I claim:

1. A method of attaching at least one cladding element sheet at least partially made of a first metal to a base element sheet at least partially made of a second metal, the method comprising the steps of:

(a) positioning said at least one cladding element sheet spaced apart from the base element sheet to locate a first inner side of said at least one cladding element sheet facing a second inner side of the base element sheet, for defining a slot therebetween having a predetermined width, said at least one cladding element sheet having a first outer side thereof opposite to the first inner side, and the base element sheet having a second outer side thereof opposite to the second inner side;

(b) locating at least one heating element in the slot;

(c) providing a non-oxidizing atmosphere in the slot, the non-oxidizing atmosphere covering the first and second inner sides;

(d) energizing said at least one heating element, to heat the first inner side and the second inner side to a first hot working temperature of the first metal and a second hot working temperature of the second metal, wherein said at least one heating element is configured to distribute heat energy therefrom evenly over each of the first and second inner sides, heating the cladding element sheet and the base element sheet to predetermined first and second depths relative to the first and second inner sides respectively, to provide heated first and second layers of the cladding element sheet and the base element sheet respectively;

(e) removing said at least one heating element from the slot;

(f) while the first and second layers are at the first and the second hot working temperatures, ~~engaging~~moving one or both of said at least one cladding element

sheet and the base element sheet in a preselected direction orthogonal to the first and second inner sides to engage the first and second inner sides with each other;

(g) while the first and second inner sides are engaged with each other and while the first and second layers are at the first and the second hot working temperatures, ~~moving at least part of one of said at least one cladding element and the base element relative to the other of said at least one cladding element and the base element, to at least partially plastically deform the first and second layers to subject the first and second layers to shear stresses; and~~

(i) percussively engaging the first outer side at a plurality of first points thereon spaced apart from each other, to push the first inner side in a direction parallel to the preselected direction, at respective first locations on the first inner side aligned with the plurality of first points respectively, against the second inner side, and

(ii) percussively engaging the second outer side at a plurality of second points thereon spaced apart from each other, to push the second inner side in the direction parallel to the preselected direction, at respective second locations on the second inner side aligned with the plurality of second points respectively, against the first inner side, the respective second locations and the respective first locations being aligned, to at least partially plastically deform the first and second layers, subjecting the first and second layers to shear stresses to achieve at least partial uniformity of microstructures of the first and second layers; and

(h) permitting the first and second layers to cool to a predetermined temperature, for recrystallization of the first and second layers, that are thereby bonded to each other.

~~2. A method according to claim 1 in which at least one of the first inner side and the second inner side is scored, for engagement of the first and second inner sides with each other.~~

3. A method according to claim 1 in which, in step (f), one or both of said at least one cladding element and the base element are moved in a preselected direction that is orthogonal to the first and second inner sides, and in step (g), the movement of said at least part of one of said at least one cladding element and the base element is transverse to the preselected orthogonal direction.

4. A method according to claim 1 in which, in step (f), one or both of said at least one cladding element and the base element are moved in a preselected direction that is orthogonal to the first and second inner sides, and in step (g), the movement of said part of said at least one of said at least one cladding element and the base element is effected by percussively engaging said part of said at least one of said at least one cladding element and the base element in a direction parallel to the preselected orthogonal direction.

5. A method of attaching at least one cladding element at least partially made of a first metal and a base element at least partially made of a second metal together, the method comprising the steps of:

(a) positioning said at least one cladding element spaced apart from the base element to locate a first inner side of said at least one cladding element facing a second inner side of the base element, for defining a slot therebetween having a predetermined width;
(b) locating at least one heating element in the slot;
(c) providing a non-oxidizing atmosphere in the slot, the non-oxidizing atmosphere covering the first and second inner sides;
(d) energizing said at least one heating element, to heat the first inner side and the second inner side to a hot working temperature of the first metal and the second metal, wherein said at least one heating element is configured to distribute heat energy therefrom evenly over each of the first and second inner sides, heating the cladding element and the base element to predetermined first and second depths relative to the first and second inner sides respectively, to provide heated first and second layers of the cladding element and the base element respectively;
(e) removing said at least one heating element from the slot;

