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J. F. MONNOT.

PROCESS OF PRODUCING COMPOUND METAL BODIES.

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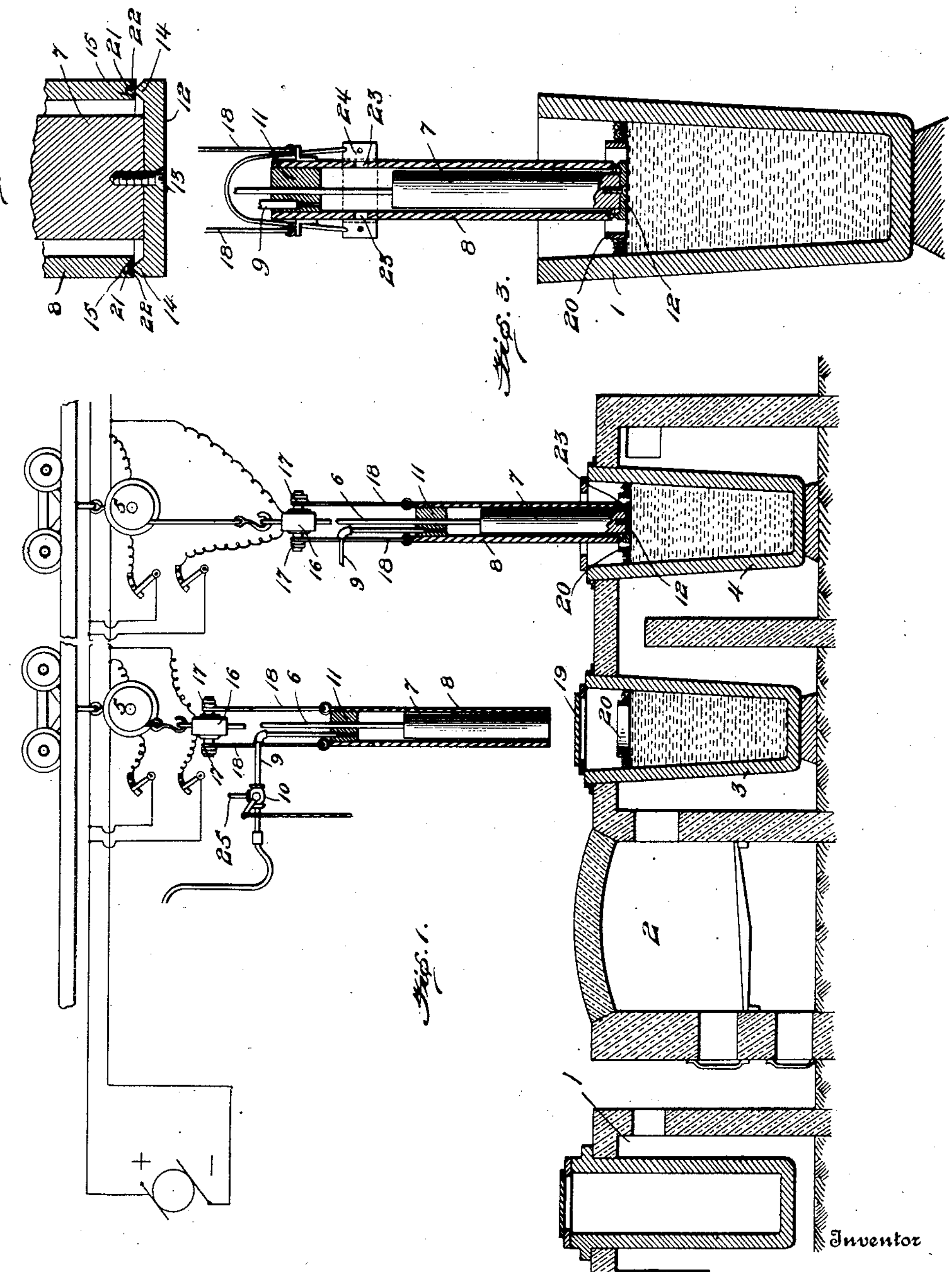

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PROCESS OF PRODUCING COMPOUND METAL BODIES.

No. 853,716. Specification of Letters Patent. Patented May 14, 1907.

Application filed September 6, 1906. Serial No. 333,570.

To all whom it may concern:

Be it known that I, JOHN FERREOL MONNOT, a citizen of the United States, residing in the city, county, and State of New York, have invented certain new and useful Improvements in Processes of Producing Compound Metal Bodies; and I hereby declare the following to be a full, clear, and exact description of the same, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to processes of producing compound metal bodies and consists in a method of uniting layers or strata of unlike metals, *i. e.*, metals or alloys of unlike chemical nature, whereby such metals and alloys are united as firmly and permanently as weld-united layers of iron or steel, for example. The union between metals which are unlike in the above sense, produced according to the method herein described is in all respects equivalent to the most perfect weld possible, insofar as the subsequent behavior of the united bodies of metal is concerned; for which reason, and because the term "weld" is the one which would most naturally be applied to such a union, by those skilled in the art, I term such union hereinafter a "weld," without intending thereby to limit or confine myself to any particular theory as to the actual nature of the union between the unlike metals.

By the method herein described it is possible to produce compound metal ingots, and also manufactured articles of compound metal, such as plates, sheets, rods, tube, wire and the like. In most cases the union between the unlike metals may be, and preferably is, an autogenous one; but in certain cases, as where one of the metals or an ingredient thereof is subject to excessive volatilization or oxidation at the temperatures required in carrying out certain stages of the process, there may be an intermediate film or coating of another metal, as hereinafter described.

It is well known that it is very difficult to unite, permanently, unlike metals; and particularly to unite a ferrous metal, such as wrought iron and the various steels, or metals like nickel and cobalt, with metals of a non-ferrous nature, such as copper, silver, gold, aluminium, cupriferous alloys, (such as bronze, brass etc.,) aluminium alloys (such as aluminium bronze), manganese bronze, etc. I have found, and it is a matter of common knowledge and experience, that iron and copper, iron and silver, iron and aluminium, and similar pairs of unlike metals, cannot be weld-united or equivalently united by casting the copper, silver, aluminium, etc. at the ordinary casting temperatures of such metals, against the surface of an iron or steel object to be coated.

