United States Patent

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[45] Patented **Nov. 10, 1970**
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[54] **CONTINUOUS FORMATION OF INTERMEDIATES**
4 Claims, 2 Drawing Figs.

[52] U.S. Cl. **118/7,** 164/155
[51] **Int. Cl.** **B05c 11/10**
[50] **Field of Search** ..... 118/7, 2, 404, 405, 429, 202; 266/33, 34(PT), 13.3; 228/40; 164/339, 335, 119, 86, 155, 275, 88, 141; 137/(Inq), 403; 75/(Inq); 117/(Inq), 114; 65/134, 346

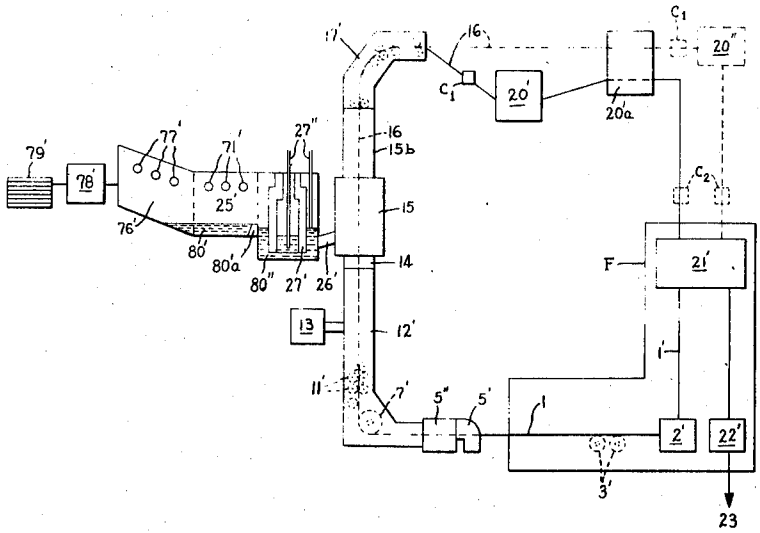
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ABSTRACT: In an apparatus for the continuous casting of metal by passing an elongated solid body upwardly through a bath of molten metal maintained in a crucible, there is provided a melting furnace, preferably having an inclined premelt section and an integral horizontal section. A holding chamber receives molten metal from the furnace and includes means for controlling molten metal in the chamber to maintain a selected level of metal in the crucible irrespective of variations between the inflow rate to the holding chamber and the outflow rate from the crucible.



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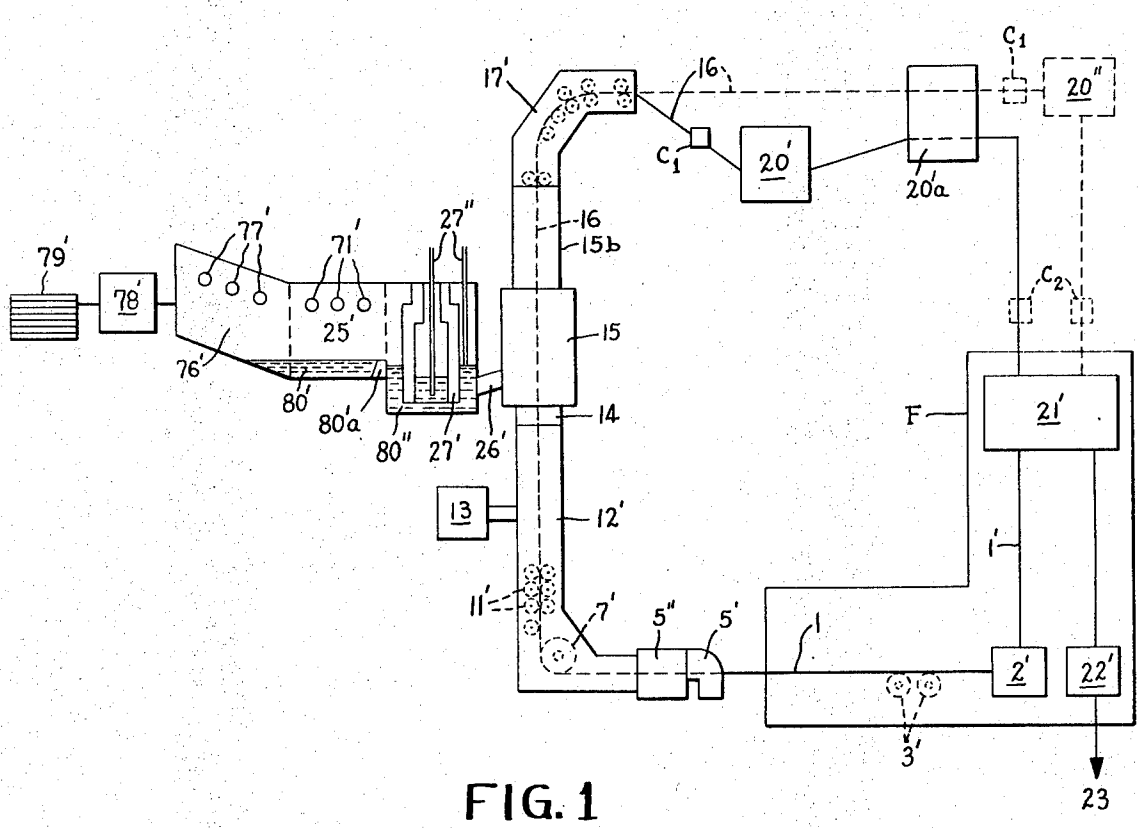


