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Valchev et al.

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[45] **Sept. 10, 1974**

[54] **D.C. ARC FURNACE FOR STEELMAKING**

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[21] Appl. No.: **384,575**

[30] **Foreign Application Priority Data**

Aug. 29, 1972 Bulgaria 20391

[52] **U.S. Cl.** **13/9**
[51] **Int. Cl.** **H05b 7/00**
[58] **Field of Search** 13/9, 12, 13, 34

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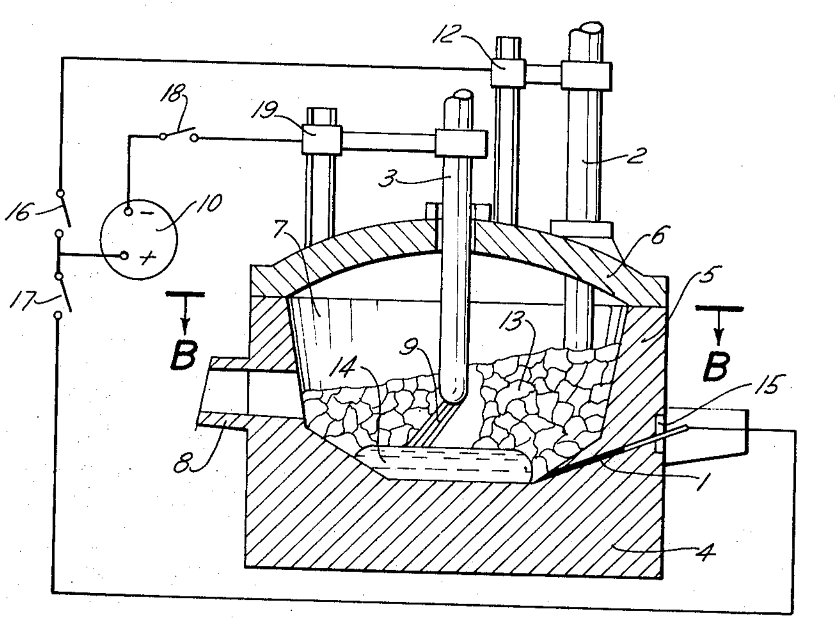
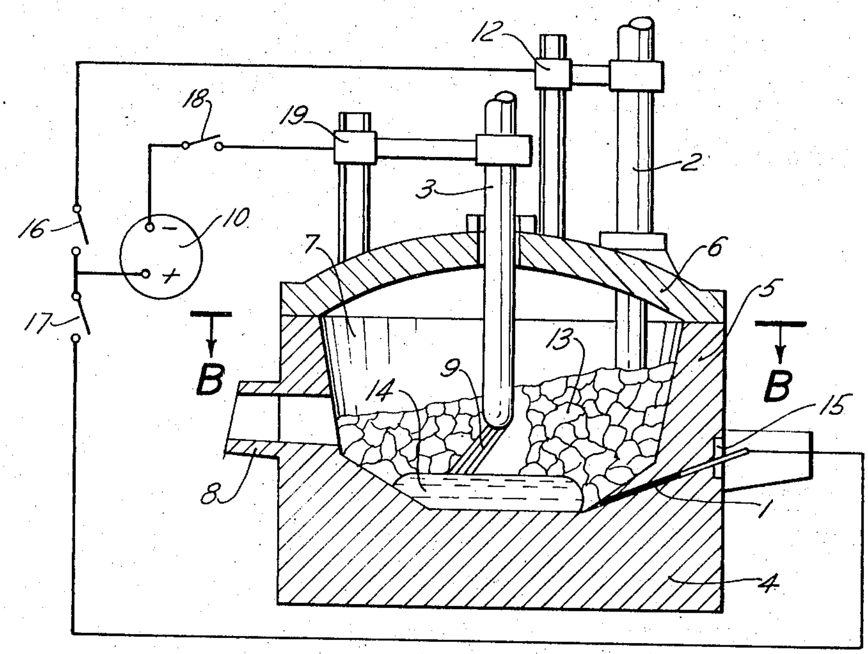
Primary Examiner—Roy N. Envall, Jr.
Attorney, Agent, or Firm—Karl F. Ross; Herbert Dubno

[57] **ABSTRACT**

A system for producing steel comprises a d-c arc furnace having at least one water-cooled anode connectable to the d-c source and effective after melting has progressed to generate an arc between the melt and a cathode juxtaposed therewith. A melting anode is connectable to the d-c source initially and is pressed against the mass to be melted for the initial melting and is movable to follow the decrease in level of this mass as the melting progresses. Switches disconnect the melting anode and connect the process anode to the source.