The fundamental discovery upon which my new process rests is, that while unlike metals of high fusing temperatures, such as those named above, do not weld readily or at all under ordinary conditions of metal working, nor by casting one of the metals at ordinary casting temperature against an unlike metal likewise of high casting temperature; yet if the metal so cast be heated, before casting, far above its melting point and ordinary casting temperature, and be cast at such abnormally high temperature, the lack of affinity between the metals observed at lower temperatures disappears, and the unlike metals contacted at such high temperature unite readily to form a union of an autogenous, permanent character equivalent to a true weld. Metals such as copper, silver and aluminium, at such a high temperature, which for the sake of a name may be called a supermolten temperature, display extraordinary chemical and physical activity, readily uniting with gases and other bodies, and also with wholly unlike metals, such as iron and the various grades of steel; and I believe that the same is true generally of other metals of relatively high melting temperature, such as gold, nickel, cobalt, etc. While the fact is as stated, I am unable to give a definite explanation of the phenomenon. Possibly it is due to dissociation of proximate molecules of the metals which still persist at and near the melting point. It is commonly believed by physicists that ultimate molecules of most substances in the solid state are associated to form larger complex molecules— an association which persists to some extent after fusion, but steadily diminishes with increase of heat; and that the influence of heat upon chemical reactivity is due partly to this phenomenon. This peculiar increase of chemical reactivity of certain molten metals and concomitant heightening of their affinities for certain other metals, whether these affinities be molecular, atomic or physicochemical, which occurs on raising their temperature much above the point where they become molten, if heretofore observed, has not to my knowledge been applied to the uniting of unlike metals of the classes herein contemplated; the sole attempt of experimenters in the field of uniting unlike metals by casting one such metal against the other having been to heat the metal to be cast to a point where it will remain liquid long enough to fill the mold completely, and, sometimes, to heat to or nearly to its melting point the metal against which the molten metal is cast. I am not, however, aware that any attempt has ever been made to produce temporarily between the contacting surfaces of the metals to be joined at the instant of casting the extremely high temperature utilized in the hereinafter described method.

Copper and steel may be taken as a pair of unlike metals affording a typical example. Copper, at its ordinary casting temperature, displays practically no affinity for the totally unlike metal, steel, hardly "wetting" it and forming no union with it which will withstand tools or heat changes, even if it be cast at such ordinary casting temperature against the surface of the steel and held there during solidification. The best union that can be formed in this manner, so far as known, is a mere adhesion or "sticking together" of the two metals, and not a true cohesion. The metals so united will separate subsequently during working or by the action of heat or shock, or can be separated readily by means of a tool. In a way, it may be said that the two metals behave as if their surfaces were merely fitted together and not really united. But if copper at the so-called "supermolten" temperature above referred to be contacted with the steel and held against the surface thereof during solidification, the temperature of the molten metal being allowed to fall as soon as true "wetting" is effected, a union is formed which is absolutely permanent and as strong as a true weld, the metals so joined being inseparable by change of temperature or by shock; and a cold chisel or like tool, applied along the line of juncture of the two metals, will not follow said line readily, as it would if the metals were merely "stuck" together, but tends to dig into the one metal or the other. Nor will reheating the joined metals to a red heat and quenching in water result in separation of the metals. The union thus produced is equivalent to what, in the case of united bodies of steel and iron, is called a weld. As to the nature of the union thus produced, uncertainty exists; but it is known that when the process is properly carried out changes in the joined metals, if any, are confined to an excessively thin film between the proximate surfaces, the main portions of the bodies of joined metals possessing their ordinary properties. It may be that the union between the metals is a mere result of thorough "wetting" of the steel by the copper; a molecular contact and coherence between adjacent molecules of copper and steel similar to that which unites the molecules of copper and the molecules of steel each among themselves; or, again, it may be that the uniting layer is of a different composition from the joined metals and is an alloy of such metals, chemically or physically combined, as combination, mixture or solution. The existence of such an alloy film seems probable, because in the carrying out of the process certain evidences of slight solution of the iron in the copper, such as might naturally accompany an alloying inter-action, have been observed; but whether or not an alloy film is formed, and without restricting myself to the theory that any true alloy is formed, it is convenient to term the uniting layer between the joined metals, for the sake of a name, an "alloy film," and I use said term in this sense hereinafter.

It is not essential, for the uniting of the supermolten copper to the iron or steel, that the copper be confined in contact with the steel while solidifying. If a cleaned piece of steel be immersed momentarily in a bath of supermolten copper and then withdrawn therefrom, under conditions precluding oxidation, and allowed to cool, it will be found to be covered with a thin coating of copper or, possibly, copper-iron alloy, so firmly united to the steel as to be "welded" thereto in the same sense as the copper coating of substantial thickness formed by confining a considerable body of supermolten copper in contact with a steel surface and then allowing the same to cool, as above described; and since this thin coating is substantially the same as the layer uniting the two layers of unlike metal joined in the manner above described, I commonly apply to it also, for the sake of convenience, the term "alloy film," sometimes, however, terming it the "weld-film" "film coating" or "alloy coating." As above explained, I do not intend by the use of the term "alloy" in these terms to commit and confine myself to the existence of what in common parlance is termed an "alloy," but merely use the terms mentioned as convenient distinguishing terms.

Whatever the nature of the alloy film or uniting film, it is capable of indefinite extension since an ingot of two metals joined thereby may be extended to any desired extent, even to the thinnest sheets or wire, without the union failing, without the separation of the two metals, and without the development of flaws, pores or seams therein or therebetween, and even with substantial maintenance of the original relative proportions of the two metals; all of which shows that the original union between the two metals still persists in the coextended ware produced by working the ingot, even down to thin sheets and wire.

In the case of copper, the supermolten temperature appears to be from 2500° to 2800° Fahrenheit or higher. The super-molten temperature of silver is about the same; that of aluminium is somewhat lower. The temperatures named have not been determined with absolute accuracy, it being well known that it is difficult, if not impossible, to measure temperatures in the neighborhood of or exceeding 2000° F. with even approximate certainty and accuracy; but I have endeavored to determine these temperatures with the best pyrometers readily obtainable, and believe the figures given to be substantially correct. In practice, it is not necessary to know accurately the temperature of the supermolten metal, as it is easy to test the molten metal from time to time, as it is being heated up, by dipping therein a test piece of the metal to be coated, withdrawing it under circumstances precluding oxidation, and allowing the adhering film of molten metal, if any, to cool. When the molten metal forms on the article so dipped a coating which, when cold, possesses the qualities of the alloy film or welding film above recited, it is known that the supermolten temperature has been reached; but even then it is desirable to heat the metal somewhat hotter still, in order that there may be a margin of temperature available. In practice, the workmen engaged in carrying out the process become able to tell by the appearance of the molten metal when the proper supermolten temperature has been reached, without the necessity of testing continually.

This property of combining with unlike metals at supermolten temperatures appears to be generic with all the metals of high melting points, and renders possible the procurance of many pairs of well-united metals which cannot be obtained at all by common methods of working.

In some cases, the coating formed by contacting a solid body of one metal with a "supermolten" body of an unlike metal and then permitting the adhering coating formed by the action of the supermolten metal to solidify, is sufficient; but in general I contemplate applying relatively thick layers or coatings to ingots, cores or bases of considerable thickness, and then coextending the metals of the compound ingot thus produced, by rolling, hammering, pressing, drawing, or other suitable method of working the metals, thereby producing compound metal plates, sheets, rods, tubes, wire, and the like. The compound metal articles thus produced may be used to great advantage in a variety of arts and for many different purposes, as combining the specific advantages of the component metals. For example, plates or sheets composed of a readily oxidizable metal, such as iron or steel, covered with an impervious coherent coating of copper or other less oxidizable metal, may be used to great advantage in place of ordinary iron or steel plates or sheets wherever such plates are exposed to the weather, air, or other oxidizing influences or to the action of corroding liquids, gases or vapors which readily attack iron or steel but do not attack at all, or at least to so serious an extent, the coating metal employed. Plates, sheets and other articles of copper, silver, gold, aluminium, brass, bronzes, etc., backed with iron or steel may be used with great advantage where considerable strength or stiffness of metal is desired, coupled with the chemical, physical, electrical or other properties or color or appearance of the non-ferrous metals mentioned. For electrical conductors, it is desirable to combine the high electrical conductivity of copper, aluminium, etc. with the great strength of steel.

