June 17, 1958 J. B. BRENNAN 2,838,814

METHOD AND APPARATUS FOR CASTING

Filed Jan. 19, 1956 5 Sheets-Sheet 1

Fig. 3

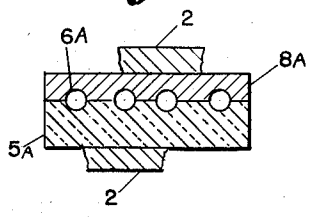
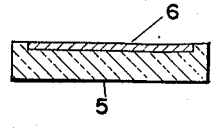


Fig. 1

Fig. 2



INVENTOR.

Joseph B. Brennan

June 17, 1958 J. B. BRENNAN 2,838,814

METHOD AND APPARATUS FOR CASTING

Filed Jan. 19, 1956 5 Sheets-Sheet 2

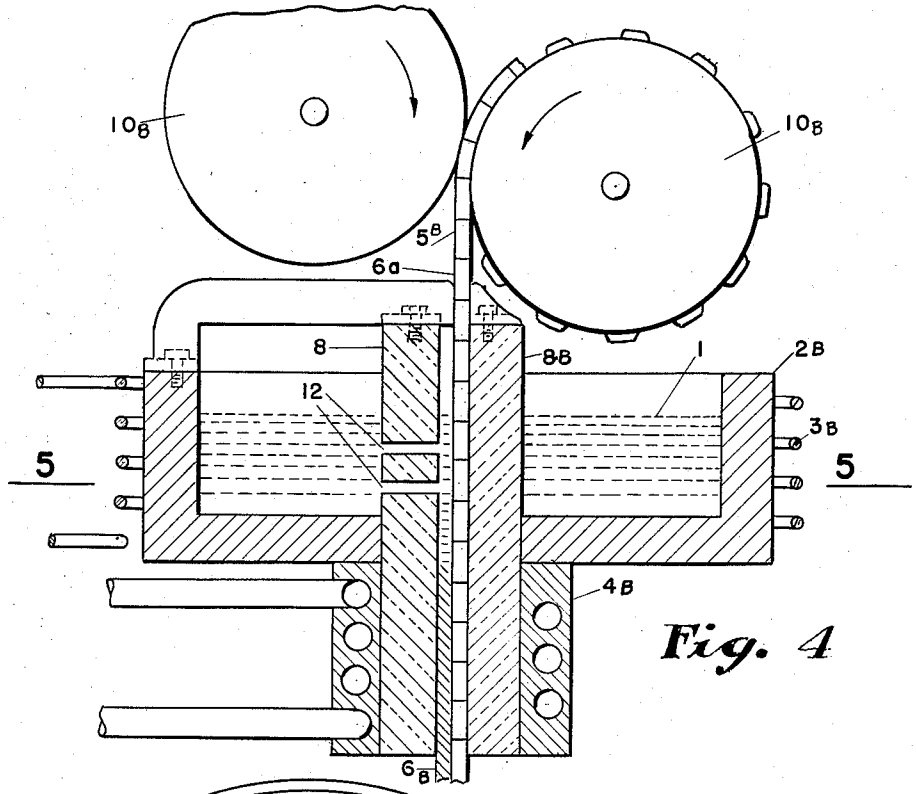


Fig. 4

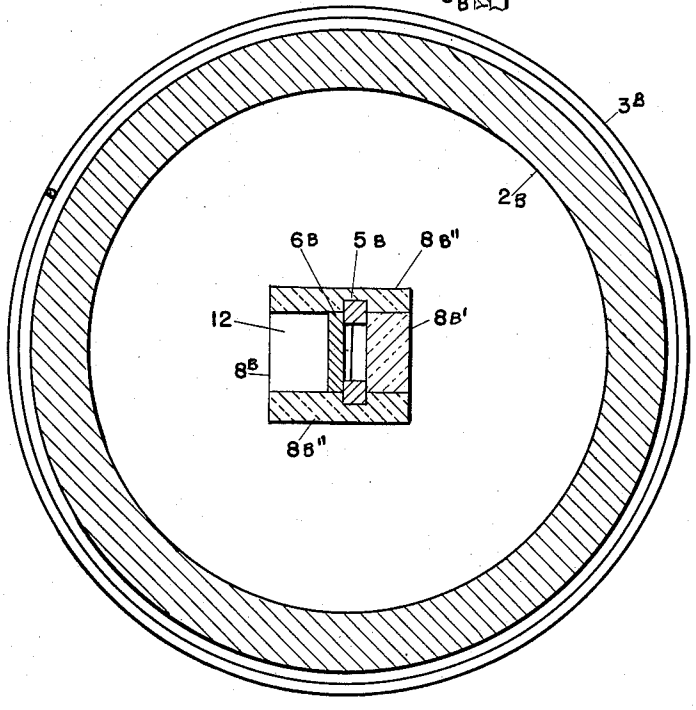


Fig. 5

INVENTOR.
Joseph B. Brennan

June 17, 1958 J. B. BRENNAN 2,838,814

METHOD AND APPARATUS FOR CASTING

Filed Jan. 19, 1956 5 Sheets-Sheet 3

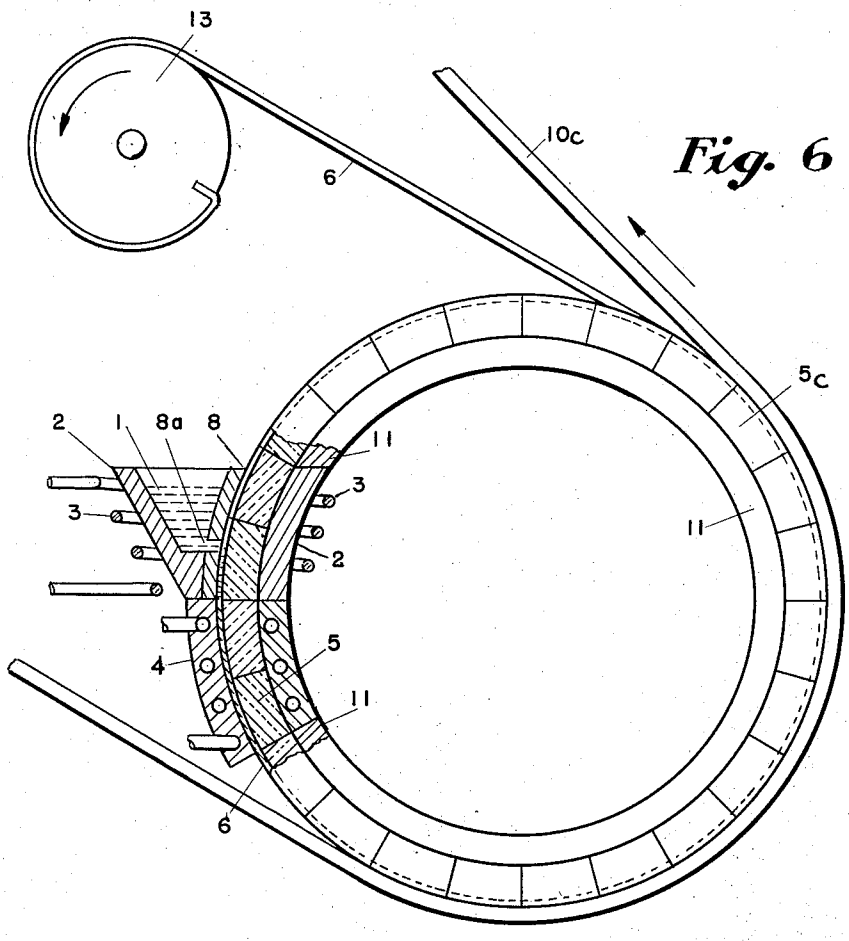


Fig. 6

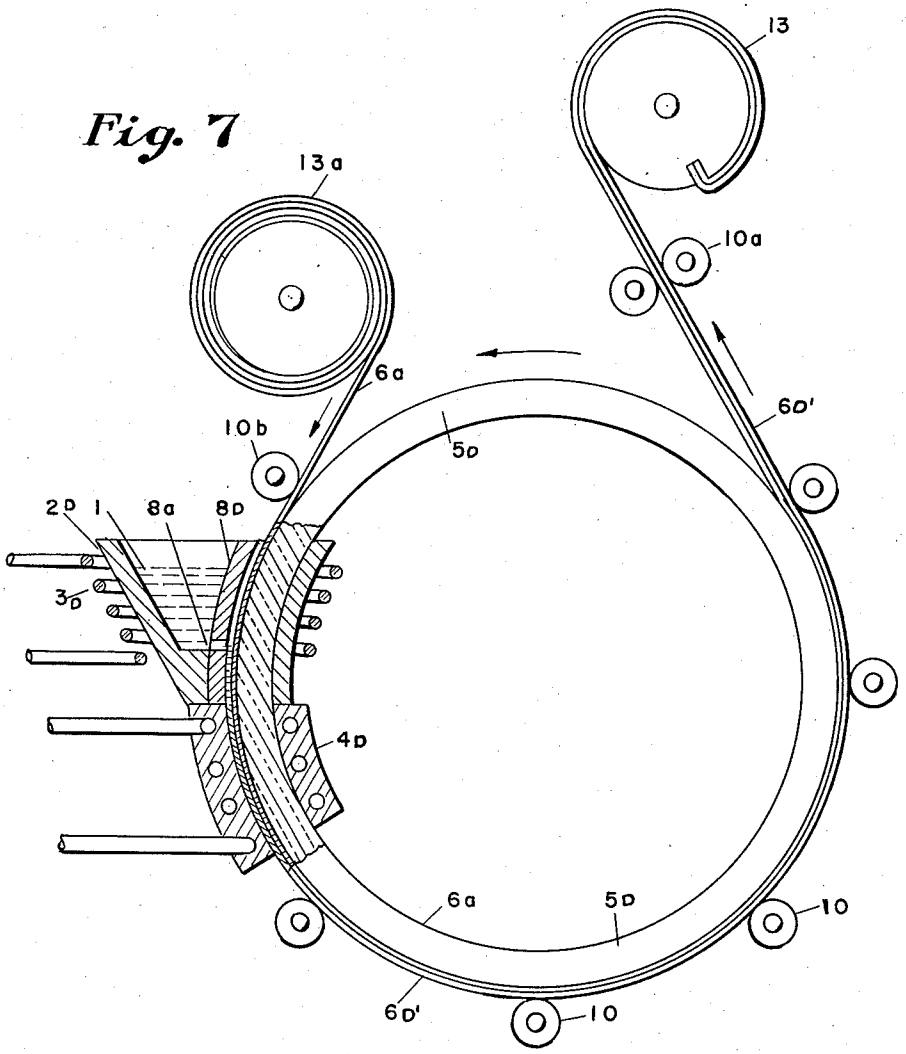
INVENTOR.
Joseph B. Brennan

June 17, 1958 J. B. BRENNAN 2,838,814

METHOD AND APPARATUS FOR CASTING

Filed Jan. 19, 1956 5 Sheets-Sheet 4

Fig. 7



INVENTOR.
Joseph B. Brennan

June 17, 1958 J. B. BRENNAN 2,838,814

METHOD AND APPARATUS FOR CASTING

Filed Jan. 19, 1956 5 Sheets-Sheet 5

Fig. 8

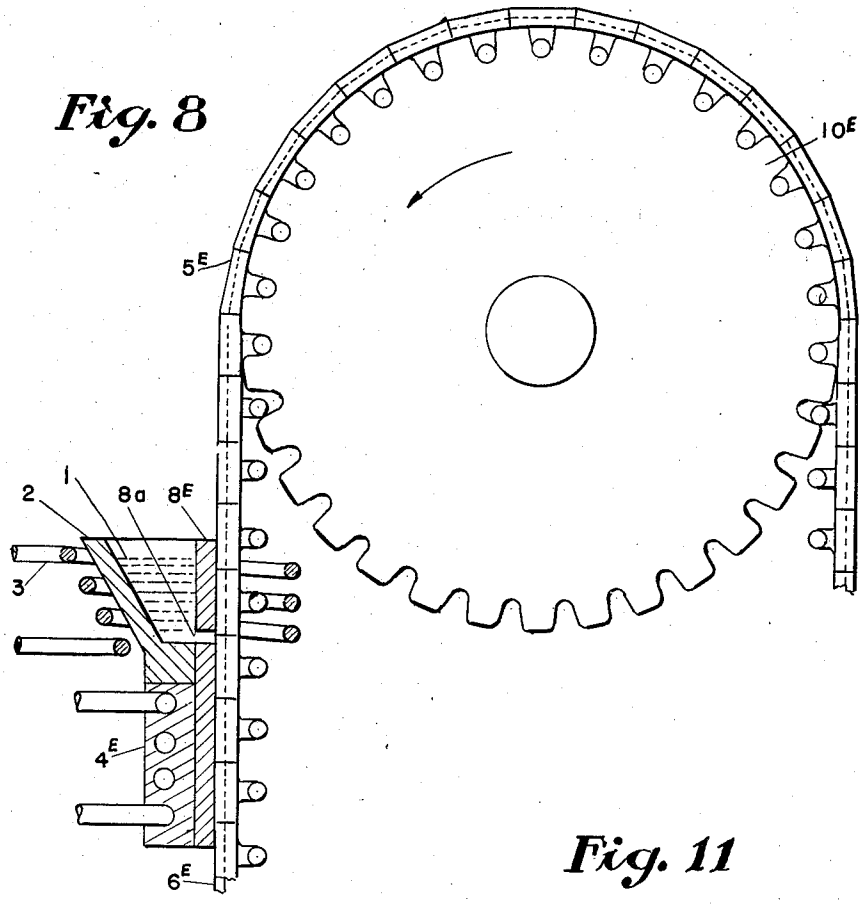


Fig. 9

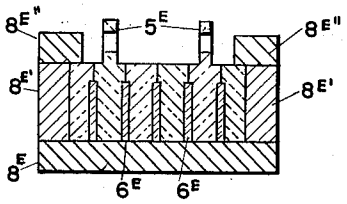


Fig. 11

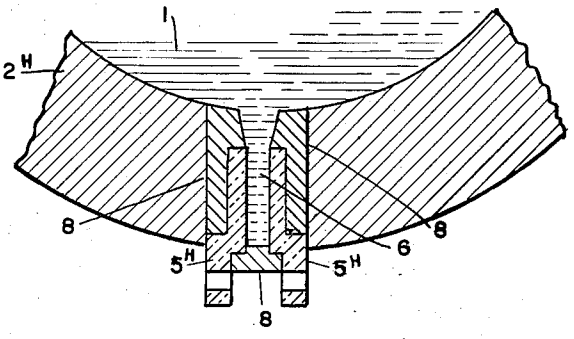
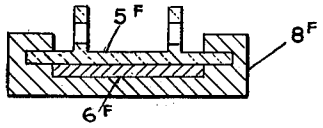


Fig. 10



INVENTOR.

Joseph B. Brennan

United States Patent Office 2,838,814 Patented June 17, 1958

