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F. P. HUSTON ET AL

2,147,407

METHOD OF PRODUCING COMPOSITE METALS

Filed Nov. 7, 1933

2 Sheets-Sheet 1

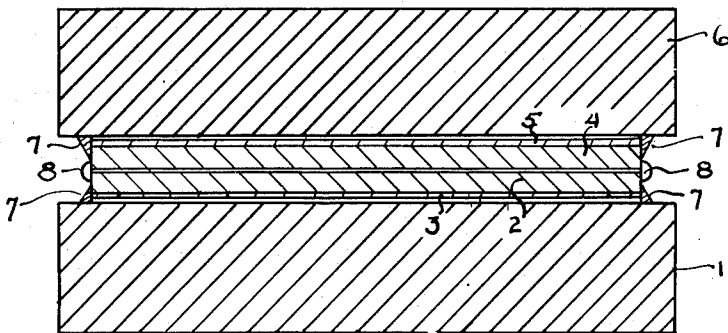


Fig. 1

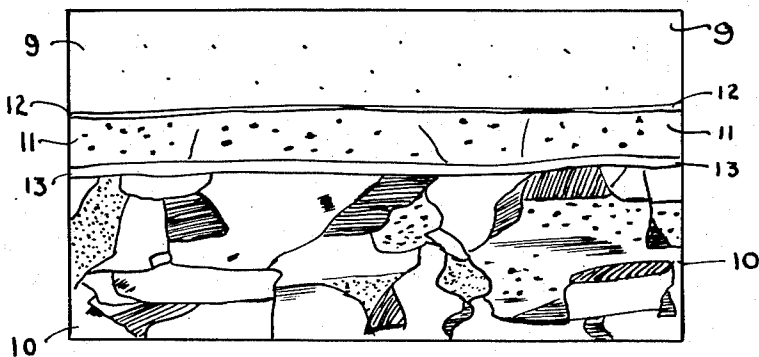


Fig. 2

INVENTOR
FREDERICK P. HUSTON
AND ANDREW WESLEY
BY

Byrnes, Stillins, Parmelee & Blenko
ATTORNEY

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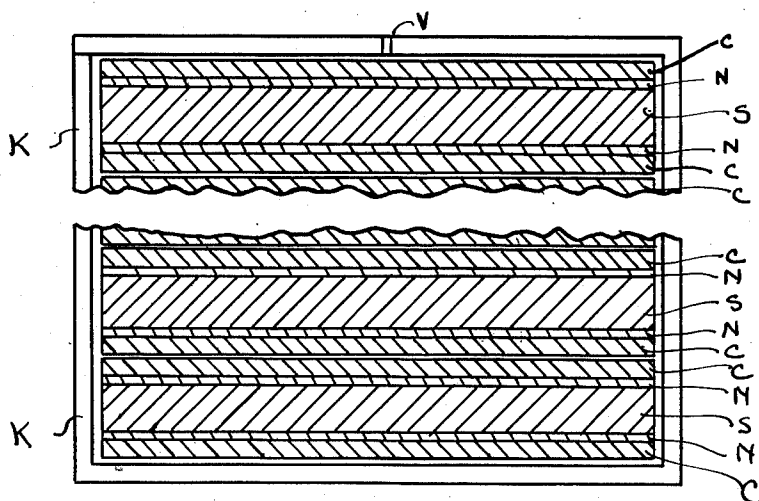


Fig. 3

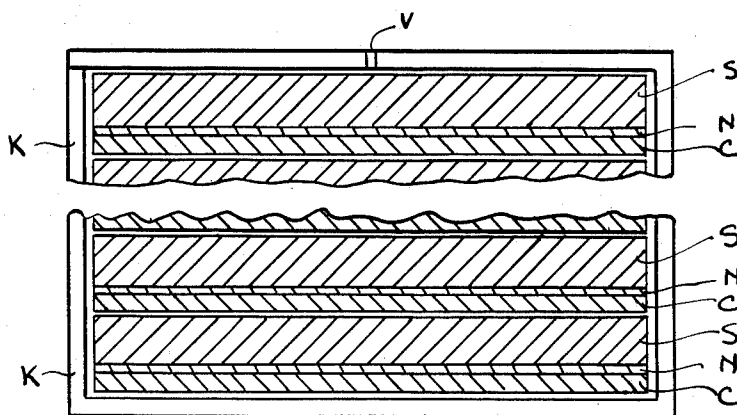


Fig. 4

INVENTOR
FREDERICK P. HUSTON
ANDREW WESLEY
BY
Byrnes, Stebbins, Parmelee & Banta
ATTORNEY

UNITED STATES PATENT OFFICE

2,147,407

METHOD OF PRODUCING COMPOSITE METALS

Frederick P. Huston, Fanwood, and Andrew Wesley, Bayonne, N. J., assignors to The International Nickel Company, Inc., New York, N. Y., a corporation of Delaware

Application November 7, 1933, Serial No. 696,946

22 Claims. (Cl. 29—188)

The present invention relates to cladded metal products containing chromium, and more particularly to composite metals integrally united and having a portion containing chromium and to a method of producing such composite metals.