For the uses mentioned, and for a great variety of other uses which might be mentioned, it is a prime requisite that the unlike metals shall be so inseparately united in the first instance that the compound ingot, sheet, rod etc. may be capable of great extension or working, as by rolling, or hammering, to thin sheets, rods, angles, tubes, etc., drawing, pressing in dies, spinning etc., without separation of the component layers, without development of seams, pores, flaws, etc; and it is in fact desirable that during such working the strata of the component metals shall maintain substantially their original relative proportions, even down to the thinnest sheets or wire. It is further highly important that the layer of coating metal shall be in such a condition as to be absolutely impervious to liquids and gases. Electroplating or other methods of deposition of metals do not produce a coating possessing these qualities. On the contrary, electrically-deposited and like coatings are porous, the metal being thrown down in granular or crystalline form, with dividing lines and interstices between the crystals or granules, so that liquids and gases penetrate the coating and attack the metal beneath; neither is the adhesion of coatings so deposited good, such coatings being merely adherent to the base and not coherent thereto, and for this reason and also because of lack of cohesion of the coating itself, it is impracticable to roll or draw electro-plated metals without destroying the continuity of the coating. For similar reasons, tinning and galvanizing do not produce as satisfactory results as is desirable, and it is not practicable by these processes to produce large coated surfaces which are everywhere free from defects and permanently united with the base; moreover for many purposes tinned and galvanized surfaces are altogether unsuitable, because not possessing the desired superficial appearance and other qualities; and a tinned or galvanized coating will not stand extension by drawing, rolling, pressing between dies, etc., to any great extent. It is in fact impossible that tinning or galvanizing shall produce a union between the metals in any way analogous to that produced by the method herein described, since it is impossible to heat tin or zinc or lead to temperatures such that any permanent union is produced by contact with the metals of high melting point, tin, zinc and lead all oxidizing or volatilizing at relatively low temperatures. Neither do brazing, soldering and similar processes satisfactorily unite unlike metals for all purposes, the metals being merely "stuck together," the articles produced by such processes being incapable of extension by drawing, rolling, etc. to as great an extent as desired, being likely to separate by heating, etc. The ideal union between unlike metals must be autogenous, *i. e.*, must be formed by a complete direct uniting of the metals, such as may for the reasons above stated, be termed "welding."

By my process I am enabled for the first time in the history of the art, as I believe, to actually and inseparably weld coherent, dense, impervious and poreless coatings of the less oxidizable and more ductile and malleable metals upon surfaces of unlike stronger and more oxidizable metals, which coatings may vary from any desired thickness to a tenuity comparable to that of ordinary electrocoatings. When the unlike metals are absolutely welded together, as by my process, no difficulties are experienced such as are encountered in the use of electroplated articles and in the use and working of tinned, soldered and galvanized articles, as, for instance weak lines of union permitting peeling and other separation, or flawed and porous coatings, but on the contrary coatings produced by my process are absolutely impervious and continuous, and cohere to themselves and to the metal to which they are joined, so that a compound plate, ingot, rod, wire or the like is produced which is capable of being rolled, drawn or otherwise extended parallel to the weld to any desired extent without interruption of the continuity of the coating, without its separation from the base and with substantial maintenance of the original thickness of coating relative to the thickness of base. Moreover, the coatings in articles so extended are in a dense, hard condition, much more so than coatings obtained by electroplating, tinning or galvanizing, and thus are far more durable.

In the many unsuccessful attempts in the prior art to produce articles similar to or equivalent to those produced by me, no one has been able, so far as I am aware, to produce a coating such as described, as for example a coating of copper on steel, which could not be separated from its base by means of a cold chisel or equivalent tool, or to produce a coating in extended ware so indivisibly welded to the steel base as to be able to rely wholly upon the steel for support. In such prior articles, owing to the lack of perfect union with the base, it has been necessary to provide in the extended ware a thickness of coating sufficient in itself to furnish its own coherence and strength to prevent destruction; in copper-steel wire, for instance, the copper has had to be sufficient in amount to furnish a tube of substantial strength, inclosing the steel core. I am not aware that in such prior articles a coating of much less than 30 per cent has ever been found practicable, whereas in ingots to be extended greatly, I may provide a thickness of coating equivalent to only 5 per cent; and when the articles to be made from such ingot are not to be greatly reduced in cross-section (as in structural steel shapes) the coating applied to the ingot may be as thin as 3 per cent.

In the heavy coated articles of the prior art just referred to, because of the lack of the intimate and perfect union, such as secured by me, there is always to be found, in the ingot for example, a large proportion of the compound metal in which there are flaws, defects and places of no union of the joined metals which must be cut out and rejected, thereby entailing an undue wastage, both of material and of the skilled labor required in such prior processes. In the article produced by my process the union is so intimate and thorough between all meeting surfaces that there is no need of loss by wastage or in labor. The process is conducted in such manner that there is no possibility of scale spots and similar defects developing. The operation is so simple that comparatively unskilled labor is sufficient, thereby materially cheapening the finished product.

In my new method, by affixing coatings of copper, silver, gold and the like to an ingot or other large body of metal and then co-extending the joined metals, I am able to secure coated artices much more cheaply that if said articles had first been produced in the base metal and then coated, as is the common practice,

Of course it may be understood that I can, when desired, apply the coating to the finished, or half finished, article and in such cases, if the article be large, the copper or other coating metal may not be more than a fractional per cent of the total.

For the production of coated surfaces of large area, like sheets and wire, my process has the advantage, as compared with the prior art, that whereas by such former processes the entire surface to be coated must receive the careful attention of the operator to avoid flaws and the like, and such surface is substantially the same as that of the finished article, according to my process the surface of union between the unlike metals is, in the first instance, relatively small, being that of the relatively thick ingot, slab, plate, etc., from which the finished article is produced by extension; and the surfaces thus united being relatively small, it is easy and economical to bestow thereon a high degree of care such as will insure an absolutely perfect union between the unlike metals. In the subsequent working of the welded ingots etc., the weld or union extends uniformly with the metals on each side of it, even to the thinnest articles, so that by the relatively small amount of care necessary to secure perfect union in the ingot or the like, the production of perfect sheets, wires rods, etc., therefrom is substantially assured.

