38** coupled with the thick compressible members **42b, 44b** in contact with the part **20** while the other forming pieces **36, 38** separate therefrom.

[0024] A coolant is then channeled through the shoes **32, 34** of the upper and lower dies **28, 30**, and heat is transferred conductively from the shaped part **20**, through the forming pieces **36, 38** that remain in contact therewith, through the thick compressible members **42b, 44b** and into the shoe **32, 34** where it is extracted from the die assembly **26** by the coolant. As such, when the upper and lower dies **28, 30** are in the intermediate positions shown in Figure 7 the portions of the shaped part **20** which remain in contact with the forming pieces **36, 38** are cooled at a relatively quicker rate than the other portions of the shaped part **20**. In the exemplary embodiment, heat is extracted from the part **20** at a

predetermined rate to form untempered martensite microstructure in these portions. However, by, for example, altering the flow of coolant through the shoes **32, 34**, the specific microstructures formed by the heat treating process can be modified.

[0025] After the portions that remain in contact with the forming pieces **36, 38** cool to a predetermined temperature (e.g., 300 °C) and after a predetermined duration of time, the upper and lower dies **28, 30** are then moved back towards one another to the positions shown in Figure 6 to bring the separated forming pieces **36, 38** back into contact with the shaped part **20**. Heat is now also extracted from the portions of the shaped part **20** in engagement with the forming pieces **36, 38** that are coupled with the thin compressible members **42a, 44a** to form these portions into a tempered martensite microstructure. In addition to further cooling the part **20**, re-closing the die assembly **26** provides the additional benefit of removing any dimensional issues in the part **20** that may have developed during the uneven cooling process.

[0026] It should be appreciated that the upper and lower dies **28, 30** could be selectively moved together and separated at predetermined intervals to selectively cool the shaped part, thereby forming a range of different microstructures other than just tempered and untempered martensite.

[0027] Another aspect of the present invention is related to a method of making a part. The method includes the step of preparing a die assembly **26** including a pair of dies **28, 30**, wherein at least one (and preferably both) of the dies **28, 30** has a shoe **32, 34**; a plurality of forming pieces **36, 38** operably coupled with the shoe **32, 34**; and at least one compressible member **42, 44** which is sandwiched between the shoe **32, 34** and at least one of the forming pieces **36, 38**. In the exemplary embodiment, each of the dies **28, 30** has a plurality of thin compressible members **42a, 44a** with a first thickness $\mathbf{t_1}$ and a plurality of

thick compressible members **42b, 44b** with a second thickness t_2 that is greater than the first thickness t_1.

[0028] The method continues with the step of positioning a blank **20** in the die assembly **26** between the upper and lower dies **28, 30**. The method proceeds with the steps of moving at least one of the dies **28, 30** towards the other die **28, 30** and compressing the at least one compressible member **42, 44** to move at least one of the forming pieces **36, 38** relative to another adjacent forming piece **36, 38**. The method proceeds with the step of compressing the at least one compressible member **42, 44** to move at least one of the forming pieces **36, 38** relative to another forming piece **36, 38**. The method proceeds with the step of deforming the blank **20** with the plurality of forming pieces **36, 38**. The method continues with the step of separating the upper and lower dies **28, 30** by a predetermined distance such that at least one of the forming pieces **36, 38** disengages from the deformed blank **20** while the at least one compressible member **42, 44** expands to maintain at least one of the forming pieces **36, 38** in engagement with the deformed blank **20**. The method proceeds with the step of cooling the deformed blank **20** with the at least one forming piece **36, 38** in engagement with the deformed blank **20** after separating the pair of dies **28, 30** by the predetermined distance.

[0029] In the exemplary method, the at least one compressible member **42, 44** includes at least one thin compressible member **42a, 44a** sandwiched between the shoe **32, 34** and at least one thick compressible member **42b, 44b** and wherein during the separation of the upper and lower dies **28, 30**, the at least one forming piece **36, 38** in connection with the at least one thin compressible member **42a** separates from the deformed blank **20** and the at least one forming piece **36, 38** in connection with the at least one thick compressible member **42b, 44b** remains in contact with the deformed blank **20**.

[0030] In the exemplary method, the shoe **32, 34** includes a cooling channel for conveying a cooling fluid to cool the forming pieces **36, 38** after the step of deforming the blank **20**.

[0031] The compressible members **42, 44** are preferably of a material having a high thermal conductivity.

[0032] The exemplary method further includes the step of heating the blank **20** before the step of moving at least one of the dies **28, 30** towards the other die **28, 30**.

[0033] The exemplary method still further includes the steps of moving at least one of the dies **28, 30** towards the other die **28, 30** to engage all of the forming pieces **36, 38** with the deformed blank **20** after the step of conductively cooling less than the entire surface of the deformed blank **20** and conductively cooling substantially the entire surface of the deformed blank **20**.