2,838,814

METHOD AND APPARATUS FOR CASTING

Joseph B. Brennan, Cleveland, Ohio

Application January 19, 1956, Serial No. 560,100

2 Claims. (Cl. 22—57.2)

This invention relates to the continuous casting of metal and other molten materials in strip, wire, or rod form or in the form of tubing or shapes, and this invention is a continuation in part of my U. S. Patent application Serial No. 213,559, filed March 2, 1951, now abandoned, in turn a continuation-in-part of my applications Serial No. 642,968, filed January 23, 1946, and Serial No. 147,466, filed February 18, 1940, both now abandoned.

This invention relates, for example, to a novel method and apparatus for casting strip metal or molten material wherein a moving cavity in the form of one or more grooves is cast full of molten material while in traversing contact with a pool of molten material situated adjacent the grooves or cavities which are filled with molten material. Thereafter, the molten material cast in said grooves or cavities is carried, while molten, into a solidification zone and cooling zone by carrier molds or surfaces and the molten material therein is solidified and subsequently removed therefrom continuously.

As a feature of this invention, a differential in adhesive friction is set up by traveling molds or cavities in such a manner that movement of the cast material through a forming and solidification die presents little difficulty in the way of die friction, and the ordinary friction which is generally found in forcing cast metal through a solidification zone and through a cooling die continuously is largely eliminated. Thus, the adherence of the cast material to the moving groove or surface overcomes other die friction.

This invention also refers to a method and apparatus for casting a layer of metal in bonded relationship against a moving band of higher temperature melting metal such as for example casting a layer of bronze in bonded relationship against a moving layer of cold rolled steel wherein the layer of cold rolled steel is moved with at least one face exposed to the pool of molten metal and a layer of molten metal is cast and held in shape on the moving strip and moved through while molten and solidified thereon.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawings:

Fig. 1 is a side elevation view, partly in section, of one form of apparatus constituting the present invention;

Figs. 2 and 3 are cross-section views taken substantially along the lines 2—2 and 3—3, Fig. 1;

Fig. 4 is a cross-section view of another embodiment of this invention;

Fig. 5 is a cross-section view taken along the line 5—5, Fig. 4;

Fig. 6 is a side elevation view, partly in section, showing an apparatus similar to that of Fig. 1;

Fig. 7 is a partial section view of apparatus for forming composite metal strip;

Fig. 8 is a partial section of yet another form of casting apparatus; and

Figs. 9, 10, and 11 are horizontal section views of molds or dies which may be employed in the Fig. 8 apparatus.

Referring to the drawings herewith, Fig. 1 is illustrative of an apparatus suitable for carrying out the purpose of this invention wherein 1 represents a pool of molten metal and 2 represents a ceramic crucible containing a pool of molten metal, 3 represents an induction heating coil for heating the metal in the ceramic crucible 2.

Below the ceramic crucible 2 containing the molten metal 1 and in cooperative relationship therewith is the cooling die 4 having a coolant, such as cold water, circulating therethrough and which is in contact with the molten metal which has been previously formed into a strip on the face of the wheel 5 which is of ceramic material and which rotates counterclockwise guided by and driven by the rollers 7 and 7*a*.