It is not always convenient, practicable or desirable to apply the entire coating in one operation, or to form the entire coating from a bath of supermolten metal. I have found that if one of two unlike metals such as referred to above have formed on it a mere film-coating of the other by the action of a supermolten body of that other, a further body of said second or coating metal can be cast against such film-coating at substantially ordinary casting temperature and will unite therewith so intimately as to be inseparable and indistinguishable therefrom. For instance, if a steel ingot be film-coated by the action of supermolten copper or silver, and a further body of copper or silver be cast against and caused to solidify against said film-coating, the metal so cast being at substantially the ordinary casting temperature, a perfect union of the cast metal with the film-coating may be obtained, and so a perfect union with the steel base. And I further find that the metal so cast is not necessarily the same as the metal which forms the film-coating. These two facts render practicable many convenient and extremely important embodiments of my process. For instance, there are many alloys containing readily fusible or oxidizable or volatilizable metals, such as the various brasses, tin bronzes, etc., which do not well withstand heating to a supermolten temperature. In the case of brass, the zinc tends to volatilize below the supermolten temperature of the copper, and in tin bronzes the tin tends to oxidize or volatilize below the supermolten temperature of the copper, and hence the supermolten temperature cannot be obtained at all, or without serious loss of zinc or tin such as will vary materially the quality of the alloy. In such cases I film coat the base metal, with a metal with which the metal of the main coating will combine readily at convenient casting temperatures, and then cast the main coating metal against such film coating. For example, when coating steel with brass or tin bronze, I film-coat the steel with supermolten copper, and then cast the brass or bronze against the copper film so produced and cause it to solidify thereagainst. The molten brass or bronze combines readily with such copper film at ordinary casting temperatures. The said double treatment, *i. e.*, film coating and then forming a further coating of substantial thickness against the film coating, is also convenient in many cases in using pure metal or in obtaining therefrom coatings of pure metal or metal of definite characteristics. When at the supermolten temperature many metals are very sensitive to flame gases and other bodies, readily becoming impure; and there is reason to believe that at such temperature such metals have a solvent action on other solid metals placed in them. By applying only a thin film-coating by the action of supermolten metal, and then applying the main coating by means of metal nearer its point of solidification, there is less probability of reduction of quality of the coating metal. However, the main coating may be, and frequently is, formed entirely from the supermolten metal, this method having the important advantages of requiring less manipulation and fewer baths of molten metal.

The metals which I have found to have a supermolten condition at which they unite with iron and steel by a union analogous to a weld, are all metals having a melting point above 900° F. I am not aware that metals melting below this point reach a similar supermolten condition before volatilization or oxidation, and it is in fact substantially impracticable to weld-coat iron or steel, with a view to subsequent extension, with metal melting below 900° F., as iron and steel require to be heated to 900° F. and above for the extension desired of compound metals.

It is not only the ferrous metals (iron and the various steels) which can be coated with unlike metals (such as copper, silver, gold, aluminium, brass, bronze, including aluminium and manganese bronzes, etc.) by the method herein described. I may coat copper with silver or vice versa; and in general I may combine by the method herein described any two of the metals of high melting point which it is difficult or impossible to combine by ordinary methods. My process makes it particularly easy to weld or braze together pieces of aluminium, which, as is well known, cannot be united satisfactorily by ordinary methods; for it is easy to coat the aluminium surfaces to be united with copper, silver or other suitable metal which brazes or welds readily, applying the coating by the process herein described, and then to braze the coatings of copper, silver or other metal. My process also makes easy the hot working of metals, such as nickel, high-carbon steel, etc., which are subject to excessive oxidation or other deterioration when worked hot in the presence of air; it being easy by my process to coat objects of such metals with a metal less subject to oxidation or deterioration. In an application for Letters Patent, filed March 2, 1906, Sr. No. 303,917, I have described and claimed such process of hot working metals.

As an illustration of my process, I will describe the uniting of copper to steel. The difficulty, or even impossibility, of uniting steel and copper by a joint equivalent to a weld between two pieces of steel, by methods heretofore known, is well recognized. And I will suppose that it is a steel ingot which is to be coated with copper, and that all surfaces of the ingot are to be coated with a substantial thickness of copper, and then the coated ingot extended by rolling, hammering, or the like, to form sheets, rods, or other extended ware.

The surface of the steel ingot is first brought to an absolutely clean metallic surface by sandblasting or other suitable mechanical method of removing scale, oxid and the like, and then customarily is pickled. In pickling I preferably use hydrochloric or hydrofluoric acid, as these acids form on the steel surface a non-oxygenated closely adhering protective coating of chlorid or fluorid, which volatilizes readily at a later stage in the operation, exposing an absolutely clean and fresh metallic surface to the supermolten metal. In pickling the steel may form an anode of an electric couple, when desired.

After pickling, it is best to heat the ingot preliminarily before contacting the same with the supermolten metal, to avoid abstraction of undue amounts of heat from the supermolten metal. One method of conducting this preliminary heating will be described hereafter, but others may be used. Customarily, I do not heat the ingot preliminarily above a red or low yellow heat. The heated ingot is then transferred to and immersed in a bath of supermolten copper, being protected from oxidation as hereinafter described, during the transfer. A few seconds contact of the supermolten metal with the heated ingot usually suffices for the copper to unite with the steel—the exact time depending somewhat upon how hot the steel was heated preliminarily; experience soon teaches the workmen how long the contact of the steel with the supermolten metal should continue. The surface of the steel ingot probably at once assumes the high temperature of the supermolten copper. When the entire coating is to be formed from the metal of the supermolten bath, I then segregate from the main body of the supermolten metal a layer thereof, in contact with the surface of the ingot, of sufficient thickness to form the desired coating, according to the method described in my application for Letters Patent filed June 16, 1905, Sr. No. 265,508, and withdraw the ingot and segregated layer of molten metal and cause the latter to solidify on the surface of the ingot. But when only a film coating is to be formed by the action of the supermolten metal, I withdraw the ingot from the supermolten bath as soon as sufficient time has elapsed for the formation of the film coating (a few seconds usually suffices), and then either place the film-coated ingot in a suitable mold and cast around or against its filmed surface the metal to form the main coating, or immerse the film-coated ingot in a second bath of molten metal maintained at substantially ordinary casting temperature, and then segregate a proper layer of such molten metal according to the method of my said application No. 265,508, and cause the same to solidify against the film-coated surface. During the solidification of the substantial layer of copper produced by any of these three methods it is desirable to use some pressure to maintain contact of the copper with the surface against which it solidifies; but if the segregated or cast-on copper layer forms an annulus surrounding the ingot, the self-compression of the copper due to its contraction during solidification and cooling, is ordinarily sufficient. And in an application for Letters Patent filed May 23, 1905, Sr. No. 261,739, I have illustrated and described means for applying positive pressure from an external source during solidification and cooling. In any of these methods the excessively high temperature of the abutting layers between copper and steel exists only temporarily as the heat of such layers "soaks" into the steel core while the heat of the copper is transferred outwardly by the cooling of the mold walls, and no opportunity is afforded for detrimental action upon either the main body of the steel or that of the copper. Such changes as take place, or may take place, in either metal, are only in the excessively thin joining layer between; and since, as already explained, I do not limit myself to any theory of how the union between the unlike metals takes place, therefore I do not assert positively, that when the operation is properly performed, any change of the two metals, or either of them, at the point of juncture, actually takes place. As previously explained, the time of contact of the steel and copper or other coating metal used, while such copper or other coating metal remains in the supermolten condition, is very brief, for long contact of the two metals with the copper or other coating metal in the very highly reactive condition afforded by the supermolten temperature, would of course be detrimental to both. By limiting to a few seconds the period of contact of the metals while one of them is in the supermolten condition, I limit to extreme thinness the joining layer of alloyed, mixed, interpenetrating, or otherwise-united metals.

