April 12, 1966 P. J. WOODING 3,246,070

CONSUMABLE ELECTRODE VACUUM ARC FURNACE

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FIG. 1

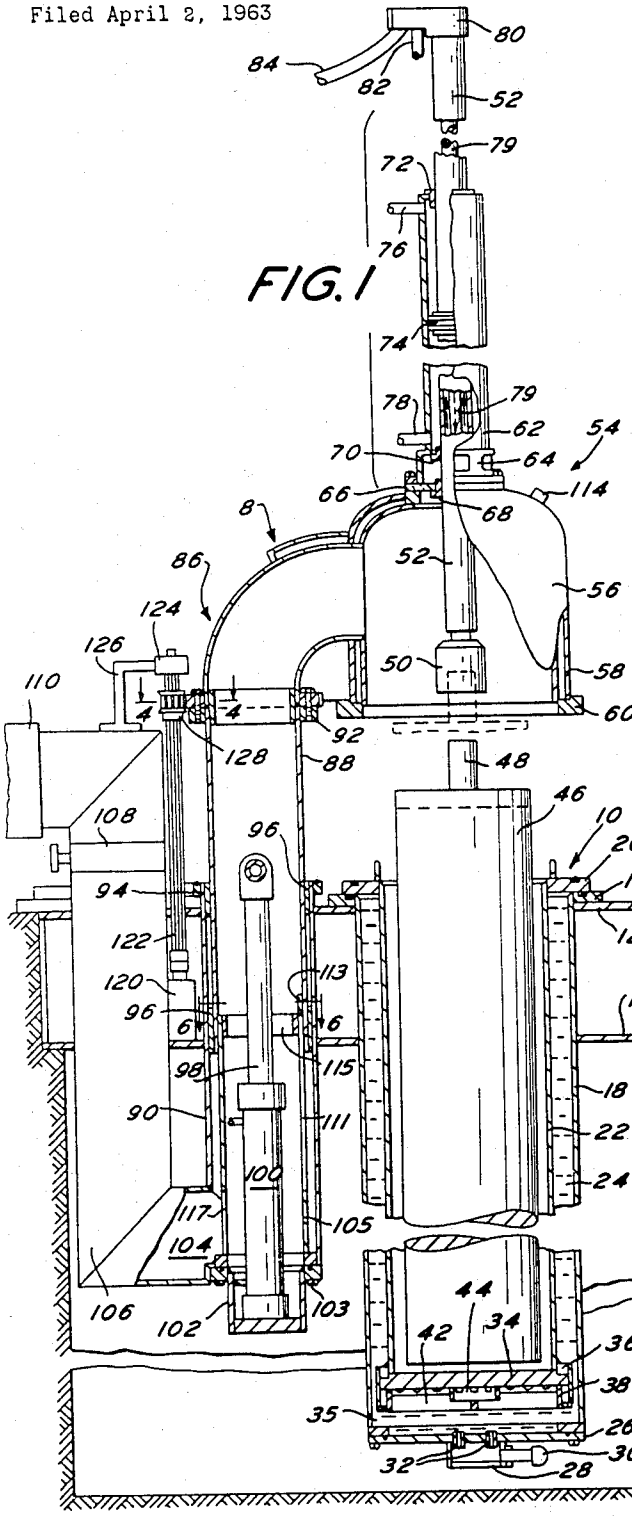


FIG. 4

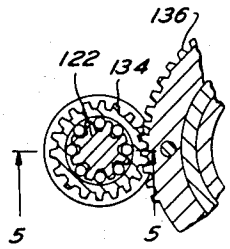


FIG. 5

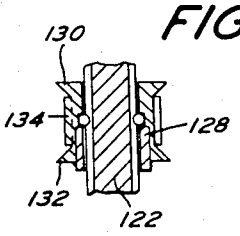
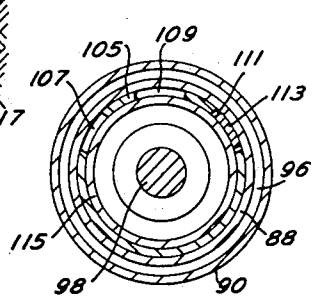