~~(f) while the first and second layers are at the hot working temperature, engaging the first and second inner sides with each other;~~

~~(g) while the first and second inner sides are engaged with each other, pressing at least part of one of said at least one cladding element and the base element against the other of said at least one cladding element and the base element, to at least partially plastically deform the first and second layers to subject the first and second layers to shear stresses; and~~

~~(h) permitting the first and second layers to cool to a predetermined temperature, for recrystallization of the first and second metals in the respective first and second layers, that are thereby bonded to each other.~~

~~6.~~2. A method ~~of attaching at least one cladding assembly at least partially made of a cladding element and a first metal element comprising a first metal, and a base element at least partially made of a second metal, the method~~ comprising the steps of:

(a) securing a non-metallic ~~the~~ cladding element and ~~the~~a first metal element comprising a first metal together, to form ~~said~~ at least one cladding assembly sheet;

(b) positioning said at least one cladding assembly sheet spaced apart from ~~the~~a base element sheet at least partially made of a second metal to locate a first inner side of said at least one cladding assembly sheet facing a second inner side of the base element sheet, for defining a slot therebetween having a predetermined width, the first inner side of said at least one cladding assembly sheet being formed to adhere to the second inner side, said at least one cladding assembly sheet having a first outer side thereof opposite to the first inner side, and the base element sheet having a second outer side thereof opposite to the second inner side;

(c) locating at least one heating element in the slot;

(d) providing a non-oxidizing atmosphere in the slot, the non-oxidizing atmosphere covering the first inner side and the second inner side;

(e) energizing said at least one heating element, to heat the first inner side and the second inner side to a first hot working temperature of the first metal and a second hot working temperature of the second metal, wherein the at least one heating element is configured to distribute heat energy therefrom evenly over each of the first and second inner sides, heating the first metal element and the base element sheet to predetermined first and second depths relative to the first and second inner sides respectively, to provide heated first and second layers of the first metal element and the base element sheet respectively;

(f) removing said at least one heating element from the slot;

(g) while the first and second layers are at the first and the second hot working temperatures, ~~engaging~~ moving one or both of said at least one cladding assembly sheet and the base element sheet in a preselected direction orthogonal to the first and second inner sides to engage the first and second inner sides with each other;

(h) while the first and second inner sides are engaged with each other~~, moving at least part of one of~~ and while the first and second layers are at the first and the second hot working temperatures,~~metal element and the base element relative to the other of the first metal element and the base element, to at least partially plastically deform the first and second layers, subjecting the first and second layers to shear stresses; and~~

(i) percussively engaging the first outer side at a plurality of first points at first locations thereon spaced apart from each other, to push the first inner side in a direction parallel to the preselected direction, at respective first locations on the first inner side aligned with the plurality of first points respectively, against the second inner side, and

(ii) percussively engaging the second outer side at a plurality of second points thereon spaced apart from each other, to push the second inner side in the direction parallel to the preselected direction, at respective second locations on the second inner side aligned with the plurality of second points respectively, against the first inner side, the respective second

locations and the respective first locations being aligned, to at least partially plastically deform the first and second layers, subjecting the first and second layers to shear stresses to achieve at least partial uniformity of microstructures of the first and second layers; and

(i) permitting the first and second layers to cool to a predetermined temperature, for recrystallization of the first and second metals in the respective first and second layers, that are thereby bonded to each other.

