United States Patent [19]

Paton et al.

[11] **3,721,286**

[45] **March 20, 1973**

[54] **METHOD OF OBTAINING METAL HOLLOW INGOTS BY THE ELASTROSLAG REMELTING**

[76] Inventors: **Boris Evgenievich Paton,** ulitsa Kotsjubinskogo, 9, kv. 21; **Boris Medovar Izrailevich,** bulvar Lesi Ukrainki, 2, kv. 8; **Jury Vadimovich Latash,** Vozdukhoflotsky prospekt, 81, kv. 14; **Leonty Vasilievich Chekotilo,** ulitsa Scherbakova, 49-a, kv. 10; **Vitaly Mikhailovich Baglai,** ulitsa semashko, 10, kv. 54/3; **Viktor Leonidovich Artamonov,** ulitsa Sovetskaya, 9, kv. 4; **Rodimir Ivanovich Garkaljuk,** ulitsa Bolshaya Kitaevskaya, 142, korpus 14, kv. 33; **Viktor Anatolievich Timchenko,** ulitsa Vladimirskaya, 98/3, kv. 36; **Evgeny Federovich Malichekno,** prospekt Entuziastov, 7/2, kv. 161; **Leonid Mikhailovich Stopak,** Brestlitovsky prospekt, 39, kv. 9; **Rudolf Solomonovich Dubinsky,** Brestlitovsky prospekt, 4, kv. 15, all of Kiev, U.S.S.R.

[22] Filed: **March 29, 1971**

[21] Appl. No.: **129,168**

Related U.S. Application Data

[63] Continuation of Ser. No. 771,165, Oct. 28, 1968, abandoned.

[52] **U.S. Cl.** **164/52,** 13/14, 164/85

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

[58] **Field of Search**.....164/85, 52, 252, 50, 51; 13/14, 18

[56] **References Cited**

UNITED STATES PATENTS

2,553,921	5/1951	Jordan	164/85
2,380,238	7/1945	Hopkins	164/52
2,405,254	8/1946	Hopkins	164/52
3,375,863	4/1968	Atkins et al.	164/85
2,740,177	4/1956	Smart, Jr.	164/85
2,466,612	4/1949	Phillips et al.	164/85 X
3,331,430	7/1967	Earl, Jr.	164/85 X
2,225,415	12/1940	Junghans	164/85
2,277,375	3/1942	Tama	164/85
2,130,202	9/1938	Tama	164/85
3,268,958	8/1966	Sickbert	164/252
2,388,974	11/1945	Hopkins	164/52

FOREIGN PATENTS OR APPLICATIONS

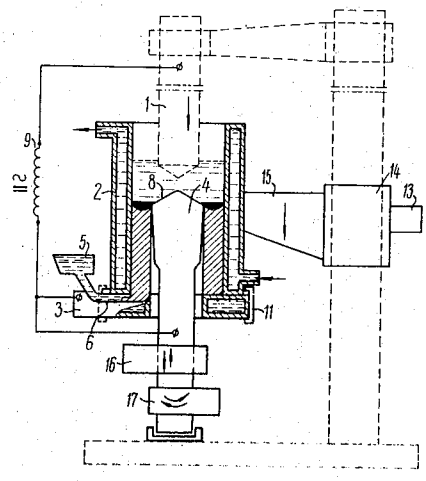
868,734	5/1961	Great Britain	164/85
515,638	5/1939	Great Britain	249/79

Primary Examiner—J. Spencer Overholser
Assistant Examiner—V. K. Rising
Attorney—Waters, Roditi, Schwartz & Nissen

[57] **ABSTRACT**

A method for electroslag remelting of at least one consumable electrode in a cooled mold assembly with a cooled bottom plate in which at least a part of the mold assembly is moved relative to the ingot being formed during forming of the ingot, and a device by which the method can be practiced. Movement of selective parts of the mold assembly relative to the ingot and/or the electrode is provided with or without movement of the electrodes itself. Bottom pouring of molten slag is provided. A specific mold assembly has, as an element, a cooled core device enabling making hollow ingots, in which case the hollow core device can be moved axially, reciprocated axially and reciprocally rotated during forming of the ingot. Electrical power for the electroslag remelting can be connected between the consumable electrode and any or all elements of the mold assembly.