[0034] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims.

CLAIMS

In The Claims:

Claim 1. A method of making a workpiece, comprising the steps of:

preparing a die assembly including a pair of dies, at least one of the dies having a shoe, a plurality of forming pieces operably coupled with the shoe, and at least one compressible member sandwiched between the shoe and at least one of the forming pieces;

positioning a blank in the die assembly and between the pair of dies;

moving at least one of the dies towards the other die;

compressing the at least one compressible member to move at least one of the forming pieces relative to another forming piece;

deforming the blank with the plurality of forming pieces;

separating the pair of dies by a predetermined distance such that at least one of the forming pieces disengages from the deformed blank while the at least one compressible member expands to maintain at least one of the forming pieces in engagement with the deformed blank; and

conductively cooling less than the entire surface of the deformed blank with the at least one forming piece in engagement with the deformed blank after separating the pair of dies by the predetermined distance.

Claim 2. The method as set forth in claim 1 wherein the at least one forming die includes at least one thick compressible member sandwiched between the shoe and at least one of the forming pieces and at least one thin compressible member sandwiched between the shoe and at least one of the other forming pieces and wherein during the separating of the dies, the at least one forming piece in connection with the at least one thin compressible member separates from the deformed blank and the at least one forming piece

in connection with the at least one thick compressible member remains in contact with the deformed blank.

Claim 3. The method as set forth in claim 2 wherein the shoe includes a cooling channel for receiving a cooling fluid to cool the forming pieces after the step of deforming the blank.

Claim 4. The method as set forth in claim 1 wherein the compressible members are of a thermally conductive material.

Claim 5. The method as set forth in claim 1 wherein each of the dies has a shoe and a plurality of forming pieces which are operably coupled with the shoe and at least one compressible member sandwiched between the shoe and at least one of the forming pieces.

Claim 6. The method as set forth in claim 1 further including the steps of moving at least one of the dies towards the other die to engage all of the forming pieces with the deformed blank after the step of conductively cooling less than the entire surface of the deformed blank and conductively cooling substantially the entire surface of the deformed blank.

Claim 7. The method as set forth in claim 1 further including the step of heating the blank to a predetermined temperature before the step of moving at least one of the dies towards the other die.

Claim 8. The method as set forth in claim 7 wherein the predetermined temperature is an austenite transformation temperature.

Claim 9. A forming assembly for shaping a blank into a workpiece, comprising:

a pair of dies that are moveable towards and away from one another;

at least one of said dies having a shoe and a plurality of forming pieces operably coupled with said shoe and at least one compressible member sandwiched between said shoe and at least one of said forming pieces;

said at least one compressible member being of a material that is elastically deformable for allowing at least one of said forming pieces to move relative to an adjacent forming piece; and

said at least one of said dies with said at least one compressible member having a cooling system for cooling a workpiece.

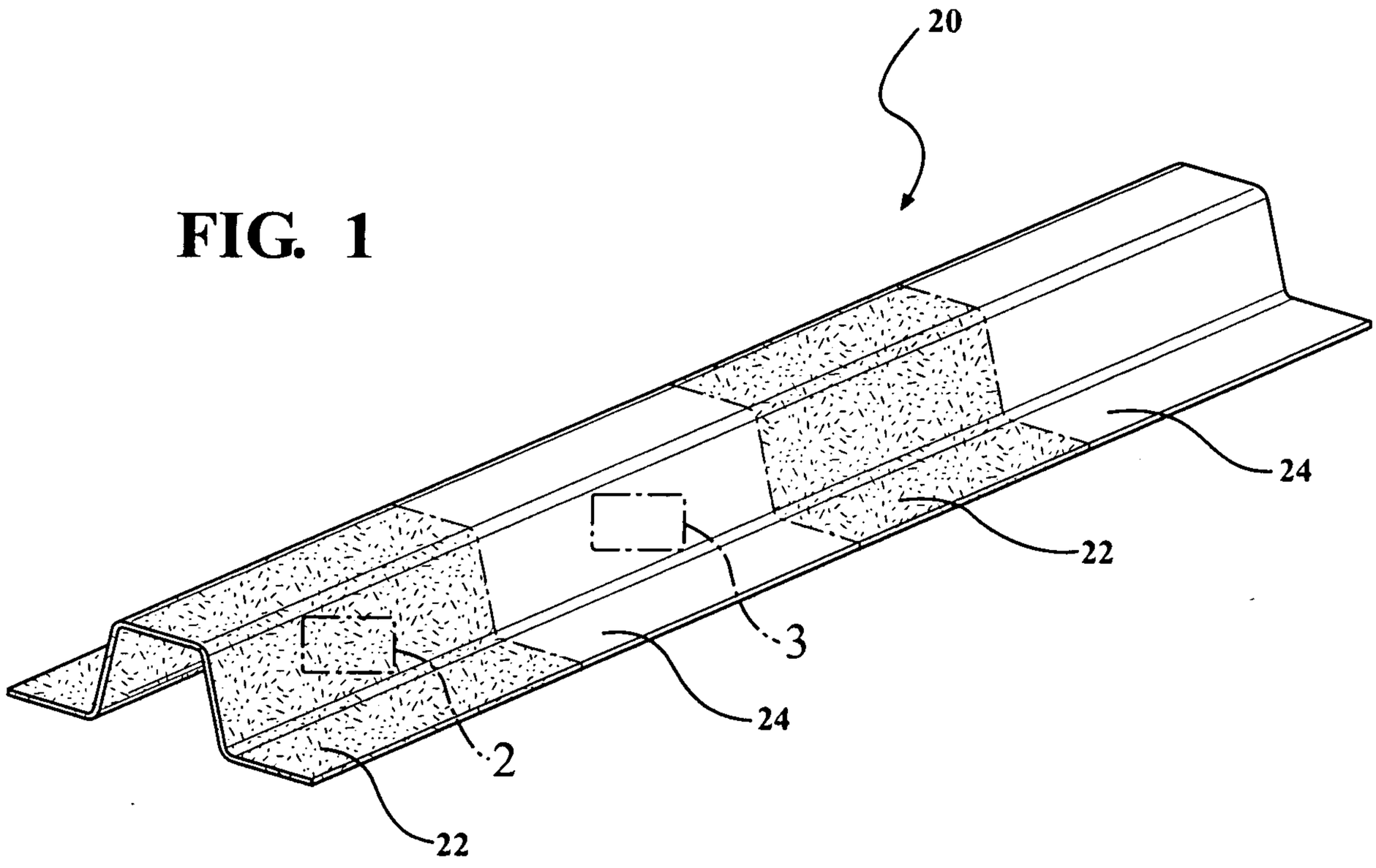
Claim 10. The forming assembly as set forth in claim 9 wherein said cooling system is in said shoe