A guide shoe of graphite 8 is situated against the face of the rotating ceramic wheel 5 and spaced therefrom, said shoe 8 having one or more openings 8*a* therein for feeding the molten metal from the pool of molten metal against the face of the rotating wheel 5 as it rotates counterclockwise past the openings 8*a*. The face of this wheel 5 may be grooved or have cavities therein and may even carry cored members therein.

In any case, a cavity is presented by the face of the wheel 5 as it passes the openings 8a leading from the molten metal pool 1 so that a layer or other form of metal is fed thereon and formed and is carried downward through the solidifying die 4, for example a solid strip 6. This metal strip 6 is then carried around substantially all the way over the outer face of the rotating ceramic wheel 5 inside the rollers 7 in such a way that there is no slippage between the cast strip 6 and the face of the wheel 5 on which it rests.

An advantage is gained by carrying this strip 6 almost all the way around the outer face of the wheel 5 due to the fact that the cast metal strip 6 tends to cling to the wheel 5 due to shrinkage so that the cast strip 6 moves in exact synchronism with the wheel 5 and without slippage. This is partly due to the fact that a certain shrinking action occurs in the cast strip 6 which causes it to cling to the outer surface of the wheel 5.

In addition to this, the pressure of the rollers 7 on the outside of the cast metal tends to keep it in place with reference to the wheel 5. The tension rollers 10 pick up the cast strip 6 after it has passed substantially around the wheel 5 and is stripped therefrom and may be used for leveling and sizing and smoothing as well as for producing tension on the strip 6 which tension can be used to cause the wheel 5 to rotate in timed relation with the rollers 10 which in this case would govern the speed of rotation of the wheel 5 as well as the speed of casting the strip 6.

A windup reel 13 picks up the cast strip 6 after it passes through the rollers 10 and coils the cast strip or wire or rod suitably for further use or process.

Fig. 2 represents a section of Fig. 1 taken on the line 2—2, the wheel 5 having a peripheral groove therein to form a cast metal strip 6.

Fig. 3 represents an alternative cross-section taken on the line 3—3 of Fig. 1 wherein the shoe 8A and wheel 5A

are formed with complementary grooves to cast wires or rods 6A.

Fig. 4 represents an alternative method and apparatus for producing strip metal according to the teachings of the invention. Reference number 1 again represents a pool of molten metal, 2B represents a crucible heated by high frequency coils 3B, for example. A coiling die 4B situated below the crucible 2B adjacent to the guide tube 8B having perforations 12 therein extends downward through the pool of molten metal 1 and an adjoining section of the guide tube 8B' then down through the pool of molten metal in fixed relationship and a chain 5B, of ceramic material is drawn down through the cavity to form a casting 6B between the sections 8B and 8B'.

The ceramic chain 5B fits closely against section 8B' and in spaced relation to the inner face of the section 8B so that a fixed spacing exists between the face of the ceramic chain 5B and is presented to the molten metal pool entrances 12. The molten metal flows into the entrances 12 and along the face of the chain 5B and is carried down through the solidification zone 4.

The joints between the links of chain 5B tend to present a somewhat irregular cavity surface to the molten metal which enters through the openings 12, and the fins of metal entering the joints assist in carrying the molten metal downward. After the molten metal 1 has been solidified in the face of the chain 5B, it is easily carried along by the chain and out of and through the solidification die 4B due to the greater adherence to the somewhat irregular jointed face of the chain 5B with reference to the smooth inner face of the section 8B. The wheels 10B guide and drive the chain 5B.

Fig. 5 represents a section view taken on the lines 5—5 of Fig. 4 wherein the crucible 2B filled with molten metal 1 and surrounded by heating coils 3B show the openings 12 which lead from the pool of molten metal 1 to make the casting 6B on the face of the chain 5B. The backing-up block 8B' guides the chain 5B. The other sections 8B'' of the guide frame are for guiding the chain 5B so that a uniform casting 6B is formed on the face of the chain 5B as it passes downward through the molten metal pool 1.

Fig. 6 illustrates a variation in construction and method of apparatus suitable for use in carrying out the purposes of this invention wherein the molten metal pool 1 is contained in the crucible 2 which has one or more openings 8*a* leading through a spacing block or spacing die 8 in spaced facial relationship with the rotating metal or ceramic wheel 5C which is rotated counterclockwise by means of the belt 10C which rides thereon and thereover.