84 Claims, 3 Drawing Figures



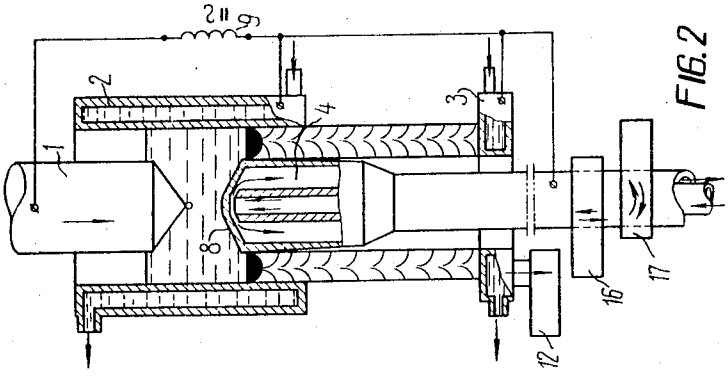


FIG. 2

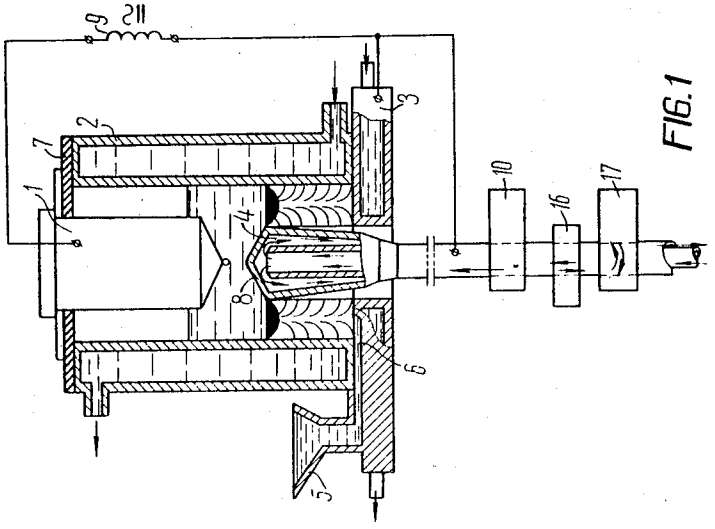


FIG. 1

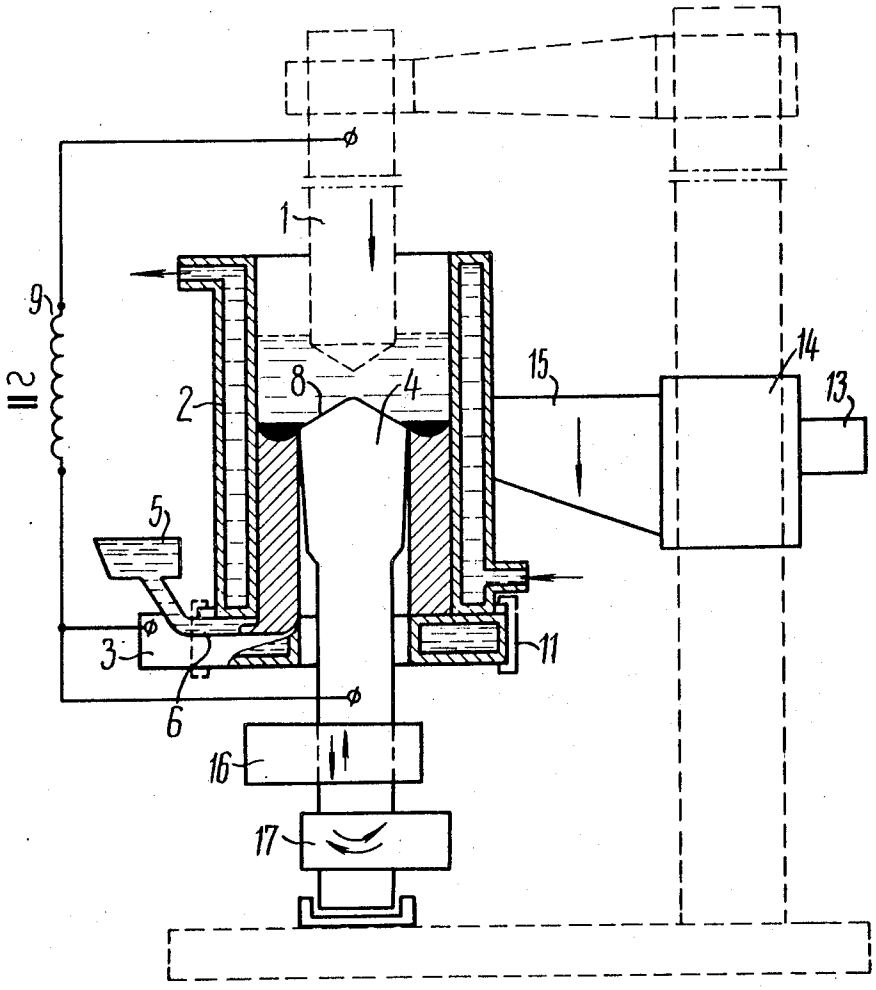


FIG. 3

METHOD OF OBTAINING METAL HOLLOW INGOTS BY THE ELASTROSLAG REMELTING

This application is a continuation of copending application Ser. No. 771,165, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to methods for obtaining metal hollow ingots by electroslag remelting, and to devices for effecting same; the invention may be made use of for obtaining hollow ingots of pipe stock from steels, alloys and metals (ball-bearing, highly alloyed, heat-resistant, anticorrosive, high-strength structural, and the like including those difficult to work), intended for subsequently processing into pipes and other articles by pressing, rolling out, rolling, etc.

Known in the prior art is a method for obtaining hollow metal ingots by the electroslag remelting of a hollow (in the tubular form) consumable electrode in a cooled annular ingot mold composed a cooled mold and a cooled bottom plate together with a cooled core being made stationary in relation therewith.

In this case, a consumable electrode is remelted in an annular gap between the mold and core. DUring the entire remelting process of a hollow ingot, the slag bath is given an annular form. Its cross section is almost equal to that of a hollow ingot to be made.

A disadvantage of the prior-art method consists first of all in that for making ingots there are employed expensive hollow (in the tubular form) consumable electrodes. Moreover, the hollow ingot to be built-up is squeezes the core during shrinkage, which may cause cracking in the ingot, whereas the core will have to be removed from each ingot by mechanical means.

An object of the present invention is to work out such a method of electroslag remelting of hollow ingots, and to provide a device for carrying into effect same, which would permit using cheap consumable electrodes of a solid section (both deformed or cast), precluding the formation of cracks in the ingot, making hollow ingots possessing a good internal surface, to be directly used for the further processing thereof.