Claim 11. The forming assembly as set forth in claim 10 wherein said at least one compressible member is of a material that has a high thermally conductivity for conveying heat from the workpiece through said at least one forming piece and through said at least one compressible member to said shoe.

Claim 12. The forming assembly as set forth in claim 9 wherein said at least one compressible member is further defined as a plurality of compressible members including at least one thin compressible member having a first thickness and at least one thick compressible member having a second thickness that is greater than said first thickness.

Claim 13. The forming assembly as set forth in claim 9 wherein each of said dies includes a shoe and a plurality of forming pieces operably coupled with said shoe and at least one compressible member sandwiched between said shoe and at least one of said forming pieces.

FIG. 1



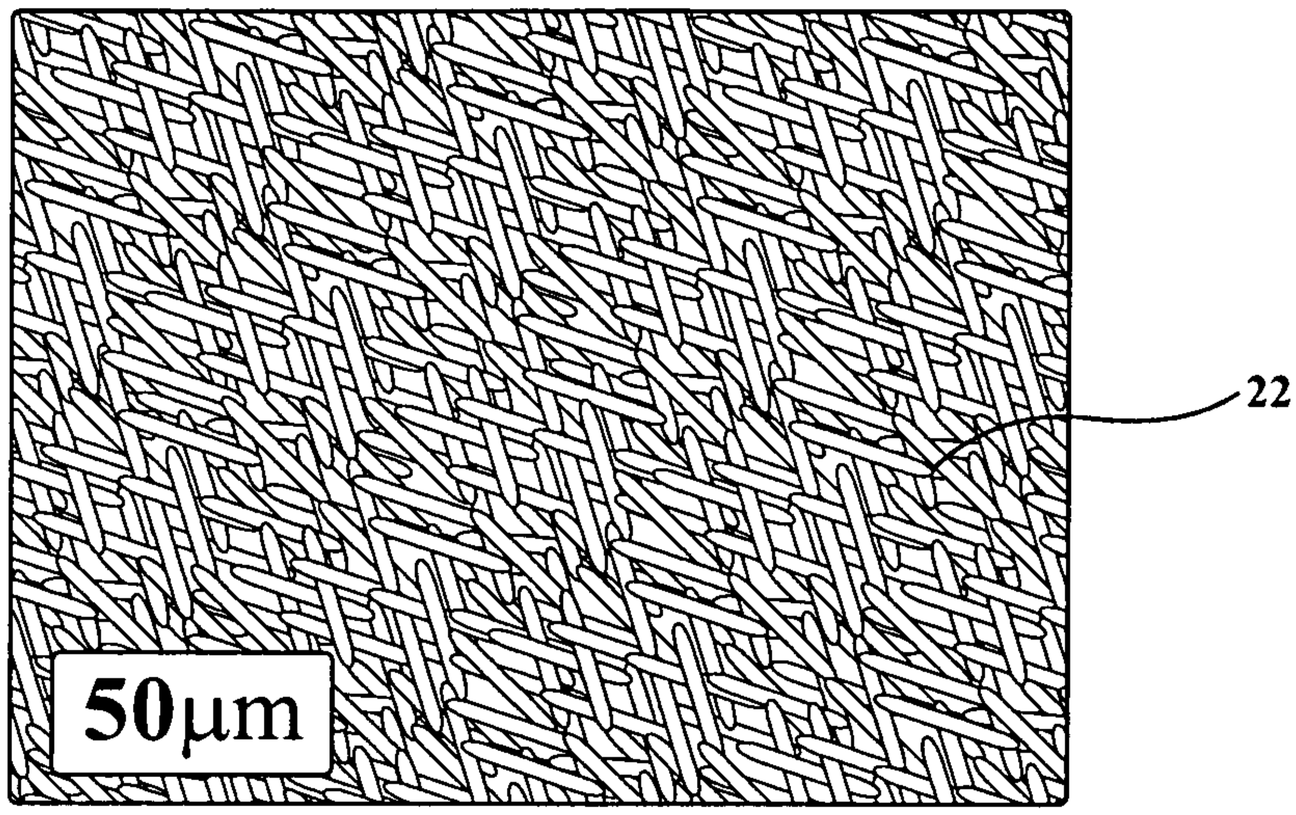


FIG. 2

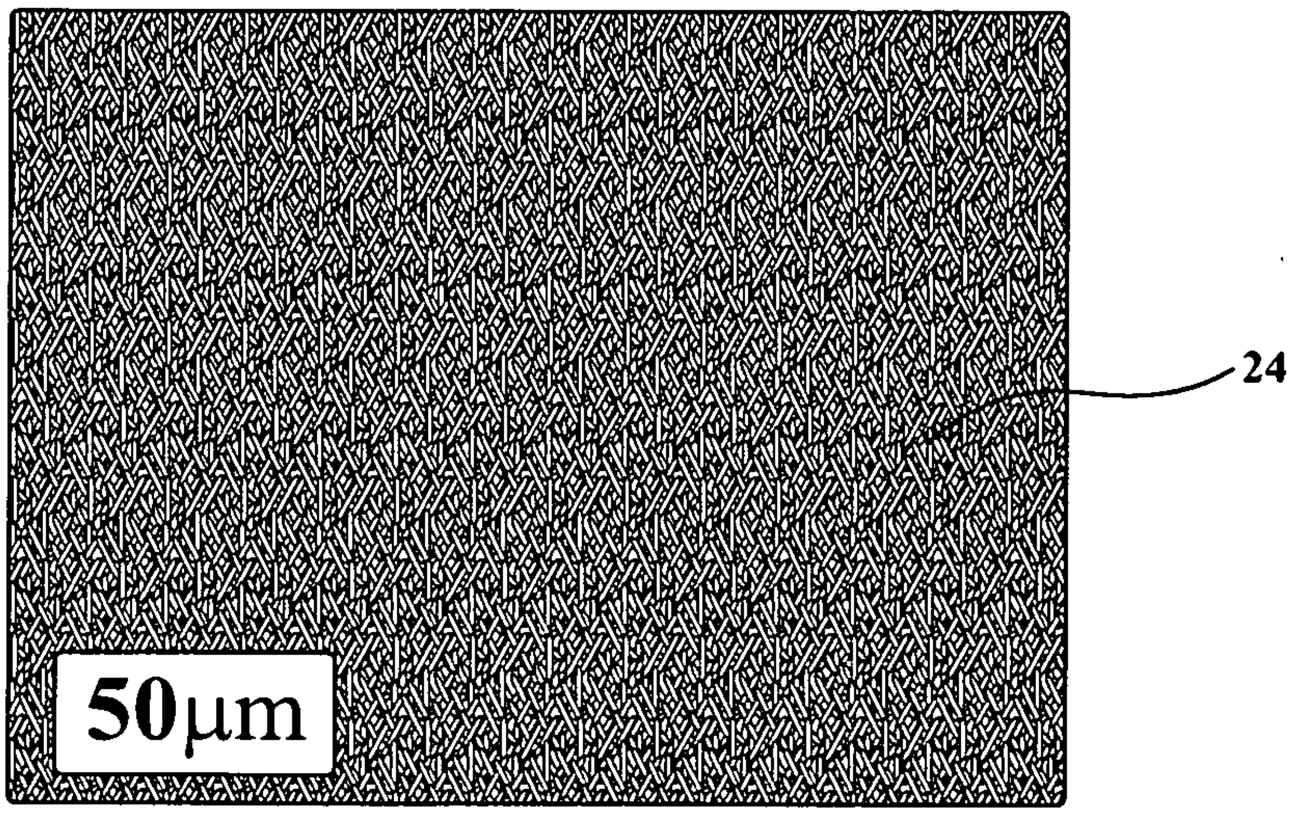
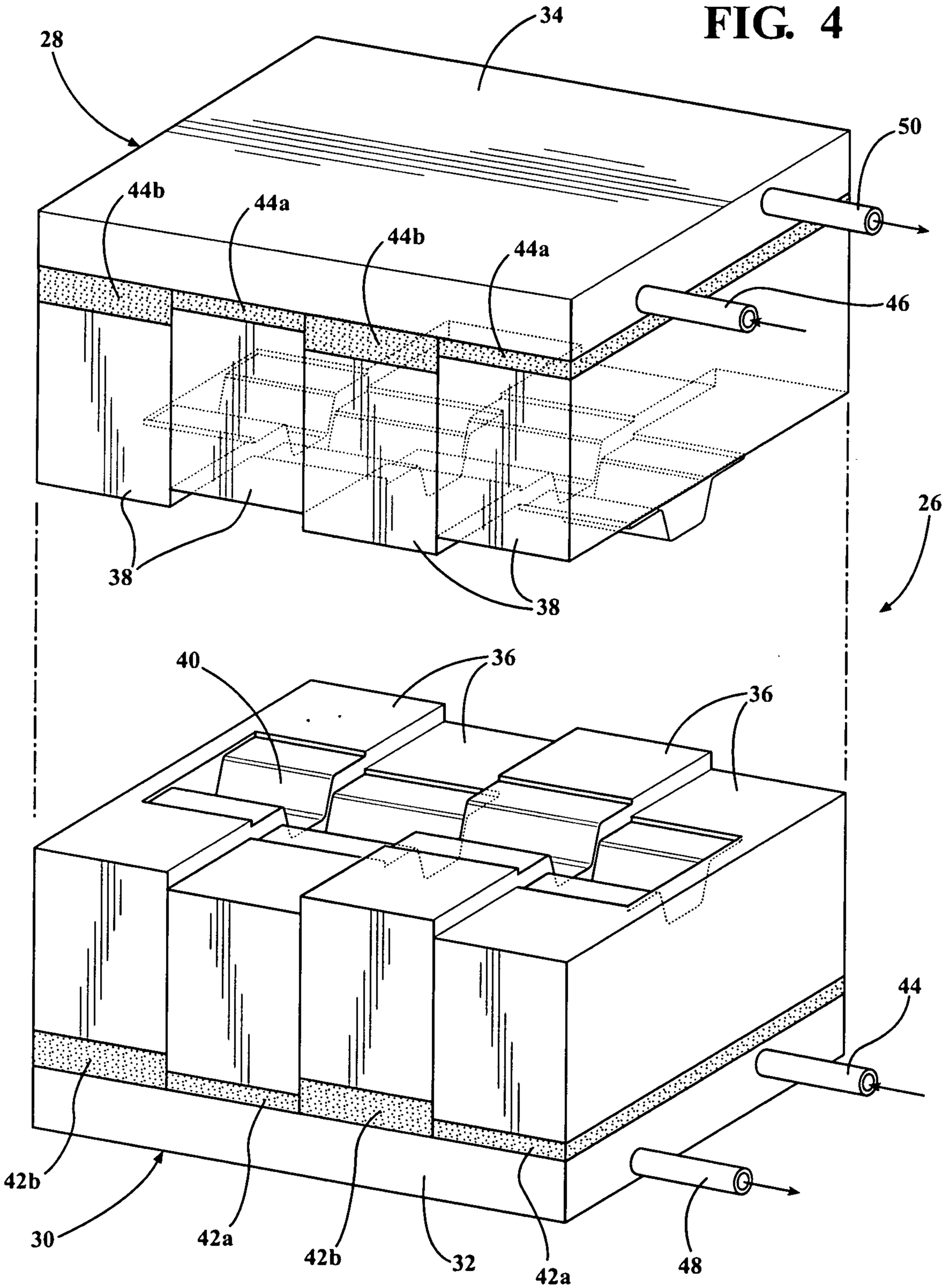


