United States Patent [15] 3,645,321

Robinson [45] Feb. 29, 1972

[54] APPARATUS FOR THE CONTINUOUS PRODUCTION OF STEEL

[72] Inventor: **Charles G. Robinson,** Sterling, Ill.

[73] Assignee: **Northwestern Steel and Wire Company,** Sterling, Ill.

[22] Filed: **Mar. 2, 1970**

[21] Appl. No.: **15,554**

[52] **U.S. Cl.** .... **164/252,** 164/52, 164/324, 164/279, 266/33 S

[51] **Int. Cl.** **B22d 27/02**

[58] **Field of Search** 164/52, 250, 251, 252, 279, 164/322, 323, 324, 329, 330, 129, 130, 80, 266; 266/21

[56] **References Cited**

UNITED STATES PATENTS

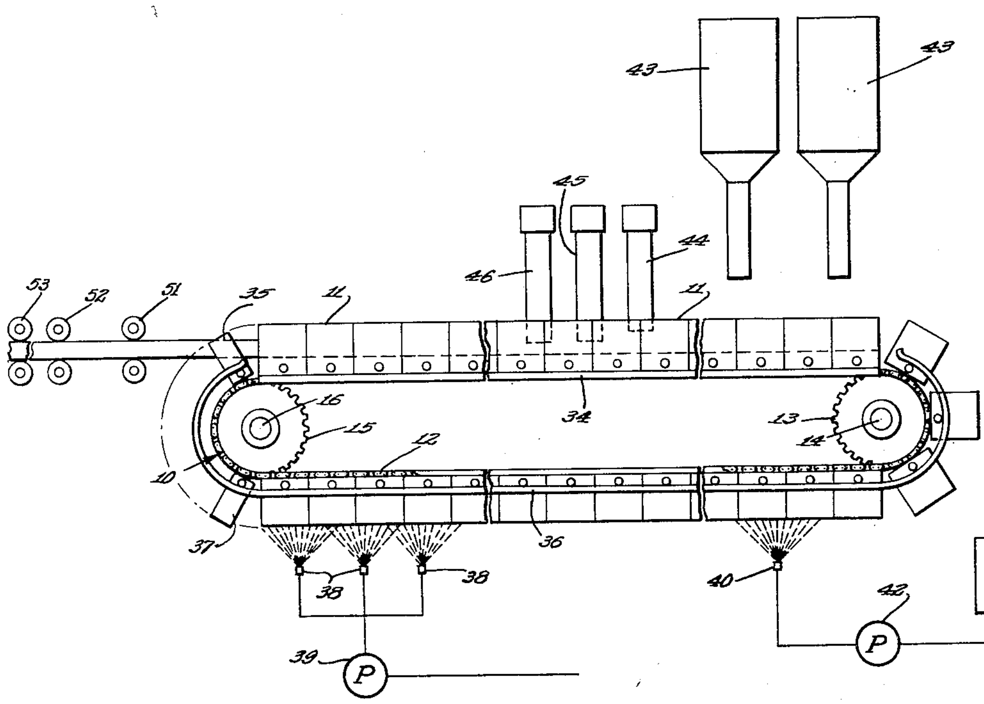
3,281,903	11/1966	Ross	164/279 X
3,244,507	4/1966	Linney	266/21 X
3,509,937	5/1970	Radd	164/276 X
2,664,592	6/1954	Ingraham	164/329 X
3,052,934	9/1962	Kerber	164/130 X
2,439,875	4/1948	Steudel	164/329

Primary Examiner—J. Spencer Overholser
Assistant Examiner—John S. Brown
Attorney—Hill, Sherman, Meroni, Gross & Simpson

[57] ABSTRACT

Apparatus for continuously casting metal, such as steel, in which a series of interlocking molds are carried on a conveyor in end-to-end relation with respect to each other, and form scrap-receiving melting and cooling vessels for the metal. One or more hoppers for charging the molds with scrap or other meltable materials are provided at the inby end of the conveyor to discharge scrap into the molds. Melting is attained by three electrodes connected in the secondaries of a transformer in a three phase delta arrangement and progressively extending into the molds, a first of which effects the melt down of the scrap or other meltable material, a second of which has a shorter arc than the first and provides an intermediate melting stage and a third of which has a still shorter arc and provides a refining stage. The molten metal as carried past the third electrode is then cooled either by convection of air or by an external coolant. As the mold turns about the conveyor sprocket at the outby end of the conveyor, the solidified metal is carried to a series of roller stands which roll the solidified metal to form, where it may be cut in the form of ingots.