FIG. 1

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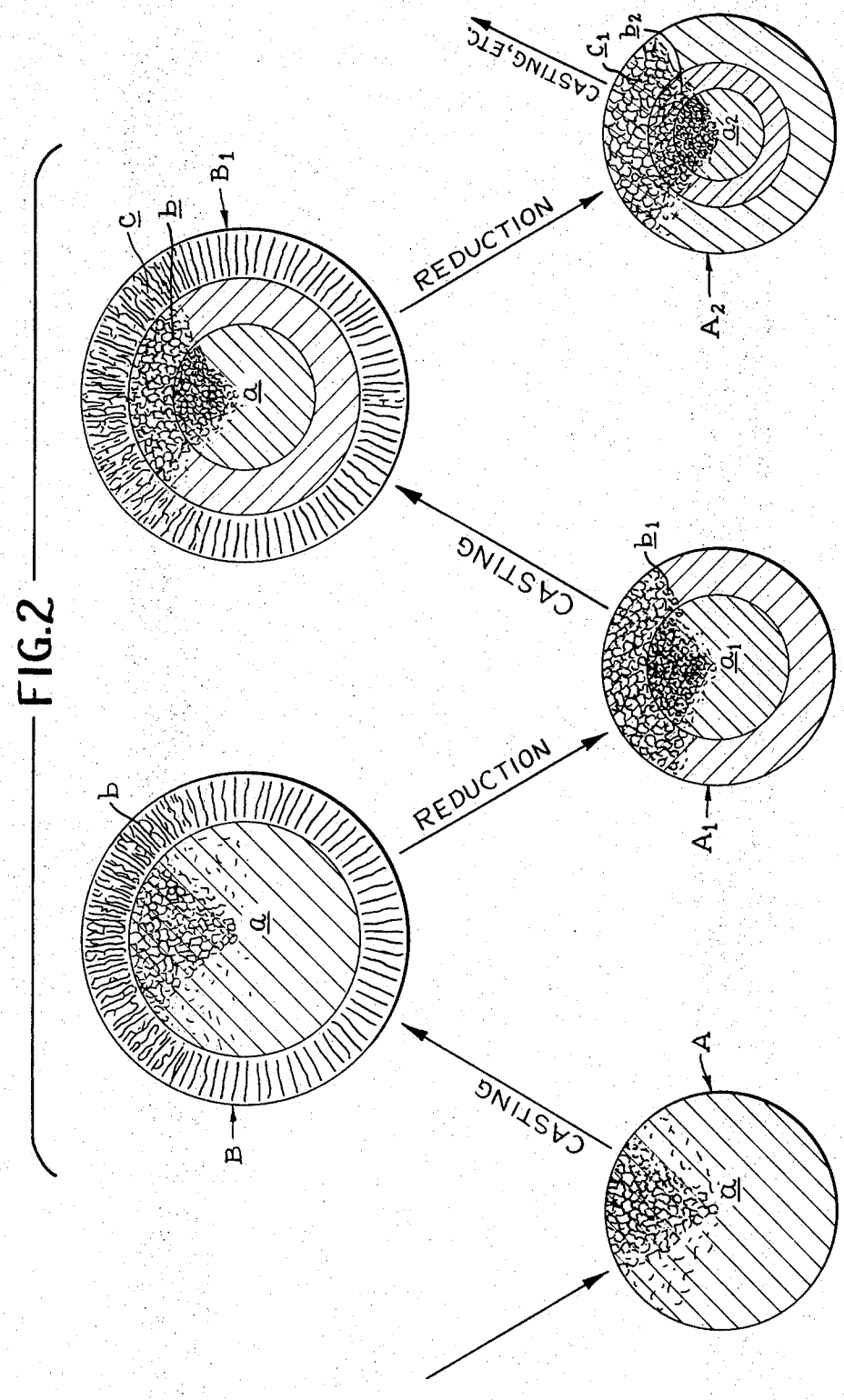


FIG.2

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CONTINUOUS FORMATION OF INTERMEDIATES

This is divisional application of copending Carreker application Ser. No. 460,020 filed June 1, 1965, now U.S. Pat. No. 3,365,037 which, in turn, is a continuation-in-part application of Carreker application Ser. No. 98,087, filed Mar. 24, 1961, now U.S. Pat. No. 3,235,960, which, in turn, is a continuation-in-part of Carreker application Ser. No. 530,283, filed Aug. 24, 1955, now U.S. Pat. No. 3,008,201, the respective specifications of which are incorporated herein by reference.

