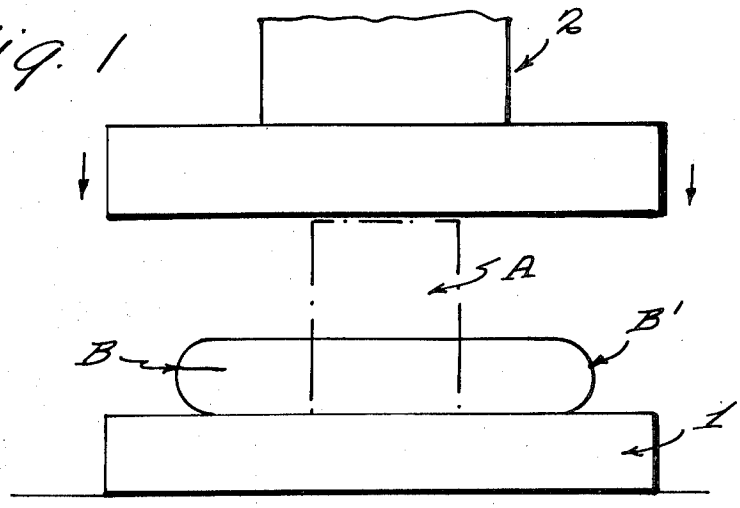
March 9, 1971 C. H. MOORE 3,568,492

MANUFACTURE OF PRESSURE RESISTANT ARTICLES WITH INTEGRAL HUBS OR FLANGES

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Fig. 1



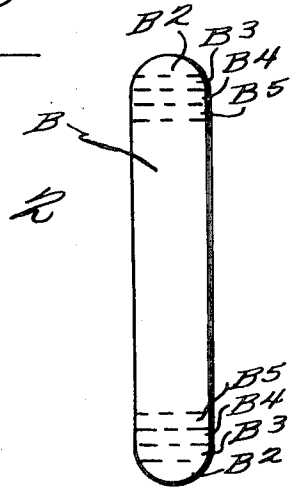
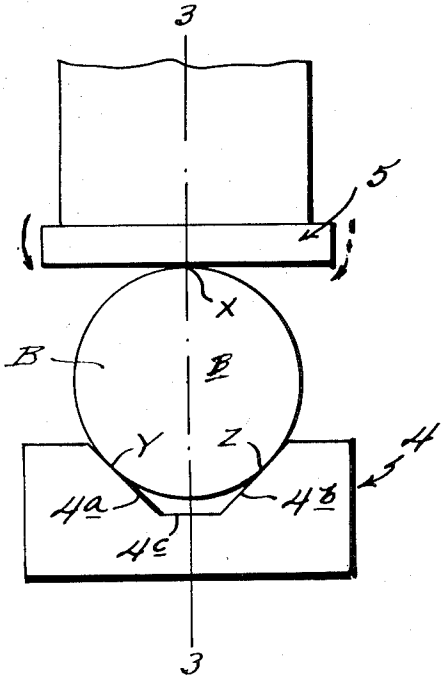


Fig. 2

Fig. 3



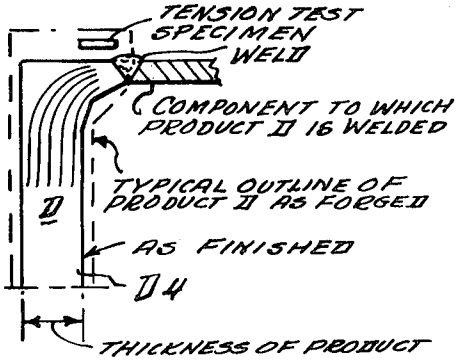


Fig. 8

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MANUFACTURE OF PRESSURE RESISTANT ARTICLES
WITH INTEGRAL HUBS OR FLANGES