6 Claims, 5 Drawing Figures



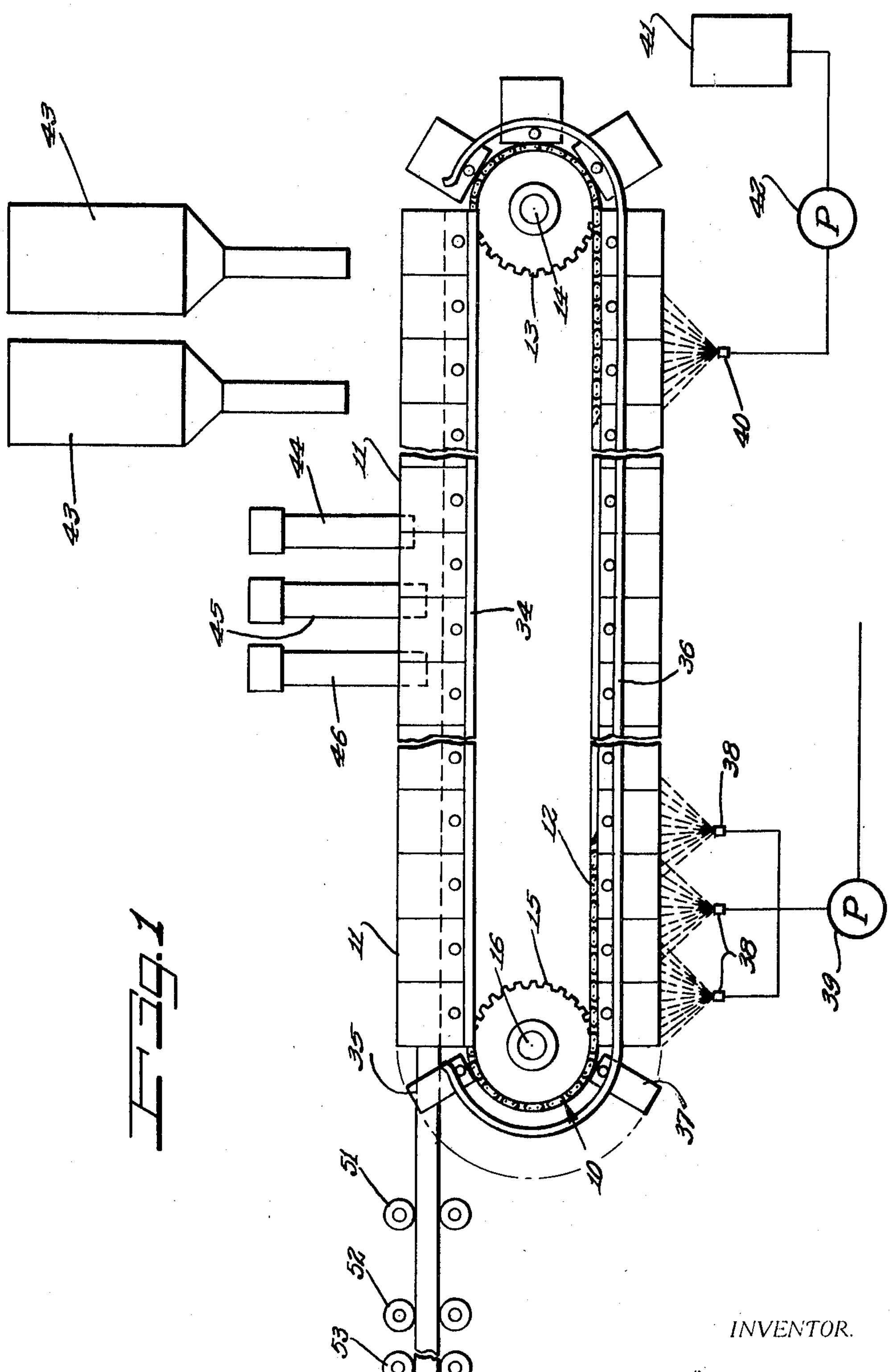


Fig. 1

INVENTOR.