In transferring the film-coated ingot preparatory to either casting or segregating a further coating around or against the film-coated surfaces it is highly important to guard against oxidation of the film-coating. This I do preferably by surrounding the film-coating with a neutral or indifferent gas, such for example as producer gas made from coke, charcoal or anthracite, and containing no decomposable hydrocarbons. A method of and means for so inclosing the film-coating are hereinafter described.

In carrying out the process by any of the above methods, as soon as the coating formed by the action of the pickling bath on the ingot encounters the supermolten metal it is volatilized, leaving an absolutely clean and fresh metallic surface for attack by the supermolten metal.

The coated ingot produced in any of the ways above described is usually worked, as by rolling, (either at once, or after submission to a "soaking" heating to bring all the parts to a uniform temperature), to condense the metal of the coating and also to extend the ingot to marketable shapes, such as bars, rods, plates, or structural shapes. In such extension the joined metals extend together without rupture of the union between them and the final article usually contains the same relative proportions of coating and base as the finished ingot. In rolling, drawing, and pressing the compound copper-steel metal, it has been observed that the metal works better than steel of corresponding grade alone, the coating of unlike metal seeming to facilitate the working of the steel.

In the accompanying drawings I illustrate, rather diagrammatically, apparatus such as may be used in carrying out my process.

In the said drawings:—Figure 1 represents a sectional view of one form of apparatus for carrying out the said process. Fig. 2 shows in detail section the construction of bottom plate and lower portion of casing preferably employed. Fig. 3 shows a sectional view of another form of casing which may be employed.

In Fig. 1, 1 is a preliminary heating chamber for the ingot or core; 2 is a furnace for heating a crucible 3 to maintain in the latter a body of supermolten coating metal; and 4 is a second similar crucible, which in this instance may be supposed to contain molten coating metal maintained at substantially ordinary casting temperature. 5 designates a power hoist, here shown as an electrical hoist, mounted on a suitable track so that it can be moved from place to place; and from said hoist is suspended, by means of a porter bar 6, the ingot 7, which is the object to be coated. Said ingot is shown surrounded by a casing 8 having an internal diameter slightly larger than the external diameter of the ingot, and to said casing is connected a pipe 9, a portion of which is flexible, said pipe provided with a three-way valve 10. This pipe and the valve 10 are provided for supplying to the casing, when desired, an atmosphere of indifferent or neutral gas, such as producer gas. Casing 8 has a weighted head 11 which insures that when the casing is lowered into the molten metal it shall sink therein to the desired depth. 12 designates a bottom plate for the casing arranged to be secured to the ingot 7 itself, by means of a screw 13. Said bottom plate is provided with a raised rib or ring 14 matching a corresponding groove 15, in the lower edge of the casing, and adapted to coact with said groove to make a tight joint. For raising and lowering the casing 8 with respect to the ingot 7, a special hoist 16, suspended like porter bar 6 from hoist 5, is provided. It has, in the form shown, two winding drums 17 upon which are wound two cables 18 connected to opposite sides of the casing, so that said casing may be raised and lowered truly vertically. I customarily provide each crucible with a loose removable cover 19, one only of which is shown in Fig. 1, which cover is designed to exclude air from the molten metal so far as possible, and is removed only when and so long as necessary to lower an ingot and casing into the crucible, or to inspect the molten metal, or for similar reason. To further exclude air from the surface of the molten metal, I cover so much of its surface as possible with a layer of charcoal, a ring 20 of refractory material which floats on the surface of the molten metal serving to maintain a clear space in the center for the passage of the ingot and casing. To assist in forming a tight joint between the bottom plate and casing, I provide in the groove 15 at the bottom of the casing a packing of asbestos cord 21 covered with graphite paste 22.

The casing and associated parts shown in Fig. 3 are substantially the same as above described; but the casing 8 is provided in addition with inlets 23 near its upper end, said inlets arranged to be closed at will by a sliding shield or valve 24.

The casing 8 I customarily use, not only as a means for surrounding the ingot with a neutral or indifferent atmosphere and so protecting it form oxidation, but as a means either for segregating the necessary amount of molten metal to form the desired coating, or as a mold into which the molten metal to form said coating is poured as hereinafter described with particular reference to Fig. 3.

In carrying out the process, a core or ingot 7, previously prepared by sandblasting and pickling as above described, or in any other suitable way, is placed within the heating chamber 1, which I customarily heat by circulating around it hot producer gas or products of combustion. When the core has been heated to the proper degree, the hoist 5 with the casing 8 suspended therefrom is moved over chamber 1, the porter bar 6 is lowered and attached to the ingot, and then said ingot is raised into casing 8. I sometimes fill the casing with a neutral or indifferent atmosphere, such as producer gas, before raising the ingot 7 into it, so as to prevent possible oxidation of the surface of the ingot while in transit to the supermolten bath; but this is hardly necessary, as the coating on the surface of the ingot formed by the pickling fluids mentioned is itself an effective protection when the preliminary heating is not too great. The casing and ingot are then moved over the crucible 3 containing the supermolten coating metal, the lid 19 of said crucible removed, and the casing with the ingot within it is dropped to the surface of the molten metal, after which the ingot is lowered from the casing 8 into the supermolten metal, by means of the hoist 5, the casing being meanwhile kept stationary by means of hoist 16, and after sufficient time for the action of the supermolten metal on the ingot has elapsed, said ingot is raised into the casing 8 again (said casing having previously been filled with the protective gas, by means of pipe 9 and valve 10) and the casing with the ingot within it is raised from crucible 1, the bottom plate 12 is applied to the ingot, the casing with the ingot within it is moved over the second bath of molten metal, in crucible 4 and is lowered to the surface of the molten metal, and then the ingot with the bottom plate attached is lowered from the casing into the molten metal and immediately thereafter the casing 8 is lowered through the molten metal until it rests upon and is closed at the bottom by bottom plate 12; a layer of the molten metal of thickness required to form the desired coating is thereby segregated from the main body of molten metal. The casing, tightly closed at the lower end by the bottom plate, is then raised, and the segregated layer of molten metal within it permitted to solidify against the film coating on the surface of the ingot; said layer of molten metal combining with said film coating before or during solidification, so that when solidification is complete and the coated ingot is removed from the mold or casing 8, the coating is permanently weld-united to the core. The coated ingot thus produced is then worked as above described.

