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METHOD AND APPARATUS FOR PRODUCING
BIMETALLIC PRODUCTS

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My present invention relates to flat metal products made directly from molten metal or other suitable molten material wherein such products are of bimetallic nature; the invention also comprises a method and apparatus for producing such products. This application is, in part, a continuation of my copping application, a new Metallic product of sheet-like form and method of making the same, filed November 3, 1937, under Serial Number 172,516.

In my said copending application, I have described the action of a stream of molten metal deposited upon a rapidly rotating cylindrical surface and upon the surface of a belt or band travelling at a high linear velocity, the thinning down of this stream into a strip or film as it contacts the cylindrical surface, belt, or band and is carried by it at the speed of the latter, the heat transfer from the molten strip or film to the cylindrical surface, belt, or band while supported thereon, and the subsequent use of the solidified metal produced as a continuous strip or sheet.

Further research and investigation of the phenomena involved in the aforesaid application have demonstrated that the procedure and apparatus there involved can be modified to produce bimetallic products having new and useful properties and characteristics which may be composed of a plurality of metal layers arranged either side by side or in superimposed layers. Further, these bimetallic flat products can be produced in strip-like form and with predetermined mechanical form, whereby products can be directly made from molten material in proper form and condition for the production of various finished products without going through the conventional intermediate procedures heretofore necessary in producing these products.

It is, accordingly, one object of the present invention to provide a method of and an apparatus for directly producing bimetallic products from molten metal and in which said products have properties at least equal to those produced when such products are made by conventional methods and with the use of conventional equipment.

Another object of my invention resides in the production of a bimetallic strip-like product wherein the metal layers may be of different composition or analyses and wherein such layers may be either disposed in edge to edge relationship or in the form of vertically superimposed laminae.

A further object of my invention resides in the production of bimetallic strip-like flat products which have predetermined variable surface irregularities and predetermined variable cross sectional configurations.

More specifically, an object of this invention resides in simultaneously discharging a plurality of consolidated streams of molten metal in side by side relationship, rapidly accelerating the velocity thereof while causing the streams to assume strip-like form, causing contiguous edges to become inseparably bonded together and then lowering the temperature of the strips sufficiently to cause solidification with a structure composed of minute stringer-like at random (unoriented) primary crystals of substantially identical size and composition uniformly distributed throughout the said strips except at the juncture thereof where the two metals somewhat diffuse into and alloy with each other.

A still further object of the invention resides in apparatus for carrying out the just-recited procedure and in the product thereby produced, as well as in the production of a composite bimetallic strip to which predetermined mechanical shape has been imparted during the production.

A still further object of the invention resides in a procedure such as that just previously defined but wherein the plurality of strips are caused to produce a laminated product wherein one strip or layer is superimposed upon and bonded with another layer throughout their contacting surfaces.

A still further object resides in producing a bimetallic strip which is composed of an initially solid pre-heated metal strip with which an initially molten strip is solidified while in contact with the first strip and under such conditions that the strips are inseparably bonded through their contacting surfaces and wherein at least one such strip has the new crystal structure hereinafter defined.

Other and further objects and advantages reside in the various combinations, subcombinations, and details hereinafter described and claimed as well as in such other objects and advantages as will be either understood by those skilled in this art or apparent from the present description.

In the accompanying drawing wherein I have illustrated embodiments of the present invention:

Figure 1 is a plan view of an apparatus adapted to produce, in accordance with this invention, a bimetallic strip composed of two layers bonded together in side by side relationship;
Fig. 1a is a sectional view through the strip formed in the apparatus of Fig. 1;
Fig. 2 is a vertical sectional view of a fragment of a modified form of apparatus which is adapted to produce a bimetallic strip composed of a plurality of layers inseparably bonded together in superimposed relationship;
Fig. 3 is a fragmentary perspective view of a modified form of bimetallic strip adapted to be produced by an apparatus similar to that of Fig. 2;
Fig. 4 is a view partly in vertical section and partly in elevation of an apparatus adapted to form a ply metal strip-like product from a solid metal strip and a molten metal stream.