Heretofore various methods have been proposed for the production of cladded metal products, especially cladded metal products in which the base metal or the cladding metal contains chromium. These prior methods involved certain disadvantages and produced products having shortcomings and/or defects. One of the worst disadvantages of prior cladded products containing chromium was that the cladded product could not be subjected to certain stresses and certain operations without the cladding metal tearing from the base metal. For instance, the bending and particularly the twisting of prior cladded products containing chromium tore the cladding metal from the base metal. Although the art was struggling for a solution to the outstanding problem, none as far as we are aware, was wholly successful and produced a completely satisfactory product.

We have discovered a method of producing cladded metal products containing chromium which is free from the disadvantages and shortcomings noted hereinabove and which is capable of producing satisfactory, successfully and commercially acceptable composite products.

It is an object of the present invention to provide a method which can be carried into practice on an industrial scale to produce commercial articles of manufacture economically and efficiently.

It is another object of the invention to provide a cladded metal product containing chromium which can be bent and twisted without falling and without coming apart.

A further object of the invention is to provide a method in which a base metal or alloy can be integrally united to a cladding metal or alloy to produce a unitary article of manufacture containing chromium.

It is also within the contemplation of the invention to provide a cladded metal product containing chromium which consists of a backing or base metal which is relatively cheap or which has some desirable properties not possessed by the surface coating and a cladding metal or alloy which may be used to cover one or both surfaces of the base metal or alloy which contains chromium and which has superior corrosion and/or heat resisting properties.

Other objects and advantages of the invention

will become apparent from the following description taken in conjunction with the accompanying drawings, in which:—

Fig. 1 is a sectional view, somewhat diagrammatic of a pack of plates to be bonded by the present method;

Fig. 2 is a diagrammatic illustration, somewhat exaggerated, of a photomicrograph of a section of the improved product showing the bond thereof;

Fig. 3 depicts a sectional view of a stack of plates encased in a metal container for double cladding; and

Fig. 4 depicts a sectional view of a stack of plates encased in a metal container for single cladding.

Generally speaking, the present discovery contemplates the provision of a film containing nickel or a nickel alloy to envelop or to coat the metal or alloy containing chromium. By incorporating the foregoing provision in the process of producing cladded metal products, it is possible to produce such products on an industrial scale readily and uniformly. The complete explanation of how the nickel film functions in the production of a satisfactory and successful composite product containing chromium has not been definitely established. As a theory, we believe that the nickel or nickel alloy forms a bond having high physical properties by partial interdiffusion into not only the chromium containing metal or alloy but also into the base metal especially during the subsequent hot working operations, and that the nickel film protects the surface of the chromium-containing alloy when it is heated. It is to be noted that the foregoing is merely advanced as a theoretical explanation of the success of the present method, but it is to be understood that if such explanation is found to be incorrect, it is to be disregarded.

Broadly stated, the invention contemplates the production of a cladded metal product containing chromium which comprises a base metal or alloy, a cladding or coating metal or alloy containing chromium and an intermediate layer or film containing nickel or a nickel alloy which is adhesively united to the entire face of said chromium-containing cladding metal to form an integral unit. In carrying the invention into practice, the surface of the chromium containing metal or alloy is adhesively coated with a film of nickel or a nickel containing alloy and the base metal having a clean surface is contacted firmly against the film of nickel and the two base metal and cladding metal are secured together

in some appropriate manner as by clamping, weighting, welding, or the like. The composite product is then heated to a relatively high temperature preferably in a reducing atmosphere. If a stack of layers are piled on each other, the weight thereof may be sufficient to cause the base metal to stick to or bond with the film of nickel on the chromium-containing cladding plate or sheet. In some cases, a heavy weight on the stack may be used to effect the sticking or bonding of the sheets. In the event that a composite product like the one shown in Fig. 1 is being made, hot working such as rolling, forging or the like may be employed. The heated composite product is then subjected to working operations such as forging, rolling or the like. After the bonding of the various layers has been accomplished not only hot working but also cold working may be employed. In the finished product the base metal or alloy and the cladding or coating metal or alloy are integrally united so thoroughly and effectively that the product can be stressed and deformed severely without rupturing the bond between the base and the coating. It is to be noted that the new composite product is particularly valuable where the product is to be used in structures which are subjected to severe stresses or where the product is to be subjected to severe fabricating operations. For instance, the improved product even in its reduced or worked condition can be twisted into a helix or the like without the cladding metal tearing away from the base metal.

