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3,234,052

BERYLLIUM SHEET AND METHOD OF PRODUCING SAME

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This invention relates to a method of producing relatively large, flat sheets and plates of beryllium by rolling a beryllium billet while the billet is clad in a removable metal jacket.

The present invention is directed to the hot rolling of jacketed beryllium billets into the form of plates and sheets of substantial area and thickness, as distinguished from small sheets of foil, which generally are less than 0.005 inch in thickness, and thin metal coupons of small area. The sheets contemplated, range, for example, from 0.020" to 0.375" in thickness, from 20" to 36" in width, and from 60" to 96" in length. In order to disclose fully the advance made in the art by the present invention, the pertinent practices heretofore performed in forming beryllium are reviewed briefly.

The prior methods contemplated the forging of beryllium and also the rolling of beryllium into coupons, foils, and shapes of limited area and thickness. There appears to be no prior method of rolling beryllium sheets and plates of substantial area and thickness.

A method disclosed in Creutz Patent No. 2,653,494, issued September 29, 1953, is directed to the forging of cast beryllium ingots and recognizes that unjacketed cast beryllium ingots cannot be forged at temperatures ranging from 500° C. to about 1200° C., without cracking, but that beryllium can be forged at temperatures in the neighborhood of 700° C. up to the melting point of the eutectic of beryllium and iron, if jacketed in a suitable metallic jacket. The patent shows that at temperatures above the minimum melting eutectic point of beryllium and the jacket metal, the beryllium tends to fuse and alloy with the jacket material. To avoid this, refractory barrier material such as a layer of calcium oxide is interposed between the beryllium and jacket. The purpose of the jacket is to prevent oxidation of the beryllium at the elevated temperatures exceeding 865° C. which are required for forging beryllium into products having satisfactory mechanical and physical properties. The higher temperature is to obtain the extremely rapid flow of beryllium necessary for forging.

Another prior method is that disclosed in Macherey Patent No. 2,872,363, issued February 3, 1959. This method is concerned with the rolling of beryllium metal into foil. It contemplates starting with a beryllium coupon of the thickness of about 0.004" and 2.5" x 2" and rolling the coupon to a thickness of about 0.002" at about 300° to 400° C., which are lower temperatures than used in Creutz. The beryllium is jacketed in a single jacket of stainless steel or is put between a folded sheet of stainless steel. Apparently, it was not considered necessary that the coupon be sealed to exclude outside air. The patent does not indicate any kind of barrier or non-oxidizing material is to be placed between the stainless steel and the beryllium coupon to prevent sticking. The method is not adapted for making sheets and plates of substantial size and thickness, but is limited rather specifically to the range of small coupons and foils, such as therein described.

In accordance with the present invention, it has been found that the results obtained in the rolling of beryllium billets into sheets of substantial area depend upon a number of factors, including the material used as the starting

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material for the rolling operation, the manner of enclosing the beryllium billets or partially formed sheets or plates in suitable jackets, and the steps and manner of initially seating the billet in the jacket, and of rolling, and in some instances, recladding, annealing, and subsequent rolling to the desired thickness. A most critical step is the initial cladding and the breakdown rolling step both as to the original billet and, if recladding is necessary, as to the newly re-clad partially rolled beryllium.

In accordance with the present invention, the starting material is vacuum hot-pressed beryllium, preferably such as made in accordance with Dodds U.S. Patent No. 2,818,339, issued December 31, 1957. In accordance with this patent, the billet is formed first by combined heat and vacuum below sintering temperature for a predetermined period, followed by continuance of the vacuum and an increase of the temperature into the sintering range while maintaining the beryllium mass under pressure to compact it during sintering into a billet which is of substantially theoretical density, for example, about 1.85 grams per cubic centimeter. The billet selected should be free from cavities and variations in density and substantially free from occlusions. The surface should be free from voids and cracks.