My investigations and studies in connection with this invention have clearly demonstrated the phenomena involved and the actions which occur in practicing the invention. For example, when a stream of molten metal or other molten substance poured from a furnace spout or pouring box nozzle at the normal pouring temperature industrially used and at a certain rate of velocity and flow as determined by the conditions of any given operation, is intercepted by a clean, colder metallic or non-metallic surface free of moisture and moving at a uniform rate of speed greater than the velocity of flow of the molten metal stream, a continuous area of contact is created at the intersection of the slow moving molten stream and the rapidly moving solid surface. Under such conditions the liquid and freely moving molten metal or substance instantaneously conforms to the solid moving surface, this being herein termed by me a wetting action. The shaped metal or other substance is instantaneously and continuously carried away from the main body of the liquid stream, being pulled away from the latter in a layer adhering to the solid moving surface. This layer self-levels itself hydrostatically, carrying with it as much of the molten metal or substance as it can attract under its intrinsic forces of atomic attraction and molecular cohesion, thus forming from the molten metal stream a continuous film or layer of uniform section and thickness which adheres to and travels with the solid moving surface. This intimate association effects a heat exchange and undercools the film or layer to a temperature slightly below its freezing point without solidifying it. This film, upon being subsequently and continuously chilled into a solid strip, sheet, or other shape, freely shrinks from the chilling surface without any interfering factors. Such products differ from those produced by other methods of production since they are formed to width and gage directly from molten metal. In the case of strip or sheet, this is accomplished without the use of molds or dies and without mechanical forming, pressing or rolling.

The cross-section of a molten metal film, for example, is directly determined and controlled by the following relation: Its cross-sectional area multiplied by the velocity of the moving metal surface carrying it, is equal to the cross-sectional area of the molten metal of the molten metal stream multiplied by its velocity of flow. Consequently, if a stream of molten metal flowing from a rectangular nozzle 2 inches wide by ½ inch thick at a velocity of 2 feet per second is laid upon a metallic surface moving at 50 feet per second (25 times faster), the molten metal film will have a section as follows: 2 inches multiplied by ½ inch multiplied by 2 and divided by 50 equals .04 square inch. The thickness of the film will be .04 divided by 2 inches, or .020 inch.

All molten metals, allows and substances in their liquid state are freely mobile, but, with the exception of mercury and perhaps the molten or metals having a high surface tension will wet and adhere to a clean, dry, colder metallic surface and be accelerated to the speed and in the direction of motion of the metallic surface in the above-stated film form, this adhesive force being of considerable magnitude. Since the wetting action between the molten metal and the moving metallic surface precludes the presence of air or gases between them,

Furthermore, the perfect contact due to the wetting action allows free play for interatomic attracting forces between the metal of the moving surface and the molten metal or alloy thereon, which force also is of considerable magnitude per square inch; and the two above indicated factors, even if others are also involved, are sufficient to account for the fact that the moving metal film dissolves the chilling surface, adhering to it as a single section moving at the same speed in the same direction up to the point where the molten metal film loses this complete adhesion by shrinkage upon solidification, although of course in the original velocity and direction imparted to it by the moving metallic surface. During such travel of the molten film and the moving surface, the molten film and the moving surface are in effect, a single bimetallic section. The heat exchange therebetween is directly proportional to their respective heat conductivities, the heat gradient between the two metal layers and the length of time this contact exists. Thus it is possible to determine and design apparatus with mathematical accuracy which will precisely accomplish any definite cooling purpose and which will keep under absolute control the amount of heat conducted away from the molten metal or substance in the film form.

For any given thickness of film and any given thickness of supporting surface the greater the velocity of the latter the longer the contact between the two must be in order to chill the film into solid condition and to lower the temperature of the chilled film to a preselected or desired value. This contact time is to be considered as starting from the initially formed and terminating at the instant the film leaves the supporting surface. Thus, heat transfer between the two throughout the contact time occurs between a selected and controlled film section and a selected metallic chilling section. This makes possible the aforesaid precision as to design, control and operation.