This invention relates to the continuous production of solid materials from the fluid state and, more particularly, to the continuous transformation of solid raw materials to solid intermediate forms without proceeding through conventional primary forms. This invention relates more specifically to systems whereby a solid metallic input may be substantially continuously transformed into continuously cast intermediates. Still more specifically, this invention relates to systems in which a constant feedback loop of formed intermediate material continuously generates derivative formed intermediates from raw material being continuously melted in said system. Still more particularly this invention relates to intermediates and stock materials produced by the continuous means of the invention.

A large portion of the cost of manufacturing sheet, rod, tube, strip and filamentary stock materials is directly assignable to the expenses incurred in the manufacture of the primary and intermediate forms of the material from which these stock materials are manufactured. For example, in the manufacture of a stock material such as copper wire, a large capital investment is required for equipment such as large melting furnaces, large casting apparatus, ingot or "wire bar" reheating furnaces, primary and secondary rolling equipment, pickling apparatus, heavy duty handling apparatus and the like, in order to produce "wire rod" (an intermediate stock material) which may then be drawn into wire of appropriate size through conventional wire drawing apparatus. Substantially the same basic apparatus is needed for the manufacture of intermediate stock material to be formed into tubes, sheets, rods, strip and like stock materials, as well as specialty stock materials such as bus bars, for example. While the foregoing examples relate to copper, it is obvious that substantially the same manufacturing procedure is followed with both ferrous and other nonferrous metals and alloys.

In general, it may be said that a large portion of the cost of such stock materials is the result of employment of expensive equipment and necessary labor to process raw materials into an intermediate material having the necessary properties and dimensions to then be formed into the above-recited stock materials.

This invention is concerned with a system for continuously producing intermediate stock materials for the further production of the above-mentioned stock materials to the intermediate stock materials thereby produced, and to apparatus and processes for the production of such intermediate stock materials. A principal object of this invention is the provision for continuously casting intermediate stock material and to the materials thereby formed. A further object of this invention is the provision of a system for substantially continuously producing stock materials such as wire, sheet, tube, strip and rod stock without employing large batch melting, casting and rolling equipment in substantially discontinuous process steps. A yet further object of this invention is the provision of a system for the continuous quantitative production of stock materials whereby a substantially constant portion of the product may be continuously recirculated in a cyclical manner.

In general this invention contemplates a system for continuously depositing by accretion, liquid or molten material upon a first elongated body having a first cross-sectional configuration and area thereby forming a second elongated body. More particularly, this invention contemplates a system for continuously depositing by accretion upon a first elongated body thereby forming a second elongated body having a cross-sectional area greater than the first, reducing the cross-sectional area of the second elongated body to form a third elongated body having a cross-sectional configuration and area substantially equivalent to that of the first elongated body, removing as the product of the system a portion of the third elongated solid body in quantity substantially commensurate to the material feed of the system, and continuously feeding back the remaining portion of the third elongated body as the first elongated body, and in incremental lengths substantially corresponding thereto, thereby forming a continuously circulating process loop of substantially constant dimensions and functioning as the heat sink for the system.

This invention further contemplates formation of novel and useful intermediates through the combination of steps which may comprise continuously feeding a solid state quantity of material into a continuous melting furnace, continuously heating said material to the molten state, continuously feeding the material melted thereby into a molten bath; continuously cleaning the surface of an elongated solid body to remove contaminants therefrom, continuously running the cleaned elongated solid body through an evacuated region to remove gaseous and vapor phase contaminants from the surface thereof, continuously introducing the clean elongated body directly from the evacuated region into the bath of molten material to cause accretion of molten material and an increase in the cross-sectional area of the said body to form a second body of greater thickness, continuously reducing the cross-sectional area of the second body to substantially that of the first body, a portion of the third body being removed as the product of said process in quantity substantially commensurate to the quantity of material fed into the continuous melting furnace and the remaining portion of the third body being continuously recycled as said first body in incremental lengths substantially corresponding thereto.