In conformity with these and other objects of the invention, the proposed method of making metal hollow ingots by electroslag remelting of a consumable electrode in a cooled mold having a core disposed therein, the core forming the internal cavity of the ingot being built up on a cooled bottom plate, features, according to the invention, a mold, a core and a bottom plate together with an ingot secured thereon in the process of remelting the consumable electrode, which are given longitudinal motion in relation to each other so that the upper end face of the core is constantly immersed into the molten slag bath.

The mutual motion of the mold, core and bottom plate may be carried into effect either by moving the cooled core upwardly in relation to the stationary mold and bottom plate, or by moving the bottom plate together with the ingot secured thereon downwardly in relation to the core and stationary mold, or, finally, by moving the mold together with the bottom plate and the ingot secured thereon and being built-up downwardly in relation to the core.

To improve the internal surface of the hollow ingot being made, the core during the remelting process should be given rocking motion.

The nature of the present invention will further be made more fully apparent from a consideration of the following description of its exemplary embodiments, taken in conjunction with the accompanying drawings, in which:

FIG. 1 represents a device for obtaining hollow ingots by the electroslag remelting of a consumable electrode, which, according to the invention, is provided with a mechanism for moving a core in relation to a stationary mold and bottom plate;

FIG. 2 shows the same device complete with a mechanism for moving a bottom plate together with an ingot in relation to the core and stationary mold;

FIG. 3 represents the same device complete with a mechanism for moving the mold together with the bottom plate and the ingot being built-up downwardly in relation to the core.

The remelting of the consumable electrode 1 (FIGS. 1, 2, 3) is carried out in a cooled mold 2. Provided under the mold is a cooled bottom plate 3 provided with an opening.