The ceramic block wheel 5C has a groove in the face thereof similar to that shown with reference to the grooves in Fig. 1 as illustrated in Fig. 2 above. This groove is filled with molten metal as it passes by the openings 8*a* and the molten metal is cast into and carried in this groove by the wheel 5C down through the solidification zone 4 and emerges as the cast strip 6 in the groove on the outer face of the rotating wheel 5C. Inasmuch as there is a belt 10C passing around the wheel 5C and over the cast strip 6 thereon, this belt 10C keeps the cast metal strip 6 in place on the outer groove or grooves on the wheel 5C and tends to keep it from slipping and tends to keep it in timed relation governed by the speed of the belt or chain 10C. The strip 6 is wound up and coiled on the winding reel 13.

A principal feature illustrated in Fig. 6 is that timed guiding in the form of a belt or chain, which may also be grooved or cavitied, tends to keep the apparatus in motion without slipping, by a simple means.

Fig. 7 illustrates a type of apparatus and method whereby a casting, bronze for example, can be continuously applied to a steel strip and bonded thereto. Again in Fig. 7, we illustrate a pool of molten metal 1 which has openings 8*a* in the crucible 2D leading to a cavity formed by the die shoe 8D in spaced relation to the wheel 5D having a strip of metal 6D held close thereto by roller 10D, which moves counterclockwise.

Said wheel 5D, having its covered face presented to the pool of molten metal with a strip of steel 6D fed under roller 10D against the outer face of the wheel 5D, and moving in synchronism therewith so that it fits snugly thereon, is moved down inside the perforate die shoe 8D so that the metal flows through the openings 8*a* against the outer surface only of the strip 6D which strip became heated to at least the melting point of molten metal 1 by high frequency coils 3D as the metal passes down through the magnetic field of the high frequency coil 3D.

The molten metal 1 is deposited on the exposed face only of the steel strip 6D as it is carried downward on the wheel 5D and through the cooling zone 4D so that the cast metal is solidified and bonded to metal strip 6D and emerges as a lamination 6D' on the exterior face of the steel strip 6D. The wheel 5D may be driven by rollers 10D' on the outside of the lamination 6D' cast on the steel strip 6D for example, rollers 10D'' may be used to produce a driving tension synchronously with roller 10D to drive the wheel 5D, alternatively it may also be used to densify and improve the uniform gauge of cast lamination strip 6D'.

The windup reel 13 is used to wind up the finished lamination, and the feed reel 13D is used to supply the steel strip 6D to the molten-metal-forming die 8D under the roller 10D, which roller 10D holds the strip 6D closely in timed relation with the wheel motion so that no buckling occurs when the steel strip 6D passes through the high frequency coil 3D in contact with the molten metal 1. Rollers 10D'' and 10D and wheel 5D are synchronized.

Fig. 8 illustrates an alternative form of apparatus wherein a ceramic chain 5E is driven by the toothed wheel 10E and the ceramic chain 5E has a deep groove at least in one face thereof or has multiple grooves in one face thereof. These multiple grooves or single grooves are moved in close relationship to the guide 8E with the grooves open to the molten metal 1. The guide 8E may be preferably exactly fitted up against the opening in the groove and the ceramic members of the chain 5E as they are carried downward in contact with the guide 8E.

The straight section of the chain 5E after it has left the wheel 10E can be very accurately aligned. Little or no metal will flow between the joints of the sections of the chain 5 when they are moved in straight and parallel alignment.

As the heated chain 5E passes downward, the groove therein being exposed to the pool of molten metal is filled with molten metal, and this is carried downward through and in contact with the solidification zone 4E, and when it emerges therefrom the cast metal 6E in the groove is solidified. The strip metal 6E can then be removed from the grooves in the chain 5E and rolled, heat-treated, or machined to suit the purpose for which it was made.

Fig. 9 illustrates a chain 5E having multiple grooves for forming strip castings 6E therein having multiple section guide blocks 8E' and 8E'' therearound. Chain such as 5E, Fig. 9, will permit parting after it passes through the guide blocks 8E and assist in the removal of the cast metal strips 6E from between the multiple members of the chain 5E.

Fig. 10 illustrates the chain 5F having a flat face and being guided by guide block 8F and having a flat strip of cast metal 6F against its face of chain 5F and interior groove of guide block 8F.

Fig. 11 is a broken-away section of the chain 5H being guided through the outer peripheral edge of the

crucible 2H and having a guide groove established therein by the blocks 8H. The molten metal 1 flows into the cavity in the chain 5H which will permit easy removal of the cast metal 6H. The cooling zone is not shown in Fig. 11 because it is thought that it is easily understood how this can be carried into practice. In Fig. 11, the guide blocks 8H are made up of three pieces and serve to accurately guide the chain 5H so as to present an accurate cavity groove to the pool of molten metal.