For the purpose of giving those skilled in the art a better understanding of the invention the following specific example is given for the purpose of illustration.

A plate which is composed of chromium-nickel alloy and which is $\frac{3}{8}$ of an inch thick and of any desired length and width is cleaned in any appropriate manner, such as by sand blasting, pickling or the like. In this manner, a clean and scale-free surface is produced. To this cleaned surface a film of nickel or of a nickel alloy is applied. The application of the nickel film may be effected, for instance, by electroplating or by metal spraying or by any other suitable process.

In practice, it is preferred to apply the film of nickel or nickel alloy by means of electrodeposition. In the event that only one surface of a plate is to be cladded, it is preferred to place two equal sized plates back to back and secure them together by means of suitable clamps or the like. The clamped plates which may be constituted of a chromium containing metal or alloy such as a chromium nickel alloy, is immersed in an electrolyte having a suitable composition for the electrodeposition of nickel or of a nickel alloy.

A film, coating or layer of nickel or nickel alloy is electrodeposited upon the cleaned surfaces of the plates arranged back to back. The electrodeposition is conducted in any appropriate manner to yield a dense, adherent deposit of nickel or nickel alloy. For instance, the chromium containing plates may be cleaned in the usual manner by treating them as cathodes in an electrolytic alkaline cleaning bath. After this operation the plates are rinsed in hot water and are immersed in a solution of muriatic acid containing 5% by weight of hydrochloric acid and heated to a temperature of about 150° F. They are held in the acid solution for several minutes and are then transferred directly to a nickel plating bath where the coating of nickel is electrodeposited. It is preferred to apply a coating of nickel hav-

ing a thickness of about 0.002" to about 0.005". Of course, the thickness of the film or coating of nickel may vary considerably. Satisfactory results have been obtained from nickel coats having a thickness as low as 0.001 of an inch and as thick as 0.005 of an inch. Of course, films having thicknesses more than about 0.005" or less than 0.001" may be used.

In conducting the electrodeposition of nickel any suitable nickel plating solution may be used. It is preferred to use the following nickel plating solution and the following operating conditions:

Temperature.....	130 to 150° F.	
Agitation.....	Moderate air agitation	15
Current density.....	50 amp. per sq. ft.	
Nickel sulphate.....	44 oz. per gallon	
Nickel chloride.....	2.2 oz. per gallon	
Boric acid.....	4.0 oz. per gallon	
Sodium sulphate (anhydrous).....	13.8 oz. per gallon	20

The nickel coated plates containing chromium are assembled in one composite pack or billet which may have any suitable arrangement. A satisfactory assembly of the pack is diagrammatically illustrated in Fig. 1 of the drawings.

Steel slabs 1 and 6 which have a thickness of about $3\frac{1}{8}$ " and of slightly greater width and length than the nickel plated chromium containing plates have at least one surface cleaned in an appropriate manner such as machining, sand blasting, grinding or the like. In this manner, a dry, grease-free, clean steel surface is obtained.

In setting up the stack or pack, it is preferred to lay steel slab 1 flat upon the floor with its clean surface facing upwardly. Upon steel slab 1 is placed the chromium containing plate 2 with the nickel coated surface 3 in contact with the clean surface of steel slab 1. A second chromium containing plate 4 is laid upon the first chromium containing plate 2 with its nickel coated surface 5 exposed upwardly. Upon the nickel coated surface, a second steel slab 6 is placed with the clean surface in contact with the nickel coated surface 5. In practice, it is preferred to use welds 7 to secure the steel plates to the chromium-containing plates and to use welds 8 to secure the chromium-containing plates together, as may be clearly seen in Fig. 1. It is to be noted, however, that these welds should preferably be discontinuous and should be disrupted at one or more points to provide vents in order to permit the escape of the expanding gases.

In the foregoing manner, a composite pack or billet is formed in which the clean surface of the steel slab and the nickel coated surface of the chromium containing plate are held together. The composite pack is heated to a temperature suitable for bonding. In the present instance where a steel slab is being cladded with a plate of an alloy of chromium and nickel, a temperature of about 2000° F. to about 2300° F. is preferred. The heating is effected preferably in a reducing atmosphere. When the entire pack has reached this temperature it is hot worked in an appropriate manner, as for example, hot rolled. It has been found that only a small amount of hot working is necessary to secure a good bond between the steel slab and the nickel coated plate containing chromium. In other instances, however, it has been found that a great reduction in area can be effected, if desired. By hot rolling the aforesaid pack, it can be reduced to an appropri-

ate over-all thickness. In the present instance, it was reduced to about $\frac{1}{2}$ of an inch.