Charles G. Robinson

BY Hill, Sherman, Meroni, Gross & Simpson ATTORNEYS

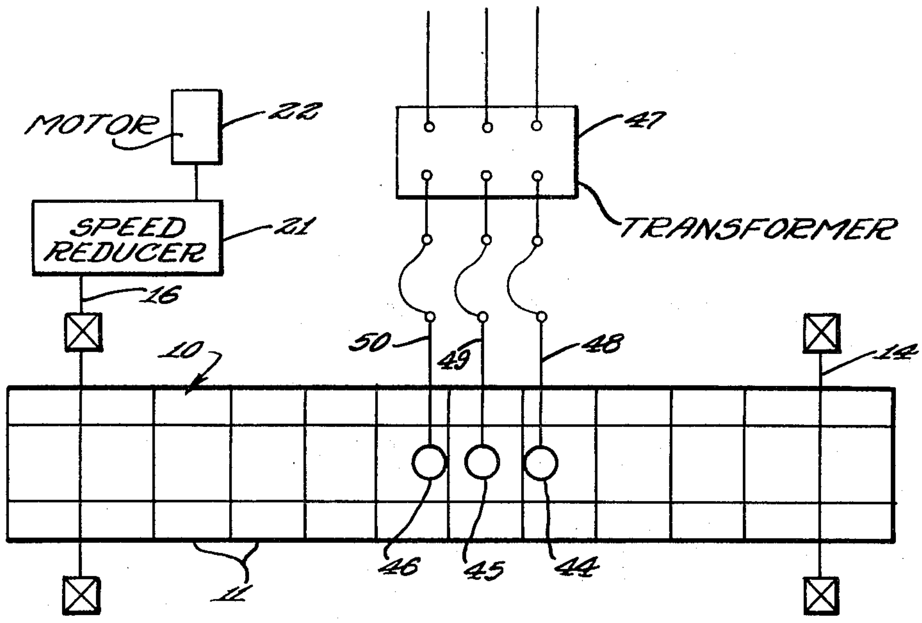


Fig. 2

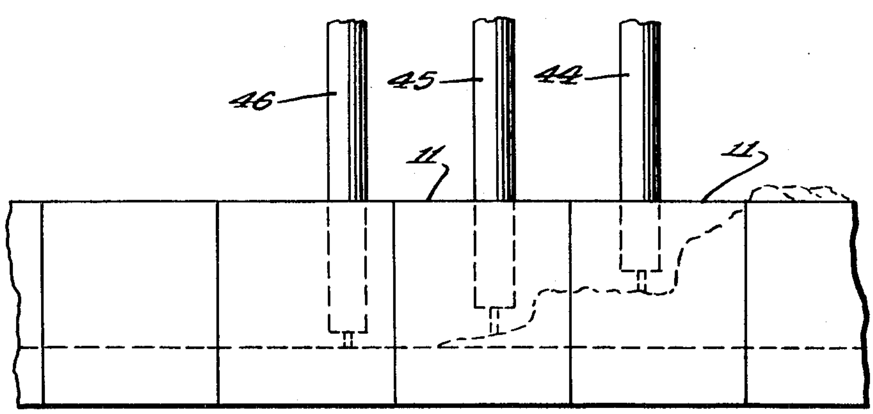