FIG. 3

FIG. 4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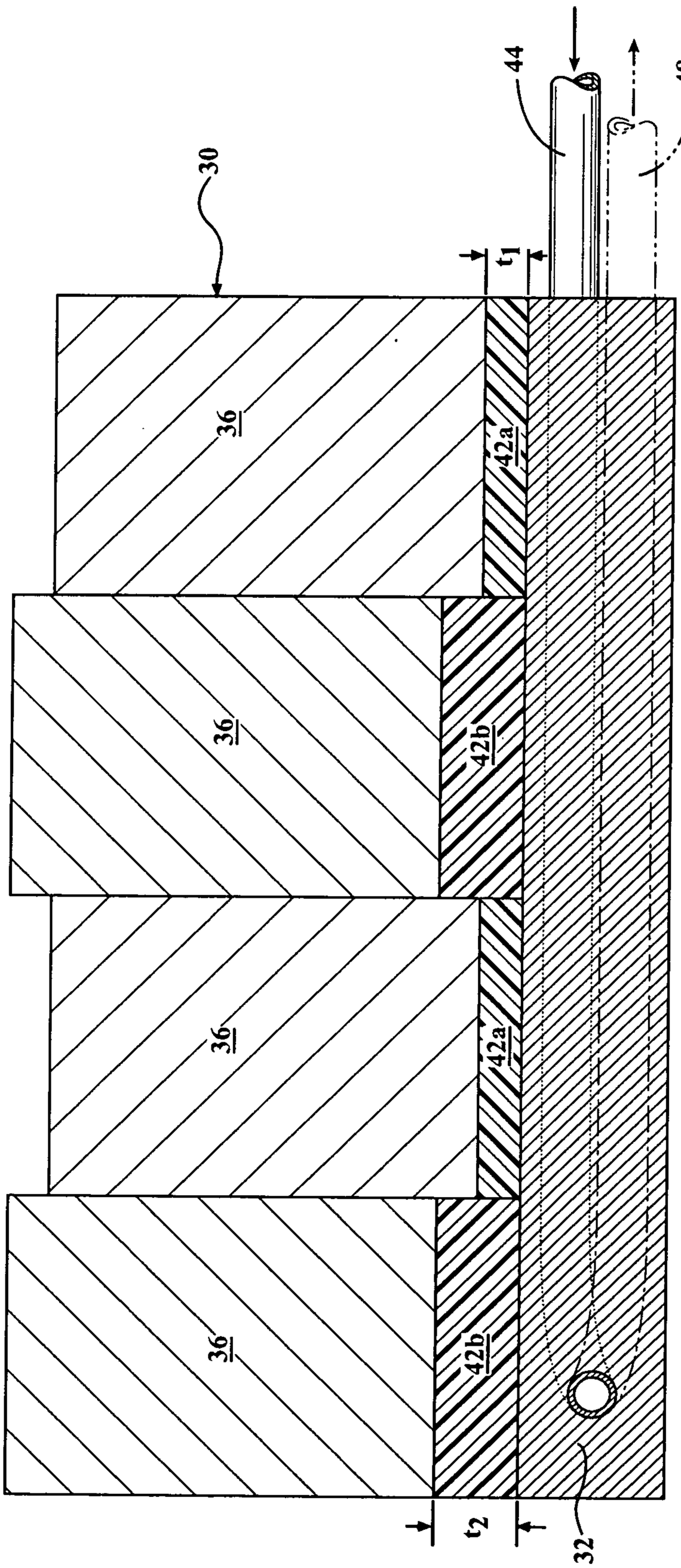