This particular billet is preferred because it has random grain distribution, i.e., isotropic properties. It is preferred over other beryllium bodies which are extruded, cast, or otherwise formed which have anisotropic properties. Billets formed by well-known melting and casting techniques have too low a density and too large a grain size to permit their being formed into sheets of substantially theoretical density, which is the preferred sheet with which the present invention is concerned. The billet which is used as the starting material is generally a block or slab, a rectangular parallelepiped being preferred. The block is machined so that all faces are smooth and the corners and edges are ground or sanded to a very small radius, for example, about 1/8 of an inch. It is cleaned to remove grease and foreign matter. As a result, it is true in shape yet free from abrupt, sharp corners and edges.

This block is coated with a thin film of parting compound. A suitable composition is colloidal graphite suspension, a form of which is sold on the market under the registered trademark "Aquadag" of which the Acheson Colloids Company, of Port Huron, Michigan, is the proprietor. Another suitable composition is a high-temperature graphite in water suspension available commercially under the registered trademark "Triple C" of which the Pro-Chem Company of Cleveland, Ohio, is the proprietor.

The parting compound is applied to the block in the form of a smooth coat, preferably by spraying or brushing an aqueous suspension thereof on the block with a spray gun or paint brush or the like, care being taken that no lumps are present, and then allowing the coating to dry. The coated block is then placed in a jacket of metal which has been similarly coated on the surfaces which are to contact the beryllium block. Such a metal jacket protects the beryllium from oxidation and confines it during the breakdown step of the rolling method employed. Preferably, the jacketing is effected by enclosing the peripheral edge faces of the block in a frame of rails formed of cold-rolled, mild steel bar stock of rectangular cross section. These rails have smooth planar faces adapted to engage the peripheral edge faces of the block. They are coated with the parting composition the same as the surfaces of the block. These rails are then clamped tightly in juxtaposition with the edge faces of the block and are welded together with mitered or butt joints, so that the block is confined peripherally.

The thickness of the rails, relative to the thickness of

the block, in the breakdown rolling step, is critical. The rails may be equal to, but must not exceed, the thickness of the block, and the optimum results are obtained when the rails are slightly less in thickness than the block, for example, the rails preferably are from 0.005" to 0.030" less in thickness than the block, the 0.005" less in thickness being preferred. Increasing the rail thickness to that of the block causes less consistent results and more rejections of sheets as scrap. Using rails greater than the thickness of the block results in a disproportionate decrease in the overall production of sheets of proper quality.

The width of the rails in the plane of the major faces of the block is generally about equal to the thickness of the block. The interior length and width of the frame as a whole are substantially equal to the like dimensions of the block itself.

With the block thus confined within the frame provided by the rails, suitable cover plates are attached. The cover plates are of hot-rolled and pickled steel; for example, commercial steel containing from 0.05 to 0.25%, by weight, of carbon generally is used. However, "stiffer" varieties of "high strength-low alloy" steel, such as SAE 4140 steels, may be used. Those faces of the cover plates which are to be juxtaposed against the block are smooth and polished. This may be accomplished by sanding the faces free and smooth from oxide, scale, and pits, and preferably by then polishing them with a fine sanding disc using 80C grits. Each plate is about one-half the thickness of the beryllium block and extends laterally and endwise of the frame a distance such that its peripheral edges are substantially flush with the outermost peripheral edges of the assembled rails. The inner faces of the cover plates are coated with the parting compound preparatory to applying them to the block. The plates are clamped in position and welded to the rails. Preferably, the rails are chamfered for welding purposes at their junctures with the plates, and the welding is done by means of welding rod. Molten welding rod material is interposed to fill up the chamfers so that the outer surfaces of the jacket define a rectangular parallelepiped.

A suitable vent is provided in the jacket to permit escape of the various gases and the like. Preferably, it is formed in one of the side rails, usually the side rail which is to be in the trailing direction in the initial or breakdown rolling operation. One or more vent holes of about 1/4" in diameter are adequate for this purpose.