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Fig. 4

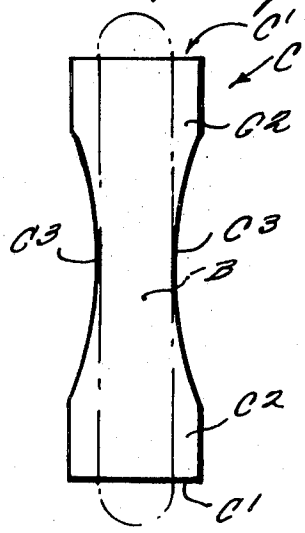


Fig. 5

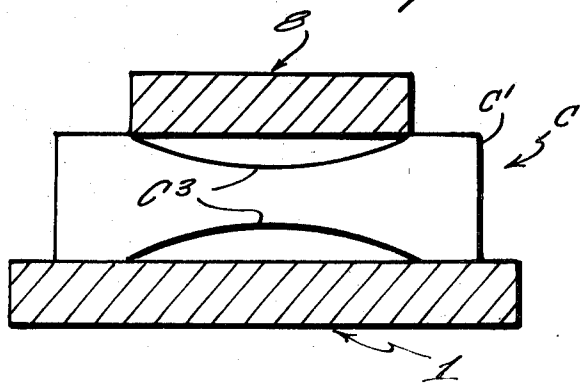


Fig. 6

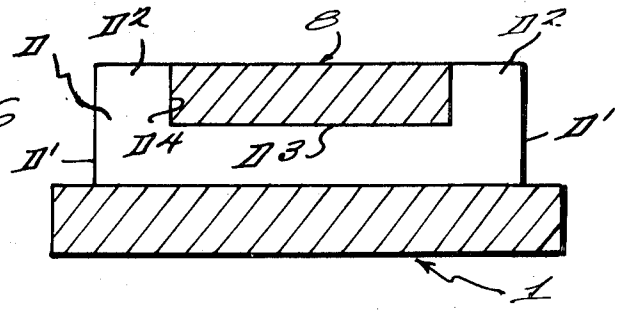
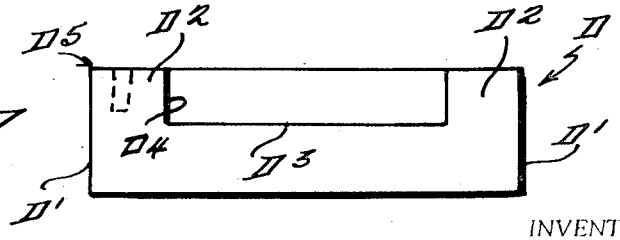


Fig. 7



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MANUFACTURE OF PRESSURE RESISTANT ARTICLES WITH INTEGRAL HUBS OR FLANGES

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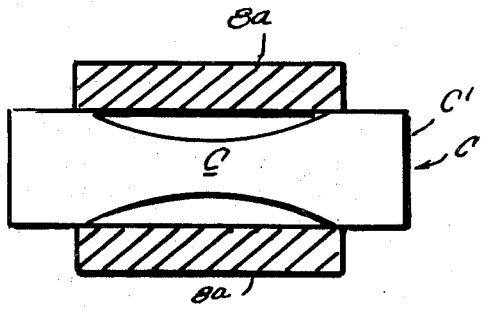
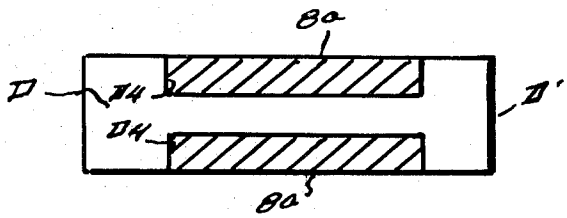