As disclosed in the aforesaid parent Carreker applications, this invention is adapted to reduce the cross-sectional area of the elongated body having the second cross-sectional area to substantially the cross-sectional area and configuration of the first elongated body and means are provided for the removal of a length of the elongated body substantially corresponding to the amount of liquid or molten material deposited or accreted, upon the first elongated body, as the product. The remaining portion of the elongated body, which is the continuous heat sink of the system, is substantially identical in composition, cross-sectional area, configuration and volume to the elongated body prior to accretion and means are provided for continuously circulating this substantially constant remaining portion through the system. The above-cited Carreker applications disclose processes and means of continuous accretion forming, or "dip-forming" of intermediates. A further exposition of both the development of the art and certain theoretical aspects thereof may be found in Carreker, Journal of Metals, Oct. 1963, pages 774—780; and Carreker and Hurst, "-General Electric Research Laboratory Report No. 64-RL-3695M", June 1964 (published in Wire and Wire Products, Aug. 1965). Each of the above-cited publications is herewith incorporated into this specification by reference. Broadly defined, then, this invention comprises improvements in the art of continuous production of intermediates as will be further apparent to those skilled in the art from the detailed description herein. In practicing this invention in its broader aspects, it will occur to those skilled in the art that the principles disclosed hereinafter may be applied for continuously casting many different materials and to form many different products.

This invention will be better understood from the following description taken in conjunction with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawing,

FIG. 1 is an illustration of the invention; and

FIG. 2 is a schematic representation illustrative of intermediate and final products of this invention with particular reference to the cyclical nature thereof.

The invention, in one of its preferred aspects, is illustrated in the schematic diagram of FIG. 1. The embodiment of FIG. 1 is preferentially used for the continuous production of homogeneous cast metal lengths, although it may, if desired, be used in the preparation of heterogeneous products. The system of this invention, according to FIG. 1 may be directed to the continuous production of continuous intermediates including continuous lengths of cast product **23** from a raw material **79'**, of preferably the same composition, which is continuously fed into the system at a rate quantitatively commensurate with the production of product **23**, by the accretion-casting of molten material upon a continuous heat sink of similar composition which may be derived from internal feedback within the system. Raw material **79'** may be in any convenient metallic form, as for example, billets, ingots, plates, sheets, rolls, powders or similar particulate form, scrap, etc. In one embodiment of this system, which is used for the continuous production of a novel copper wire rod, the input to the system is preferably in the form of copper cathodes. Input **79'** is, in continuous operation of the system of this invention, continuously fed into furnace **25'** by continuous feeding means **78'** which may be of any appropriate type as, for example, an endless conveyor belt, a roller-type conveyor, a gravity feed, etc. In continuous furnace means **25'** the material fed therein is continuously melted and continuously fed therefrom into casting crucible **15**. While furnace means **25'** may be of any convenient configuration, there is shown schematically in FIG. 1 a preferred and novel furnace means which has been found of special utility in the practice of this invention.

The material **79'** is fed by feed means **78'** into a sloping hearth portion **76'** of furnace means **25'**. Materials **79'** are continuously passed through sloping hearth portion **76'** at a rate which may be determined by feed means **78'**, which rate is commensurate with the product requirements of the process. In the case of copper cathode plates the plates are continuously pushed end to end through sloping hearth portion **76'** at the desired melting rate. Heat is supplied to sloping hearth portion **76'** by heating means which may desirably be heating elements **77'** positioned across the top of the furnace as shown. During the slow, controlled passage down the sloping hearth the materials therein are preheated to the melting point before entering the molten metal blending portion **80'** of furnace means **25'**. The material in the sloping hearth is not necessarily melted therein to the liquid state but may be heated to substantially the thermal fusion point so that upon entering portion **80'** the bath temperature therein is not substantially disturbed. The temperature of the pool of molten metal in blending portion **80'** is maintained by means of heating elements which, as shown, may preferably be heating elements **71'** disposed across the top of the furnace. The pool of metal in furnace portion **80'** is quite shallow as determined by dam **80'a** and the dimensions of furnace portion **80'** are such as to insure a rapid blending and turnover of the molten material therein contained which continuously overflows **80'a** into holding portion **80''** from which the molten metal may then be fed into crucible **15** through suitable means such as conduit means shown at **26'** which should desirably 'bottom-tap' the copper in portion **80''** to prevent the entry of slag, etc. into the crucible. To control the flow of molten material from furnace **25'** into crucible **15** there are further provided appropriate flow regulating means which, in this embodiment, are shown as positioned within holding portion **80''** of furnace **25'**. While the flow regulating means may comprise any suitable combination of elements, it is preferred in this embodiment of the system of this invention that the flow regulating means function as fluid displacement means whereby the flow of molten material from furnace **25'** into crucible **15** may be most conveniently controlled.