Synthesized mica may be cast from its constitutents and crystallized in sheet, bar, or tube form, using the apparatus and principles of this invention.

It is necessary, under these conditions, that the rate of withdrawal from the enclosing die, such as is used in Fig. 11 for example, be somewhat slower than the crystal growth.

The graphite crucible 2H is charged with a mixture of the following ingredients:

	Percent by weight
SiO_2	35–39
$(Al, Fe, Cr, V)_2O_3$	11–12
$(Mg, Fe, Mn, Zn)O$	29–35
$(Na, K)_2SiF_6$	11–13
$(Na, K)F$	6–7

or another mixture, using the purest components, may be:

	Percent
Al_2O_3	11.6
MgO	32.6
SiO_2 (diatomite)	30.7
K_2SiF_6	25.1

can be used to charge the graphite crucible 2H, and such charge is melted therein or may be charged molten therein.

Initial temperature would have to be approximately 1450° C. after being maintained for a time like this, the charge can be slowly cast into the cavity of the mold 5H such as shown in Fig. 11, so that the filled mold and its contents are lowered and cooled until the solidification point of 1320° C. is reached. Cooling must be kept within the crystallization velocity of the mica which is about 2 mm. per minute. This would be the rate of withdrawal, the rate of the movement of the mold on chain 5H, Fig. 11.

By way of specific example, apparatus of the type disclosed in Fig. 1 has been employed to continuously cast metal strip 6 of 4–44 bronze and of size 1/16 x 1⅛" at the rate of 18 in./min. In this case, the wheel 5 was of ceramic material, specifically silicon carbide lava, having an outside diameter of 5 inches, an inside diameter of 4 inches, and was formed with a peripheral groove of 1⅛ inch width and 1/16 inch depth. The crucible 2 was made of silicon carbide lava and was formed with an arcuate passage of 2 x 5 inch radial cross-section to slidingly embrace the wheel 5, a graphite shoe 8 of about 7 inch length being engaged with the peripheral surface of the wheel 5.

The induction heating coil 3 was operated at a frequency of 9600 cycles/sec. and energy of 30 kva. and was operative to keep the metal in the crucible 2 and in the die passage for a distance of about 2 inches below the feed opening 8a at a temperature of about 1950° F. The cooling die 4 was made of copper and water was circulated therethrough at a rate so that the cast strip 6 emerged from the lower end thereof at a temperature of about 700° F. and at the lineal speed of 18 in./min. as aforesaid.

Because the wheel 5 was made of poor conducting ceramic material, that is, lava and carborundum, the frequency field heats the metal directly, rather than by conduction from the die walls, whereby the heating energy is not wasted in first heating the wheel 5 to a temperature exceeding the melting point of the metal in the forming zone and then subsequently cooling the wheel to a temperature less than the freezing temperature of the metal in the cooling die 4. Volcanic lava contains pumice which is 65–75% silica and 9–20% alumina, the electrical resistivity of silica being about 77,500 ohms per centimeter cubed.

In the instant example, the operating temperature of the wheel 5 is about 1000 to 1200° F. opposite shoe 8 and about 700° F. inside the cooling die 4.

The shoe 8 may be made of the same poor conducting ceramic material as the wheel 5, but it has been found preferable to use graphite (electrical resistivity of only about .0014 ohm per centimeter cubed) as previously stated because it makes a smooth iron, it keeps one surface of the casting labile and lubricated, and it keeps the casting surface slick due to low friction.

Similar operating conditions apply to the Figs. 4, 6, and 8 apparatuses. Now, with reference to forming composite metal strip as in Fig. 7, the Fig. 7 apparatus has been used to form composite strip metal continuously at the rate of 18 in./min. As an example, a .040 x 1⅛" steel strip was run around the 1⅛ x 1/16" peripheral groove of the 5 inch outside diameter ceramic wheel 5D of Al_2O_3 and a .022 x 1⅛" layer of 4–44 bronze was cast against the exposed exterior face of the steel strip.

The induction heating coil (9600 cycles, 20 kva.) was operative to maintain the bronze at a temperature of 2250° F. in the casting and forming zone (below opening 8a) and to heat the steel strip to about 1950° F. whereby the bronze welds to the steel. The cooling die trowels smooth the surface of the bronze layer and the latter solidifies during the course of its movement through the cooling die 4D and issues therefrom at a temperature of about 700° F.

Again, as in Fig. 1, the steel strip and the bronze are inductively heated to the proper temperatures without alternately heating and cooling the wheel 5 as would otherwise be required if flame, resistance, or other heating means were employed.