In addition, the heat transfer from the self-forming thin film of molten metal to the supporting surface, which may be freely chosen from high conductivity metals or alloys as it has no mechanical stresses to stand such as stretching, rolling or pressing, is so rapid that no unduly long lengths are required even in making sheet, strip, or plate of heavy gauge for rerolling or cold finishing. Hence, the proper machinery can be designed and built to form these solid products and to bring back to its chilling surface any portion of the chilling surface heated by the formed strip by cooling the same before it again comes in contact with the molten metal stream.

Required lengths of contact of the chilling surface can always be provided for, whatever may be the speed of motion of each chilling surface, as long as the metal film is supported by the chilling
The speed of operation of the process generally depends somewhat on the subsequent machinery such as a rolling mill, finishing mill or blanking or forming press and the speed at which this equipment can be operated.

Furthermore, the above length of contact required to cause freezing and further cooling of a metal film to form a strip, sheet, or plate can be exactly and mathematically calculated and the machinery set accordingly for any given metal film thickness, chilling surface thickness, heat conductivity characteristics and velocity.

Strip, plate, and sheet can be so chilled at a sufficiently high rate of production to absorb the output of large melting furnaces as this metal is generally cast in ingot molds and as fast as the present coldier equipment can handle them, such as over 2,000 feet per minute; and, as a matter of fact, with a chilling plate such as a steel belt moving at 8,000 feet per minute, complete chilling of steel, aluminum, zinc brass and other metals into strips has been obtained by this invention.

Furthermore, as a film of molten metal of the ultimate thickness of the finished product contacts and transmits heat to the metal chilling surface at all times, the section of this surface can readily be determined so that taking in account the amount of heat it receives while chilling the strip or plate it can be prevented from exceeding about 500° F. or any other temperature which will cause protection against surface erosion or distortion. Consequently, a metal or alloy of very high conductivity, such as silver, copper or copper alloys, can be used for the chilling surface to quickly conduct the heat through its section and prevent the existence of a high skin temperature on the surface in contact with the molten metal. This eliminates all possibility of checking erosion, sticking and welding of the chilling surface such as now occurs in those methods which resort to rolling a V-shaped pool or bath of molten metal between two rolls, pinching the solidified end of the V-shaped ingot or casting formed between the two rolls in the upper bight between such rolls and mechanically shaping the V-shaped casting into a flat product.

In such prior procedures also, the fixed area of contact, and, consequently, of heat conductivity of the concave faces of the V-shaped casting— which has a liquid core continuously created between the crotch of the two rolls— with the colder roll surface area forming and cooling it is so small in relation to the volume of the V-shaped casting and its heat content that, in order to form a solid continuous flat product; out of it, the velocity of these roll surfaces has to be kept very low. This limiting factor is inherent in procedures of that nature and induces a dendritic, weak cast structure in the ingot. The above referred-to high skin temperature of the roll surfaces causes the same to check and crack and to stick to the V-casting, thus creating ridges and internal ruptures in the flat products formed or shaped under the roll pressure at the roll bight and making these flat products of doubtful or decreased commercial value. In addition, the weight of flat product that can be solidified per minute per foot of width is so low as to be impracticable because present industrial melting furnaces are designed for a large tonnage output which must be disposed of quickly to retain the desired composition and fluidity of the molten metal and hence cannot economically supply the “trickle” of molten metal capable of being chilled and solidified between two rolls.

In my invention, in contrast with the above, the film of molten metal which forms on, adheres to and is carried by the chilling surface does not adversely affect or deteriorate the chilling surface. The wetting of the chilling surface by the molten film results in reproducing the smoothness of that surface on the metal film when the latter solidifies. By using a polished chilling surface the formed solid strip, sheets or plate have an identical surface, thus producing a highly desirable product. As the chilling surface cannot, under any conditions here involved, be eroded or raised to a temperature at which it will crack or check, no such cracks or check marks or resulting internal stresses and ruptures are induced in the formed, solid strip which therefore is in a form and condition suitable for commercial use. This special new surface obtained by vacuum wetting of the molten metal without any mechanical deformation is a definite characteristic of my invention.