FIG. 6



INVENTOR.
PATRICK J. WOODING
BY
Arthur H. Seidel
ATTORNEY

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FIG. 2

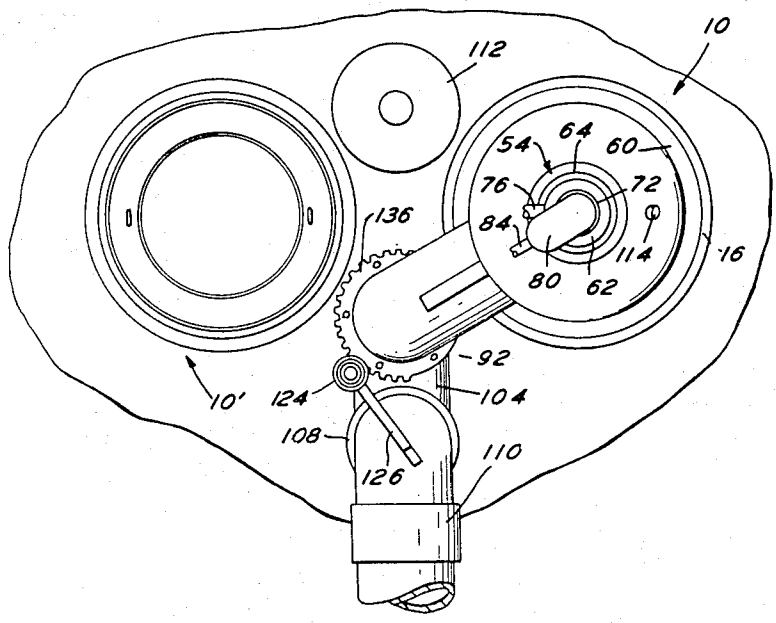
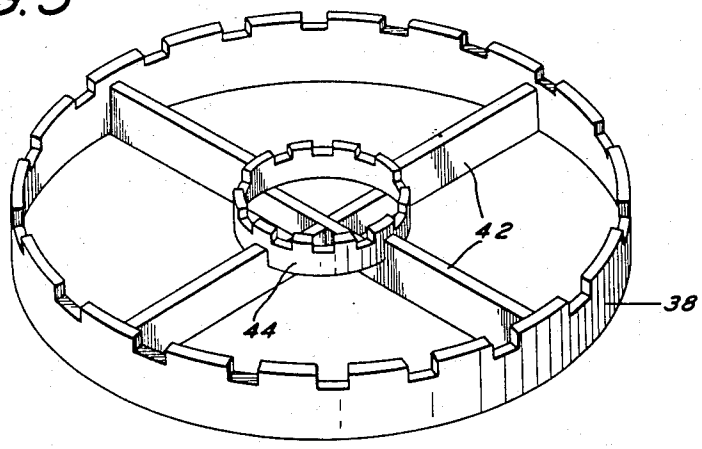


FIG. 3



INVENTOR.
PATRICK J. WOODING

BY

Arthur H. Seidel

ATTORNEY

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CONSUMABLE ELECTRODE VACUUM ARC FURNACE

Patrick J. Wooding, Moorestown, N.J., assignor to Consarc Corporation, Rancocas, N.J., a corporation of New Jersey

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16 Claims. (Cl. 13—31)

This invention relates to a consumable electrode vacuum arc furnace, and more particularly, to such a furnace wherein a single head is alternatively capable of being used with identical crucible units.

In a consumable electrode vacuum arc melting furnace, a metal electrode is melted by means of a high current, low voltage arc to form an ingot in an evacuated, water cooled copper crucible. The arc which is normally direct current with the electrode negative and the ingot grounded, is struck between the tip of the electrode and the bottom of the crucible and is maintained during melting between the electrode tip and the molten top surface of the ingot being formed. Normally this melting process takes place at pressure levels between .001 and 1.0 millimeter of mercury, with the vacuum system working continuously to remove the evolved gases. For some grades of metals, for example high temperature stainless steel, the furnace may be flooded with inert gas such as argon before, during or after melting the electrode. This is done to preserve the alloy composition in cases where one or more constituents vaporize at pressures above the levels normally used for vacuum melting.

In accordance with the present invention, the furnace head is supported by the vacuum system for use with two or more crucible units. The vacuum system which is used is sufficiently strong to support the head for vertical movement toward and away from a crucible unit and for rotative movement of the head between crucible units. The furnace of the present invention is simplified in its construction by use of the vacuum system as the support for the head.