When casting is done against a rotating wheel 5, the extensive arc of contact of the metal therewith results in shrink adherence to ensure carrying of the metal by the wheel through the casting and cooling zones. The arc of contact preferably should be in excess of one-third of the wheel circumference.

Further noteworthy features of this invention are that castings can be continuously made as long as metal is supplied to the pot or crucible 2; that variable head feed may be utilized if desired; that metal strips composed of metals having melting points in excess of 500° C. may be satisfactorily and continuously cast; that the casting zone of the die is less receptive to inductive heating than the metal being cast whereby the induction heating field acts principally on the metal being cast; and that the casting produced has a slick, ironed surface which is uninterrupted on at least one face and is of such flexibility as to be coilable and windable upon itself after being produced.

Another point which should be emphasized is that, although there is a pot of molten metal within an induction heating coil, which pot is spaced about ¼ inch from the coil, not enough heat is radiated from the pot to evaporate atmospheric moisture which condenses on the water-cooled induction coil. Thus, there is considerable economy of energy and lack of radiation losses.

It is to be noted that the moving die member has a greater area thereof in contact with the casting metal or the base strip, as the case may be, and that said moving member is less affected by the induction heating field because of its continuous movement past said field and because of its being made of ceramic material as indicated.

Stated in another way, the heat is cumulative in the stationary member of the die, but the moving wheel or moving member has a different portion thereof exposed to the influence of the induction heating field as it moves with respect to said field. Preferably, a major portion of the cooling of the cast strip metal or of the lamination is through the moving die member.

It is to be further noted that the stationary member of the die may be at least partly cooled by the heat extracted from and through the moving member or wheel.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims, or the equivalent of such, be employed.

I therefore particularly point out and distinctly claim as my invention:

1. The method of continuously casting metal strip and the like which comprises the steps of continuously feeding molten metal into the upper end of a downwardly extending, open-ended die passage of which one wall is movable downwardly and is of ceramic material having a relatively low electrical conductivity comparable with that of silicon carbide lava and of which the opposite wall is stationary and is of ceramic material having a relatively high electrical conductivity comparable with that of graphite; continuously moving such die wall to carry the metal downwardly therewith through the die passage; passing the downwardly moving body of molten metal in the die passage through an induction heating field which is effective to inductively heat the metal itself to a temperature exceeding its melting point without such die wall attaining that temperature from the effects of the induction heating field it is fed into the die passage and which is effective to inductively heat such stationary die wall so as to keep the metal in contact therewith labile and lubricated and to keep its surface slick due to low friction and as it flows downwardly through the die passage whereby the metal is formed, while molten, to the cross-section shape of the die passage; passing the formed body of molten metal through an adjacent cooled portion of the die passage to solidify the metal in its thus hot-formed shape before it emerges from the lower end of the die passage by extraction of heat therefrom by the movable wall of the die passage and by an opposite wall of the die passage; and continuously removing the solidified metal from the movable wall after the metal has emerged beyond the lower end of the die passage.

2. Apparatus for continously casting metal strip and the like which comprises a downwardly extending, open-ended die of which one wall is movable downwardly and is of ceramic material having a relatively low electrical conductivity comparable with that of silicon carbide lava and of which the opposite wall is stationary and is of ceramic material having a relatively high electrical conductivity comparable with that of graphite; means for continuously moving such die wall to carry downwardly molten metal fed into the upper end portion of said die; induction heating means around said die effective to inductively heat the metal itself to a temperature exceeding its melting point without such die wall attaining that temperature from the effects of the induction heating field as it is fed into the die passage and effective to inductively heat such stationary die wall so as to keep the metal in contact therewith labile and lubrication and to keep its surface slick due to low friction and as it flows downwardly through the die passage whereby the metal is formed, while molten, to the cross-section shape of the die passage; and cooling means around a downwardly adjacent portion of said die effective to solidify the metal in its thus hot-formed shape before it emerges from the lower end of the die passage by extraction of heat therefrom by the movable wall of the die passage and by an opposite wall of the die passage; the solidified metal being removed from the movable die wall after the metal has emerged beyond the lower end of the die passage.

References Cited in the file of this patent

UNITED STATES PATENTS

359,349	Daniels	Mar. 15, 1887
368,817	Daniels	Aug. 23, 1887
437,509	Pielsticker	Sept. 30, 1890
1,651,678	Davis	Dec. 6, 1927
2,092,284	McCarroll et al.	Sept. 7, 1937
2,139,215	Wasson	Dec. 6, 1938
2,206,930	Webster	July 9, 1940
2,242,350	Eldred	May 20, 1941

FOREIGN PATENTS

734,890	Germany	Apr. 30, 1943