Inasmuch as the molten metal is immediately shaped into a thin film as soon as it touches the chilling surface and is chilled in film and the film spontaneously crystallizes throughout its thickness with a single new and special primary crystal structure free of separate or distinct zones or layers of crystallization. Such crystallization occurs when the film reaches freezing temperature; i.e., when the superheat of fusion and the latent heat of fusion have been conducted away.

This primary structure, although obtained without mechanical working or heat treatment, is of very high strength and physical properties equal to or better than conventional castings and metal. The structure is characterized by minute stringer-like at random (unoriented) crystals substantially identical in size and section which are homogeneously and uniformly distributed throughout the whole mass of the solid product. by a uniformity of chemical composition throughout the whole mass of the product identical to that of the molten metal supplied by the melting furnace and by improved physical properties free of any directional effect as a result of the prevention of the defects generally inherited from a primary ingot structure, such as segregation, non-uniform chemical composition, concentration of impurities and inclusions at the grain boundaries of columnar crystals, pipe, gas pockets, etc., and flow lines due to mechanical working and crushing of large crystals. This new special primary structure retains most of the above characteristics even after mechanical working such as rolling, forging, extruding and heat treating which it responds more readily on account of its uniformity, giving the so-worked or treated product a distinctive structure different from similar products originating from an ingot of cast molten metal.

Another result of this invention is the production of a new crystalline structure in alloys and more especially in alloys high in non-ferrous components such as high speed tool steels and the stainless irons and steels. In these alloys, as cast from the molten state either in sand castings or in ingot molds, a selective solidification of the component metals within the columnar and equiaxed crystals which form is unavoidable, and as this occurs it imparts to the crystals a very heterogeneous chemical composition with segregation of certain components and impurities at the crystal boundaries. This considerably re-
duces the inherent, special and specific properties for which these alloys have been developed and used, such as resistance to corrosion, acids, abrasion and red hardness as well as cutting quality and other physical properties.

In my above described method of undercooling the molten alloy in a continuous thin section to the point where it will spontaneously crystallize throughout the mass of the solid strip, sheet or plate formed, the original homogeneous composition of the alloy in the molten state is fully retained in every one of the minute crystals formed and is, moreover, still retained after mechanical working and heat treating. This entirely new and different structural crystalline condition considerably increases the known intrinsic properties of these alloys over those as now commercially produced and consequently broadens the field of their usefulness.

As most metals and alloys in their molten state contain occluded or dissolved gases which are liberated when the solid phase precipitates and the metals solidify in a mold and in prior practice, these gases are entrapped within the solidified metal products in the form of gas pockets which are especially numerous in efficaceous steels. However, it will be appreciated that in practicing my invention subintentially all these gases are free to escape and will be liberated during the time that the metal film is rapidly cooling while adhering to the moving surface and the solid phase is starting to precipitate before the under-cooled film is solidified.

In connection with non-metallic substances, such as molten glass, my invention differs considerably from conventional or prior art practice which latter usually involves the forming and shaping of cooled glass not molten glass; viz., glass which has been slowly cooled from a temperature above 2700° F. at which it is in a fluid state to a temperature of about 2200° F. at which it is still plastic but has a considerable tenacity.

Applying my invention, fluid molten metal glass freely running from the refining chamber of the melting furnace is supplied in a free running stream to the moving cooling surface and is formed on such surface into a film of controlled width and thickness by hydrostatic action without any mechanically applied pressure as by rolls and this film is subsequently and continuously cooled by heat exchange with the cooling moving surface through its plastic range to the solid state and then tempered and collected as a strip, plate or other shape of plate glass or window glass.