In general, the object of the present invention is to provide an electric arc furnace having a wide range of flexibility combined with an ability to effect rapid production. This general object is accomplished while maintaining the furnace simple, sufficiently strong to accomplish its purpose, with minimum cyclic down time and minimum maintenance. These and the other objects of the present invention are accomplished while providing a furnace arrangement which permits maximum utilization of the power units and the vacuum system and eliminates unnecessary motions.

It is another object of the present invention to provide a novel consumable electrode vacuum arc furnace.

It is another object of the present invention to provide a consumable electrode vacuum arc furnace wherein the head and ram are supported by the vacuum system.

It is another object of the present invention to provide a consumable electrode vacuum arc furnace wherein a single head is adapted to be alternatively used with two or more crucible units which are stationary with the head being rotatably supported and adapted for movement in an upright direction.

It is still another object of the present invention to provide a consumable electrode vacuum arc furnace wherein the vacuum system is not coupled directly to the crucible but rather through the head thereby eliminating the necessity for sliding joint vacuum seals.

It is another object of the present invention to provide a novel consumable electrode furnace structurally interrelated in a manner to facilitate ease of maintenance.

It is still another object of the present invention to

provide a means to facilitate ease of installation while providing for rigidity of support of the components of a consumable electrode arc furnace.

Other objects will appear hereinafter.

For the purpose of illustrating the invention, there is shown in the drawings a form which is presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

FIGURE 1 is a vertical sectional view of the furnace in accordance with the present invention.

FIGURE 2 is a top plan view of the furnace in accordance with the present invention.

FIGURE 3 is a perspective view of the spider ring support means for the crucible base.

FIGURE 4 is a sectional view taken along the lines 4—4 in FIGURE 1.

FIGURE 5 is a sectional view taken along the lines 5—5 in FIGURE 4.

FIGURE 6 is a sectional view taken along the lines 6—6 in FIGURE 1.

Referring to the drawing in detail, wherein like numerals indicate like elements, there is shown in FIGURE 1 a consumable electrode electric arc furnace designated generally as **8**. The furnace **8** includes a head adapted to be alternatively and sequentially used with a pair of crucible units **10** and **10'**. The units **10** and **10'** are identical. Accordingly, only the unit **10** will be described in detail.

The crucible units **10** and **10'** extend into a pit and are supported in depending relationship from a frame **12**. Frame **12** is a prefabricated unit with cut out holes to receive the crucible units and other elements of the furnace **8**. Frame **12** includes plates **13** and **15** supported by ledge **17** in the pit. The frame **12** facilitates ease of installation since it is the core of a prefabricated unit comprising other elements to be described hereinafter. An annular water jacket flange **16** having a water jacket **18** depending therefrom is supported by but is not secured to the frame **12**. A crucible flange **20** having a crucible **22** depending therefrom is supported by but not secured to the flange **16**. An O-ring seal is provided between the flanges **16** and **20**.

Water or other coolant medium is adapted to be circulated in the space **24** between the crucible **22** and the water jacket **18**. The crucible **22** is preferably made from copper and provided with a taper of approximately three-fourths of an inch from top to bottom to facilitate ingot stripping. The crucible **22** is provided with a copper base **34** which is spaced from and substantially parallel to the bottom plate **26** on the water jacket **18**. A housing **28** is secured to the bottom plate **26**. Water or other coolant medium is introduced through conduit **30** into the housing **28** and through sleeve **32** into the space **35** between the base **34** and plate **26**.

The lowermost end of the crucible **22** terminates in a stainless steel ring **36**. The base **34** is removably coupled to the ring **36** by bolts which extend through a spider ring **38**. The spider ring **38** is provided with spider arms **42**. Each spider arm **42** has a centrally disposed notch within which is disposed a spider hub **44**. The uppermost surface of the ring **38** and hub **44** are notched so as to provide for maximum circulation of water or other coolant adjacent the base **34**.

An electrode **46** is adapted to be remelted within the crucible **22**. The furnace of the present invention is adapted to receive electrodes having a diameter of up to thirty-six inches and a weight of up to 45,000 pounds. It will be noted that the diameter of the electrode **46** is smaller than the diameter of the crucible **22** so as to provide a vacuum gap as is well-known in the art. The elec-

trode 46 is preferably provided with a stub 48 which cooperates with a clamp 50 to suspend the electrode 46 within the crucible 22. For the purposes of the present invention, the clamp 50 may be any one of a wide variety of conventional clamps. Preferably, the clamp 50 is of the type disclosed in copending patent application Serial No. 253,220 filed on January 22, 1963 and entitled Electrode Stub Clamp.