With the block jacketed as above described, the breakdown rolling is initiated. For this purpose, the jacketed block assembly is heated to a temperature of from about 675° C. to about 860° C., about 760° C. being preferred. Care is taken that the temperature is relatively uniform throughout.

The initial passes of the breakdown step are referred to herein as the seating passes and the first one of these is used to effect approximately 0.1 to 0.5% reduction in thickness of the block and may be accomplished under the mere weight of the upper roll of the mill stand. This first pass is to compress the juxtaposed surfaces of the jacket and block throughout their extent into contact and conformity with each other, thus assuring that the billet fills the jacket uniformly. The seating passes are preferably bidimensional, comprising four successive passes in a rolling direction which is shifted progressively either counterclockwise or clockwise at 90° per pass. As mentioned, the first of these passes causes 0.1 to 0.5% reduction in thickness of the block and may be effected by the mere weight of the upper roll of the mill stand. In the next three passes, each reduction is increased over the preceding one from the 0.1 to 0.5% of the first pass up to a maximum of 10%, a reduction of from 6% to 10% is preferred.

Breakdown rolling follows seating and may be unidimensional, alternating in direction of rolling 180° at successive passes, that is, rolling from one edge to the opposite edge, and then from said opposite edge to the one

edge. Passes subsequent to seating can approach maximum permissible reduction per pass of 15% of the thickness of the block at the start of the pass, and as mentioned, can be either unidimensional or bidimensional, thus alternating in direction 180° per pass or 90° per pass. Usually unidimensional rolling is preferred.

An indefinite number of passes may be used in the breakdown rolling step, but if the overall thickness of the jacketed block is one inch or more, the temperature should preferably remain about 760° C., and if the thickness is less than one inch, then generally it is preferable to heat to 760° C. and employ one pass per heat.

The total reduction per pass during the breakdown rolling step should not be greater than 15% nor less than 6% of the thickness of the beryllium metal existing at the beginning of the particular pass. The total overall reduction, regardless of the number of passes, during the breakdown operation should not be greater than a maximum of 8:1 for any single jacketing or cladding of the block.

Upon completion of the breakdown rolling, the block is clad stress relieved in its original jacket. Preferably, this done by raising it to a temperature of about 760° C. and holding it at that temperature for a period of about ten minutes after it is heated uniformly throughout, following which the clad block assembly is slowly cooled in vermiculite to a temperature below red heat and preferably to about room temperature. After it reaches the latter temperature, the jacket is removed, either by torch cutting or otherwise, care being taken that the torch does not impinge upon the block and subject the beryllium metal to thermal shock which is apt to cause cracking and other deleterious effects.

After the original jacket has been removed from the block, the block is stress relieved, preferably by heating it to about 760° C., maintaining that temperature from about ten to about thirty minutes dependent upon the gauge or thickness of the block. It is then slid from the furnace onto an asbestos board which allows it to lie flat. When it starts to lose color, it is turned over and after all color is gone, it is stood on edge and allowed to cool to room temperature. If badly warped, it may be flattened by heating it in the same manner and then placing it under pressure between hot or insulated platens for about ten minutes, and then removing it from the platens and allowing it to cool as above.

Following the breakdown rolling, one or more additional rolling operations may be provided and these are generally termed intermediate rolling operations. However, it is to be borne in mind that the number of these will be determined by the thickness of the starting block and the thickness desired in the finished piece. Sometimes a single so-called intermediate rolling operation is all that is necessary.