The internal surface of the hollow ingot being built-up is formed by means of a cooled rod 4 passing through the opening in the bottom plate. A bottom-pouring device 5 and a runner 6 are provided in order to supply the molten slag into the mold. Slag may be also top-poured into the mold. During the remelting process, a consumable electrode 1 is fed into the slag bath. The process of remelting a hollow ingot, however, may be also carried into effect with the consumable electrode being stationary. In this case, the electrode is secured on the upper edge of the mold, being insulated therefrom by means of a packing 7, whereas the cross-sectional area of the electrode will have to be selected equal or approximating that of the hollow ingot being made in the remelting process.

Before starting the remelting process, the rod 4 is inserted in the opening of the bottom plate in such a manner that the upper end face thereof be projected over the bottom plate and will form together with the mold an annular gap. The gap between the core and opening in the bottom plate must be as small as possible in order to prevent slag from flowing out from the mold at the beginning of the remelting process. The molten slag is poured into the mold, thus forming the slat bath. Then voltage from an alternating or direct-current source such as the power source 9 is applied to the electrode 1, the bottom plate 3 and the core 4.

With the voltage applied, as soon as the lower end of the consumable electrode reaches the slag bath, its melting begins. The melting of the consumable electrode results in molten metal, which gets into the annular gap, thus flowing around the upper end face 8 of the cooled core 4 projecting into the slag bath. This brings about the formation of a molten annular metal bath, from which a hollow ingot solidifes. In the remelting process, the upper end face of the cooled core will have to be maintained in the slag bath so as to prevent a solidifed crust from being formed thereon, which may interfere with the further proceeding of the remelting process.

For constantly maintaining the upper end face 8 of the core in the slag bath in the process of building up the hollow ingot, there is carried into effect the mutual movement of the mold, core and bottom plate together

with the ingot being built-up and secured thereon, at a speed near that of rising of the slag bath.

Motion of the core upwardly in relation to the stationary mold and bottom plate is carried into effect by means of a mechanism **10** (FIG. **1**) provided on the rod of the core. In this case, the mold is stationary and is secured on the bottom plate, for example, by means of a screw clamp **11** (FIG. **3**). Pick-ups (which are not shown in the drawing) are employed for controlling the position of the upper end of the core in the slag bath.

In conformity with the second embodiment of the invention, the internal cavity of the ingot is formed by moving the bottom plate together with the ingot in relation to the core and stationary mold by having recourse to a mechanism **12** (FIG. **2**) connected to the bottom plate (for example, a screw pair).

FIG. **3** represents a device for casting a hollow ingot, in which, in the process of its remelting, the mold is moved in relation to the core together with the bottom plate and the ingot secured thereon. A mechanism **13** (FIG. **3**) is connected with the mold through a support **14** and a bracket **15**. In this case, the mold is secured on the bottom plate by means, for example, of screw clamps **11**.

To improve the internal surface of the hollow ingot the core may be connected to a mechanism **16**, imparting thereto rocking motion in the longitudinal direction and/or to a mechanism **17** imparting thereto reciprocal rotary motion.

As soon as the hollow ingot of the required length is made, the voltage is disconnected and the consumable electrode is removed. In all the above-mentioned embodiments of the device, disconnection of voltage is followed by the mutual motion of the mold, core and bottom plate together with the ingot secured thereon until the core completely emerges from the ingot's cavity so as to prevent the core from being clamped in the ingot during its shrinkage in cooling.

Thereafter, the core is disengaged from its rod, and the hollow ingot is extracted.

The proposed method and device for effecting same permit hollow ingots to be produced without internal, nor external defects, from a high-quality, electroslag metal. Application of this method and device for effecting same permit elimination of expensive operations, such as drilling and piercing, when manufacturing pipe stock from cores of solid section which is of a special importance when manufacturing pipe stock from metals and alloys that are difficult to work.

What is claimed and desired to be secured by Letters Patent is:

1. A method of manufacturing hollow metal ingots by the electroslag remelting of a consumable electrode in a cooled mold having disposed therein a cooled core terminating in an upwardly directed end face forming the internal cavity of an ingot to be formed in said mold, said ingot being secured on a bottom plate, comprising forming a molten slag bath in said mold, immersing the lower end of said consumable electrode and the upper end face of said core in the molten slag bath, connecting said consumable electrode, core and bottom plate to a current source, providing relative movement in the axial direction between said core and said bottom plate with the ingot secured to said bottom plate in such a manner that the upper end face of said core is constantly immersed in the molten slag bath in said mold during remelting.

2. A method as claimed in claim **1**, wherein the core is moved upwardly in relation to the stationary mold and bottom plate having the ingot being formed secured thereon.