In carrying out the process, as just described, the protection of the film coating formed in the supermolten bath, against oxidation, by the protective atmosphere within casing 8, is an important feature. The film coating formed by the supermolten metal on the surface of the ingot, is at a very high temperature at first, and at least in the case of a metal such as copper, would oxidize instantly if exposed to the air. By the described method of procedure, involving the passage of this film coating direct from the molten metal into a neutral or indifferent atmosphere, all oxidation of the coating is avoided. As above stated, the preferred gas is producer gas formed from coke, charcoal or anthracite; such gas containing no constituents which will decompose upon contact with the highly heated surfaces and deposit carbon or other undesirable substance thereon. Such gas, though of about the same specific gravity as air of corresponding temperature, does not escape from the bottom of the casing except as an excess of the gas is supplied to the casing, because it is highly heated by contact with the hot ingot and so made much lighter than the air surrounding the casing. In practice, to provide for leakage around the porter bar, and for the tendency of gases to diffuse notwithstanding differences in specific gravity, I provide a steady flow of gas into the casing through pipe 9, until the bottom of the casing has been immersed in the metal of bath 4, the excess of gas escaping at the bottom of the casing and burning there harmlessly.

Instead of carrying out the process as above described, by segregating a layer of metal of bath 4 to form the main portion of the coating, I sometimes use the form of casing shown in Fig. 3, provided with filling openings 23 and a closure 24 therefor. Up to the point of dipping into bath 4 this casing is used the same as that shown in Fig. 1, openings 23 being kept closed during transfer of the ingot from preliminary heating chamber 1 to the supermolten bath 3, and the casing, filled with a protective atmosphere, serving to protect the film coating from oxidation upon withdrawal of the ingot from the supermolten bath. But with this form of casing shown in Fig. 3, the bottom plate 12 is caused to close the bottom of the casing tightly before the casing, with the ingot within it, is immersed in the metal of bath 4; and when said casing is immersed in the metal of said bath 4, it is lowered therein until the filling openings 23 have passed beneath the surface of the molten metal and beneath the layer of bad metal which is usually at the surface into the body of good metal beneath the surface, the closure 24 being raised just as it nears the surface of the molten metal. The molten metal then flows in through openings 23, filling the casing, and as soon as the casing is filled, it is raised, the molten metal within it permitted to solidify against the film-coated surface of the ingot and to combine with such film coating, and then the ingot is removed through the bottom of the casing and treated to such working as desired or required, as already explained. In carrying out the process in this manner, the protective atmosphere already within the casing when the filling holes 23 are opened protects the film coating and the molten metal which enters the casing against oxidation; and in fact no air can enter the casing, because the holes 23 are submerged by the molten metal almost instantly after the closure 24 is raised, and during the possible brief instant while said openings are open but not completely submerged the outrush of gas from the casing will prevent entrance of air.

To hasten the filling of the casing with molten metal, and to prevent trapping of gas in the molten metal as it solidifies, I preferably apply suction to the outlet 25 of valve 10, having first set said valve so as to cut off the entrance of gas and to place outlet 25 in communication with the interior of the casing. This is done, however, only after the molten metal has commenced to flow in. And when necessary or expedient, I reduce the fluid pressure upon the joint between the bottom plate and casing, while raising either the casing shown in Fig. 1 or the casing shown in Fig. 3, by applying suction to the outlet 25 of valve 10.

Instead of carrying out the process in two steps, as above described, I may form the entire coating from the metal of the supermolten bath 3, either by segregating the metal to form the desired coating by means of the form of casing shown in Fig. 1, or by lowering a casing such as shown in Fig. 3, with the preliminarily heated ingot within it, into the metal in bath 3, and withdrawing the casing as soon as the latter is filled. In this way I avoid the use of more than one bath of molten metal. However, as above explained, when the main portion of the coating is to be formed of a metal or alloy which cannot be heated safely or with advantage to the supermolten temperature, I conduct the process in two stages, film-coating the ingot with a supermolten metal with which the metal of the main coating will readily unite, and then applying such second coating as above described.

To improve and condense the molten metal, I may apply pressure to the interior of the casing, after the same has been removed from the molten metal and the joint at its bottom has been sealed thoroughly by solidification (which will take place there while the greater portion of the metal is still fluid.) The pressure may be applied through valve 10, or in any other suitable manner.

Obviously, it will often be desirable to apply the coating merely to one or more, but not all, of the sides or surface of an ingot or other object; in which case those portions which are not to be coated will be protected from contact with the molten metal, as for example by covering such portions with a protective shield, or by causing the casing to fit such portions so tightly as to exclude molten metal, or by contacting the molten metal only with such portions of the surface as are to be coated. To protect the casing and bottom plate from the action of the molten metal, I cover the surfaces of the same with a graphite wash.

The complete protecting of the heated surfaces against oxidation afforded by the film produced by the pickling liquor, by the described method of preliminarily heating the ingots, and especially by the chamber 8 containing a neutral or indifferent or non-oxidizing atmosphere, enables me to use as coating metals such readily oxidizable metals as nickel and cobalt, or to coat rods or ingots of metals such as oxidize very readily (for example, nickel, cobalt, or very pure iron or steel, high-carbon steel, etc.) with unlike metals.

The core or base need not be iron or steel, but for most purposes an iron or steel base or core will be preferred. Hence in certain of the following claims I specify steel as the metal of such core or base; and this term "steel" I employ generically to designate all forms of iron, including not merely ordinary carbon steel, both low-carbon or mild and high-carbon or hard, but also wrought iron (the properties of which are nearly identical with those of mild steel) and various compound steels, such as tungsten steel, titanium steel, vanadium steel, chrome steel, nickel steel, manganese steel, cobalt steel; also substantially pure iron—*i. e.*, the chemical element Fe, substantially free from carbon and other metalloids or impurities and modifying ingredients.

The process herein described is an improvement upon and modification of the process described in my application for Letters Patent filed Oct. 6, 1905, Sr. No. 281,680; however I have elected to claim the process generically in this application rather in said application 281,680, the claims of which will be limited to those features of the process specifically different from those specifically claimed herein.

In an application for Letters Patent filed June 16, 1905, Sr. No. 265,508, I have illustrated, described and claimed a process for forming coatings by segregation from molten metal, and in an application filed Dec. 26, 1905, Sr. No. 293,411, I have illustrated, described and claimed segregation apparatus such as referred to. In an application filed April 10, 1906, Sr. No. 310,910, I have claimed the process of protecting the heated surfaces from oxidation by means of an indifferent or protective atmosphere; and in an application filed July 31, 1906, Sr. No. 328,606, I have illustrated, described and claimed the metal coating apparatus herein illustrated and described. Therefore I do not claim any of said inventions herein.

The thorough protection against oxidation provided in my process makes it possible to work according to it, any of the sensitive metals, such as nickel, cobalt, manganese, chromium, tungsten, etc. Likewise steels containing such metals, also vanadium, phosphorus, etc., and high carbon steel may be worked. It is very difficult to maintain the same grade in steel during working, when its surface is exposed while hot to the air. But in my process the surface of the steel is never exposed to the air after the pickling.

What I claim is:

1. The process of producing compound bodies of unlike metals welded together which consists in contacting a surface of one such metal with a supermolten mass of an unlike metal and confining a body of molten metal of substantial thickness in contact with such surface and causing it to solidify thereon.

2. The process of producing compound bodies of unlike metals welded together which consists in weld-filming a surface of one such metal by contacting therewith a supermolten mass of an unlike metal and then confining a second body of molten metal of substantial thickness in contact with such film-coated surface and causing it to solidify thereagainst and combine therewith.