~~7. A method according to claim 6 in which at least one of the first inner side and the second inner side is scored, for engagement of the first and second inner sides with each other.~~

~~8.~~3. A method according to claim 1 in which:

~~(a)~~ ____said at least one cladding element sheet comprises first and second cladding element~~s~~ sheets, each of said first and second cladding element sheets having an edge, the edges of the first and second cladding element~~s~~ sheets being located proximal to each other after the first and second cladding element~~s~~ sheets are attached with the base element sheet, said edges defining an opening therebetween, each of said first and second cladding element sheets comprising a thick region extending along the edge thereof respectively, each of the thick regions being thicker than ~~the~~a balance of the respective first and second cladding element~~s~~ sheets;

~~(b)~~ ____at least one supplemental heating element is positioned proximal to the thick regions of the first and second cladding element~~s~~ sheets;

~~(c)~~ ____said at least one supplemental heating element is energized, to heat the thick regions of the first and second cladding element~~s~~ sheets to a thick region hot working temperature, in a non-oxidizing atmosphere; and

~~(d)~~ ____with at least one forming device, the thick regions are plastically deformed, to fill the opening.

~~9.~~4. A method according to claim ~~8~~3 in which the thick regions are overlain by an additional cladding element that is heated to an additional cladding hot working temperature in a non-oxidizing atmosphere by an energized heating element, and secured to the thick regions by said at least one forming device while the additional cladding element is at the additional cladding hot working temperature and the thick regions are at the thick region hot working temperature.

~~10.~~5. A method according to claim 1 in which:

~~(a)~~ said at least one cladding element sheet comprises first and second cladding element~~s~~ sheets, each of said first and second cladding element~~s~~ sheets comprising an edge, the edges of the first and second cladding element~~s~~ sheets being located proximal to each other after the first and second cladding element~~s~~ sheets are attached to the base element sheet to define a boundary region including an opening therebetween;

~~(b)~~ at least one additional cladding element is located spaced apart from the first and second cladding element~~s~~ sheets proximal to the edges thereof to define an additional element gap between said at least one additional cladding element and the first and second cladding element~~s~~ sheets;

~~(c)~~ at least one heating element is positioned between said at least one additional cladding element and the first and second cladding element~~s~~ sheets;

~~(d)~~ said at least one heating element is energized in a non-oxidizing atmosphere, to heat said at least one additional cladding element and respective portions of the first and second cladding element~~s~~ sheets that are proximal to the edges thereof to an additional cladding element hot working temperature;

~~(e)~~ while said at least one additional cladding element and the respective portions of the first and second cladding element~~s~~ sheets are at the additional cladding element hot working temperature, engaging said at least one additional

cladding element with the respective portions of the first and second cladding element~~s~~ sheets at the edges thereof wherein said at least one additional cladding element covers the boundary region;

~~(f)~~ while said at least one additional cladding element is engaged with the respective portions of the first and second cladding element~~s~~ sheets, moving at least part of said at least one additional cladding element relative to the respective portions of the first and second cladding element~~s~~ sheets, to plastically deform said at least one additional cladding element and at least ~~a portion~~parts of the respective portions of the first and second cladding element~~s~~ sheets; and

~~(g)~~ permitting said at least one additional cladding element and the respective portions of the first and second cladding element~~s~~ sheets to cool to the predetermined temperature, for recrystallization of said at least one additional cladding element and the respective portions of the first and second cladding element~~s~~ sheets for bonding thereof, wherein said at least one additional cladding element is thereby bonded to the respective portions of the first and second cladding element~~s~~ sheets and said at least one additional cladding element at least partially fills the opening.

6. A method according to claim 3 in which, when the thick regions of the first and second cladding element sheets are at the thick region hot working temperature, a part of the thick region of the second cladding element sheet is first pushed in one direction into the opening, and the thick region of the first cladding element sheet is subsequently pushed in another direction onto the part of the thick region of the second cladding element sheet that is in the opening.

7. A method according to claim 1, wherein the first hot working temperature of the first metal is less than a melting temperature of the first metal and the second hot working temperature of the second metal is less than a melting temperature of the second metal.

8. A method according to claim 1, wherein percussive engagement at the plurality of first points pushes the first inner side in a first direction and percussive engagement at the plurality of second points pushes the second inner side in a second direction opposite of the first direction.

9. A method according to claim 8, including simultaneously plastically deforming portions of the first layer at the first locations and plastically deforming portions of the second layer at the second locations that are aligned with the first locations as a result of percussive engagement in opposing directions such that the first and second layers are bonded with each other, and wherein such bonding takes place only at aligned locations of the first and second heated where percussive engagement is effected.