3. A method as claimed in claim **1**, wherein the bottom plate together with the ingot being formed and secured thereon is moved downwardly in relation to the core and stationary mold.

4. A method as claimed in claim **1**, wherein the mold together with the bottom plate and the ingot being formed secured thereon are moved downwardly in relation to the core.

5. A method as claimed in claim **1**, wherein a rocking motion in the axial direction is imparted to the core.

6. A method as claimed in claim **1**, wherein reciprocal rotary motion is imparted to said core.

7. A method of electroslag remelting of at least one consumable electrode in a mold having a remelting zone defined by the lower portion of the mold and having a bottom plate, and a cooled core terminating in an upper end face disposed in the mold to form an internal cavity in the ingot being built-up by the remelting of the consumable electrode, comprising the steps of connecting the consumable electrode, the bottom plate and said cooled core to a source of electrical power, bottom pouring a predetermined quantity of molten slag into said remelting zone, contacting the lower end of the consumable electrode with the molten slag, controlling the axial movement of the mold during remelting, and controlling the axial movement of the consumable electrode during remelting, the axial movement of the mold being controlled in such a manner that the upper face of the cooled core is constantly in contact with the molten slag in the mold.

8. A method as defined in claim **7**, wherein said electrode is moved axially with respect to said mold during remelting and wherein said cooled core is moved axially with respect to said mold during remelting.

9. A method of electroslag remelting of at least one consumable electrode in a mold having a remelting zone defined by the lower portion of the mold and having a bottom plate, and a cooled core terminating in an upwardly directed end face disposed in the mold to form an internal cavity in the ingot being built-up by the remelting of the consumable electrode, comprising the steps of connecting the consumable electrode, the bottom plate and said cooled core to a source of electrical power, bottom pouring a predetermined quantity of molten slag into said remelting zone, contacting the lower end of the consumable electrode with the molten slag, controlling the axial movement of the mold during remelting, maintaining the consumable electrode in fixed axial position with respect to the mold during remelting, and moving the cooled core axially with respect to the mold during the remelting, the axial movement of the mold being controlled in such a manner that the upper face of the cooled core is constantly in contact with the molten slag in the mold.

10. A method of electroslag melting of metal in a molten slag bath maintained in a mold, wherein the mold is provided with a core member terminating in an upper free end, at least a portion of the free end being positioned within the molten slag for causing a hollow

ingot to be produced, comprising the steps of bottom pouring molten slag into the mold to start the melting, and providing relative movement between the ingot being formed and the core member along the hollow portion of the ingot being formed during the melting of the metal.

11. A method as defined by claim 10, wherein at least one consumable electrode is moved axially into the molten slag bath during melting.

12. A method as defined by claim 11, wherein the movements of the mold and the consumable electrode are in the same direction.

13. A method as defined by claim 10, wherein a bottom plate is provided for the mold and wherein the mold and the bottom plate are fluid cooled.

14. A method as defined by claim 11, wherein a source of electric power is connected to the consumable electrode and to the mold.

15. A method as defined by claim 14, wherein a bottom plate is provided for the mold and wherein the source of electric power is also connected to the bottom plate and wherein the mold and the bottom plate are at a common electrical potential.

16. A method as defined by claim 14, wherein the electric power is A.C.

17. A method as defined by claim 14, wherein the electric power is D.C.

18. A method as defined by claim 10, wherein a bottom plate is provided for the mold and wherein movement of the core member relative to the bottom plate is controlled in a fashion to maintain at least a portion of the upper face of the core member in constant contact with the molten slag.

19. A method as defined by claim 10, wherein the core member is fluid cooled.

20. A method as defined by claim 10, wherein the core member is reciprocated axially within the hollow ingot during its formation.

21. A method as defined by claim 10, wherein the core member is rotated reciprocally within the hollow ingot during its formation.

22. A method as defined by claim 10, wherein a consumable electrode is melted in the slat bath and wherein a source of electric power is connected to the consumable electrode, the mold, and the core member and wherein the mold and the core member are at a common electrical potential to provide a common potential for the core member and the hollow ingot being formed.

23. A method as defined by claim 22, wherein a bottom plate is provided for the mold and wherein the bottom plate has the same electrical potential as the core member.