Such a desirable flow regulating means has been achieved by the provision, for example, of an inverted bell **27'** within holding portion **80''**, and operating by pneumatic means (not shown) to controllably raise and lower the level of molten metal within holding portion **80''** according to the requirements of the overall system of this invention. Further, the pneumatic means of such a pressure bell system may be controlled automatically by means of any convenient level sensing device in cooperation with appropriate pneumatic control means, whereby in continuous operation the levels of molten metal in holding portion **80''** and crucible **15** are maintained substantially equal and constant. Convenient level sensing means may be provided by metallic probes or the like **27''** which in cooperation with the appropriate or convenient pneumatic control means operate to maintain the molten metal depth in crucible **15** at the desired level. The pressure bell may also be pressurized or depressurized on command, a feature of significance in the starting up and the shutting down of the system of this invention which is, however, herein generally described in terms of its continuous, or steady-state, operation wherein the bath depth in crucible **15** may be maintained substantially dimensionally constant.

A metallic core rod **1**, which may be of substantially the same composition as the molten metal in crucible **25**, is continually fed into crucible **15**, at a substantially constant rate, through cleaning means comprising, preferably in this embodiment, drawing means **5'** and shaving means **5''**, shaving means **5''** further providing an entrance seal into a vacuum entrance chamber **12'** provided with vacuum source **13**. From vacuum entrance chamber **12'** core rod **2** enters crucible **15** directly, and without intervening atmospheric exposure, through an entrance port **14**. As shown, in this embodiment, the main drive system is positioned within vacuum entrance chamber **12'** and may comprise a capstan or the like **7'** and drive means **11'** which may be pinch rolls, drive rolls, or the like.

As the core rod passes upwardly through the molten metal bath contained in crucible **15** there is accreted thereupon a continuously "frozen-on" metallic cladding. The core rod, preferably entering the crucible at substantially ambient temperature, provides a continuously circulating heat sink to which a portion of the molten metal gives up its heat of fusion in accreting thereupon. Since the molten metal in crucible **15** is maintained at normally, slightly above its melting point, the efficiency of the process may be determined predominantly by the rate at which the core rod may be moved through the crucible and by the depth at which the bath therein may be maintained. Except for mechanical constraints imposed by the system itself there is no theoretical upper limit to the speed of the process. Within crucible **15** the heat flow is inward toward a substantially constant moving heat sink which provides further a simultaneous relative motion between the molten metal source and the metal cast thereupon.

It has been demonstrated experimentally that a maximum pickup rate may be achieved in an immersion time less than a third of that required for thermal equilibration, at which time the core rod would melt out. Because of these and other considerations the rate at which the core rod may be passed through the crucible, and the system, is substantially determined by the rate of feed of molten metal into the crucible and thus by the initial rate of feed of input metal **79'** into the system. There may thus be achieved an optimum casting ratio, in the case of copper, of between 1.5 and 2.2 pounds of metal cast per pound of copper core rod fed.

The system of this invention enables, for example, the continuous production of substantially seven-sixteenths inch diameter copper wire rod at a net output rate of about 400 feet per minute, or about 5 tons per hour, from melted cathode copper, which corresponds to a feed rate of about 200 feet per minute of a substantially **seven-sixteenths inch core rod 1 to crucible 15 being constantly supplied with molten copper at a rate of about** 5 tons per hour. Upper according to the demand upon lower outputs are readily achievable according the system as well as upon appropriate system design.

The hot core rod issuing from crucible **15** has accreted thereupon a clad metal layer, increasing the rod thickness as a function of the casting ratio, thus forming metallic rod **16** of substantially greater thickness. When casting upon a substan-

tially six-sixteenths inch copper core, at a casting ratio of about 2 to 1, rod 16 will have a thickness of about five-eighths inch. Since the tensile strength of rod 16 is greatly diminished, relative to that of core rod 1, it is essential to provide preliminary cooling to avoid hot-short inter-crystalline cracking and to limit the tensile forces as might be imposed upon the rod by means necessary for the conveyance and guidance thereof as, for example, a top tension drive means 17' which may be actuated by an eddy current coupling or the like. Thus, it is desirable to pass the rod 16 as it issues from crucible 15 through a preliminary cooling means as, for example, cooling tower 15*b* which may contain any appropriate cooling means therein as, for example, water sprays or the like.