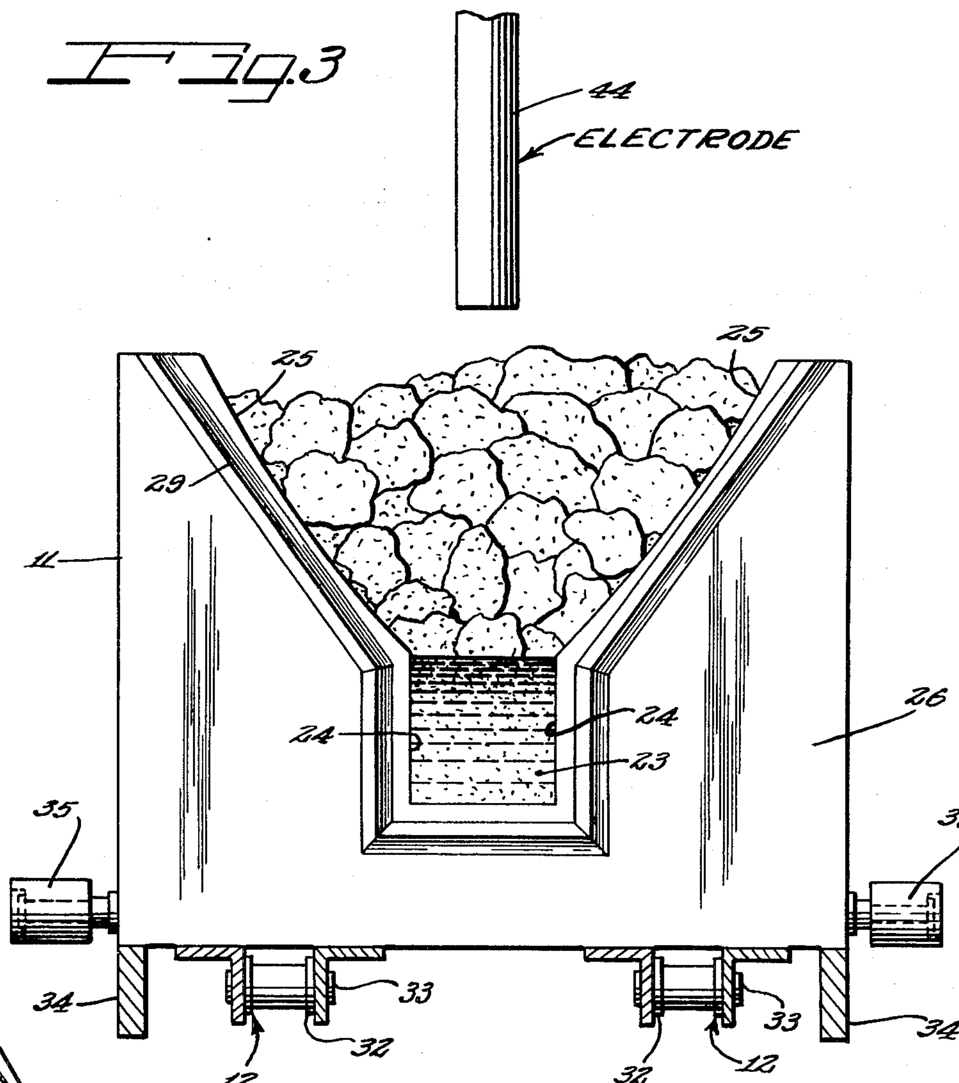
Fig. 5

INVENTOR.

Charles G. Robinson

BY Hill, Sherman, Meroni, Gross & Simpson ATTORNEYS

Fig. 3



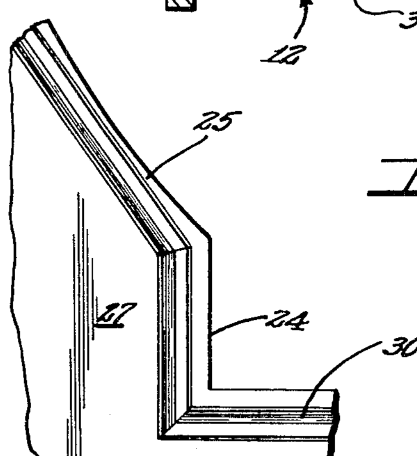


Fig. 4

INVENTOR.