24. A method as defined in claim 22, wherein the electrical power is A.C.

25. A method as defined in claim 22, wherein the electrical power is D.C.

26. A method as defined by claim 10, wherein the core member is axially aligned with the mold.

27. A method as defined by claim 10, wherein a bottom plate is provided for the mold and wherein the mold, bottom plate, and core member are fluid cooled.

28. A method as defined by claim 10, wherein the core member is reciprocated axially and is simultaneously rotated reciprocally within the hollow ingot during its formation.

29. A method as defined by claim 10, wherein a bottom plate is provided for the mold and wherein the bottom plate and the mold are maintained in contact with each other and are moved in the same direction.

30. A method as defined in claim 10, wherein a bottom plate is provided for the mold and the mold is moved axially relative to the bottom plate.

31. A method as defined by claim 30, wherein the bottom plate is held in fixed position and the movement of the mold relative to the bottom plate is in a direction away from the bottom plate.

32. A method as defined by claim 30, wherein at least one consumable electrode is axially moved into the molten slag bath during melting.

33. A method as defined by claim 30, wherein the mold is held in fixed position and the bottom plate is moved axially away therefrom.

34. A method as defined by claim 32, wherein a source of electric power is connected to the consumable electrode and to the mold.

35. A method as defined by claim 34, wherein the source of electric power is also connected to the bottom plate and wherein the mold and the bottom plate are at a common electrical potential.

36. A method as defined by claim 34, wherein the electric power is A.C.

37. A method as defined by claim 34, wherein the electric power is D.C.

38. A method as defined by claim 30, wherein movement of the core member relative to the bottom plate is controlled in a fashion to maintain at least a portion of the upper face of the core member in constant contact with the molten slag.

39. A method as defined by claim 30, wherein the core member is reciprocated axially within the hollow ingot during its formation.

40. A method as defined by claim 30, wherein the core member is rotated reciprocally within the hollow ingot during its formation.

41. A method as defined by claim 30, wherein a consumable electrode is melted in the slag bath and wherein a source of electric power is connected to the consumable electrode, the mold, and the core member and wherein the mold and the core member are at a common electrical potential to provide a common potential for the core member and the hollow ingot being formed.

42. A method as defined by claim 41, wherein the bottom plate has the same electrical potential as the core member.

43. A method as defined by claim 30, wherein the core member is axially aligned with the mold.

44. A method as defined by claim 30, wherein the mold, bottom plate, and the core member are fluid cooled.

45. A method as defined by claim 30, wherein the core member is reciprocated axially and is simultaneously rotated reciprocally within the hollow ingot during its formation.

46. A method of manufacturing a hollow metal ingot by electroslag melting in a mold having disposed therein a core member terminating in an upwardly directed free end portion for forming the internal cavity of a hollow ingot formed in the mold, the ingot resting on a bottom plate, the core member being projected up through the bottom plate of the mold com-

prising: forming a molten slag bath in the mold; forming a molten metal pool below the molten slag bath; and during the electroslag melting providing relative movement at least in an axial direction, between the core member and the bottom plate, in such a manner that at least a portion of the upper end of the core member is maintained in contact with the molten slag bath during formation of the hollow ingot.

47 A method as defined by claim 46, wherein said forming of the molten metal pool is carried out by the melting of at least one consumable metal electrode in the molten slag bath.

48. A method as defined by claim 47, wherein the consumable electrode is moved axially into the molten slag bath during melting of the same.

49. A method as defined by claim 46, including the additional step of moving the mold along its axis during the formation of the hollow ingot.

50. A method as defined by claim 47, including the additional step of moving the mold along its axis during the formation of the hollow ingot, the movement of the consumable electrode and the mold being in the same axial direction.

51. A method as defined by claim 46, wherein the mold and the core member are fluid cooled.

52. A method as defined by claim 46, including the step of bottom pouring molten slag into the mold to start the melting.

53. A method as defined by claim 46, wherein the mold moves relative to the bottom plate.

54. A method as defined by claim 53, wherein the bottom plate is in fixed position and the movement of the mold relative to the bottom plate is in a direction away from the bottom plate.

55. A method as defined by claim 53, wherein the mold is held in fixed position and the bottom plate is moved axially away therefrom.

56. A method as defined by claim 46, wherein the bottom plate is fluid cooled.

57. A method as defined by claim 47, wherein a source of electric power is connected to the consumable electrode, the mold and the core member.

58. A method as defined by claim 57, wherein the source of electric power is connected so that the core member and the bottom plate are at a common electrical potential.