After the block has been cooled following the stress relief, its surface is cleaned by a light sanding or by means of an abrasive wheel or disc which removes the parting compound and surface oxides. After abrasive cleaning of the clad-rolled beryllium surface, the metal is pickled in an aqueous solution containing twenty-five percent nitric acid and one-half of one percent sulfuric acid. Abrasion and pickling of the surface is continued until the surface is free from beryllium oxide. After final pickling, the plate is flushed with water and allowed to dry. Thereupon, the plate thus produced is cut to size in any suitable manner, such as by abrasive or band saws. The edges are then sanded and abraded so as to remove sharp corners, preferably to a radius of about 1/16 of an inch, and the entire surface of the workpiece may be smoothed if desired by grinding, polishing and the like. It is then spray coated with the parting compound. The coating is applied smoothly and then allowed to dry, and the piece then enclosed in a frame, all as heretofore described, with rails of a thickness equal to approximately the block or slab thickness and of a width of approximate-

ly one inch. Rails with square ends shall be used for a butt type frame for unidimensional rolling. Rails with mitered ends shall be used for bidimensional rolling. The faces of the rails facing the block and also those faces which will face the cover plates are then coated with the parting composition. The cover plates, prepared as heretofore described, and from one half to four times the thickness of the beryllium, are applied. The sheets have a width and length such that they extend beyond the outer peripheral edge face of the frame an amount equal to about one-half the thickness of the rails in a direction parallel to the plane of the major faces of the block. The plates, when clamped in this position, are then welded in place and the space between the outer edge of the frame and the overhanging margins of the cover plates is filled with molten welding material so that the outer surface of the jacketed piece is again substantially a rectangular parallelepiped. If the rails are one inch or more in thickness, they are chamfered and the mitered ends V-grooved and filled with the welding material. If the rails are less than one inch in thickness, this is not necessary. The trailing edge rail is vented.

For the intermediate rolling, the jacketed block is preheated uniformly to from about 650° C. to about 860° C., and preferably to 760° C., and the latter temperature maintained for an hour per inch overall thickness of the jacketed assembly to assure uniform heating. It is reheated between passes, if necessary, to provide and maintain a temperature ranging from about 650° C. to about 860° C. during rolling.

The initial pass effects a reduction of 0.1 to 0.5% which may be accomplished under the mere weight of the upper roll of the mill stand. The reduction effected in each of the next two seating passes is increased to approach the 10% reduction employed in subsequent rolling passes. Reductions per pass, after the initial passes, shall not exceed 15% nor be less than 6% of the beryllium metal thickness at the beginning of the pass. An overall reduction of 6:1 shall be the maximum for each cladding.

The intermediate rolling shall generally be unidimensional, alternating rolling directions 180° each pass. Bidimensional rolling will only be used in special cases. However, the intermediate slab rolling, when unidimensional, will generally be in a cross dimension, that is, a dimension 90° to the dimension in which the breakdown rolling was carried out. Generally, only one pass per heating is used so as to assure that the rolling temperature is not less than 650° C., and preferably is about 760° C., when the metal becomes relatively thin. Reduction less than the 6% lower and greater than the 15% upper critical limits described above results in defective plates or sheets. If bidimensional rolling is used, then the intermediate rolling may start in any direction, but preferably at right angles to the initial pass of the breakdown rolling operation. After the rolling operation, the jacketed sheet is clad stress relieved in the same manner as after the breakdown operation, usually heating it to about 760° C. for about ten minutes and cooling it in vermiculite. Thereafter, the jacket is removed.

As many intermediate rolling steps as required to reduce the sheet to the desired thickness may be employed. Furthermore, depending upon the desired reduction, the stock can be reclad and rolled any number of times until the final thickness is reached. The stock is bare stress-relieved when the jacket is removed prior to each recladding operation, followed by clad stress relief of the assembly. After the final clad stress relief, and removal of the cladding material, the sheet is bare stress relieved, and also flattened, if required, as above described. Thereafter, it is cleaned by grinding and is pickled, as above mentioned, in an aqueous solution of nitric and sulfuric acid, following which it is dried and trimmed to size.

The following examples are illustrative of a preferred

operation of the process of the invention and are not to be considered limiting thereof in any respect.