3. The process of producing compound bodies of ferrous and non-ferrous metals welded together which consists in weld-filming the surface of a metal of one such group by contacting therewith momentarily a molten mass of a metal of another such group having a melting point above 900° F., such second metal maintained at a temperature much above its melting temperature, and thereafter welding a substantial coating of metal of such second group on such film.

4. The process of producing compound bodies of ferrous and non-ferrous metals welded together which consists in weld-filming the surface of a ferrous metal by contacting therewith momentarily a molten mass of a non-ferrous metal having a melting point above 900° F., such second metal maintained at a temperature much above its melting temperature, and thereafter welding a substantial coating of non-ferrous metal on such film.

5. The process of producing compound bodies of unlike metals welded together autogenously, which consists in weld-filming a surface of one such metal by contacting therewith a supermolten mass of an unlike metal and thereby coating the surface so coated with a welded-on film of metal derived from the molten mass.

6. The process of producing a film-coating of non-ferrous metal on a surface of a ferrous metal which consists in exposing such surface momentarily to contact with a body of supermolten non-ferrous metal having a melting temperature above 900° F., and then withdrawing from such contact.

7. The process of producing a film-coating of non-ferrous metal on a surface of a ferrous metal which consists in exposing such surface momentarily to contact with a body of supermolten copper and then withdrawing from such contact.

8. The process of producing compound bodies of unlike metals welded together which consists in contacting a surface of a steel base with a supermolten mass of a non-ferrous metal having a melting point above 900° F. and confining a body of molten metal of substantial thickness in contact with such surface and causing it to solidify thereon.

9. The process of producing compound bodies of unlike metals welded together which consists in contacting a surface of a steel base with a supermolten mass of copper, and confining a body of molten metal of substantial thickness in contact with such surface and causing it to solidify thereon.

10. The process of producing compound bodies of unlike metals welded together which consists in contacting a surface of a steel base with a supermolten mass of copper, and confining a body of molten copper in contact with such surface and causing it to solidify thereon.

11. The process of producing compound bodies of unlike metals welded together which consists in weld-filming the surface of one such metal by contacting therewith another unlike metal at a temperature much above its melting temperature and thereafter welding a substantial coating of unlike metal on the film coating so formed.

12. The process of producing compound bodies of unlike metals welded together which consists in weld-filming a surface of a steel base by contacting therewith an unlike metal having a melting point above 900° F. and which is at a temperature much above its melting point and thereafter welding to such surface a substantial coating of metal having a melting point above 900° F. and of a nature unlike steel.

13. The process of producing compound bodies of metals welded together which consists in weld-coating a surface of a ferrous-metal base by contacting momentarily a molten mass of a non-ferrous metal having a melting point above 900° F., such second metal maintained at a temperature much above its melting temperature, and thereafter welding to such surface a substantial coating of a cupriferous metal.

14. The process of producing compound bodies of metal welded together which consists in weld-coating a surface of a ferrous-metal base by contacting therewith momentarily a molten mass of a non-ferrous metal having a melting point above 900° F., such

second metal maintained at a temperature much above its melting temperature, and thereafter welding to such surface a substantial coating of copper.

15. The process of producing compound bodies of metals welded together which consists in weld-coating a surface of a ferrous-metal base by contacting therewith momentarily a molten mass of copper maintained at a temperature much above its melting temperature and thereafter welding to such surface a substantial coating of copper.

16. The process of producing compound bodies of metals welded together which consists in weld-coating a surface of a ferrous-metal base by contacting therewith momentarily out of contact with the air a molten mass of copper maintained at a temperature much above its melting temperature, excluding air from contact with such filmed surface, and thereafter welding to such surface a substantial coating of copper.

17. The process of producing compound bodies of unlike metals welded together which consists in weld-filming the surface of a body of one metal by contacting with such surface a supermolten mass of an unlike coating metal, and causing a body of coating metal to solidify against such film coating under conditions affording pressure between it and said coating.

18. The process of producing compound bodies of ferrous and non-ferrous metals welded together which consists in exposing a body of metal of one such class first and momentarily to a bath of molten metal of the other class having a melting point above 900° F., such second metal maintained at a temperature much above its melting temperature, and then to a lower-temperature bath of molten metal of such other class.

19. The process of producing compound bodies of ferrous and non-ferrous metals welded together which consists in exposing a body of ferrous metal first and momentarily to a bath of non-ferrous metal having a melting point above 900° F., such second metal maintained at a temperature much above its melting temperature, and then to a lower-temperature bath of molten non-ferrous metal.

20. The process of producing compound bodies of ferrous and non-ferrous metals welded together which consists in exposing a body of ferrous metal first and momentarily to a bath of non-ferrous metal having a melting point above 900° F., such second metal maintained at a temperature much above its melting temperature, and then to a lower-temperature bath of molten copper.

21. The process of producing compound bodies of ferrous and non-ferrous metals welded together which consists in exposing a body of ferrous metal first and momentarily to a bath of molten copper maintained at a temperature much above its melting temperature, and then to a lower-temperature bath of molten copper.

22. The process of producing compound bodies of unlike metals welded together which consists in weld-filming the surface of a steel base by contacting therewith a supermolten mass of an unlike metal, and causing a body of coating metal to solidify against such film coating under conditions affording pressure between it and said coating.

23. The process of producing compound bodies of unlike metals welded together which consists in producing an absolute metallic surface on a body of one metal, weld-filming such surface by contacting therewith a supermolten mass of an unlike coating metal and causing a body of coating metal to solidify on such film coating under conditions affording pressure between it and said coating.

24. The process of producing compound bodies of unlike metals welded together which consists in producing an absolute metallic surface on a steel base, weld-filming such surface by contacting therewith a supermolten mass of an unlike metal, and causing a body of coating metal to solidify on such film coating under conditions affording pressure between it and said coating.

25. The process of producing compound metal bodies comprising steel and a cupriferous metal welded together, which consists in producing an absolute metallic surface on a steel base, weld-filming said surface by contacting therewith a supermolten mass of another metal, and causing a body of cupriferous metal to solidify on such film coating, under conditions affording pressure between it and said coating.

26. The process of producing compound metal bodies comprising steel and copper welded together, which consists in producing an absolute metallic surface on a steel base, weld-filming such surface by contacting therewith a supermolten mass of copper, and causing a body of copper to solidify on such film coating, under conditions affording pressure between it and said coating.

27. The process of producing compound bodies of unlike metals welded together which consists in film-coating a surface of a body of one metal by contacting therewith a body of molten metal of unlike nature at a temperature much above its melting temperature, and then contacting a second body of molten metal likewise unlike said first metal with said film coating and causing a substantial layer of said second body of molten metal to solidify against and combine with said film-coating.

28. The process of producing compound bodies of unlike metals welded together which consists in film-coating a surface of a body of steel by contacting therewith a body

of molten metal of unlike nature at a temperature much above its melting temperature, and then contacting a second body of molten metal likewise unlike steel with said film coating and causing a substantial layer of said second body of molten metal to solidify against and combine with said film-coating.