8 Claims, 12 Drawing Figures

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19
18
3
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7
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13
B
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9
14
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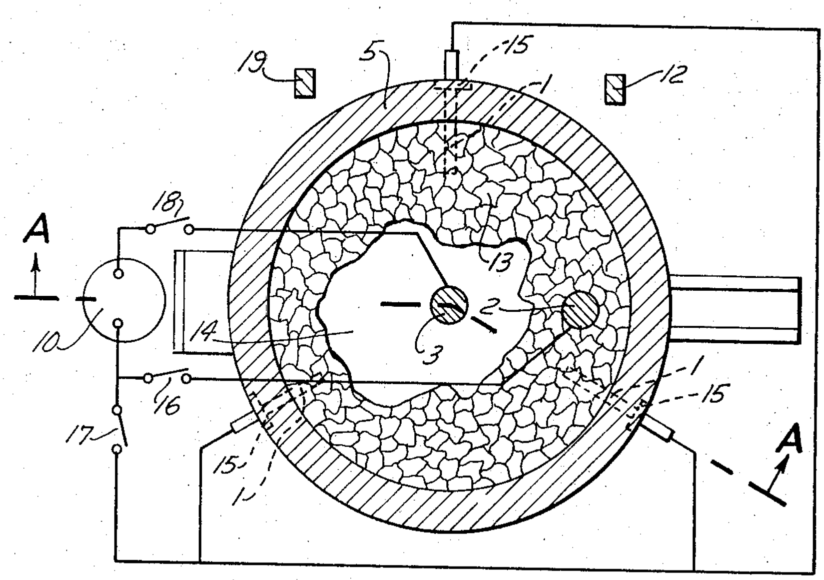
4

FIG. 1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A

FIG. 2

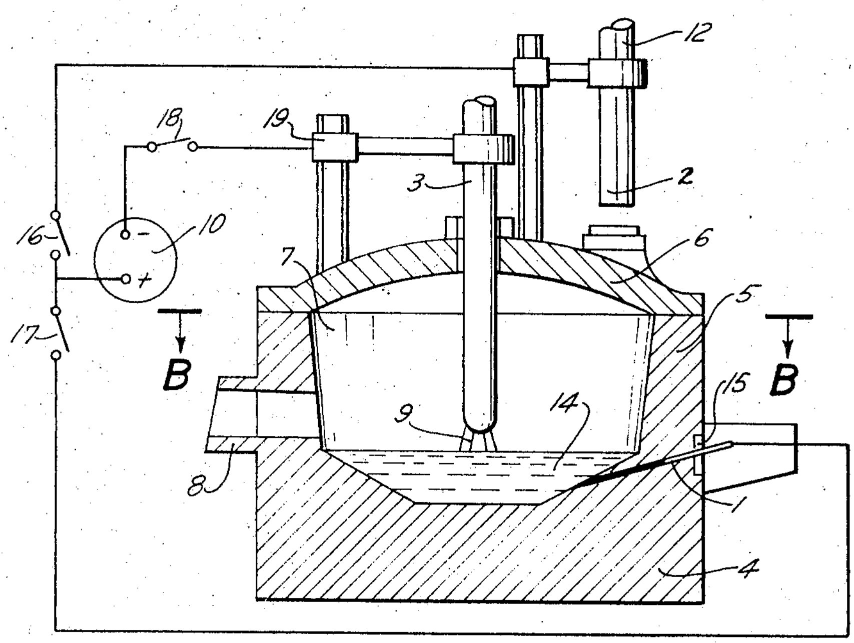
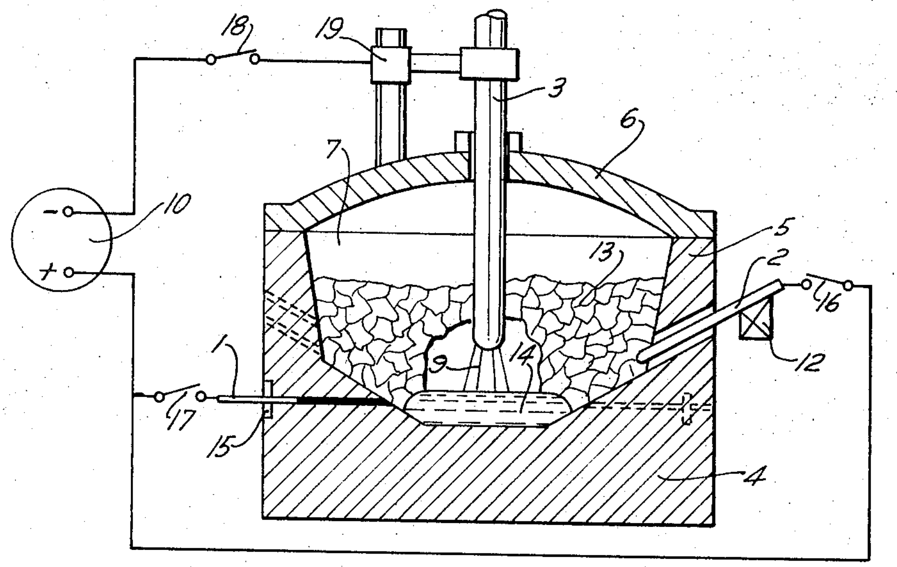