After the pack has been worked or rolled to the desired extent the edges thereof can be trimmed. In this manner, two clad steel products are produced each of which are about $\frac{1}{4}$ of an inch in thickness. The cladding is equal to about 10% of the total thickness. Of course, the amount of cladding can be varied depending upon the particular conditions. For most practical purposes, the thickness of the clad metal is from five to twenty per cent of the total thickness, depending on the thickness of clad metal needed to withstand the particular conditions of corrosion, abrasion, scaling, etc.

In Fig. 2 a diagrammatic illustration of a photomicrograph of the product produced in accordance with the foregoing method is depicted. It will be observed that the reference character 9 depicts a portion of the alloy of chromium nickel and reference character 10 depicts a portion of the steel layer. Between the two layers 9 and 10 is an intermediate layer 11 constituting the nickel coat. Between the nickel layer and the steel layer is a bond 12. In the same way, between layer 9 and 11 is a bond 13. It was found that the product produced in accordance with the present method could be subjected to severe stresses and could be subjected to various fabricating operations. Not only could the product be subjected to stresses and fabricating operations, but it could also be subjected to intense bending and twisting without the cladding metal tearing from the base plate of steel or without the bonds rupturing or falling in any way. As a result of practical tests it has been found that the present product can be produced on an industrial scale and the product used commercially.

Under certain conditions, it may be desired to heat a multiplicity of compost products at one time. For instance, if it is necessary to obtain a large production from a furnace in a short period of time, then it is preferred to use the arrangement shown in Fig. 3. In this figure, the reference character K designates a metal container which completely encloses the composite products to be bonded. In practice, it is preferable to employ sheet metal, such as sheet steel, for container K because of its light weight, its ability to expand freely, its low cost, its adaptability for folding, welding, etc., and its easy cutting properties. Of course, the conventional containers or boxes of cast metal or alloy may be used, if desired.

It is to be observed that chromium containing plates 2 and 4 do not weld to each other because their contacting surfaces have not been nickel coated. Moreover, it is preferred to leave the surfaces of plates 2 and 4 which are to be plated back to back in an uncleaned condition. Furthermore, the surfaces placed back to back can be coated with some refractory material or the like which will eliminate all possibility of plates 2 and 4 being stuck together mechanically or otherwise.

It is to be noted that the present invention provides a method of producing useful products. Thus, a composite metal may be produced which is cheaper than a solid alloy of the same composition as the cladding metal or alloy while at the same time possessing the desirable corrosion and/or heat resistance of the chromium containing cladding, and that the composite metal possesses overall properties superior to either the solid base metal or alloy or the solid coating or

cladding metal or alloy. For example, stainless steel clad copper would have the corrosion resistance of stainless steel but would have a considerably greater heat conductivity than stainless steel.

A stack of plates may be arranged as shown in Fig. 3 with a chromium-containing plate C at the bottom. This plate is placed so that the nickel film N faces upwardly. Upon the nickel film, a steel plate S is mounted. A second chromium-containing plate C with a nickel film N facing downwardly engages the top of steel plate S. This stack of plates is herein termed a "set".

As many sets as desired may be stacked up. A sheet of steel may then be folded around the stack and secured together as by welding or the like. In order to completely enclose the stack, end portions of sheet steel may be welded to the open ends of the folded sheet. For the purpose of permitting the escape of gas from the welded container, a vent V may be provided, preferably in the top of the container.

That stack of sets enclosed in the container is heated sufficiently high to effect bonding of the nickel to the adjacent faces of the steel plates. Due to the fact that the stack is sealed in a container, the heating is practically independent of the furnace atmosphere. If the weight of the stack is heavy enough, the nickel will be stuck or united to the steel. Usually, it has been found sufficient to press down on the top of the stack. For instance, a heavy plate, weight or the like may be placed on the top of the stack or the stack may be placed in a hydraulic press. After this each unit set may be subjected to working operations, such as hot or cold rolling, forging, etc. When the units have been worked or reduced to the desired extent, the clad product is ready for fabricating operations to convert the same into articles of manufacture.

In the foregoing operations, it has been found that the bottom and top plates of chromium-containing material do not stick or bond to the adjacent walls of the enclosing container or stick together. It appears that a greenish scale is formed on the chromium-containing plates which prevents sticking or bonding. The composite units comprising a steel base plate having a nickel coated cladding plate containing chromium on each face of the steel plate may be taken from the stack and handled or treated separately. Under the influence of the conditions within the container including heat, pressure and atmosphere, a diffusion bond is effected between the nickel film or layer and the steel plate and between the nickel and the chromium-containing plate. In this manner the two chromium plates and intermediate steel plate are united into an integral double clad unit. Of course, the integral double-clad units may be removed from the container by opening the same in any appropriate manner. If a container made of sheet steel is used, it can be easily cut apart and the stack of sets may be easily removed therefrom.