Charles G. Robinson

BY Hill, Sherman, Meroni, Gross & Simpson ATTORNEYS

APPARATUS FOR THE CONTINUOUS PRODUCTION OF STEEL

BACKGROUND, OBJECTS AND SUMMARY OF THE INVENTION

The conventional systems for producing iron and steel are batch types of systems. This is true of the blast furnace, basic oxygen furnace, electric furnace, open-hearth furnace and smelting furnaces. All such furnaces tap into a ladle and the ladles are then moved to areas where the hot metal is teemed into ingots. The teeming operations are also batch operations, as are the operations of removing the ingots from the molds.

With advent of continuous casting, the hot metal batch is taken from the furnace, which may either be a basic oxygen or electric furnace, and then poured into a tundish, which in turn feeds the casting molds. With such continuous casting systems it is required that the mold be vertically oscillated and higher furnace-tapping temperatures are required to augment the heat loss in the handling of the hot metal through the various steps. The continuously cast bars as coming from the casting machine are then cut to length, so they can be rolled into a marketable product.

Such furnaces are necessarily large and the molds into which the molten metal is poured must be quite high if proper cooling characteristics are to be achieved. This results in large installations and is not suitable for mills which do not have the capacity to warrant the investment in such equipment.

The method and apparatus of the present invention improves upon prior iron and steel making batch and continuous casting techniques in that it makes it possible to continuously supply scrap to the casting mold and progressively melt and refine the scrap and then cool the molten metal to a solidified state in a continuous line without interrupting the charging, melting, refining and cooling stages of the apparatus. As the product is solidified, the molds return to continue the casting cycle and deliver finished steel, rolled to be cut to ingot forms. This process makes it unnecessary to vertically oscillate the molds and attain the higher tapping temperatures required in previous continuous casting processes.

Another object of the invention is to provide an improved continuous casting apparatus in which a meltable charge is progressively melted down and refined by a delta three-phase, three-electrode system, in which each individual electrode is performing a separate and specific task.

Still another object of the invention is to improve upon the melting of metals by the use of a three-phase delta three-electrode system in which the arcs of the successively arranged electrodes are of different lengths for more efficient arc efficiencies, in which the meltdown electrode has the longer arc, the intermediate electrode has a shorter entering arc and the third electrode is a refining electrode and has a short arc for best heat absorption.

A still further object of the invention is to provide an improved form of straight line horizontally oriented continuous casting apparatus including a plurality of hoppers charging the molds with meltable materials, so arranged as to be capable of being charged on a continuous basis, and to be computer controlled for the rate of feed and degree of alloying desired.

Still another object of the invention is to provide an improved apparatus for the continuous casting of metal, in which a meltable charge is continuously moved under a plurality of electrodes at one end of the apparatus, and a usable product is delivered from the other end of the apparatus.

Still another object of the invention is to provide a more flexible horizontally oriented continuous casting assembly in which the molds are carried in end-to-end relation by an endless conveyor beneath a charge hopper, and three progressively arranged electrodes, in which rolling stands may be coupled directly to the apparatus to roll the solidified product to a required bar or ingot and shearing means may be provided to shear the rolled product to length.

Still a further object of the invention is to provide an improved form of apparatus for continuous casting utilizing a series of interconnected molds carried by an endless conveyor, in which the melting and delivery of the solidified metal is attained without the necessity of vertically oscillating the molds as in previous continuous casting processes, and thereby attaining a better ingot surface and product, eliminating scarfing and surface perforation of the product.

A still further object of the invention is to provide a more flexible continuous casting apparatus than has heretofore been employed, which makes it unnecessary to superheat the metal heretofore required to take care of the temperature loss in the various batching steps in previous continuous casting processes.

Another and important object of the present invention is to provide a continuous casting apparatus having a better yield from the melting furnace with no scrap loss from the molten metal to solidification and ingot form, and thereby improving upon the yield normally lost in batch and previous continuous casting processes.

Other objects, features and advantages of the invention will be readily apparent from the following description of a certain preferred embodiment thereof, taken in conjunction with the accompanying drawings, although variations and modifications may be effected without departing from the spirit and scope of the novel concepts of the disclosure.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic fragmentary side elevational view diagrammatically illustrating a continuous casting apparatus constructed in accordance with the principles of the present invention.