FIG. 3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10
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13
2
16
12
9
14
1
17
15
4

FIG. 4

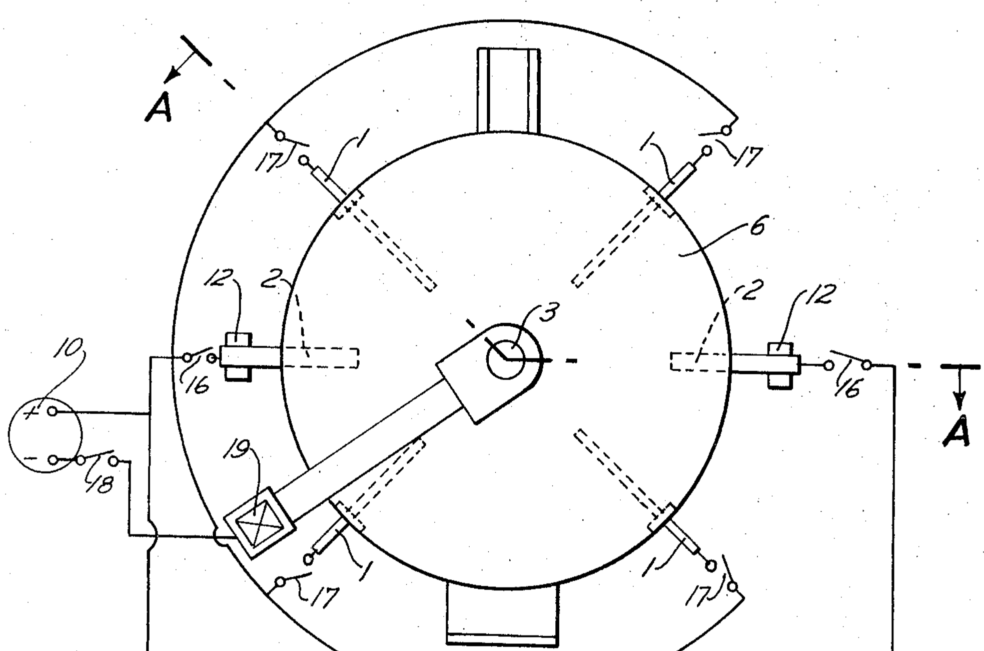

A
17
1
1
17
6
12
2
2
12
3
10
16
16
A
18
19
1
1
17
17

FIG. 5

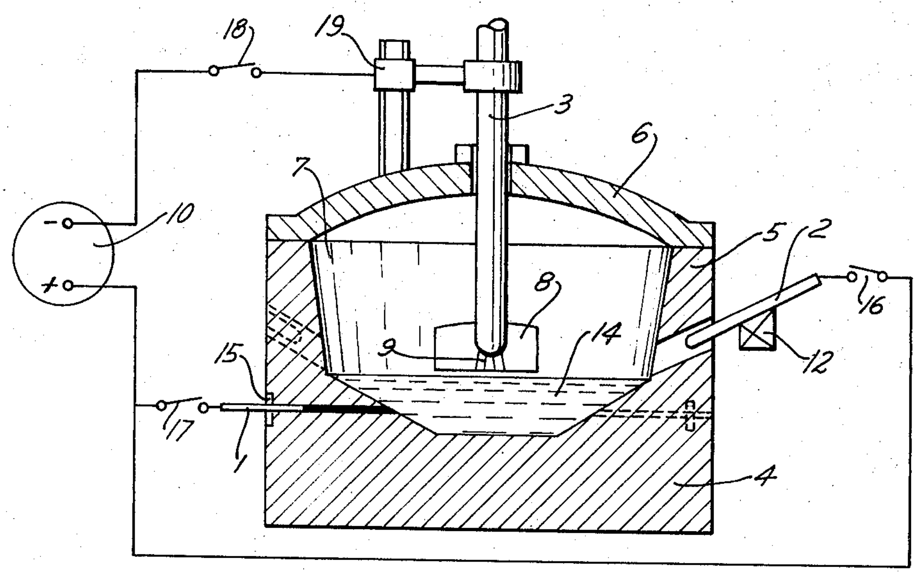