29. The process of producing compound bodies of unlike metals welded together which consists in film-coating a surface of a body of steel by contacting therewith a body of molten copper at a temperature much above its melting temperature, and then contacting a second body of molten copper with said film-coating and causing a substantial layer of it to combine with and solidify against said film-coating.

30. The process of producing compound bodies of unlike metals welded together, which consists in exposing a surface of a body of one metal to the action, first of a bath of molten metal of unlike nature at a temperature much above its melting temperature and then to a lower-temperature bath of coating metal, likewise unlike said first metal, and by pressure completing the weld, thereby forming on said surface a coating of an unlike metal.

31. The process of producing compound bodies comprising steel and an unlike metal welded together, which consists in exposing a surface of a steel base to the action, first of a bath of molten metal of unlike nature at a temperature much above its melting temperature and then to a lower-temperature bath of metal, likewise unlike said steel, and by pressure completing the weld, thereby forming on said steel surface a coating of an unlike metal.

32. The process of producing compound bodies comprising steel and an unlike metal welded together, which consists in exposing a surface of a steel base to the action, first of a bath of molten metal of unlike nature at a temperature much above its melting temperature and then to a lower-temperature bath of copper, and by pressure completing the weld, thereby forming on said steel surface a coating of copper.

33. The process of producing compound bodies comprising steel and an unlike metal autogenously welded together, which consists in exposing a surface of a steel base to the action, first of a bath of molten metal of unlike nature at a temperature much above its melting temperature and then to a lower-temperature bath of said metal, and by pressure completing the weld, thereby forming on said steel surface a coating of an unlike metal.

34. The process of producing compound bodies comprising steel and copper autogenously welded together, which consists in exposing a surface of a steel base to the action, first of a bath of molten copper at a temperature much above its melting temperature and then to a lower-temperature bath of copper, and by pressure completing a weld, thereby forming on said steel surface a coating of copper.

35. The process of producing compound bodies of metal welded together which consists in contacting a metallic surface with a body of molten metal at a temperature much above its melting point, withdrawing said surface from such contact into a protective atmosphere, and contacting said surface with a further body of molten metal and causing a substantial layer thereof to combine with and solidify on such surface.

36. The process of producing compound bodies of metal welded together which consists in contacting a metallic surface with a body of molten metal of unlike nature maintained at a uniting temperature much above its melting point, withdrawing said surface from such contact into a protective atmosphere, and contacting said surface with a further body of molten metal and causing a substantial layer thereof to combine with and solidify on such surface.

37. The process of producing compound bodies of metal welded together which consists in immersing a metallic object in a bath of supermolten metal of unlike nature, withdrawing said object therefrom into a protective atmosphere, and then contacting with said object a further body of molten metal of unlike nature and causing a layer thereof to solidify upon such object.

38. The process of producing compound bodies of metal welded together which consists in film-coating a metallic object by contacting with it a body of supermolten metal of unlike nature, protecting the film coating from oxidation by enveloping the same with a non-oxidizing atmosphere, and contacting with said film coating a body of molten metal and causing a layer thereof to combine with and solidify against said film coating.

39. The process of producing compound bodies of metal welded together which consists in forming a chlorid coating on a surface of a metal object, exposing said surface to a supermolten body of unlike metal and thereby volatilizing said coating and filming over the surface of the metal, and causing a substantial coating of molten metal to solidify on such filmed surface.

40. The process of producing compound bodies of metal welded together which consists in forming a volatilizable coating on a surface of a metal object, exposing said surface to a supermolten body of unlike metal and thereby volatilizing said coating and filming over the surface of the metal, and causing a substantial coating of molten metal to solidify on such filmed surface.

41. The process of producing compound

bodies of metal welded together which consists in forming a volatilizable coating on a surface of a metal object, exposing said surface to a body of unlike molten metal at a temperature much above its melting point and thereby volatilizing said coating and film-coating the surface of the metal object, withdrawing the film-coated object from contact with said molten metal into a protective atmosphere to prevent impairment of the film-coating, and causing a substantial coating of molten metal to solidify on such filmed surface.

42. The process of producing compound bodies of metal welded together which consists in forming a volatilizable coating on a surface of a metal object by chemical attack of such surface, exposing said surface to a body of unlike molten metal at a temperature much above its melting point and thereby volatilizing said coating and film-coating the surface of the metal object, withdrawing the film-coated object from contact with said molten metal into a protective atmosphere to prevent impairment of the film-coating, and causing a substantial coating of molten metal to solidify on such filmed surface.

43. The process of producing compound bodies of metal welded together which consists in pickling a surface of a metal object and thereby forming on such surface a volatilizable coating, exposing such surface to a body of unlike molten metal at a temperature much above its melting point and thereby volatilizing said coating and film-coating the surface of the metal object, withdrawing the film-coated object from contact with said molten metal into a protective atmosphere to prevent impairment of the film-coating, and causing a substantial coating of molten metal to solidify on such filmed surface.

44. The process of applying cast-on coatings which consists in inclosing a heated object to be coated in a closed casing containing a protective atmosphere, introducing molten metal into such casing and exhausting therefrom such protective atmosphere, and applying pressure to the interior of the casing and causing the molten metal therein to solidify on the surface of said object.

45. The process of producing compound bodies of ferrous and non-ferrous metals inseparably united, which consists in contacting a surface of one such metal with a supermolten mass of the other metal, limiting the uniting layer thereby formed by limiting the time of contact between the two metals while one of them remains in the supermolten condition, and causing a layer of molten metal to solidify on such surface.

46. The process of producing compound bodies of ferrous and non-ferrous metals inseparably united, which consists in contacting a surface of one such metal with a supermolten mass of the other such metal, limiting to infinitesimal thickness the uniting layer thereby formed by limiting to a brief period the time of contact between the two metals while one of them remains in the supermolten condition, and causing a layer of molten metal to solidify on such surface.

47. The process of producing compound bodies of ferrous and non-ferrous metals inseparably united, which consists in thoroughly cleansing and protecting the surface of a ferrous metal body of suitable shape and thickness, heating such a body to a temperature between a red heat and a yellow heat, melting an adequate mass of non-ferrous metal and superheating such mass to the described supermolten condition, and bringing the cleansed, heated and protected surface of the ferrous-metal object into momentary contact with the supermolten metal, maintaining the contact for substantially only that time which is required for union of the two metals, and then causing cooling below the supermolten temperature of the metal immediately surrounding said ferrous object and causing a layer of molten metal to solidify thereon.

48. The process of producing compound bodies of steel and copper inseparably united, which consists in thoroughly cleansing and protecting the surface of a steel body of suitable shape and thickness and heating such body to a temperature between a red heat and a yellow heat, melting an adequate mass of copper and superheating such mass to the desired supermolten condition, and bringing the cleansed, heated and protected surface of the steel body into momentary contact with the supermolten metal, maintaining the contact for substantially only that time which is required for union of the two metals, and then causing cooling below the supermolten temperature of the metal immediately surrounding said steel object and causing a layer of the molten metal to solidify thereon.

In testimony whereof I affix my signature, in the presence of two witnesses.

JOHN FERREOL MONNOT.

Witnesses:
MAY I. TRIMBLE,
H. M. MARBLE.