Fig. 9

Fig. 10



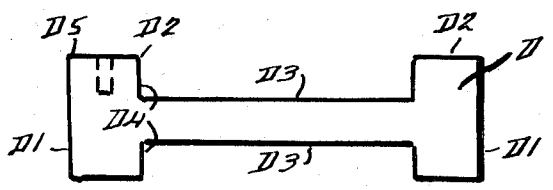


Fig. 11

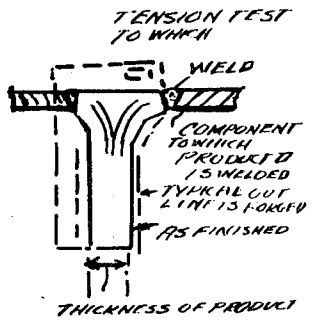


Fig. 12

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3,568,492

MANUFACTURE OF PRESSURE RESISTANT ARTICLES WITH INTEGRAL HUBS OR FLANGES

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Int. Cl. B21j 5/00; B21k 21/00
U.S. Cl. 72—374 6 Claims

ABSTRACT OF THE DISCLOSURE

Tube-sheets with integral hubs, channel forgings for heat-exchangers, pressure vessels with flat heads and similar articles which are subjected to high-pressure etc. are formed by a series of forging steps which result in greatly improved grain orientation and, accordingly, greater resistance to pressures.

The present invention relates to shells, heads and other pressure-resistant parts and the attachment thereof to a forged or rolled plate or the like by welding.

Due to safety provisions the forming of the welds is governed by rigid requirements of rules which are established by the American Society of Mechanical Engineers' Boiler and Pressure Vessel Code.

In general, heads or other pressure parts may be attached to a forged or rolled plate to form a corner joint, but only if the joint meets a prescribed set of requirements as delineated by Section VIII, Paragraph UW–13(e) and Figure UW–13.2 of the aforementioned Code. These requirements are rather stringent and make necessary the employment of sizeable welds which are generally difficult to examine radiographically. Since the joint in question occurs right at a severe discontinuity, high quality vessels for critical service seldom utilize this type of construction; preferring, instead, heads or tube-sheets with integral hubs for butt-welding to the adjacent shell, head or other pressure part.

Acceptable constructions are depicted in the aforementioned Figure UW–13.3 of the Code and Paragraph UW–13(f) thereof emphatically prohibits the use of rolled plate for this construction where hubs could be machined from such plate.

Paragraph UW–13(f) also requires that "The component having the hub shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. Proof of this shall be furnished by a tensile test specimen (subsize if necessary) taken in this direction and as close to the hub as is practical. In no case shall the height of the hub be less than 1.5 times the thickness of the pressure part to which it is welded."

When a metallic cylinder or disc is hot-worked to increase its diameter while its periphery is unconfined, the direction of maximum work and metal displacement near the outer edge is tangenial; and the orientation of the grain of the metal in this direction results in high loss of ductility in the transverse direction which is the direction in which the testing must be performed.

Rarely, if ever, do longitudinal specimens, parallel to the axis atken from the periphery of a cylinder or disc which is worked in the manner described hereinbefore, meet the requirements of the Code.

As a matter of fact, A–105 Grade II material requires 22% minimum elongation in a longitudinal direction, and generally the highest value obtained if a billet is simply spread, as illustrated in FIG. 1, is only 11% elongation.

It is among the objects of the present invention to provide a method for readily and relatively inexpensively producing flat heads, tube-sheets and other pressure-resistant parts which meet all of the established requirements.

Another object is the provision of articles of the class described which possess greatly improved grain orientation and which, accordingly, are more resistant to strains induced by fluid pressures.

The foregoing and other objectives and advantages will become more readily understood from the following specification and annexed drawings wherein like parts are designated by like reference characters and wherein:

FIG .1 is a schematic elevational view of a conventional forging press which possesses the usual lower and upper die elements, and between which the initial work-piece or billet is disposed preparatory to conducting the method of the invention;

FIG. 2 is an edge-elevational view of a disc-like work-piece which has been obtained from the operation of the forging press of FIG. 1 and illustrating in dotted-lines certain sections or areas of metal which it is desired to displace for reasons which will appear hereinafter;

FIG. 3 is a front view which is related to FIG. 2, but disclosing a lower die element for use in achieving the displacement of the areas or sections of metal which are illustrated in FIG. 2;