EXAMPLE 1

A beryllium billet of dimensions 0.770" x 13" x 16", vacuum hot pressed in accordance with the teachings of U.S. Patent No. 2,818,339, was encased in a picture frame assembly as hereinbefore described, the mild steel rails of the picture frame assembly were machined at their top edges so that their vertical height was about 0.005" less than the 0.770" vertical height of the beryllium billet. The mild steel covers were each about one half the thickness of the beryllium billet. The assembly was then welded together as described above, so that the beryllium billet was tightly sealed in the covered frame, the interior peripheral edge faces of the rails and the inner faces of the cover plates having been coated with "Aquadag," an aqueous colloidal graphite suspension, prior to welding rails and cover plates into a unit assembly containing the beryllium block. The picture frame assembly was then heated to about 790° C. and passed through the rolls of a two-high Mesta mill with the initial seating passes made under only the weight of the top roller of the two 30-inch wide rollers to properly seat the assembly. Four initial successive seating passes were made in a clockwise direction alternating 90° per pass. The heated assembly, while being maintained at a temperature of between 760° C. and 790° C., was then unidimensionally rolled to an overall reduction ratio of about 4.25:1. After completion of the breakdown rolling, the clad block was stress relieved at a temperature of about 760° C., maintained for about 10 minutes, and followed by cooling in vermiculite. The jacket assembly was removed by torch cutting. The dimensions of the beryllium block at this state of the operation were 0.178" x 47 $\frac{7}{8}$ " x 18 $\frac{1}{2}$ ". The clad-rolled beryllium plate was then bare stress-relieved for about 10 minutes at about 760° C. after which it was cooled to room temperature on a flat insulated surface. After being cooled, the plate was lightly sanded with sand and water to remove the parting compound and subsequently further sand cleaned alternated with pickling in an aqueous solution containing 25% nitric acid and 0.5% sulfuric acid until the surface was free from excessive oxides. The beryllium plate was then sawed in half to provide two plates each having the dimensions of 0.178" x 22" x 18 $\frac{1}{2}$ ". The edges were then sanded to remove sharp corners and burrs. The surfaces of the plate adjacent to the frame were then coated with a composition of Aquadag and the top and bottom faces of the rails coated with chromium sesqui-oxide, and the coating dried. Each plate was then encased in a picture frame assembly in a similar manner as in the above breakdown rolling operation. In this case, however, the cover plates extended beyond the outer peripheral edge or face of the frame an amount equal to about one half the thickness of the rails in a direction parallel to the plane of the plate. The assembly was then uniformly heated to a temperature of 745° C. to 760° C. and unidimensionally rolled to an overall reduction ratio of 2.84:1, in a direction transverse to that of the breakdown rolling. The encased beryllium sheet after being clad-annealed, cooled, and removed from the jacket as in the above breakdown rolling step, had the dimensions of 0.06" x 22" x 53". The sheet was subsequently bare stress relieved, sanded and pickled as in the breakdown rolling operation, and trimmed to dimensions of 0.055" x 22" x 50 $\frac{1}{2}$ ". The beryllium sheet was then coated with Aquadag, the top and bottom edge faces coated with chromium sesqui-oxide, and the sheet encased in a picture frame assembly in the same manner as for the intermediate rolling operation, with the exception that stainless steel interleaves were interposed between the top and bottom surfaces of the beryllium sheet and the inner faces of each of the two cover plates of the picture frame assembly prior to welding the unit.

Said stainless steel interleaves were unattached to and supported only by the welded assembly. The assembly was then uniformly heated to a temperature range of between about 745° C. to 760° C. and unidimensionally rolled to an overall reduction ratio of 1.275:1 in the same direction as in the first above intermediate rolling operation, then clad stress relieved and removed from the jacket.

The sheet having the dimensions 0.045" x 22 $\frac{3}{16}$ " x 64 $\frac{7}{16}$ " was then cleaned by grinding and pickling and bare-annealed as in the first intermediate rolling step. The sheet after being trimmed to final dimensions of 0.040" x 20" x 40", had the properties noted below in Table I.