FIG. 6

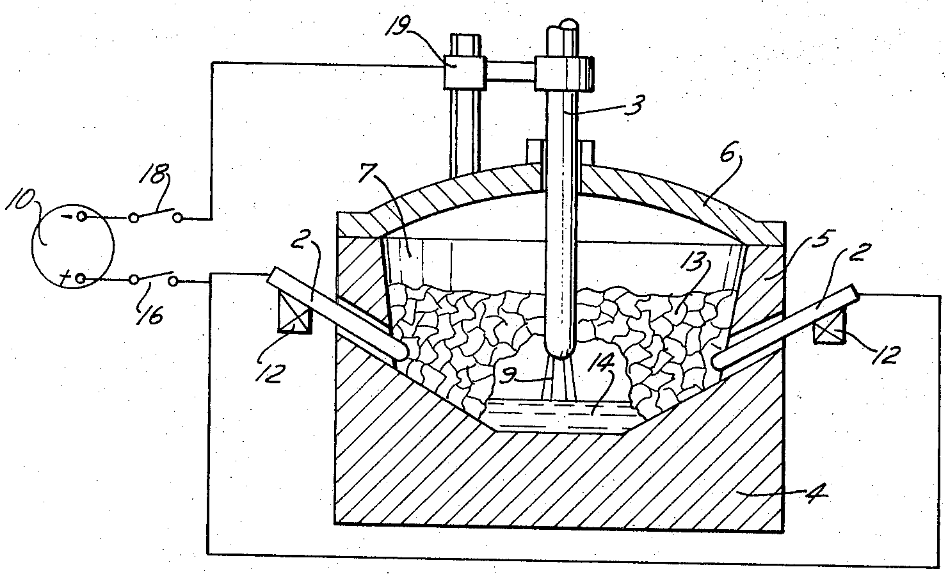


FIG. 7

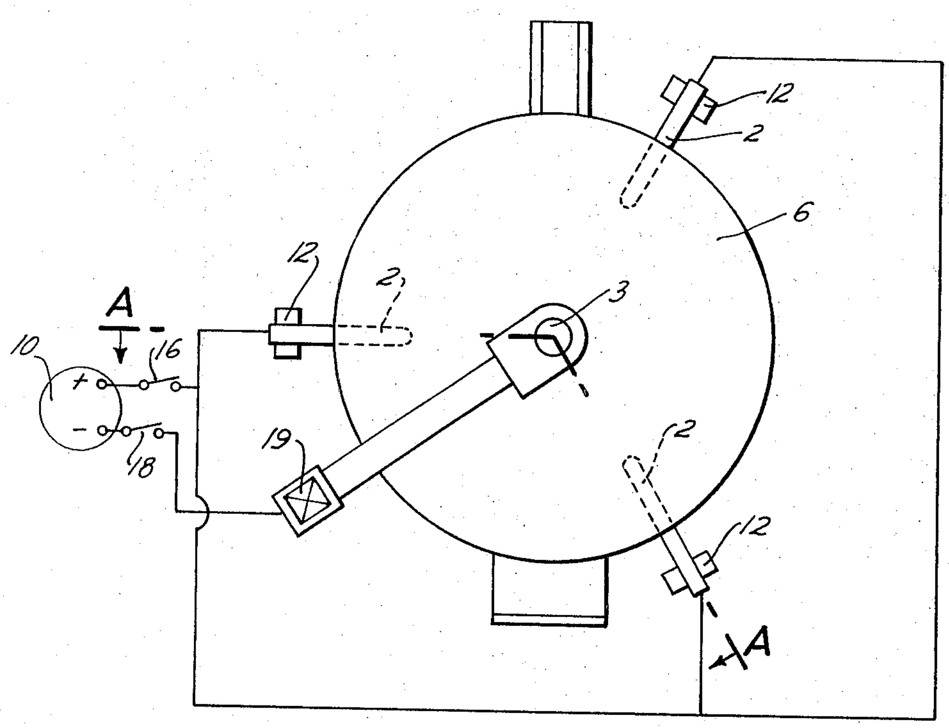


FIG. 8

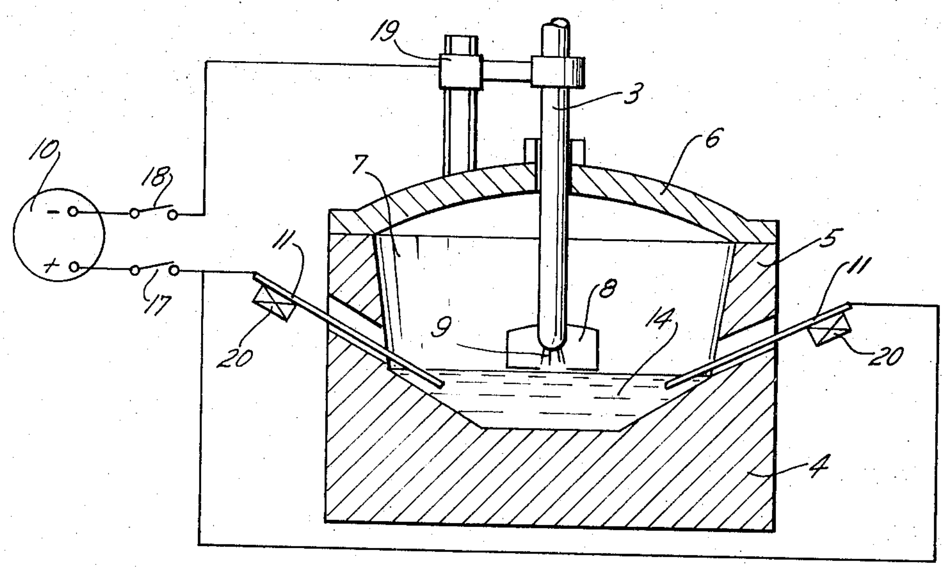