FIG. 4 is an edge-elevational view of a work-piece which has been obtained by the operation of the forging press of FIG. 3;

FIG. 5 is an elevational view of the forging press with the work-piece illustrated in FIG. 4 horizontally disposed on the lower die member together with a superposed displacement tool which will be later described;

FIG. 6 is an elevational view of the set-up of FIG. 5 but with the displacement tool shown in the position it occupies at the conclusion of the operation of the forging press pursuant to the teachings of the invention;

FIG. 7 is an edge-elevational view of the work-piece at the conclusion of the method and with dotted lines representing the area from which a longitudinal test speciment may be taken;

FIG. 8 is a diagrammatic representation of a work-piece which has been made according to the method of the invention as welded to the component for which it is intended; and illustrating the flow pattern produced by the forging action, together with the location of a longitudinal test specimen; and

FIGS. 9, 10, 11 and 12 correspond to FIGS. 5, 6, 7 and 8 respectively, but illustrate a modification which comprises the formation of a final product wherein a right-angular flange or hub extends from both sides of the periphery of the central portion thereof.

According to the teachings of the present invention there is first obtained a solid metallic billet of desired composition which is heated to forging temperature.

Referring to FIG. 1 of the drawings, this solid metallic billet A is compressed between lower and upper die members **1** and **2**, respectively whose work-surfaces are flat and parallel with each other. The lower die member **1** may be stationary, with the upper die member **2** relatively movable with respect thereto in the manner illustrated by the arrows in FIG. 1.

While between the flat die members **1** and **2**, the periphery of the billet A is unconfined and, accordingly, made to acquire the rounded peripheral conformation as indicated at B'.

During this flattening step the direction of maximum work or metal displacement adjacent the periphery of the billet is tangential and results in high loss of ductility in the axial direction.

Referring to FIG. 3, the next step of the method involves the use of a lower die member **4** and cooperating upper flat die members or platen **5** with the heated and flattened billet B vertically disposed on its edge.

As shown, the working surface of the lower die member **4** comprises a pair of flat convergent surfaces **4***a* and **4***b* which are connected by a horizontally extending flat surface **4***c*.

While between the lower die member **4** and the platen or upper flat die member **5** the flattened and disc-shaped billet B is subjected to repeated compressional forces which are applied by the platen, and between which the billet is partially rotated on its axis as indicated by the accompanying arrow.

In moving downwardly the flat working-surface of the platen **5** applies flattening forces to the periphery of the disc-shaped billet B at the points indicated at *x*, *y* and *z*; and in between the application of these flattening forces the billet is rotated to an extent which is substantially the same as the length of the area of distortion, or metal displacement, which has just been obtained.

The direction of rotation is entirely optional as is the position of the edging die, and the degree thereof roughly a matter of several inches or so.

The application of the flattening forces at the points indicated at *x*, *y* and *z* achieves the working-down of the periphery of the disc-shaped billet B in increments which are represented in FIG. 2 at B^2, B^3, B^4 and B^5; and the end result is a periphery which is substantially flat in a direction which is parallel to the axis thereof, as represented by the line B^5 in FIG. 2.

Referring to FIGS. 2 and 3, while being so worked in the forging press those portions of the side surfaces of the transitory work-piece B which are adjacent the flat periphery described immediately hereinbefore retain their flatness to a degree but are moved outwardly as represented in solid lines in FIG. 4 due to the displacement of metal in the manner described.

At the same time, a substantial mass of metal is displaced toward the axis of the disc-shaped work-piece and it, accordingly, assumes the conformation illustrated in FIG. 4, wherein the work-piece C is generally indicated by the solid outline and the upset periphery and immediately adjacent portions of the side-wall are represented at C^1 and C^2, respectively. The intermediate portions of the sides of the work-piece C are concave as shown at C^3.

According to the teachings of the invention, FIG. 5 shows the work-piece C with its concave sides C^3 positioned horizontally on the lower flat die member **1** of the conventional forging press of FIG. 1 and with a disc-like displacement tool **8** having flat sides horizontally superposed thereon.