EXAMPLE 2

The same procedure was followed as in Example 1 with the exception that the block used for breakdown rolling had the dimension 1.05" x 17" x 17" which after being subjected to an overall reduction ratio of 4.6:1 had the dimensions 0.222" x 19 $\frac{1}{16}$ " x 68". This plate was sawed into three equal sections, and one section having the dimensions 0.222" x 19 $\frac{1}{16}$ " x 22", after being reclad following the procedure of Example 1, was rolled to an overall reduction ratio of 2.8:1 to the dimensions of 0.076" x 55" x 22". This sheet was then trimmed to the dimensions of 0.076" x 46 $\frac{3}{4}$ " x 21" and clad in the aforescribed picture frame with the stainless steel interleaves between the cover plates and the top and bottom surfaces of the billet and rolled to an overall reduction ratio of 1.49:1 to the dimensions of 0.052" x 69 $\frac{5}{8}$ " x 21 $\frac{1}{16}$ ". The sheet of Example 2, after being bare-annealed, ground, pickled and trimmed, had the final dimensions 0.04" x 60" x 20", and the properties noted below, in Table I.

Table I

PROPERTIES OF CLAD-ROLLED AND GROUND BERYLLIUM SHEET

Example	Tensile Properties								Surface Hardness Rockwell B Scale	Density (g./cc.)
	Direction of Test	Strain Rate (in./in./min.)	Ultimate Tensile Strength (k.s.i.)	Yield Strength 0.2% Offset (k.s.i.)	Proportional Limit (k.s.i.)	Percent Elongation	Percent Reduction in Area	Modulus of Elasticity (10 ⁶ p.s.i.)		
1-----	Longitudinal-----	0.0171	77.4	56.5	48.8	16.2	14.2	41.3	*71	1.854
	Transverse-----	0.0138	74.4	52.2	41.2	11.7	11.4	41.7	*71	1.854
2-----	Longitudinal-----	0.0088	72.2	58.9	40.9	7.5	8.2	41.8	94	1.86
	Transverse-----	0.0085	75.9	58.3	44.6	13.2	12.2	41.2	94	1.86
3-----	Longitudinal-----	0.0075	77.8	56.3	38.3	14.0	12.2	42.0	97	1.858
	Transverse-----	0.0097	75.6	52.8	39.5	16.5	15.2	42.3	97	1.855

*Rockwell 45T Scale.

EXAMPLE 3

Following the procedure of Example 1, a block of the dimensions 0.755" x 17" x 17" was rolled to an overall reduction ratio of 3.2:1 to dimensions of 0.204" x 54 $\frac{7}{8}$ " x 19 $\frac{1}{2}$ ". This plate was then heated, cleaned and pickled in accordance with the procedure of Example 1. The plate was then subjected to one intermediate rolling reduction at a ratio 4.95:1 on a large Hyde Park two-high rolling mill to final as-rolled dimensions of 0.042" x 38 $\frac{1}{2}$ " x 96 $\frac{1}{16}$ ". This sheet was then trimmed and ground to the dimensions of 0.040" x 36" x 78". In this example, only one intermediate rolling step was required because of the large size of the Hyde Park rolling mill, and this example is representative of the process of the invention where only one intermediate rolling step is required. The final sheet product of Example 3 had the properties noted above, in Table I.

If desired, for the final rolling, two stainless steel sheets of 0.035" of the same length and width as the block, may be placed between the polished and coated faces of the block and the cover plates. Also, if desired, up to 0.005" of metal may be removed from each face of the sheet, for

example, by grinding with a pinch-roll sheet grinder. The ground sheet may then be pickled, as described, to reduce the thickness of the beryllium sheet a total of 0.003 to 0.004 of an inch.