In the event that it is desired to single clad a metal or alloy, such as a steel plate, sheets or the like, an arrangement such as illustrated in Fig. 4 may be employed.

Within container K and at the bottom thereof, a chromium-containing plate C is placed with the surface bearing chromium in contact with the surface of the container which may be steel. The surface of the nickel film or layer N of the chromium containing plate faces upwardly. Upon the nickel film or layer N, a steel plate S is mounted

ed. Of course, the surface of the steel plate S, which makes contact with the nickel, is thoroughly cleaned as explained hereinbefore. A chromium-containing plate and a steel plate with a nickel film intermediate thereof is herein termed a single clad unit.

By placing a plurality of single clad units in container K, the latter may be filled and may then be closed as by welding or the like. A vent V is preferably provided to permit the escape of gases from the container K during heating operations.

In the event that it is desired, it is preferred to insert a separator between the top of the steel plate of any unit and the bottom of the chromium-containing plate of the next higher unit which makes contact with the steel plate. It has been found that one or more uncleaned sheets of chromium-containing material function satisfactorily as a separator. Of course, a layer of refractory material may likewise be used as a separator instead of the uncleaned sheets.

When the container is charged with single-clad units and is sealed, it may be introduced into a furnace and heated to a temperature of at least about 1800 to 2000° F. and preferably 2300° F. for a period of at least about ½ to 2 hours. In other words, the container is subjected to heat and pressure sufficient to insure the bonding of the steel plate to the nickel film or layer and of the latter to the chromium-containing plate to form an integral unit. The container may then be opened and each unit may be subjected to working, as rolling, forging and the like. By applying the desired amount of working, an appropriate reduction of area may be effected and the unit may be reduced to the desired size. The final product is a single clad unit which has such a tenacious bond that a sample of about 5 inches long may be subjected to a twisting test which involves twisting the sample through 360 degrees and then retwisting the sample to its original condition without the bond rupturing.

It is to be further noted that in the present instances the chromium nickel alloy contains 14% of chromium, 6% of iron and 80% of nickel but other chromium-containing alloys may be substituted therefor. Thus, for instance, any of the stainless steels, particularly those containing about 18% of chromium and about 8% of nickel may be used and steel clad products made with a clad of stainless steel may be produced. Similarly, copper or other metals or alloys containing little or no chromium can be substituted for steel to produce a composite product having a base of copper or the like and a cladding of a chromium-containing alloy.

It is also to be observed that the composite product can be subjected to the same fabricating operations as would be employed on a sheet or plate composed of the base metal. The composite product with steel as the base metal can be worked either hot or cold by spinning, pressing, drawing, flanging, bending, dishing, hammering, etc., and by the usual cold working operations such as shearing, punching and drilling; joining by riveting, welding, lock-seaming, soldering, etc. It is preferred to cold work the composite product clad on copper as a base, and it may be subjected to spinning, stamping, drawing, pressing, flanging, joining, etc.

Furthermore, it is to be noted that the addition of the bonded layer of chromium containing alloy to mild steel, copper, etc. gives added strength

to the base metal and enables the composite product to be more highly stressed in tension, compression, or shear than would be safe with a plate or sheet of the solid base metal.

Moreover, the articles of manufacture which can be produced from the composite product include autoclaves, kettles, dye vats, soap boiling equipment, dairy tanks, truck tanks, beer fermenting and storage tanks, cooking utensils, and other equipment for the chemical, dairy, food products, and allied fields, and the home.

It is to be noted that the present invention is not to be confused with proposed processes in which a separate sheet of iron is laid between a steel plate and a chrome alloy plate. In this proposed process, it is necessary to provide special means in order to produce a bond for union between the various parts. Thus, a deoxidizing agent such as an aluminum powder or the like must be provided in order to dissipate oxygen gases which are present in the air spaces between the steel plate and the intermediate iron sheet and between the chrome alloy plate and the iron sheet. Furthermore, various fluxes have been proposed to facilitate the bonding of the various sheets and plates or the like. The present invention avoids the foregoing complicated process and provides a procedure which produces reliably, consistently and uniformly coated products with a tenacious bond throughout the inter-face of the connecting surface of the plates or the like which are to be joined together.

Although the invention has been described in conjunction with preferred embodiments, it is to be observed that modifications and variations may be resorted to as one skilled in the art can readily understand. Thus, various modifications can be made in the individual steps of the novel process and the invention can be applied to the production of coated wire, tubes, rods and the like by altering the shapes of the parts constituting the composite pack or billet.