As further shown in FIG. 5 the horizontally disposed displacement tool **8** is of considerably smaller diameter than the diameter of the work-piece C and terminates adjacent the inner margin of the upper flat side surfaces C^2 and out of contact with the adjacent and connecting concave side portion C^3.

Next, the upper die element or platen **2** of the forging press is moved downwardly with adequate pressure to result in a work-piece D which possesses a flat bottom terminating in a flat and right-angularly extending periphery D^1, as shown in FIG. 6.

In lieu of an upper and lower concave side-wall portion (as in the case of the work-piece identified at C), the final work-piece D, as shown in FIG. 7, is provided by the displacement tool **8** with a flat inner wall D^3 which

is parallel to the bottom of the work-piece, and which is now also flat; together with a straight (i.e. flat) and right-angularly extending connecting wall D^4, the latter terminating in a right-angularly extending side-surface D^5 which, in turn, connects with the flat periphery D^1.

The transition represented by the changes in shape from the disc-like billet or work-piece B, shown in FIG. 1, to the work-piece C as illustrated in FIG. 4 results from a relatively light amount of hot-working of the metal at and adjacent the areas C^1 and C^2; with the maximum working direction near the periphery becoming longitudinal with an accompanying change in grain orientation.

Thus, the loss in ductility which resulted from the very substantial tangential flow of the metal adjacent the periphery in converting the work-piece or billet A to the disc-shaped work-piece B as represented in FIG. 1 is fully restored, and preferably improved, depending, of course, upon the extent of metal displacement which is achieved by the apparatus of FIG. 3.

As indicated earlier herein, it is particularly important in making articles such as heads, tube-sheets, and other pressure-resistant parts, that as prescribed by existing code requirements, there be provided in the hub the full minimum tensile strength and elongation specified for the material in a direction which is longitudinal or parallel to the axis of the work-piece or vessel on which it is employed; and this is readily achieved, and in a relatively inexpensive manner, by the method of the invention.

With a steel consisting essentially of:

	Percent (approx.)
Carbon	.28
Manganese	.79
Phosphorous	.016
Sulphur	.028
Silicon	.26

Iron the balance.

which is identified as A105 Grade II the minimum requirements of the American Society of Mechanical Engineers are as follows:

Location of test	-----
Orientation of test	-----
Ultimate tensile strength	70,000
Yield strength	36,000
Percentage of elongation	22
Percentage of reduction of area	30

EXAMPLE NO. 1

A disc-shaped work-piece B of the same steel as aforementioned was normalized at 1650° F., air-cooled, and given a relatively slight amount of working in the forging press of FIG. 3 (at the points represented at *x*, *y* and *z*) to reduce the outside diameter from 37 inches to 36⅛ inches (or only 2.5% reduction in circumference). As a result, the loss in ductility which was produced by the tangential flow at the periphery in converting from the initial solid work-piece A as shown in FIG. 1 to the disc-shaped solid work-piece B was not only restored to its initial value but was actually increased as demonstrated by the elongation of longitudinally oriented test specimens of a longitudinally worked forging of the same heat as demonstrated by the following:

No. of test	Location of test	Orientation of test	Ultimate tensile strength	Yield strength	Percentage of elongation	Percentage of reduction of area
1	¾″ from edge	Longitudinal	74,840	45,460	32.1	47.1
2	¾″ from edge but 180° from No. 1	do	74,000	48,100	30.7	49.6
3	2½″ from edge	do	73,400	43,600	29.3	39.3
4	2½″ from edge but 180° from No. 3	do	75,000	50,000	30.7	54.0
5	¾″ from edge	Tangential	74,600	44,400	33.6	48.6
6	2½″ from edge	do	75,200	44,900	33.6	54.8
7	2½″ from edge but 180° from No. 6	do	75,200	44,050	33.6	46.1