In my invention, therefore, the plate glass or window glass is directly formed to its final width and thickness directly from fluid molten glass without the usual crushing of its surfaces such as occurs when forming plastic glass between rolls which chill a skin on both sides and then break it, thus destroying the transparency of the glass.

Referring now to the drawing, Figure 1 illustrates an apparatus characterized in that two distinct molten metals or substances are mechanically fed by a metering valve in two contiguous streams upon a cooling belt or cooling section, these two molten streams are deposited in non-turbulent condition side by side and the strips or films subsequently formed are united at their edges to produce a bimetallic strip having longitudinal bands of different metals. The double-compartmented receptacle 10 has a chamber 11 into which molten metal is poured, a port 12 in partition 13 and through which the molten metal flows free of slag into chamber 14 from which it then flows through outlet 15 under metering cylinder 16 to be laid upon moving belt 17 running in grooved guides 18 which causes it to assume the form of a film or strip 18.

The receptacle 16 has a compartmentated chamber 20 into which another molten metal is poured simultaneously, port 21 through which it flows into chamber 22 free of slag and from which it flows through outlet 23 under metering cylinder 24 which controls the stream upon moving belt 17, thinning it and converting it to strip 18 or film 24. The outlets 15 and 23 are shaped so that their streams will merge at 25 when propelled by metering cylinder valve 16. The belt 17 consequently carries a single film or strip formed of two distinct metals, mixed and bonded at their contiguous edge, of preselected width and thickness and of a total width 28 which is also preselected.

At the point where this bimetallic film has lost enough heat by conduction to belt 17 so that it is still pliable but has a part of the solid phase precipitated, the water-cooled forming cylinder 26 is adjusted to press upon this film to reduce its thickness and while doing so expands the width of the film 24 to square it against the straight edge of rim 26 of this roll and expands the opposite edge of film 18 against toothed rim 25 of the same roll 27 so as to mold that edge in the shape of saw teeth 19 or any other desired shape. Furthermore, the face of roll 27 can be set out of parallel (inclined) with respect to the surface of the belt 17 and the film 18 it carries so that the flat solid product will be wedge-shaped, as shown in Fig. 1a, this being a very desirable section for saw blades or other products. Furthermore, the tooth-edge band or strip 18 can be made of a good cutting steel alloy, such as high speed steel, and the other band or strip 26 of a strong and tough alloy steel, such as chrome vanadium steel. As 19 and 24 merge and unite the strongest possible bond and union of these two alloy steels is effected as they readily mix at their edge in the molten state, free of any oxidizing agent or fluxing material and be solidly or substantially simultaneously. Similar arrangements with various molten metals can be produced for various commercial purposes. This whole operation can be carried out under an air-tight hood, in a vacuum or in any special or desired atmosphere of stagnant or circulated pre-selected gases as will be more fully understood from my aforesaid copending application.

It will, moreover, be observed from Figure 1 that roll 21 is rotatably mounted in bearings 30 in which hollow trunnions or the like 31 turn. The hollow trunnions communicate with a passage 32 in the roll 21 via openings 33 in members 28 and 29. A coolant, such as water, enters an intake 34 and leaves via the outlet 35, suitable connections being made at the trunnion ends to permit relative rotation. This cooling prevents undesired heating or rise in temperature of roll 27. One trunnion 31 has a gear 36 secured thereto which is driven or rotated at requisite speed by any suitable associated equipment (not shown).