Of course, equivalents of nickel or nickel alloys such as cobalt, iron and the like, may be employed provided the metal or alloy is adhesively united to the entire surface of the chromium-containing plate or the like in order to form an impervious protective film. For adhesively uniting the nickel or nickel alloy or equivalent metal or alloy to the face of the chromium-containing plate, electroplating, spraying by the Schoop process, or the like may be utilized.

Claims directed to the novel composite metals disclosed herein are contained in applicants' co-pending divisional application, Serial No. 246,946, filed December 21, 1938.

We claim:—

1. The process of producing a clad product which comprises treating a mass of a chromium-containing alloy to produce a metallic surface substantially free from film forming ingredients of a type tending to interfere with welding, said chromium containing alloy having such a chromium content as to make the alloy substantially non-weldable by customary and conventional procedures, applying a substantially impervious nickel-containing film to a treated surface of said chromium containing alloy while the surface is substantially free from such films, cleaning a surface of a ferrous alloy, placing the cleaned ferrous surface in contact with the nickel surface, subjecting the same to a heat sufficient to bond the iron to the nickel, and working the same under pressure to form a ferrous product clad with a chromium-containing alloy, said

clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the clad of chromium-containing alloy separating from the ferrous base.

2. The process of producing a clad product which comprises cleaning the surface of a clad constituted of a chromium containing alloy to remove from said surface films of a type tending to interfere with welding, said clad having such a chromium content as to make the alloy substantially non-weldable by customary and conventional procedures, applying a substantially impervious nickel-containing film to a cleaned surface of said chromium-containing clad while the surface is substantially free from such films, cleaning a surface of a ferrous base, placing the cleaned ferrous surface in contact with the nickel surface, securing said ferrous base to said chromium-containing clad, subjecting the same to a heat sufficient to bond the iron to the nickel, and working the same under pressure to form a ferrous product clad with a chromium-containing clad, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium containing clad separating from the ferrous base.

3. The process of producing a clad product which comprises thoroughly cleaning one surface of each of two chromium-containing plates having such a chromium content as to be substantially non-weldable by customary and conventional procedures, depositing a substantially impervious nickel-containing film on each cleaned surface while said surface is substantially free from film forming ingredients of a type tending to interfere with welding, interposing said two chromium-containing plates back to back with the nickel coated faces exposed between two steel plates, each of said steel plates having a clean surface to contact with said nickel film, partially sealing the edges of said plates together to form a composite unit, and subjecting said composite unit to heat sufficient to bond the nickel to the steel and the chromium-containing material to the nickel, and working said plates under pressure to form an integral clad product, said integral clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the steel plate.

4. The process of producing a clad product which comprises thoroughly cleaning one surface of each of two chromium-containing plates having such a chromium content as to be substantially non-weldable by customary and conventional procedures, depositing a substantially impervious nickel-containing film on each cleaned surface while said surface is substantially free from film forming ingredients of a type tending to interfere with welding, interposing a steel plate with clean surfaces between the nickel coated faces of said two chromium-containing plates to form a double clad set, stacking a plurality of said sets upon each other to form a stack, subjecting said stack to heat sufficient to bond the steel to the nickel and the chromium containing plate to the nickel to form integral units, and then subjecting said units to work under pressure to produce a double clad product, said integral clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests

without the chromium-containing plate separating from the steel plate.

5. The process of producing a clad product which comprises thoroughly cleaning one surface of a chromium containing plate having such a chromium content as to be substantially non-weldable by heat and pressure, depositing a substantially impervious nickel film on said cleaned surface while said surface is substantially free from film forming ingredients of a type tending to interfere with welding, placing a steel plate having a clean surface in contact with said nickel film to form a single clad set, stacking up a plurality of said sets, encasing said stack in a metal-container, subjecting said container to heat sufficient to cause a bonding of said steel surface to said nickel and said chromium containing plate to said nickel to form an integral unit and working said integral unit under pressure to form a single clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the steel plate.

6. The process of producing a clad product which comprises thoroughly cleaning a surface of a chromium-containing clad having sufficient chromium to interfere substantially with welding by heat and pressure, electrolytically applying a substantially impervious nickel-containing film to said cleaned surface of the chromium-containing clad to form an adhesive union throughout substantially the entire interface and to protect the cleaned surface, cleaning a surface of a metallic base, placing the metallic base with the cleaned surface in contact with the nickel surface, subjecting the same to a heat sufficient to bond the base to the nickel, and working the same under pressure to form a base product clad with a chromium-containing clad, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing clad separating from the metallic base.