The clamp 50 is connected to a water-cooled current-carrying ram 52 which is supported by a head 54. The head 54 includes a hollow water-cooled body 56 having a coolant chamber 58 in the walls thereof. The body 56 is provided with a radially outwardly directed flange 60 adapted to mate with the flange 20 in the lowermost position of the body 56 as will be made clear hereinafter. The head 54 also includes a cylinder 62. The cylinder 62 has a base 64 coupled to the body 56 with an electrical insulation material 66 disposed therebetween thereby electrically isolating the cylinder 62 from the body 56.

The ram 52 extends through a vacuum seal 68, through the cylinder 62, and extends thereabove. In passing through the cylinder 62, the ram 52 extends through guide seals 70 and 72.

The ram 52 is preferably a hollow cylinder having a chrome-plated outer peripheral surface. A piston 74 is fixedly secured to the outer peripheral surface of the ram 52 in any convenient manner such as by welding. The piston 74 is adapted to be reciprocated within the cylinder 62 by selectively introducing a fluid medium into the cylinder 62 by way of conduits 76 and 78.

A current-carrying copper pipe 79 is disposed within the ram 52 and spaced radially inwardly from the inner peripheral surface of ram 52. The uppermost end of ram 52 terminates in a head cap 80. One or more conduits 82, 84 extend through the head cap 80 and are coupled to the current-carrying copper pipe 79. Conduits 82 and 84 are water-cooled current carrying hose covered flexible cables which introduce both the cooling water and the current to the ram 52 and carry the cooling water away from the ram 52 in a series circuit. Coolant introduced down through the pipe 79 is removed from the space between the outer peripheral surface of the pipe 79 and the inner peripheral surface of the ram 52 as shown by the arrows in FIGURE 1. Preferably two such conduits are provided so that the conduits are sufficiently flexible to enable the ram 52 to receiprocate in an upright direction without interference.

The head 54 is supported for reciprocation toward and away from the crucible unit 10 and for rotation through an arc of approximately 120 degrees, as illustrated in FIGURE 2, by means of a conduit 86 which is the main element through which the crucible 22 is evacuated during melting. The conduit 86 includes a first conduit section 88 telescopically coupled to a second conduit section 90. Section 88 is provided with a radially outwardly directed flange 92 adapted to cooperate with a radially outwardly directed flange 94 on the upper end of conduit section 90 when flange 60 is mated with flange 20.

Flange 94 is preferably provided with an O-ring seal or the like on its upper surface. Conduit section 88 is guided for reciprocation with respect to conduit section 90 by one or more bronze bearings 96 which may be shrunk fitted in conduit section 90. There is no vacuum seal between the conduit sections 88 and 90 except for the seal provided when the flanges 92 and 94 are juxtaposed to and engaging one another. Hence, the telescopic arrangement between sections 88 and 90 is materially simplified since the necessity for having a rotary and/or sliding vacuum seal has been eliminated.

One end of piston rod 98 is coupled to conduit section 88. The other end of piston rod 98 is coupled to a piston (not shown) disposed within cylinder 100. The lowermost end of cylinder 100, as illustrated, is an element of dirt receptacle 102 which in turn is removably

coupled to the stationary conduit section 90 by bolts 103. Motive fluid may be conveniently introduced into the cylinder 100 by conventional flexible conduits extending through the receptacle 102 in a rigid vacuum tight manner. A conduit elbow 104 is coupled to conduit section 90 adjacent the lowermost end thereof to facilitate and cause the flow of removed vapors to make a 180 degree turn. Hence, elbow 104 is coupled to conduit section 106 which extends substantially parallel to conduit section 90.

The conduit section 106 may be provided above floor level with a selectively operable valve 108 of the supply and exhaust type. A vacuum pump or the like 110 is coupled to the conduit 106 to facilitate evacuation of the crucible 22 during melting.

As shown more clearly in FIGURES 1 and 6, a cylindrical sleeve 105 is supported at its lower end by the elbow 104. Sleeve 105 has a diameter which is less than the diameter of conduit section 88. Sleeve 105 is provided with longitudinally extending slots 107, 109 and 111 extending downwardly from the upper edge thereof and spaced approximately 60° apart. The conduit section 88 is provided with a radially inwardly directed projection 113 which is adapted to be disposed in one of the slots 107, 109 and 111 when the head 54 is in its lowermost position.