10. A method according to claim 2, wherein the first hot working temperature of the first metal is less than a melting temperature of the first metal and the second hot working temperature of the second metal is less than a melting temperature of the second metal.

11. A method according to claim 2, wherein percussive engagement at the plurality of first points pushes the first inner side in a first direction and percussive engagement at the plurality of second points pushes the second inner side in a second direction opposite of the first direction.

12. A method according to claim 11, including simultaneously plastically deforming portions of the first layer at the first locations and plastically deforming portions of the second layer at the second locations that are aligned with the first locations as a result of percussive engagement in opposing directions such that the first and second layers are bonded with each other, and wherein such bonding takes place only at aligned locations of the first and second layers where percussive engagement is effected.

~~11.~~13. A method of ~~covering a base element that defines a vessel including a tube portion and a body portion defining a chamber therein, the tube portion defining a channel therein in fluid communication with the chamber, to permit flow through the tube portion in a predetermined downstream direction~~attaching at least one cladding element sheet at least

partially made of a first metal to a base element sheet at least partially made of a second metal, the method comprising:

(a) providing inner and outer cladding elements;

(b)(a) securing innerseparating the at least one cladding element sheet to from the base element sheet by a slotdownstream relative to the downstream direction, the inner cladding element having at least one edge thereof positioned proximal to the channel;

(c) positioning the outer cladding element to cover said at least one edge and at least part of the inner cladding element;

(d) heating the outer cladding element to a hot working temperature thereof, in a non-oxidizing atmosphere;

(b) locating at least one heating element in the slot;

(c) providing a non-oxidizing atmosphere in the slot, the non-oxidizing atmosphere covering a first inner side of the at least one cladding element sheet and a second inner side of the base element sheet;

(e) with at least one forming device, forming the outer cladding element to cover said at least one edge and said part of the inner cladding element.

12. A method of filling an opening in a cladding element secured to a base element, the opening being defined by at least one side of the cladding element, the method comprising:

(a) providing a patch cladding element having a central region with a central region thickness and an outer region with an outer region thickness that is greater than the central region thickness, the difference between the outer region thickness and the central region thickness being an outer region projection;

(b) securing the patch cladding element in the opening wherein the patch cladding element is located in the opening to define a trough between the patch cladding element and the cladding element;

(d) energizing the at least one heating element to heat the first inner side to a first hot working temperature of the first metal and to heat the second inner side to a second hot working temperature of the second metal, wherein the first hot working temperature of the first metal is less than a melting temperature of the first metal and the second hot working temperature of the second metal is less than a melting temperature of the second metal, and heating the at least one cladding element sheet and the base element sheet to predetermined first and second depths relative to the first and second inner sides respectively, to provide heated first and second layers of the at least one cladding element sheet and the base element sheet respectively;

(c)(e) with aremoving said at least one heating element from the slot, heating the outer region to a hot working temperature thereof in a non-oxidizing atmosphere;

(d) with a forming device, pushing the outer region projection into the trough; and

(e) permitting the patch cladding element to cool to a predetermined temperature, for recrystallization of the outer region projection in the trough, for bonding the outer region projection with the base element and the cladding element.

13. A method of covering a base element that defines a vessel including a tube portion and a body portion defining a chamber therein, the tube portion defining a channel therein in fluid communication with the chamber, to permit flow through the tube portion in a predetermined downstream direction, the method comprising:

(a) providing a cladding element formed for engagement with a first selected part of the body portion and a second selected part of the tube portion;

(b) positioning the cladding element spaced apart from the body portion to define a slot between an inner side of the cladding element and the body portion;

(c) locating at least one heating element in the slot;

(d) providing a non-oxidizing atmosphere in the slot, the non-oxidizing atmosphere covering the inner side and the first and second selected parts;

(e) energizing said at least one heating element, to heat the inner side and the first and second selected parts to a hot working temperature;