Fig. 2 is a modification of Fig. 1 in that two or more streams of molten metal are laid in successive superimposed layers on the chilling belt or section instead of side by side. This view shows a molten metal receptacle 37 with a metering cylinder valve 38, like that (16) described above, which lays on belt 41 a stream of molten
metal 39 of preselected and controlled width and thickness from the body of molten metal or other substance 40 in receptacle 31. Stream 39 is supplied at a definite rate of flow as controlled by the metering valve. This stream 39 is thinned down and carried by moving belt 45 in the form of film 42 of uniform width and thickness. This film cools down under known conditions by transfer of heat to belt 41; hence, a definite temperature convenient for proper bonding with another metal film or strip can be secured by predetermining the length of contact, e.g., by adjusting distance 43, which will produce this temperature. This contact length can be mathematically calculated. At this point, a stream 44 of another or different metal 45 supplied from receptacle 46 by metering cylinder valve 47 is supplied and deposited over the film 42 to form another superimposed film 48 by the same wetting action already described. Film 48 may be of the same or different width, as it may be desired to cover only part of the surface of film 42, and of a preselected thickness as controlled by the rate of flow of molten metal 45 propelled by metering valve 47 and the velocity of belt 41 and film 42 adhered to it.

From such point, the belt 41 carries two superimposed metallic films which can be submitted to the action of forming roll when reaching a preselected temperature, and the whole operation can be carried under an airtight hood, in a vacuum or in any desired stagnant or circulating gaseous atmosphere so as to keep a clean unoxidized film surface to properly unite the metal of film 42 with it. By proper selection of the metal used, the film, and temperature of first film when the second one is formed upon it, many metals or alloys can be united to form bimetallic strips and the bond and union between the two superimposed layers made very effective. Three or more layers can be also formed in the same manner to obtain specific, multimetallic, flat, solid products.

Instead of another molten metal or alloy, the receptacle 46 with metering valve 47 can be used to mechanically distribute over the surface of film 42 a layer of finely powdered material, such as ferrous base, to mix and combine, for instance, with a molten film of ordinary steel and give the solid, flat product an alloyed surface resisting heat and corrosion; or pulverized ferro-manganese to make the surface wear and abrasion resisting, or any of the hard facing powdered materials such as boron crystals or others, or diamond powder can be embedded in the whole width or part of it to make special tools. Also metallic powder, such as aluminum, copper, brass, etc., can be mechanically distributed so as to fuse over the surface of the molten metal film which subsequently is subjected to the action of a forming roll to embed any one or a combination of the above materials into the carried metal film and at the same time to smooth or shape its top surface. Furthermore, by providing the forming roll with a grooved or corrugated surface, grooves or corrugations 48 can be reproduced and molded in the solid flat product 40 as illustrated in Fig. 3. In this same manner other different shapes, impressions or irregularities can be reproduced such as serrations, corrugations, markings, dividing lines, embossed content, etc.

Fig. 4 illustrates a variation of the apparatus of Figs. 1 and 2 in that it is adapted to make ply-metal flat products. In this form of the invention, the molten metal stream 51 discharging from receptacle 52 is formed into and carried as a metal film 53 by belt 54. Forming roll 55 is set so that a solid strip or sheet 56 of another metal unrolling from coil 57 will press down over the metal film 53 and bond 58 with the film 53, when reaching that point, has lost enough heat by conduction to belt 54 to be still liquid but has part of its solid phase precipitated so that it will wet the strip 58 unrolled under roll 55 and will bind and unite with this solid strip to form a ply-metal flat product.

Referring further to Fig. 4, the belt 54 is an endless belt of suitable metal passing around wheels or pulleys 39 either of which is suitably driven. The surface of belt 54 which contacts the film 53 is preferably of such nature as to impart a smooth surface to such film.

Receptacle 52 is preferably in the form of a metal container 60 having a refractory lining 61. A partition 62 is provided with a port 63 so that molten metal free of slag can be discharged through nozzle 56.

Solid strip 56 is preheated prior to contact with strip 53. This is accomplished by mounting an electric or other heating device 64 in such manner as to form a sealed chamber 65 to which active or inert gas may be admitted to maintain constant temperature which depends on the particular composition of strip 56.

The composite strip may be formed into a coil around core or wheel 67 and in such strip at least the strip 53 has the primary crystal structure above referred. Strip 55 may be made by the present procedure and in such has a similar crystal structure.