When the projection 113 is disposed within the slot 111, the head 54 is disposed over the crucible 10. When the projection 113 is disposed within the slot 109, the head 54 is disposed over the change station 112. When the projection 113 is disposed within the slot 107, the head 54 is disposed over the crucible unit 10'. If desired, slot 109 may be eliminated.

The upper end of the sleeve 105 is reinforced internally by a ring 115. When the head 54 is not disposed over the crucible units 10 or 10' or the change station 112, the upper end of the sleeve 105 will be in contact with the lower surface on the projection 113 thereby preventing descent of the head 54. This provides a precautionary feature to enable workmen to work on the head 54 with confidence that the same will not descend. The lowermost end of the sleeve 105 is provided with an opening 117 providing communication between elbow 104 and the interior of sleeve 105.

A motor means is provided to selectively rotate the head 54 and conduit section 88 relative to the crucible units when the head 54 is in its uppermost position so that projection 113 clears the upper end of sleeve 105. Such motor means includes a motor 120 supported by the plate 15 of the frame 12.

The motor 120 is provided with an output splined shaft 122 which extends upwardly through a hole in plate 13 of the frame 12. The upper end of the shaft 122 is provided with a bearing 124 which in turn is supported from the conduit 106 by a standard 126. A ball nut 128 surrounds the shaft 122 and is disposed for reciprocal movement therealong. The ball nut 128 includes a plurality of balls which partially extend into the splines on the splined shaft 122. While the ball nut 128 may reciprocate along shaft 122, the ball nut 128 will transmit any rotary motion imparted to the shaft 122 by the motor 120.

As shown more clearly in FIGURES 4 and 5, the ball nut 128 is provided with a top flange 130 and a bottom flange 132 and a pinion 134 between the flanges. The pinion 134 is in meshing engagement with the outer periphery of a gear 136.

The gear 136 is fixedly secured to the flange 92 on the conduit section 88. The top flange 130 is adapted to overlie the gear 136. The bottom flange 132 is adapted to be juxtaposed to the lowermost surface of the gear 136. Accordingly, the ball nut 128 will reciprocate with the gear 136 and yet be capable of rotatingly driving the gear 136 when desired.

The frame 12, conduit sections 88, 104, 106, cylinder

100, motor 120, shaft 122, etc. may be shipped as a prefabricated unit capable of being inserted into the pit. This feature enables the installation of a furnace to be accomplished more rapidly. Thereafter, the remaining components may be provided in the orientation illustrated by means of lift hooks or the like.

The operation of the furnace 8 is as follows:

With the head 54 disposed over the change station 112, an electrode 46 may be positioned within the water jacket 18 as illustrated by means of an overhead crane. By means of motor 120, the head 54 will be rotated to a disposition over the electrode. By introducing a motive fluid through conduit 76, the ram 52 may be caused to descend to a position wherein the clamp 50 will be coupled to the stub 48. Thereafter, motive fluid will be introduced into cylinder 62 through conduit 78 and removed through conduit 76 to facilitate raising of the ram and the electrode to the phantom position illustrated in FIGURE 1. Prior to raising the electrode, the electrode will have been centered with respect to the crucible so that proper orientation will be attained during the melting.

Thereafter, the motive fluid in cylinder 100 maintaining head 54 in its elevated position will be slowly removed thereby causing the head 54 to descend to a position wherein the flanges 60 and 20 will be juxtaposed to one another and in sealing contact. At the same time, the lowermost end of the electrode will be spaced from the base 34. Valve 108 may now be opened and the space between the electrode and the crucible evacuated by pump 110 by way of the body 56 and the conduit 86. When the desired controlled atmosphere is attained, electrical power may be coupled to the electrode by way of pipe 79, clamp 50 and stub 48 to strike an arc between the lowermost end of the electrode and the base 34.

By means not shown and conventional in the art, the arc gap may be sensed and the ram 52 caused to descend by introducing a motive fluid through conduit 76 as the electrode is consumed. Eventually the electrode will be consumed until only a short stub indicated by the dotted line at the upper end of the electrode in FIGURE 1 remains. This condition may be detected and signaled by any convenient means. The consumed electrode is permitted to remain within the crucible 22 for a sufficient period of time so as to permit cooling of the ingot until the molten pool at the top end of the ingot has fully solidified. As a general rule, the head 54 will remain sealed to the crucible until a chilled skin has formed on the surface of the molten pool. At this point, the power is shut off and valve 108 may be closed. Thereafter, the vacuum seal is broken and the head 54 is raised by means of cylinder 100 and piston rod 98 to a point where projection 113 clears the upper end of sleeve 105. Since the head moves relative to the molten pool, the molten pool will not be disturbed and the chilled skin will protect the pool from contamination. If the molten pool is disturbed before it is solidified, a substantial portion of the ingot may be wasted.