Issuing from the top torsion drive 17', rod 16 is continuously passed into hot reducing means 20' which is preferably a hot rolling mill. The combination comprising crucible 15 and rolling means 20' cooperate as means amplifying core rod 1. Between top torsion drive 17' and rolling mill 20' there may, as necessary, be positioned conventional or convenient cooling means, guide means, drive means, tension control means, etc. In this embodiment, the reducing means 20' will preferably be a four-stand tandem hot rolling mill directly coupled to the above-described casting system. The coupling to the casting system may be by control regulator means C_1 which may be preferentially embodied by a dancer loop control or the like. In the reducing means 20' the cross-sectional area of rod 16 is continuously reduced to a cross-sectional area and configuration substantially corresponding to the cross-sectional area and configuration of core rod 1. When copper is continuously cast by the system of this invention the output of rolling mill 20' may be approximately seven-sixteenths inch copper wire rod, the increase of length thereof being proportional to the amount of reduction obtained in the mill. The rolled wire rod produced per unit time corresponds in length to the core rod being passed through crucible 15, in the same identical unit time, plus a length corresponding substantially identically in weight to the weight of metal cast upon said core rod in the same period of time.

From mill 20' the hot rolled rod is then continuously passed through final cooling means 20'*a* and then to feedback means F comprising material handling stations, or the like, 2', 21', and 22'. In another mode of practice of the system of this invention rod 16 may be directly passed through cooling means 20'*a*, as shown by the dotted lines, through cold reduction means 20'', such as, for example, a cold drawing mill, and then to feedback means F. The amplifying means of this invention are also defined by the combination comprising crucible 15 and reducing means 20''.

Feedback means F may comprise any convenient, appropriate, or conventional apparatus, or combination thereof, for removing, in the overall continuous operation of the system of this invention, a weight of product commensurate with the weight of metal cast, and for recycling a weight of wire rod substantially commensurate to the weight of core rod (and of substantially identical incremental length therewith) being continuously entered into crucible 15, in substantially the same unit period of time. In one embodiment, feedback means F may comprise any conventional or convenient coiling means 21' as, for example, a torque-regulated "dead-block" coiler, operating at a rate corresponding to the rate at which wire rod exits from mill 20' or 20'', in combination with appropriate severing means, and material handling and/or conveying station 2' whereby incremental lengths of wire rod are recycled. If desired, appropriate control regulating means C_2, such as a dancer loop control, may be provided to isolate the pull of coiler, or the like 21' from the casting system. Feedback means F may further comprise appropriate conveying, handling, and/or storage means 22'', whereby product 23 may be removed from the system in substantially quantitative yield.

Material for recycling, in the form of wire rod 1', is passed through guide means, conveyor means, and/or temporary storage means 2' and reenter the system through "pay-off" rolls or the like 3'. From station 3', of feedback means F, there is provided a continuous feedback of wire rod 1' as core rod 1, thus closing the continuously circulated feedback loop of this invention. This closed process loop is of substantially constant dimensions with respect to the metal in continuous circulation, and, of course, exclusively of any material being temporarily stored or accumulated. Thus, in the definition of this invention with respect to the material in continual circulation, that portion of said material being passed through, accumulated, or the like, in feedback means F is considered as being of zero length, the stations therein, or their equivalents, functioning as material sumps which serve to maintain the substantially constant continuous flow of material in the process loop described hereinabove with reference to the embodiment of FIG. 1.

As there is a substantially constant quantity of recirculating material serving as the heat sink for the system, the amount of material that becomes useful product corresponds substantially to the amount of material melted, neglecting, of course, scrap losses which are relatively insignificant. The cost of maintaining the self-generating feedback loop is the cost of reducing, in the case of copper, about one-third of the cast output back to input size plus the inventory cost of the relatively small amount of metal in circulation. At this relatively small and substantially constant cost, the feedback loop rather surprisingly provides a system of thermomechanical amplification whereby there may be effected continuous, constant generation of cast product at costs per pound, and at a substantially more rapid output rate, than have heretofore been known to the industry, and requiring a substantially reduced operating and capital investment. The amount of material which is accreted on the core rod is a function of time, influenced by the dimensions of the molten bath, the rate of movement of the heat sink, the initial temperature thereof, as well as other theoretical influences, operating optimally in the process, such as the heat capacity and thermal conductivity of the core and the melting temperature thereof, the heat of fusion, super heat, and heat capacity of the molten material; as well as the heat transfer coefficient between the liquid and solid.