7. The process of producing a clad product which comprises thoroughly cleaning a surface of a chromium-containing clad having sufficient chromium to interfere substantially with welding by heat and pressure, electrolytically applying a substantially impervious nickel-containing film to said cleaned surface of the chromium-containing clad to form an adhesive union throughout substantially the entire interface and to protect the cleaned surface, cleaning a surface of a metallic base, placing the metallic base with the cleaned surface in contact with the nickel surface, securing said base to said chromium-containing clad, subjecting the same to a heat sufficient to bond the base to the nickel, and working the same under pressure to form a base product clad with a chromium-containing clad, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing clad separating from the metallic base.

8. The process of producing a clad product which comprises thoroughly cleaning one surface of each of two chromium-containing plates having sufficient chromium to interfere substantially with welding by heat and pressure, adhesively coating each cleaned surface with a substantially impervious nickel-containing film while said surface is substantially free from film forming ingredients of a type tending to interfere with weld-

ing, interposing said two chromium-containing plates back to back with the nickel coated faces exposed between two base plates, each of said base plates having a clean surface to contact with said nickel film, discontinuously securing the edges of said plates together to form a composite unit, and subjecting said composite unit to sufficient heat to bond the nickel to the base and the chromium-containing plates to the nickel, and working said plates under pressure to form an integral clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the base plate.

9. The process of producing a clad product which comprises thoroughly cleaning one surface of each of two chromium-containing plates having such a chromium content as to be substantially non-weldable by customary and conventional procedures, depositing a substantially impervious nickel-containing film on each cleaned surface while said surface is substantially free from film forming ingredients of a type tending to interfere with welding, interposing a base plate with clean surfaces between said nickel-containing surfaces of said chromium-containing plates to form a double clad set, stacking a plurality of said sets upon each other to form a stack, enclosing said stack of sets in a metal container, subjecting said container to sufficient heat to bond the base to the nickel and the chromium-containing plate to the nickel to form integral units, and then subjecting said units to work to produce a double clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the base plate.

10. The process of producing a clad product which comprises thoroughly cleaning one surface of a chromium-containing plate having sufficient chromium to interfere substantially with welding by heat and pressure, depositing a substantially impervious nickel film on said cleaned surface while said surface is substantially free from film forming ingredients of a type tending to interfere with welding, placing a base plate having a clean surface in contact with said nickel film on the chromium-containing plate to form a single clad set, stacking up a plurality of said sets, encasing said stack in a metal container, subjecting said container to sufficient heat to cause a bonding of said base surface to said nickel and said chromium-containing plate to said nickel to form an integral unit and working said integral unit to form a single clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium containing plate separating from the base plate.

11. The process of producing a clad product which comprises thoroughly cleaning a surface of a chromium-containing clad, electrolytically applying a substantially impervious nickel-containing film to said cleaned surface of the chromium-containing clad, while the cleaned surface is substantially free from film forming ingredients of a type tending to interfere with welding, said chromium being present in such content as to be substantially non-weldable by customary and conventional procedures, clean-

ing a surface of a copper-containing base, placing the cleaned copper surface in contact with the nickel surface, subjecting the same to a heat sufficient to bond the copper to the nickel, and working the same under pressure to form a copper product clad with a chromium-containing clad, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the copper base.

12. The process of producing a clad product which comprises thoroughly cleaning a surface of a chromium-containing plate, applying a substantially impervious nickel-containing film to the cleaned surface of said chromium-containing plate while said cleaned surface is substantially free from film forming ingredients of a type tending to interfere with welding, said chromium being present in such content as to be substantially non-weldable by customary and conventional procedures, cleaning a surface of a copper-containing plate, placing the cleaned copper surface in contact with the nickel surface, securing said copper plate to said chromium-containing plate by spot edge welding, subjecting the welded plates to sufficient heat to bond the nickel to the copper and the chromium-containing plate to the nickel, and subjecting said plates to working under pressure to form a clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the copper plate.

13. The process of producing a clad product which comprises thoroughly cleaning one surface of each of two chromium-containing plates having such a chromium content as to be substantially non-weldable by customary and conventional procedures, electrodepositing a substantially impervious nickel-containing film on each cleaned surface while said surface is substantially free from film forming ingredients of a type tending to interfere with welding, interposing said two chromium-containing plates back to back with the nickel coated faces exposed between two copper plates, each of said copper plates having a clean surface to contact with said nickel film, sealing the edges of said plate together to form a composite unit, and subjecting said composite unit to sufficient heat to bond the nickel to the copper and the chromium-containing material to the nickel, and working said plates under pressure to form an integral clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the copper plate.