EXAMPLE NO. 2

A disc-shaped work-piece B of the same steel as aforementioned, was normalized at 1650° F., air-cooled and reduced, in the forging press (FIG. 3) from 37 inches in outside diameter to 35¼ inches (or 5% circumferential reduction) and showed even greater tensile strength and elongation than was the case in Example No. 1, as demonstrated by the following test results:

No. of test	Location of test	Orientation of test	Ultimate tensile strength	Yield strength	Percentage of elongation	Percentage of reduction of area
1	¾" from edge	Longitudinal	73,800	45,000	34.3	56.3
2	¾" from edge but 180° from No. 1	do	75,200	49,000	34.3	56.3

The teachings of the present invention contemplate the restriction of the downward movement of the disc-shaped displacement tool **8** into the work-piece to that point where the best physical properties are obtained. Excessive displacement of the metal will lower the values sought, as demonstrated by the following tests data which resulted from the practice of Example II as modified by continuing the downward movement of the disc-shaped displacement tool **8** for one (1) additional inch:

No. of test	Location of test	Orientation of test	Ultimate tensile strength	Yield strength	Percentage of elongation	Percentage of reduction of area
1	¾" from edge	Longitudinal	75,000	42,900	27.1	43.1
2	2½" from edge	do	74,600	41,300	26.4	42.8

It will be understood by those skilled in the art that the teachings of the present invention are applicable to most carbon steels and ferrous alloy steel combination, and that the particular steel described herein is by way of example only.

Due to the edging step which comprises the edge-wise hot-working of the metal with the apparatus shown in FIG. 3 the orientation of the grain of the metal at and adjacent the rim extends longitudinally of the axis of the work-piece, with the attendant improvement in the physical properties as described hereinbefore. This highly desirable effect is further improved when the work-piece (which is now of the modified hour-glass contour when viewed in transverse cross-section) is operated upon by the disc-shaped displacement tool **8** in the manner illustrated in FIGS. 6 and 7.

In addition, the combined edging operation and the effect of the displacement or plastic deformation by the displacement tool **8** results in such refinement of the central portion of the final product as to permit it to pass all of the required tests, including present day ultrasonic tests, etc.

The transition of the peripherally supported work-piece from the flattened disc-shape of FIG. 2 to the (hour glass) contour illustrated in solid lines in FIG. 4 has, for convenience, been described and shown (FIG. 3) with the modified V-shaped die member **4** beneath the flat die member **5**; but it will be understood by those skilled in the art that the position of these die members may readily be reversed; and the same holds true for the relationship of the displacement tool **8** (FIGS. 5 and 6) to the flat die member **1**.

Finally, all of the results and advantages of the method of the invention are obtained without the employment of expensive machining operations. Due to the operation in the apparatus of FIG. 3 the work-piece is upset on the rim as shown in FIG. 4 at C^2. The hour glass shape shown in FIG. 5 is then flattened in the center by displacement tool **8** and the cavity remaining in FIG. 7 is plainly shown, and it is likewise shown in FIG. 8 wherein the dotted lines delineate "Typical Outline of Product D as Forged," thus eliminating tremendous man-hours of machining. This is clearly the case if consideration is given to the machining of the product D of FIG. 8 from the mashed disc of FIG. 1.

Referring to FIGS. 9 through 12 of the drawings the modification comprises the manufacture of a final product which provides all of the advantages and objectives of the invention as described hereinbefore, but which is characterized by a right-angular flange or hub extending from both sides of the periphery of the central portion thereof.

According to this modification, two displacement tools **8'** are employed, one on either side of the concavities C^3 as shown in FIG. 9, each of the same being approximately ½ of the thickness of the previously described single displacement tool **8**. The conclusion of the forging operation employing two displacement tools **8'** is represented in FIG. 10; and FIG. 12 illustrates the final product with the two displacement tools removed and with the dotted lines representing the two areas from which the longitudinal test specimens should properly be taken.