FIG. 2 is further illustrative of the operation of the system of this invention with reference especially to the novel and surprising properties of the intermediate and final products of the system. Consider, in any arbitrary cycle of the process feedback loop system, that a length of copper core rod A is being continuously introduced into crucible 15 of FIG. 1. In FIG. 2 a core A is shown in cross section to have configuration *a*. Assuming that the past thermal and mechanical history of core rod A is unknown, then for the purposes of this discussion the cross section A will be described as comprising randomly oriented equiaxed crystals of substantially pure copper, and this is schematically indicated in the drawing. In this exemplary discussion, core rod A has a diameter of seven-sixteenths inch and this, it will be understood, is illustrative of only one mode of practice of the system of this invention. Core rod A may be of any of the cross-sectional dimensions characteristic of commercial copper wire rod. In the practice of this embodiment of the invention the diameter of core rod A is reduced to 6/16 inch at a draw head preceding the entry to the casting system. In passing through crucible 15 at a constant rate of, for example, 200 feet per minute, shaved core rod A has accreted thereupon a substantially constant incremental thickness of accreted copper *b* to form rod B. At a casting ratio of substantially 2:1 the diameter of rod B will be substantially five-eighths inch. Concentric cast ring or layer *b* is characterized by relatively coarse, radial, columnar crystals radiating outwardly from the core *a* and further generally being of increasing average width in the direction outwardly from the core and along both the transverse and longitudinal axes.

Cast copper rod B is then continuously passed through hot rolling mill 20' where it is constantly reduced in diameter to wire rod A_1, as shown. Wire rod A_1 is approximately of seven-sixteenths diameter and comprises core a_1 and concentric

laminar ring or layer b_1, derived, respectively, from a and b which have been respectively reduced proportional to the overall reduction in diameter of the rod. In wire A_1 concentric clad layer b of cast rod B has been transformed by the hot working, and the annealing resulting therefrom, to concentric outer ring or layer b_1 of wire rod A_1. Following from this transformation outer ring b_1 now comprises, metallographically, randomly oriented equiaxed crystals of copper. Wire rod A_1, as an intermediate product of the system of this invention, will, as hereinabove described, be partially recycled while about two-thirds of its continuously produced length will be removed as the product of the system, since, in this example, every foot of feedback loop generates about two feet of product per cycle.

The recycled portion of wire rod A_1 will then reenter the feedback cycle through the shave and draw head and, at the same constant rate, be passed through the crucible to accrete thereupon cast ring or layer c, thus forming cast rod B_1. Cast layer c is substantially identical with cast layer b produced in the preceding cycle, and likewise comprises relatively coarse, radial, columnar crystals. Between concentric layers b_1 and c there is a visibly distinct boundary. At a constant casting ratio there will exist, and will be maintained, a constant relationship between concentric rings b_1 and c, which is that the ratio of the area of the outer concentric laminar ring to the area of the next inner concentric laminar ring will always be a substantially constant function of the casting ratio. This relationship will remain substantially constant throughout the operation of the system, or until the respective concentric layers become metallographically indistinguishable. This relationship further holds true for all concentric adjacent layers as may develop through the course of the cyclical operations being herewith described. Thus, in a continuous casting operation according to this invention wherein there is accreted a substantially continuous weight W_a of molten metal per unit length of a substantially continuous metallic core of linear density W_c, the casting ratio K_c equal to W_a/W_c, will remain substantially continuously constant. At a substantially constant casting ratio K_c the proportion of the cast rod which may be continuously removed as product may be determined by multiplying the as-cast weight, or the rolled length, by the product ratio K_p which is equal to $W_a/(W_a+W_c)$. It is a further discovery of this invention that the substantially constant ratio of cross-sectional area of the outermost of any two adjacent pair of rings to the cross-sectional area of the innermost ring of that pair will be at least substantially numerically equal to K_c/K_p. This value, it will be understood, is stated as a substantial identity in view of the drawing and shaving operation hereinabove discussed.

Continuing through the system rod B_1 is reduced to form wire rod A_2 which is again of approximately seven-sixteenths inch diameter. The respective concentric rings of wire rod A_2 have all been reduced proportionately and outer ring C_1, derived from ring c of rod B_1, has been transformed by the hot working and consists of equiaxed, randomly oriented copper crystals. As will be appreciated from the discussion above, the ratio of the areas of ring c_1 to ring b_2 remains substantially constant.

About two-thirds of the continuously produced length of intermediate product A_2 may again be removed as the amplified product of the system, while approximately one-third of the continuously produced length thereof is recycled through the molten bath and the described feedback loop may then be repeated interminably with continuous generation of product. Thus, product and intermediate wire rods A_n will in the steady state operation of the system of this invention be characterized by a novel and unique "tree-ring" structure comprising a plurality of metallographically distinct concentric rings, each ring comprised of equiaxed randomly oriented copper crystals, and each ring further being characterized by the substantially constant relationship of its area to the area of the next innermost ring. The product copper wire rod continuously produced by the system of this invention, with its novel concentric laminar "tree-ring" characteristics, is a new product and has been found to be especially suitable for a subsequent wire drawing operation.