FIG. 5

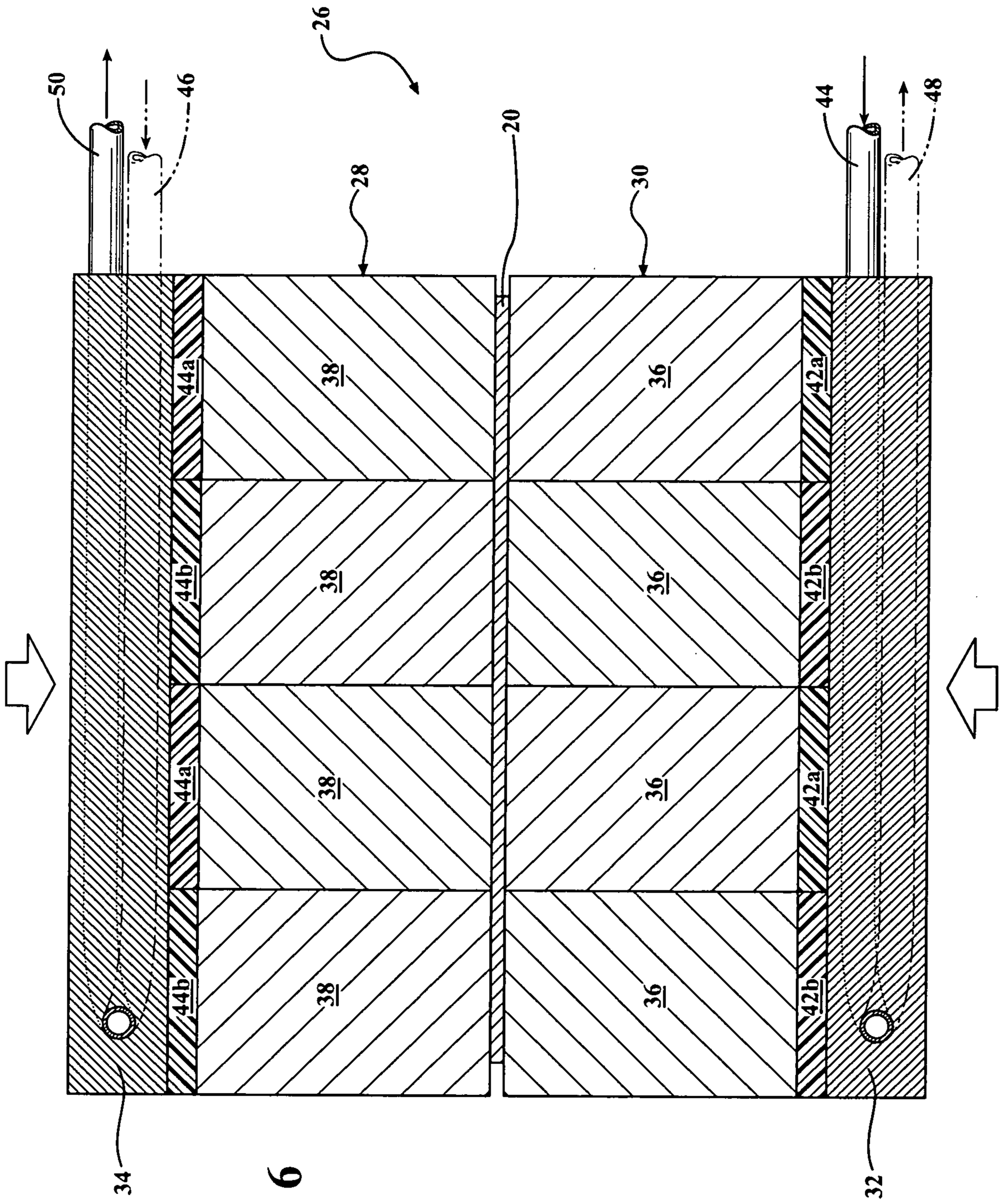
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FIG. 6