FIG. 12 is a diagrammatic representation of a dual-hubbed, or dual-flanged work-piece which has been made in accordance with the modified form of the invention as welded to the components for which it is intended; and illustrating the flow pattern which has been produced by the forging action, together with the appropriate locations of the (2) longitudinal test specimens.

Having thus described the invention what I claim as new and desire to secure by Letters Patent is:

I claim:

1. The method of contour cavity forming by forging which consists essentially in:

obtaining a solid metallic work-piece;

flattening said work-piece between relatively flat and parallel die surfaces with accompanying increase in diameter and resultant disc-shape;

positioning in close adjacency to the disc-shaped work-piece, and in edgewise relationship thereto, a die member having spaced and outwardly convergent flat work-engaging surfaces;

applying forging pressures to the peripheral surfaces of said disc-shaped work-piece which are opposite said die member;

periodically imparting partial rotation to said work-piece;

continuing the application of said forging pressures until the disc-shaped work-piece assumes a modified hour-glass contour when viewed in transverse cross-section;

positioning the work-piece so formed with one of its major surfaces in contact with a relatively flat die member;

centering with respect to the opposite major surface of said work-piece a disc-shaped flat-sided die member of appreciably smaller diameter; and

applying pressure to said last-named die member until the entire area of the first-mentioned major surface of the work-piece becomes flat;

thereby obtaining a flat-bottomed cavity on one of the major surfaces of said work-piece with an adjacent annular rim with a relatively flat continuous side surface.

2. The method of claim **1** wherein the pressure applied to said last-named die member is discontinued at approximately the point where maximum physical properties are obtained.

3. The method of claim 1 wherein the solid metallic work-piece is a round billet with flat ends.

4. The method of producing a work-piece having a central wall portion and an integral rim of substantially rectangular cross-section which consists essentially in:

obtaining a solid metallic work-piece which is heated to forging temperature;

flattening said work-piece with its periphery substantially unconfined to thereby obtain an accompanying increase in diameter;

positioning in close adjacency to the flattened work-piece of increased diameter, and in edge-wise relationship thereto, a die member having spaced and outwardly convergent substantially flat work-engaging surfaces;

applying forging pressures to the peripheral surfaces of the work-piece which are opposite said die member;

periodically imparting partial rotation to said work-piece;

continuing the application of said forging pressures until the work-piece assumes a modified hour-glass contour when viewed in transverse cross-section;

positioning the work-piece so formed with one of its major surfaces in contact with a relatively flat die member;

centering with respect to the opposite major surface of said work-piece a die member of appreciably smaller diameter and having a relatively flat contact surface; and

applying pressure to said last-named die member until the entire area of the first-mentioned major surface of the work-piece becomes flat;

thereby obtaining a flat-bottomed cavity on one of the major surfaces of said work-piece with an adjacent annular rim with a relatively flat and continuous side surface.

5. A method of forming a peripherally curvilinear metallic body capable of withstanding high fluid pressures and adapted for welding to another fluid-handling body which includes:

obtaining a cylindrical metallic body of greater height than width and which is heated to forging temperature;

longitudinally compressing said cylindrical metallic body while peripherally unconfined between two flat-sided die members to form a flat-sided disc-shaped work-piece;

applying compressive forces to said flat-sided disc-shaped work-piece at spaced points about its periphery to thereby form a disc-shaped work-piece possessing an area adjacent its periphery which is of increased thickness and more centrally disposed and opposing concave portions which are of lesser thickness but greater width than said first-named area;

positioning a disc-shaped flat-sided displacement tool of substantially smaller diameter than the diameter of said work-piece over at least one of the centrally disposed concave portions thereof; and

applying compressive forces to cause said disc-shaped flat-sided displacement tool to form in said work-piece a disc-shaped cavity with a flat bottom and a right-angularly extending side-wall the top of which connects with a substantially flat right-angular surface which extends to the periphery.

6. The method of claim 5 wherein a disc-shaped flat-sided displacement tool is applied to each of the centrally disposed concave portions of the work-piece.

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U.S. Cl. X.R.

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