The as-cast copper rods B_n are also a novel discovery of this invention. All cast rods B_n, which are produced as intermediates in the system of the invention, are characterized by an outermost ring comprising radial, columnar crystals, and a plurality of inner rings, each of said rings having an area in cross section which stands in constant ratio to the area of the respective next inner ring. With the exception of the outermost ring, each of the plurality of inner rings is characterized identically with the concentric laminar rings as described with reference to wire rods A_n. Wire rods B_n have certain unusual and unexpected characteristics as, for example, their great resistance to annealing, by virtue of which, as intermediate products of the system of this invention, they are especially suitable for many applications.

In certain of their embodiments the intermediates and products of the invention will preferably comprise substantially oxygen-free, or deoxidized, copper. Oxygen-free copper is conventionally defined in the industry as that type of copper which is free from cuprous oxide as determined by microscopic examination at a magnification of 75×. However, within the meaning of this specification substantially oxygen-free copper and substantially deoxidized copper are further defined as being copper containing less than about 20 parts per million of oxygen.

In the steady state operation of the system of this invention the number of metallographically distinguishable concentric laminar rings appearing in the cross sections of rods B_n and A_n is indefinable. In general, in a continuously recycled system the innermost rings may tend to merge into a separate core at the point where the boundaries therebetween are no longer observable visually. It is, however, not possible to say at what point this occurs since it is dependent upon the entire past thermal, mechanical and chemical history of each section of the respective rods and of each concentric ring thereof. However, it can be stated from experimental results that as many as ten, or more, successive rings may be visually observable in rods A_n and B_n, dependent, as mentioned of course, upon the entire previous history of the system. Thus, with reference to FIG. 2, rod A is shown as being substantially homogeneous. This showing, however, is merely for convenience and it may be further assumed that the rod as illustrated may comprise a plurality of "tree-ring" laminar concentric layers, the area of each respective ring standing in the same constant relationship to the area of the next inward ring.

While the foregoing discussion has been concerned predominantly with the continuous casting of copper, it will be understood that the teachings thereof are fully applicable to the continuous casting of other metals. Further, while the system of the invention has been principally described and discussed with respect to the continuous formation of a continuously cast final product in a procedure incorporating the novel feedback loop of the invention, it will be understood that the intermediate products thereof are of themselves of distinct inventive novelty and are uniquely useful in many applications. It will be further understood that certain of the elements hereinabove described, their apparatus embodiments, and, in the several modes of practice of this invention, the process steps required, include novel inventive features singely and in the combinations hereinabove discussed.

While there has been described herein preferred modes of practice and preferred embodiments of the invention, it will be understood that the invention is not limited thereto since it may be otherwise practiced within the scope of the appended claims.

We claim:

1. In an apparatus for the continuous casting of metal by passing an elongated solid body upwardly through a bath of molten metal maintained in a crucible, the improvement comprising:

a. a furnace for continuously receiving solid metallic feed stock and including means for melting said stock to form a continuous source of molten metal;

b. a holding chamber for receiving the molten metal from said furnace;

c. communication means opening to said holding chamber and said crucible for establishing communication therebetween;

d. an inverted pressure bell disposed within said holding chamber and having its side walls at least partially immersed in the molten metal in said holding chamber thereby dividing said holding chamber into a first section and a second section, said first and second sections being in communication, and

e. means for controlling the pressure in said inverted bell thereby controlling the level of said molten metal in said holding chamber to maintain the molten metal in said crucible at a selected level irrespective of variations between the inflow rate to said holding chamber and the outflow rate from said crucible.

2. In an apparatus according to claim 1 wherein said communication means is disposed below the level of molten metal maintained in said holding chamber and said crucible.

3. In an apparatus for the continuous casting of metal by passing an elongated solid body upwardly through a bath of molten metal maintained in a crucible, the improvement comprising:

a. a furnace having a premelt section inclined from the horizontal and an integral horizontal section;

b. means for supplying solid metal feedstock to said premelt section;

c. heating means for melting said feedstock in said premelt section and for maintaining said stock in a molten condition in said horizontal section, whereby said feedstock is in a molten state when moved to the bottom of said premelt section and blended with the molten metal in said horizontal section;

d. a holding chamber for receiving molten metal from said furnace;

e. communication means opening to said holding chamber and said crucible for establishing communication therebetween; and

f. means for controlling the level of molten metal in said holding chamber whereby the level of molten metal in said crucible is maintained at a selected level irrespective of variations between the inflow of molten metal to said holding chamber and the outflow from said crucible.

4. In an apparatus according to claim 3 wherein said level control means comprises an inverted pressure bell disposed in said holding chamber and having its side walls at least partially immersed below the level of molten metal maintained in said holding chamber, and including means for controlling the pressure in said inverted bell thereby controlling the level of molten metal in said holding chamber.