The head 54 is then rotated to a position so that the stub is above the change station 112. At the change station 112, the stub 48 is separated from the clamp 50. While the head 54 was supporting the electrode being melted in unit 10, a crane will have previously provided a new electrode and crucible in unit 10'. Hence, the head 54 may be rotated to a position over the new electrode in unit 10' and the above operation repeated. As soon as the previously formed ingot has solidified, it may be removed by a crane and a new crucible and electrode substituted therefor.

If it is desired that the controlled atmosphere within the crucible during melting be inert gas rather than vacuum, the inert gas may be introduced through conduit 86. Hence, the inert gas or other gas may be introduced into the furnace body by way of conduit 86 and removed therefrom by means of an exhaust valve on the body 56. To facilitate rapid equalization of pressure prior to raising the head 54, the body 56 may be provided with a manually operable exhaust valve 114. If desired, auxiliary tangential coolant inlets may be provided in water jacket 18 to increase the coolant velocity at the outer surface of the copper crucible 22. If desired, the support provided by ring 38, spider arms 42 and hub 44 may be eliminated if the base 34 is dish-shaped.

In order to provide for ease of maintenance, the pit is of sufficient depth so as to enable the cylinder 100 to be maintained. In order to accomplish this, the bolts 103 will be removed. With the head 54 in its lowermost position, motive fluid will be supplied to the cylinder 100 in an attempt to raise the head. Since the lowermost end of the cylinder is no longer coupled to the elbow 104, the cylinder 100 and receptacle 102 will descend. Thereafter, any dirt or contaminant in receptacle 102 may be removed and the necessary maintenance operation is performed.

The frame 12 will be provided with the necessary lifting eyes or the like to facilitate manipulation by a crane. Also, a convenient entryway will be provided to facilitate the entry of a person into the pit for maintenance purposes and the like. Suitable bracing should be provided between the plates 13 and 15 of the frame 12 so that resistance to dead-load and turning forces may be compensated for. For added strength and support, it will be noted that the bearing 96 lies in the plane of the plates 13 and 15 of the frame 12. It will be obvious to those skilled in the art that the head 54 should only be rotated when it is in its uppermost position.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. In an electric arc melting furnace comprising a head having an electrically conductive water-cooled ram, a crucible disposed below the horizontal plane containing said head, said crucible being adapted to cooperate with said head to define a chamber within which an electrode may be melted under controlled atmospheric conditions, a hollow conduit communicating with said chamber through said head, means coupled to said conduit for controlling the atmosphere of said chamber by way of said conduit, said head being supported by said conduit, and means for raising and lowering said head with respect to said crucible, and motor means to rotate the head and a section of the conduit connected thereto about an upright axis substantially coinciding with a major portion of said conduit.

2. In an electric arc melting furnace comprising a head having an electrically conductive water-cooled ram, a crucible disposed below the horizontal plane containing said head, said crucible being adapted to cooperate with said head to define a chamber within which an electrode may be melted under controlled atmospheric conditions, a hollow conduit communicating with said chamber through said head, means coupled to said conduit for controlling the atmosphere of said chamber by way of said conduit, said head being supported by said conduit, means for raising and lowering said head with respect to said crucible, and said last-mentioned means being disposed within a portion of said conduit.

3. In a furnace in accordance with claim 1 wherein said conduit has first and second telescoping sections, one of said sections being stationary, the other of said sections being coupled to said head.

4. In a furnace in accordance with claim 1 wherein said head includes hydraulic means for selectively reciprocating said ram in an upright direction with respect to said head.

5. In a furnace in accordance with claim 1 including a vacuum pump coupled to said conduit for selectively

controlling the pressure within said chamber when said head is sealingly coupled to said crucible.