FIG. 9

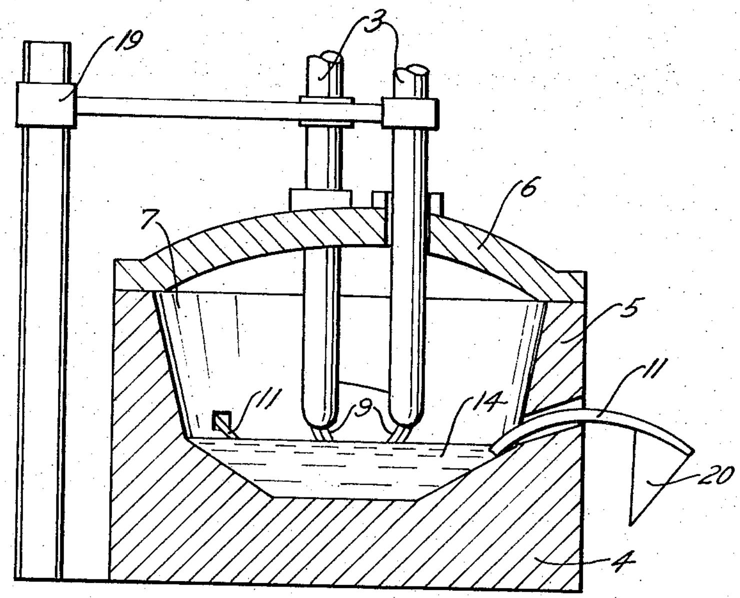


FIG. 10

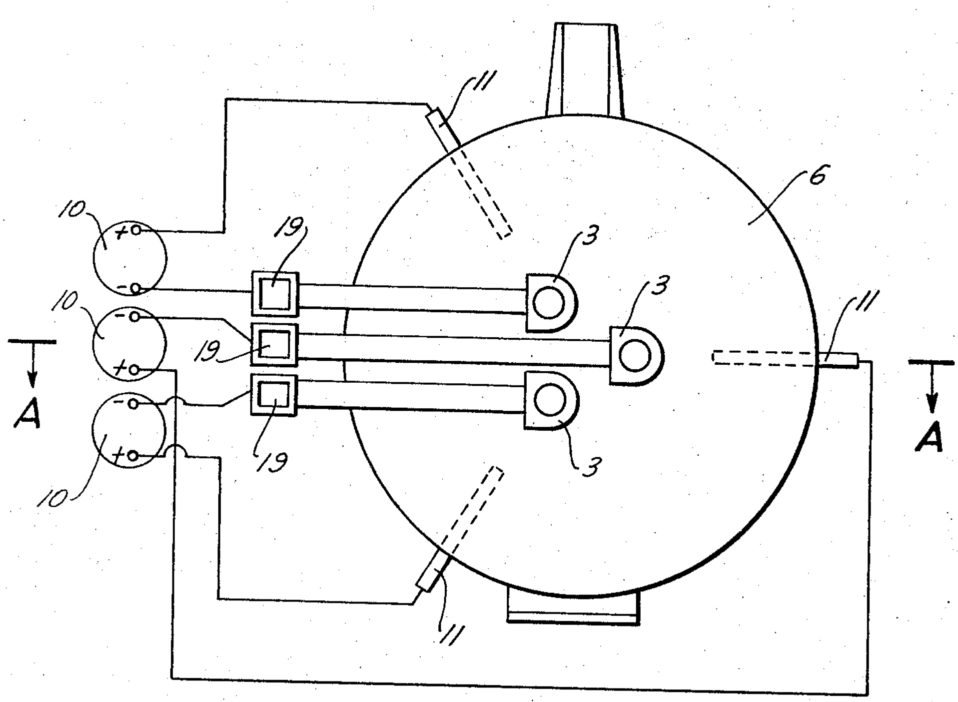
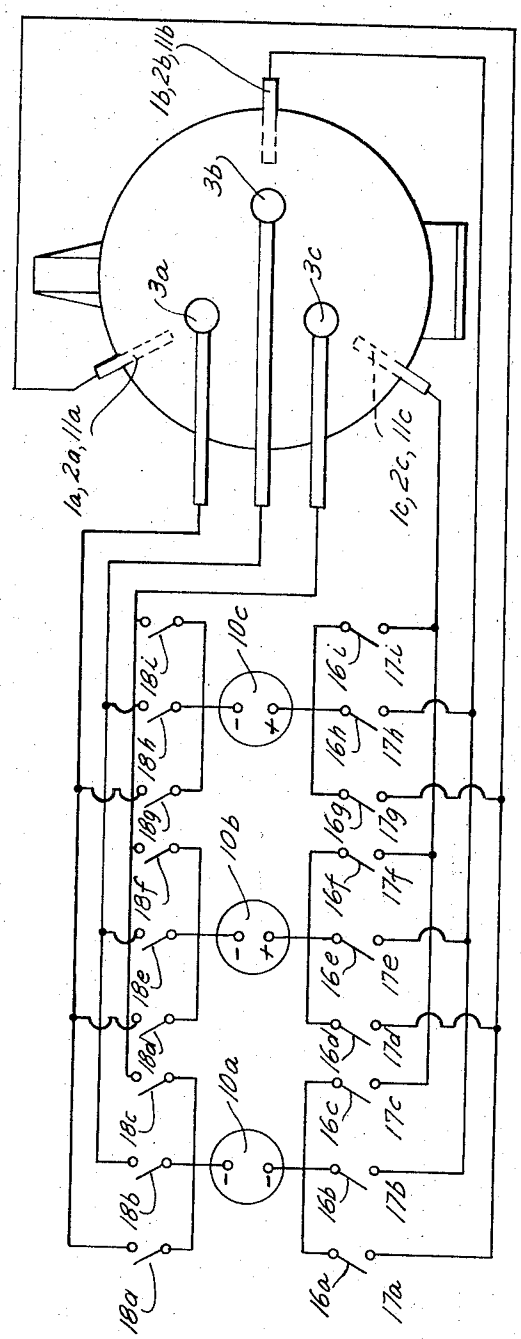