FIG. 2 is a schematic plan view of a portion of the continuous casting apparatus diagrammatically shown in FIG. 1, diagrammatically illustrating the energizing circuits to the three electrodes and the drive to the conveyor carrying the ingot molds of the apparatus.

FIG. 3 is a schematic front end view of a form of mold that may be used to carry out the invention.

FIG. 4 is a fragmentary rear end view of the mold shown in FIG. 3; and

FIG. 5 is a schematic detail side elevational view illustrating the positions of the three electrodes and the lengths of the arcs to attain the melting and refining of the meltable material.

DESCRIPTION OF PREFERRED EMBODIMENT OF INVENTION

In the schematic illustration of the continuous casting process and apparatus of the invention shown in FIG. 1 of the drawings, **10** designates an endless conveyor carrying a series of aligned and interengaging open-ended molds **11** sealed in engagement with each other when traveling along the charging, melting and refining and the solidification run of the process. The conveyor **10** may be a chain type of conveyor in which laterally spaced endless chains **12** are trained about laterally spaced idler sprockets **13,13** on a transverse shaft **14** suitably journaled and supported at the inby end of the conveyor. The chain is shown as extending from said idler sprockets in a horizontal plane to and about a pair of laterally spaced drive sprockets **15,15** at the outby end of the conveyor and keyed or otherwise secured to a drive shaft **16**, suitably journaled in the main frame for the apparatus (not shown). The length of the conveyor is determined by the cross-sectional area of the final product cast and the length of time required to melt, refine the scrap or other metal and to cool the product to a solidified form.

The product and molds may be cooled sufficiently to deliver the solidified product at the outby end of the conveyor **10** by natural convection of air, or by cooling the molds as they leave the electrodes by forced water cooling (not shown) either by external cooling or by water-jacking the molds and providing a continuous forced circulation of coolant through the molds. External water cooling materially shortens the length of the conveyor.

As shown in FIGS. 1 and 2, the drive shaft 16 and sprockets 15,15, keyed or otherwise secured thereto are driven from a speed reducer 21, which may be of a conventional form. The speed reducer 21 is suitably driven from a motor 22. The motor 22 may be a variable speed motor of a commercial form, in which the output speed of the motor may be varied at the selection of the operator, to provide sufficient time for charging, melting and solidification to take place for the different metal alloys melted and cast. The speed reducer 21 may also be a variable speed reducer. The motor and speed reducer are no part of the present invention so need not herein be shown or described further.

The molds 11,11 are each of a similar construction and may be cast iron molds as in conventional ingot molds, or may be cast iron or steel lined with a suitable refractory material. Each mold 11 has a troughlike ingot molding area 23 at the bottom of the mold and opening to each end of the mold. Vertical sidewalls 24 of the ingot molding area terminate at their upper ends into diverging slightly concave hopperlike walls 25 extending at equal angles with respect to the sidewalls 24 to form a volumetric scrap or meltable metals containing area into which the meltable metals are delivered.

The inclined sidewalls 25,25 of the scrap area provide a hopperlike chamber in which the ratio of the scrap area to the ingot area may be 7 to 1. Thus, when the scrap is completely melted down the molten metal will be contained in the ingot area 23 for solidification into a continuous ingot for rolling and shearing to length.

The mold 11 also has vertically extending front and rear end walls 26 and 27. The front end wall 26 has a sealing lip 29 spaced inwardly of and extending along the inclined sidewalls 25 of the scrap area and along the troughlike ingot area 23. The sealing lip 29 is adapted to have engagement with a sealing groove 30 in the rear wall 27 of the mold, conforming to the form of said sealing lip, to seal the molten metal to the mold during the melting period and until solidification of the metal. The sealing lip and groove herein shown are illustrative only and may be of various forms so need not herein be shown or described in detail.

Each mold 11 also has laterally spaced attachments 31,31 depending from the bottom thereof along opposite sides of the endless chain 12. The attachments 31,31 are shown as connected to certain links 32 of the conveyor chain 12 by pivot pins 33. The molds may travel along rails 34, supporting the molds when traveling along the charging, melting, refining and solidifying stages of the process. Rollers 35 may be rotatably supported to extend from opposite sides of the molds, and guide the molds when traveling about the drive and idler sprockets and along the return run of the conveyor. The rollers 35 are guided and supported on rails 36, extending along the sprockets 13 and 15 and along the return run of the conveyor.