6. In an electric arc furnace wherein an electrode is adapted to be remelted within a crucible under reduced atmospheric pressure conditions effected by a vacuum pump coupled to a chamber formed by the crucible and a head, wherein a means is provided to raise and lower the head and rotate the head with respect to the crucible, and wherein the head is adapted to support the electrode during melting, the improvement comprising a conduit coupling the vacuum pump to the chamber, said conduit including first and second telescopic sections, and said head being supported by and coupled to said first section of said conduit and motor means to rotate the head and said first conduit section about a vertical axis substantially coinciding with a major portion of the longitudinal axis of said second conduit section.

7. A consumable electrode electric arc furnace comprising first and second crucible units, a head adapted to cooperate with said units selectively to define a chamber within which an electrode may be remelted, said head including a ram adapted to support the electrode during melting, said head being hollow, a hollow upright conduit supporting said head and in communication with the interior of said head, means coupled to said conduit for evacuating the chamber through said conduit, and means for rotating said head about an axis coincident with said conduit so that said head may selectively cooperate with each of said crucible units.

8. In a furnace in accordance with claim 7 wherein said conduit includes telescoping sections, one of said sections being coupled to said head, and means coupled to said one section for raising and lowering said one section with respect to the other section.

9. In a consumable electrode electric arc melting furnace comprising a head having an electrically conductive water cooled ram, a hollow conduit means supporting said head for rotation about the longitudinal axis of a portion of the conduit means, means for reciprocating the head in a direction substantially parallel to the longitudinal axis of the portion of the conduit means, motor means to rotate the head and a portion of said conduit means about a vertical axis corresponding to a longitudinal axis of a portion of the conduit means, and means for evacuating the conduit means and the head.

10. In a furnace comprising a hollow open top receptacle, a hollow head above said receptacle, cooperating elements on said head and receptacle defining a vacuum seal therebetween when said head is juxtaposed to the open end of said receptacle, a hollow conduit supporting said head and communicating with the interior of said head through which the chamber defined by said head and receptacle may be evacuated, and means coupled to said head for moving said head toward and away from said open end of said receptacle, and means for rotating said head and at least a portion of said conduit with respect to said receptacle about an upright axis corresponding to a longitudinal axis of said conduit.

11. In a furnace in accordance with claim 10 wherein said means includes a power cylinder at a right angle bend of said conduit, said cylinder having a base forming a part of said conduit at said right angle bend, said cylinder and base being reciprocal as a unit to a position below said right angle bend to facilitate maintenance and cleaning of said conduit and said cylinder.

12. In a furnace in accordance with claim 10 including a floor having a pit, a support frame in said pit, said frame having a first hole through which a portion of said conduit extends and a second hole through which a portion of said receptacle extends, the longitudinal axes of said conduit and receptacle portions being substantially parallel.

13. A furnace in accordance with claim 10 wherein means are provided to prevent descent of the head except in predetermined rotary dispositions of said head with respect to said conduit.

14. In a furnace in accordance with claim 13 including a motor means for selectively rotating said head with respect to a portion of said conduit only when said head is adjacent its uppermost position.

15. In a furnace comprising a hollow open top receptacle, a hollow head above said receptacle, cooperating elements on said head and receptacle defining a vacuum seal therebetween when said head is juxtaposed to the open end of said receptacle, a hollow conduit supporting said head and communicating with the interior of said head through which the chamber defined by said head and receptacle may be evacuated, and means coupled to said head for moving said head toward and away from said open end of said receptacle, said means including the provision of a seal associated with said conduit, which seal functions as a vacuum seal only when said vacuum seal is effected between said head and said receptacle, and motor means to rotate the head and a section of the conduit connected thereto about an upright axis substantially coinciding with a major portion of said conduit.

16. A furnace comprising a floor having a pit, a prefabricated support frame in said pit, a hollow open top receptacle, a hollow head above said receptacle, cooperating elements on said head and receptacle defining a vacuum seal therebetween when said head is juxtaposed to the open end of said receptacle, a hollow conduit communicating with the interior of said head through which the chamber defined by said head and receptacle may be evacuated, means coupled to said head for moving said head toward and away from said open end of said receptacle and for rotating said head about an axis disposed to one side of said receptacle, said frame having aperture means through which a portion of said receptacle extends, said frame having separate aperture means through which a portion of said conduit extends, the longitudinal axes of said conduit and receptacle portions being substantially parallel to one another, said receptacle and conduit extending into said pit below said frame, and said conduit having a right angle bend within said pit, said right angle bend being accessible for maintenance, and said pit being sufficiently large so as to enable the right angle bend to be maintained.

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RICHARD M. WOOD, *Primary Examiner.*