(f) while the first and second layers are at the first and the second hot working temperatures, moving one or both of the at least one cladding element sheet and the base element sheet in an orthogonal direction relative to the first and second inner sides to engage the first and second inner sides with each other;

(f) removing said at least one heating element from the slot;

(g) while the inner side and the first and second inner sides arepreselected parts are at the hot working temperature, engaging a first segment of the inner side with the first preselected part;

(h) with a forming device, engaging a second segment of the inner side with the second preselected part;

(i) while the inner side is engaged with each other and only after the first and second preselected parts, pressinglayers are at the first and second hot working temperaturessegment and the first preselected part together, and pressing the second segment and the second preselected part together, to

(i) moving one or both of the at least one cladding element sheet and the base element sheet in a direction transverse to the orthogonal direction to at least partially plastically deform the first segment and second layers to achieve at least partial uniformity of microstructures of the heated first preselected part, and to plastically deform the second layers,segment and

the second preselected part, to subject the first segment, the first preselected part, the second segment, and the second preselected part to shear stresses; and or

(ii) percussively engaging a first outer side of the at least one cladding element sheet at a plurality of first points spaced apart from each other, to push the first inner side in a first direction parallel to the orthogonal direction, and percussively engaging a second outer side at a plurality of second points spaced apart from each other and aligned with the plurality of first points, to push the second inner side in a second direction parallel to the orthogonal direction and opposite of the first direction, wherein the heated first and second layers are at least partially plastically deformed to achieve at least partial uniformity of microstructures of the first and second layers; and

(j)(h) permitting the inner side and the first and second preselected partslayers to cool to a predetermined temperature, for recrystallization of the inner side and the first and second preselected partslayers, that are thereby bonded withto each other.

14. A method according to claim 13, including scoring at least one of the first inner side and the second inner side.

14.15. A method according to claim 13, wherein theof covering a boundary region defined by two pipes made of a base element abutting each other at their respective ends, the boundary region being defined by the abutted respective ends, the method comprising:

(a) providing at least one cladding element sheet;

(b) locating said at least comprises first and second one cladding element proximal to the boundary region; sheets, each first and second cladding element sheet having an edge, and including:

~~(c) locating at least one heating element proximal to said at least one cladding element;~~

locating the edges of the first and second cladding element sheets proximal to each other after the first and second cladding element sheets are attached with the base element sheet, said edges defining an opening therebetween;

~~(d) providing a non-oxidizing atmosphere covering said at least one cladding element;~~

~~(e) energizing said at least one heating element, to heat said at least one cladding element to a hot working temperature thereof;~~

forming each of the first and second cladding element sheets to have a thick region extending along the edge thereof respectively in a direction parallel to the orthogonal direction, each of the thick regions being thicker than a balance of the respective first and second cladding element sheets;

~~(f) removing said at least one heating element;~~

positioning at least one supplemental heating element proximal to the thick regions of the first and second cladding element sheets;

~~(g) with a forming device, while said~~subsequently energizing the at least one supplemental heating element to heat the thick regions of the first and second cladding element ~~is at the~~sheets to a thick region hot working temperature~~,~~ in a non-oxidizing atmosphere; and

plastically deforming ~~said~~the thick regions with at least one ~~cladding element, to cover the boundary region, for bonding the cladding element with the base element; and~~ forming device to fill the opening.

~~(h) permitting said at least one cladding element to cool to a predetermined temperature.~~

16. A method according to claim 15, wherein the at least one forming device comprises that least one wheel or roller.

17. A method according to claim 15, including moving the at least one forming device in a direction that is transverse to the orthogonal direction to at least partially fill the opening with at least one of the thick regions.

18. A method according to claim 15, overlying the thick regions with an additional cladding element that is subsequently heated to an additional cladding element hot working temperature in a non-oxidizing atmosphere by an energized heating element, and securing the additional cladding element to the thick regions with at least one forming device subsequent to the additional cladding element being at the additional cladding element hot working temperature and the thick regions being at the thick region hot working temperature.

19. A method according to claim 13, including performing step (g)(i).

20. A method according to claim 13, including performing step (g)(ii).