59. A method as defined by claim 57, wherein the electric power is A.C.

60. A method as defined by claim 57, wherein the electric power is D.C.

61. A method as defined by claim 46, wherein the core member is reciprocated axially within the hollow ingot during its formation.

62. A method as defined by claim 46, wherein the core member is rotated reciprocally within the hollow ingot during its formation.

63. A method as defined by claim 46, wherein the core member is axially aligned with the mold.

64. A method as defined by claim 46, wherein the core member is maintained in fixed position and the bottom plate is moved relative thereto.

65. A method as defined by claim 46, wherein the bottom plate is maintained in fixed position and the core member is moved axially relative thereto.

66. A method as defined by claim 65, wherein the mold is maintained in fixed position and is maintained in contact with the bottom plate.

67. A method as defined by claim 46, wherein said step of forming a molten metal pool is conducted by maintaining a consumable metal electrode in contact with the molten slag bath within the mold.

68. A method as defined by claim 67, wherein the consumable metal electrode is held in fixed position relative to the bottom plate.

69. A method as defined by claim 68, wherein the mold is maintained in fixed position and the core member is moved relative thereto.

70. A method as defined in claim 69, wherein the consumable metal electrode is held in fixed position relative to the mold during remelting.

71. A method as defined by claim 67, wherein said step of forming a metal pool is conducted by moving a consumable metal electrode into the molten slag bath.

72. A method as defined by claim 46, wherein the mold moves simultaneously with the bottom plate relative to the core member which is maintained in fixed axial position.

73. A method as defined by claim 72, wherein said step of forming a molten metal pool is conducted by moving a consumable metal electrode into the molten slag bath.

74. A method as defined by claim 46, wherein the core member is reciprocated axially and is simultaneously rotated reciprocally within the hollow ingot during its formation.

75. A method of electroslag remelting of at least one consumable electrode in a mold having a remelting zone defined by the lower portion of the mold and having a bottom plate and a cooled core terminating in an upwardly directed free end portion disposed in the mold to form an internal cavity in the ingot being built-up by remelting of the consumable electrode comprising the steps of connecting the consumable electrode and bottom plate and core to a source of electric power, bottom pouring a predetermined quantity of molten slag into the remelting zone, contacting the lower end of the consumable electrode with the molten slag, controlling the axial movement of the mold during remelting so that at least a portion of the upper end of the cooled core is constantly in contact with the molten slag in the mold, and controlling the axial movement of the electrode during remelting.

76. A method as defined by claim 75, wherein the consumable electrode is maintained in fixed axial position with respect to the mold during remelting and wherein the cooled core is moved axially with respect to the mold during remelting.

77. A method as defined in claim 75, wherein the consumable electrode is moved axially with respect to the mold during remelting and wherein the cooled core is moved axially with respect to the mold during remelting.

78. A method of manufacturing a hollow metal ingot by electroslag melting a consumable metal electrode in a cooled mold having disposed therein a cooled core member terminating in an upper free end face for forming the internal cavity of a hollow ingot to be formed in the mold, the ingot resting on a bottom plate, comprising: forming a molten slag bath in the mold; forming a

molten metal pool below the molten slag bath; and providing relative movement at least in the axial direction, between the core member and the bottom plate, in such a manner that at least a portion of the upper end face of the core member is maintained in contact with the molten slag bath during formation of the ingot; and the mold, core member, and bottom plate being connected to one potential point of an electric power source and the consumable electrode being connected to the other potential point of the electrical power source; and wherein the core member is both reciprocated axially and rotated reciprocally within the hollow ingot during its formation.

79. A method as defined by claim **78**, including the step of bottom pouring molten slag into the mold to start the melting of the consumable electrode.

80. A method as defined by claim **78**, wherein the core member is maintained in fixed position and the mold and bottom plate together with the hollow ingot are moved axially downwardly over the core member.

81. A method as defined by claim **78**, wherein the consumable electrode is moved axially into the molten slag bath during melting and wherein the consumable electrode and the mold are moved in the same direction relative to the core member which is maintained in fixed axial position.

82. A method as defined by claim **78**, wherein the mold, bottom plate, and the core member are fluid cooled.

83. A method as defined by claim **78**, wherein the electric power is A.C.

84. A method as defined by claim **78**, wherein the electric power is D.C.

* * * * *