14. The process of producing a clad product which comprises thoroughly cleaning one surface of a chromium containing plate, depositing a substantially impervious nickel film on said cleaned surface while said surface is substantially free from film forming ingredients of a type tending to interfere with welding, said plate having a chromium content such as to be substantially non-weldable by customary and conventional procedures, placing a copper plate having a clean surface in contact with said nickel film to form a single clad set, stacking up a plurality of said sets, encasing said stack in a metal container, subjecting said container to sufficient heat to cause a bonding of said copper

surface to said nickel and said chromium-containing material to said nickel to form an integral unit, and working said integral unit under pressure to form a single clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the copper plate.

15. The process of producing a clad product which comprises thoroughly cleaning a surface of chromium-containing clad having sufficient chromium to interfere substantially with welding by heat and pressure, applying an electrodeposited protective coating to said cleaned surface of said chromium-containing clad to form an adhesive union throughout substantially the entire interface and to protect the same, placing a cleaned surface of a metallic base in contact with said protective coating to form a unit, subjecting said unit to a heat sufficient to bond the base to the protective coating and working the same under pressure to form a base product clad with a chromium-containing clad, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing clad separating from the metallic base.

16. The process of producing a clad product which comprises thoroughly cleaning a surface of a chromium-containing plate having sufficient chromium to interfere with welding by heat and pressure, applying an electrodeposited protective coating to said cleaned surface of said chromium-containing plate to form an adhesive union throughout substantially the entire interface and to protect the same, securing a metallic base plate to said chromium-containing plate by welding, subjecting the welded plates to heat sufficient to bond the protective coating to the metal of the base plate and also to bond the chromium-containing clad to the protective coating, and subjecting said plates to working under pressure to form an integral clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the metallic base plate.

17. The process of producing a clad product which comprises thoroughly cleaning one surface of each of two chromium-containing plates having such a chromium content as to be substantially non-weldable by customary and conventional procedures, applying a protective film to the cleaned surface of each of said chromium-containing plates, interposing said chromium-containing plates back to back with the protective films exposed between two base plates, each of said base plates having a clean surface to contact with said protective film, discontinuously securing the edges of said plates together to form a composite unit, and subjecting said composite unit to sufficient heat to bond the protective film to the base and the chromium-containing plate to the protective film, and working said plates under pressure to form an integral clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the base plate.

18. The process of producing a clad product

which comprises thoroughly cleaning one surface of each of two chromium-containing plates having such a chromium content as to be substantially non-weldable by customary and conventional procedures, applying a protective film to the cleaned surface of each of said chromium-containing plates, interposing a base plate having clean surfaces between the two chromium-containing plates with said clean surfaces in contact with said protective films to form a double clad set, stacking a plurality of said sets upon each other, enclosing said stack of sets in a metal container, subjecting said container to sufficient heat to bond the base and the chromium-containing plate to the protective film to form integral units, and then subjecting said units to work under pressure to produce a double clad product, said clad product being capable of being subjected to commercial fabricating operations and subjected to bending and twisting tests without the chromium-containing plate separating from the base plate.

19. The method of making composite metal articles composed of a facing metal consisting of a chromium containing ferrous alloy having sufficient chromium to interfere substantially with welding by heat and pressure and a ferrous backing metal of different characteristics, which comprises the steps of treating a mass of such a chromium containing alloy to produce a metallic surface substantially free from film forming ingredients of a type tending to interfere with welding, depositing electrolytically on such a surface, while substantially free from such films, a closely adhering layer of nickel, and thereafter welding such nickel coated surface to a backing of ferrous metal by the action of heat and pressure.

20. The method of welding high melting point chromium-containing metals having a strong tendency toward formation of film of a type tending to interfere with welding, which comprises cleaning the surface of a body of such a metal to remove such film therefrom, building up over such surface while substantially free from such a film, a layer of electrolytically deposited nickel adapted to bond with such body of metal, causing such layer of nickel to diffuse with the body of metal, and uniting to such layer coated surface a ferrous body under conditions adapted to produce a weld.

21. The method of welding ferrous bodies which comprises thoroughly cleaning the surface of a body of ferrous metal containing sufficient chromium to render the same substantially non-weldable to another ferrous body by heat and pressure forming on the surface of said chromium-containing body of ferrous metal while clean an electro-deposited, closely adherent protective layer of nickel, and thereafter welding additional ferrous metal to such face by heat and pressure.

22. The method of uniting two not readily mutually weldable ferrous bodies one of which contains sufficient chromium to interfere substantially with welding by heat and pressure which comprises cleaning a face of each such body to remove oxide, electro-depositing over each such face, while substantially oxide-free, a strongly adhering layer of nickel, and thereafter welding together such nickel layers by heat and pressure.

ANDREW WESLEY,
FREDERICK P. HUSTON.