An end dam 37 is provided to close the end of the advance mold when starting a casting operation, charge melting and molding operation. Similar end dams, (not shown) may be placed along the conveyor between the molds where required. An end dam 37 may close the trailing mold.

As the molds 11 turn about the drive sprockets 15 on their return travel to the idler sprockets 13, the inverted molds may be first cooled by a series of spray nozzles 38,38 supplied with coolant such as water by a pump 39. The spray nozzles 38 may be arranged to spray the insides of the mold walls and to cool the molds an amount approximating the heat increase in the molds during melting and refining. A mold leaving the cooling area is, therefore, cooled to approximately 300° F. The molds then moving along the return run of the conveyor are sprayed with a coating solution by one or more sprays 40, supplied with coating solution from a tank 41 and pump 42. The coating solution places a protective grain boundry in the mold, to prevent the molten steel from sticking to the mold surface.

Two scrap hoppers 43,43 are shown as being provided for supplying scrap or other meltable materials to the molds 11. These scrap hoppers are spaced along the conveyor 10, adjacent the inby end thereof, for discharging the scrap or other meltable materials into the molds to be progressively melted down and refined by a series of three aligned electrodes 44,45 and 46 extending into the molds. The electrodes 44,45 and 46 are energized through a conventional three-phase delta system, to provide a direct arc with the meltable and molten metal, to effect the melting down of the scrap and the refining of the material as will hereinafter more clearly appear as this specification proceeds.

The scrap feeders or hoppers 43 may be of any well-known form commercially available, for feeding scrap or other meltable materials to the molds and can be computer controlled for the rate of scrap feed to the molds, in accordance with the speed of the conveyor and the degree of alloying desired. While I have herein shown two hoppers, it should be understood that one or any other number of hoppers may be used, depending upon the size of the charge required to fill the ingot areas of the molds when melted down by the progressively arranged electrodes 44,45 and 46.

The electrodes 44,45 and 46 may be hollow graphite or carbon electrodes having central passageways extending for the length thereof, the hollow interiors of which may be used for feeding meltable materials or arc-stabilizing gases into the charge, as shown in my prior art U.S. Pat. Nos. 3,101,385 and 3,105,864. The electrodes may also be consumable electrodes such as are shown in the Corso et al. U.S. Pat. Nos. 3,368,018 and 3,368,019 and the Corso U.S. Pat. Nos. 3,369,047 and 3,389,209, assigned to Westinghouse Electric Corporation of Pittsburgh, Pennsylvania. Laser heads, as shown and described in my joint patent with Paul Dillon, U.S. Pat. No. 3,244,412 may be used in place of the electrodes for certain melting conditions.

The electrodes may be energized through a closed circuit delta system in which each electrode is connected with one phase of a three-phase secondary of a transformer 47 through cables 48,49 and 50, connected to the respective electrodes 44,45 and 46. The return may be through the metal being melted through a suitable grounding system (not shown). The arcs of the electrodes and heights of the individual electrodes may be controlled as in my U.S. Pat. No. 3,097,252, and no part of the present invention so not herein shown or described further.

As diagrammatically shown in FIG. 3, the electrodes 44,45 and 46 are at different levels to effect a most efficient arc and melting and refining of the scrap or other metals. The electrode 44 has the longest arc and consequently is the highest electrode, and serves as a meltdown electrode. The electrode 45 is at a lower level and has a shorter arc than the electrode 44 and serves as an intermediate electrode. The electrode 46 extends lower down into the mold in close proximity to the melted metal and has the shortest arc and is used to do the refining.

As the product is melted into a liquid state, as traveling with the molds 11,11 along the conveyor 10, it is cooled in the molds by natural convection of air, or by forced liquid cooling, as previously mentioned. The cooled solidified product is discharged from the end of the leading mold 11 to roll stands 51,52 and 53, which may be operated by variable speed motors (not shown), synchronized with the output of the molds. The product coming from the roll stands can then be sheared into ingots of preselected lengths.