In the description and claims, the word "sheets" is used in the sense of metal sheets and plates of substantial area, body, and thickness, and having sufficient strength and rigidity for use in fabricated structures, as distinguished from foils of small size, and small thin coupons having negligible strength for structural purposes, as disclosed in the prior art methods hereinbefore described. Typical dimensions, physical and other properties of sheets made by the present process are shown in the examples listed hereinbefore.

Having thus described my invention, I claim:

1. In the method of making flat beryllium sheets, the breakdown rolling step comprising providing a beryllium block of substantially theoretical density and in the form of a right angled parallelepiped of accurate dimension and having its opposite major faces and its edge faces smooth and planar and its corners and corner edges rounded to a short radius, snugly embracing the block peripherally edgewise in a rigid frame of metal rails of which the thickness normal to the planes of the major faces of the block approximates but does not exceed that of the block, and which are welded securely together at their corners, providing on the block surfaces a coating of a composition for reducing oxidation and facilitating parting, covering the major faces of the block and of the frame by applying to opposite major faces of the block and the frame metal cover plates which are substantially coextensive with the outer peripheral limits of the frame, bonding each plate along its entire peripheral edge to the frame to form a

jacket, relief venting the jacket, then heating the block and jacket assembly into a temperature range of about 650° C. to 860° C. uniformly throughout, rolling the assembly while it is within said temperature range with an initial pass under relatively light pressure sufficient to cause the complementary surfaces of the jacket and block to be in firm contact and planar conformity with each other throughout their extent, then rolling the assembly, while it is in said range, at a predetermined pressure to cause an overall reduction ratio not to exceed 8:1, characterized in that the breakdown rolling step is followed by stress relieving the rolled assembly at about 760° C., de-jacketing the stress relieved block, cleaning the de-jacketed block, and bare stress relieving it at a temperature of about 760° C.

2. The step according to claim 1 wherein the side rails of the frame are from 0.005" to 0.030" less in thickness than the beryllium block.

3. The step according to claim 1 wherein the composition is a colloidal graphite composition.

4. The step according to claim 1 wherein the composition is chromium sesqui-oxide.

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5. The step according to claim 1 wherein the initial pass is followed by three successive passes in directions 90° apart from each other.

6. The method according to claim 5 wherein, after said initial and said three succeeding passes, the rolling is continued unidimensionally.

7. The step according to claim 5 wherein each of said successive passes provides a reduction from about 6% to about 10% of the thickness of the beryllium block existing at the start of the particular pass.

8. The method according to claim 5 wherein after said initial and said three succeeding passes, the rolling is continued bidimensionally.

9. The method according to claim 1 wherein the block is rejacketed, the assembly rolled at a temperature in the range of 730° C. to 790° C. at a pressure to cause not more than an overall reduction ratio of 6:1 and stress relieved, then the block is dejacketed and bare stress relieved.

10. The method according to claim 1 wherein the bare stress relieved sheet does not exceed 0.08" in thickness, and the sheet is cleaned and re clad, then further reduced by hot rolling the assembly.

11. The method according to claim 9 wherein the re-rolling is by an initial light pressure seating pass, followed by additional seating passes at greater pressure, and is carried out one reduction pass per heat, and the reduction per pass is from 6% to 15%.

12. The method according to claim 1 wherein the block is cleaned and pickled preparatory to rejacketing, the re-jacketing is in a frame comprising rails having a thickness

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in a direction normal to the plane of the major faces of the block equal approximately to the block thickness and of a width at least as great as the block thickness, and cover plates equal to one-half to four times the thickness of the block being rejacketed, and each cover plate extends outwardly beyond each peripheral face of the frame approximately one-half of the rail thickness, the channels defined by the outer peripheral edge faces of the frame and the adjacent faces of the plates outwardly therefrom being filled with weld metal.

13. The method according to claim 12 wherein composition is disposed between the faces of the rejacketed block and the cover plates and rails, and also between the margins of the cover plates and the rail faces contacting said margins.

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