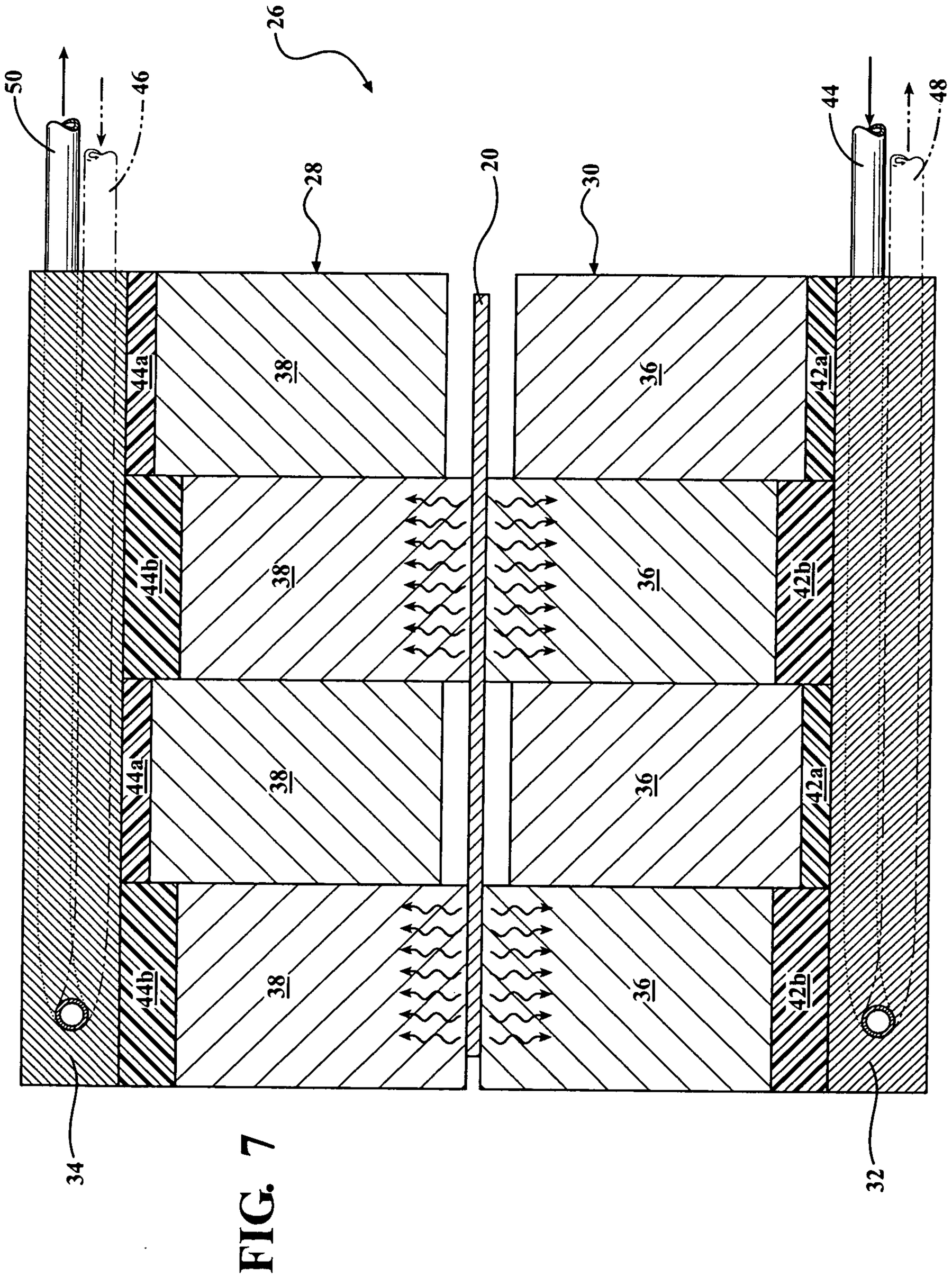
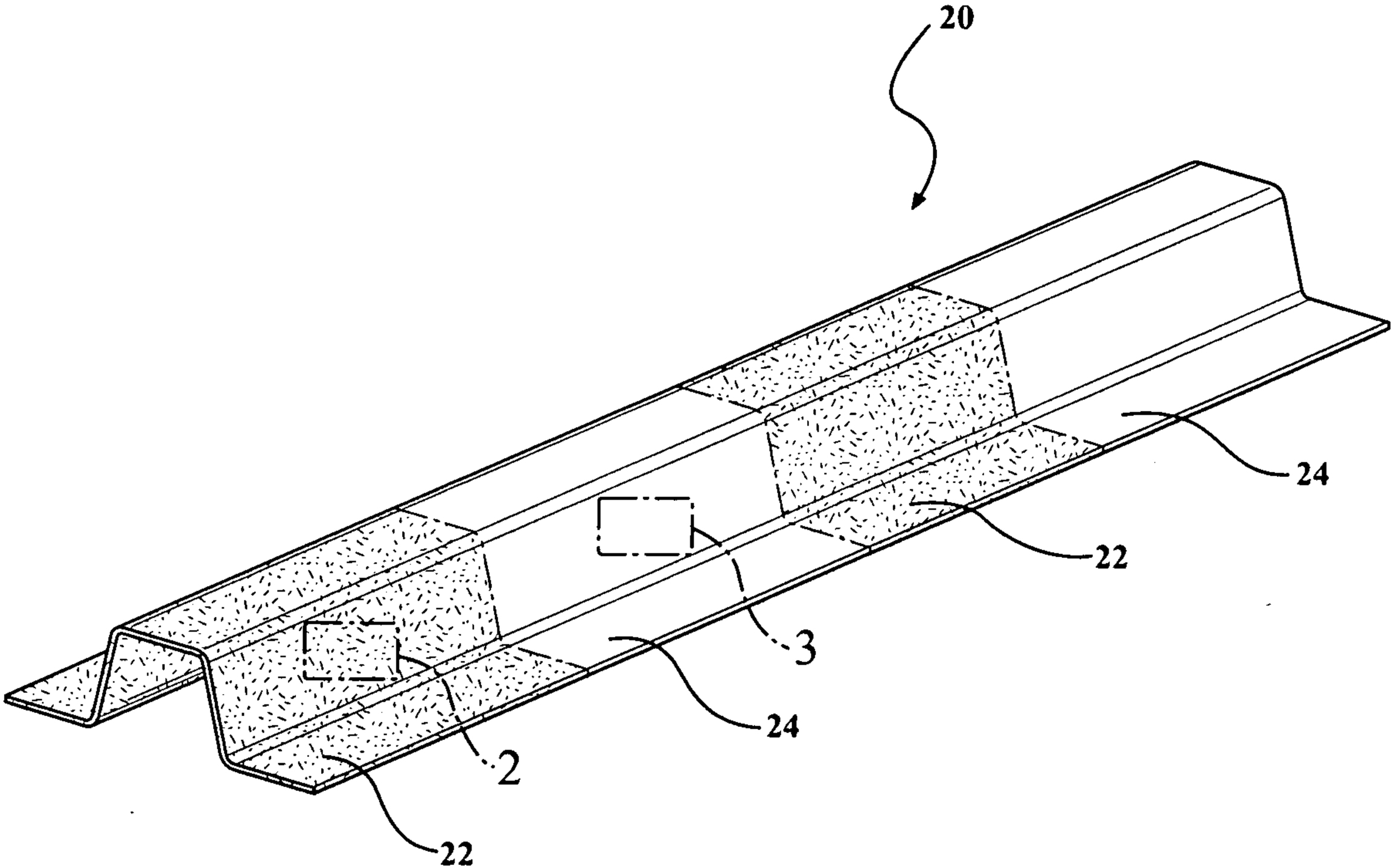


FIG. 7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