The foregoing is intended to be illustrative rather than limiting, and within the scope and principles hereof I may resort to many modifications, substitutions, additions or omissions which will be understood or appreciated therefrom or which will be apparent to those skilled in this art. While, in certain respects, certain portions of the apparatus have been illustrated and described only in fragmentary form, the construction and operation thereof will, nevertheless, be clearly understood from the foregoing particular in connection with my aforesaid copending application, Serial Number 172,516. Rather, the invention is to be defined by the appended claims and, as will be ascertained from such claims, comprises the products set forth as well as the method and apparatus for producing the same. While I have not herein described in detail the water-cooled metering valves 39, the construction and operation thereof will be apparent both from the above and from the aforesaid copending application.

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

1. A method of making a bimetallic flat strip-like metal product direct from molten metal which comprises simultaneously discharging a plurality of streams of molten metal of diverse composition side by side in non-turbulent condition, subjecting each such stream of metal to forces which convert it to strip form, conveying the strips in side by side relation at the same speed in such condition, uniting adjacent mar
snormal edges of such strips and rapidly extracting
heat from the strips to produce a solid integral
strip having longitudinal bands of diverse metals.
2. A method of making metal strip having
longitudinal bands of different composition which
comprises producing and maintaining a plurality
of bodies of molten metal out of contact with
each other, withdrawing molten metal from each
such body and simultaneously depositing the
same in non-turbulent condition upon a rapidly
moving surface in such manner that a plurality
of strips are formed side by side on such surface,
uniting adjacent marginal edges of such strips
prior to solidification thereof and cooling the
composite strip to solidify it in such form.
3. A method of the character set forth in claim
2 wherein the metal is subjected to the influence
of a shaping force between the deposition and
the solidification thereof.
4. A method of the character set forth in claim
2 wherein the metal is subjected to a shaping
force after deposition but before full solidification
which imparts a wedge-shaped cross-section to
the completed strip.
5. A method of the character set forth in claim
2 wherein a serrated outer edge is formed in one
of said strips.
6. In an apparatus for producing a flat metal
strip having longitudinal bands of different com-
position united into an integral whole, a rapidly
moving metallic heat absorbing surface adapted
to have a plurality of streams of molten metal
discharged thereon in side by side relationship
for undercooking and accelerating the streams of
molten metal into a ribbon-like form, and means
for separately containing and discharging a plu-
rality of compositions of molten metal in the
form of separate consolidated streams onto said
heat absorbing surface and in directions towards
each other to merge and unite contiguous edges
of said streams as they are discharged onto and
accelerated by said moving heat absorbing ele-
ment into a strip-like form.
7. In an apparatus for producing a flat metal
strip composed of integrally united longitudinal
bands of different composition, a plurality of re-
ceptacles for molten metal of different analyses,
a metal support rapidly moving beneath said re-
ceptacles, an outlet leading from each of said re-
ceptacles, for depositing a stream of molten metal
onto said support, one of said outlets being di-
rected towards the other, for directing one stream
of metal towards the other and merging contigu-
ous edges of said streams as they are discharged
onto said support, and said metal support having
a heat absorbing chilling surface to undercool
and accelerate said streams into a strip-like form
and unite them into a solid permanent form with
a structure composed of minute stringer-like at
random (unoriented) primary crystals of uniform
size, composition and distribution.
8. A method of making a bimetallic flat strip-
like metal product direct from molten metal
which comprises discharging a plurality of con-
solidated streams of molten metal of pre deter-
mined composition in a non-turbulent condition,
intercepting at least one of said molten streams
by a rapidly moving relatively cool smooth heat
absorbing surface which is moving past the point
delivery of each such stream at a speed great-
er than the speed of discharge of each such
stream, to accelerate and form at least one of said
streams into a strip-like form, and at substan-
tially the same time merging adjacent streams
along a common surface, under-cooling such
streams by said heat absorbing surface to com-
plete union thereof and reducing the temperature
of all such streams until complete solidification
is effected and while producing a primary crystal
structure of the character herein described in at
least one of such strips.

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