In carrying out the continuous casting process of the present invention, the conveyor 10 is first started to bring the molds 11 under the scrap hoppers 43 where the molds are charged with scrap or scrap and alloys or other agents required to make a particular grade of steel. This is all done during continuous travel of the molds 11 and conveyor 10, and as the charged molds come to the electrodes 44,45 and 46, the electrode 44 will serve to melt down the charge while the electrodes 45 and 46 will continue the melting of the charge at an intermediate stage and refine the charge, as refining agents are introduced therein. As the advance mold 11 advances past the electrode 46, cooling will commence to take place, either by convection of the air or by forced water cooling, it being understood that the conveyor may be long enough to allow the metal to completely solidify as the advance mold reaches the drive sprockets **15** at the outby or delivery end of the conveyor. As the metal is cooled sufficiently to solidify, the molds will start to turn about the drive sprockets **15** and the formed product may continue its travel in a straight line to the roll stands **51**,**52** and **53**, reducing the metal to a preselected ingot size. The rolls in the roll stands **51**,**52** and **53** may be driven by variable speed motors, which can be synchronized with the output of the continuous system.

The molds **11** as traveling about the drive sprockets **15** to be returned to the hoppers **43** in inverted form are first sprayed with coolant and cooled by an amount approximating the heat increase in the molds, which may be of the order of 300° F. and are then sprayed with coating solution to put a protective grain boundry on the molds to prevent the molten steel from sticking to the mold surfaces. The molds then continue about the idler sprockets **13** to again be charged with scrap and passed through the successive meltdown intermediate melting and refining stages, to provide a substantially continuous casting process of steel and other products, doing away with all batch operations, and enabling the casting to be carried out at normal furnace temperatures, without the necessity of having to superheat the metal to take care of the heat loss by transfer from the furnace to the tundra or by vertically oscillating the molds.

I claim as my invention:

1. In an apparatus for the continuous casting of metal, a series of longitudinally aligned open-ended molds having sealing engagement with each other,
   means moving said molds in a straight line,
   a series of electrodes extending into said molds in longitudinally aligned relation with respect to each other, one after the other, and energized by the secondaries of a three-phase transformer to progressively effect an initial melting stage, an intermediate melting stage and a final refining stage of the product, including
   a first electrode being a meltdown electrode and having the longest arc of the three electrodes,
   a second electrode being located lower down in the mold than the first electrode and having a shorter arc, and
   a third electrode being a refining electrode and extending downwardly into the mold a farther distance than the first two electrodes, and having a short arc for more efficient heat absorption, and
   means continuing the travel of said molds upon solidification of the product to continue travel of the solidified product in a straight line and carrying said molds back to the charging means in an inverted condition.

2. The continuous casting apparatus of claim **1**, wherein the means carrying and moving the molds in a straight line comprises,
   a power-driven endless conveyor traveling in accordance with the time required to effect continuous charging, melting, refining and solidification of the metal and returning the molds for recharging in a downwardly facing cooling and mold coating position.

3. The continuous casting apparatus of claim **2**,
   wherein means are provided for spraying coolant in the molds on their return travel in downwardly facing positions, to cool the mold walls by an amount approximating the heat increase in the molds during the casting operation, and
   wherein means are provided for spraying coating solution in the cooled molds prior to recharging.

4. The continuous casting apparatus of claim **2**,
   wherein the molds each have a troughlike ingot area extending along the bottom thereof and opening to each end thereof, and a diverging scrap area extending upwardly of said ingot area and diverging therefrom.

5. The continuous casting apparatus of claim **4**,
   wherein the molds each have plane front and rear faces extending parallel to each other, and
   wherein sealing lips and sealing grooves extend from the adjacent faces of the molds and have interengagement with each other during the continuous casting operation.

6. The continuous casting apparatus of claim **5**,
   wherein roll stands are provided in alignment with said molds as said molds change their directions of travel to return to said charging means, to roll the solidified product to ingot size.

* * * * *