FIG. 11


1b,2b,11b
3b
3a
3c
1a,2a,11a
1c,2c,11c
10c
10b
10a
18a
18b
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18d
18e
18f
18g
18h
18i
16a
16b
16c
16d
16e
16f
16g
16h
16i
17a
17b
17c
17d
17e
17f
17g
17h
17i

FIG. 12

D.C. ARC FURNACE FOR STEELMAKING

FIELD OF THE INVENTION

This invention relates to a method of and a DC arc furnace for steelmaking.

BACKGROUND OF THE INVENTION

A method of making steel with three-phase electric current is known in which the electric arcs burn between the carbon electrodes and ferrous materials, i.e., melted steel. During melting the voltage and the current vary within a given range, but the whole process of steelmaking from the beginning of the melting till the end of the refining takes place without changes in the way the current is supplied to the furnace. This method has been applied in the three-phase arc furnace of Heroult, where three carbon electrodes are connected with the respective electric phases.

There is yet another method of steelmaking with two- or three-phase current, where the electric arc burns between carbon electrodes, and the iron materials, i.e., the molten steel, are excluded from the electric circuit. The Stassano furnace is based on this method, the current being supplied across two or three carbon electrodes. This furnace has limited application, mainly for casting nonferrous metals.

There exists a method, according to which the current is brought in through the bottom of the furnace directly to the iron materials, i.e., the molten steel, the latter being included in the electric circuit. A disadvantage of this method is the fact that it has unsatisfactory operation reliability. Arc furnaces based on this method have been tried, but have not found any industrial application.

It is a well known fact that from the point of view of electro-thermics the DC electric arc has considerable advantages over an alternating current arc. With the latter, the same quantities of heat are liberated at the two poles, while with the DC electric arc the heat liberated at the anode is several times greater than the heat liberated at the cathode. Moreover, a DC electric arc is more stable than an AC arc.

In spite of this advantage, however, nowadays electric steel is not produced in DC furnaces as the conventional physical arrangement of an AC electric arc furnaces doesn't provide any advantage when DC is substituted. Another important shortcoming is the fact that in today's high-power and ultrahigh-power furnaces the connection of the DC source with the iron material, i.e., the molten steel, cannot be accomplished by the method by which the current is directly connected through the furnace bottom with the iron materials, which are included in the electric circuit. In the present specification the term "iron materials" covers all metal materials which are fed into the arc furnaces, such as steel scrap (incl. high-alloy scrap), sponge iron, metallized pellets, ferrous alloys, alloying metals, etc.

OBJECT OF THE INVENTION

The object of this invention is to provide a new method of steelmaking with direct current, where the advantages of the DC arc will be used, as well as a DC arc furnace for steelmaking, where the positive pole of the DC electric source is stably brought to the iron materials during the melting and to the melted steel during the metallurgical processes (oxidation, alloying, refining, etc.), the operation of that furnace being reliable and causing no difficulties in operation.

This object is achieved, according to the method of steelmaking with direct current, the electric arcs being ignited (burned) by means of one or more movable carbon cathodes, connected with the negative poles of the DC source throughout the whole heat, and one or more movable melting anodes, connected with the positive poles of the DC source and closely pressed to the solid iron materials. The burning takes place between the movable carbon cathodes and the iron materials, and later on between the cathodes and the molten steel. After the bottom of the furnace is covered with molten steel the positive poles of the DC source are connected with one or more metallic water-cooled process anodes, which are in contact with the melted steel in such a way, that till the end of the heat the arcs burn only between the movable carbon cathodes and the melted steel.

The term "carbon cathodes" stands for carbon electrodes that carry the current into the furnace space, which are connected with the negative poles of the DC sources.

The term "movable melting anodes" identifies movable electrodes which, during the melting, are connected with the positive poles of the DC sources, which maintain constant electric contact with the iron materials.

The metallic water-cooled electrodes, which are connected with the positive poles of the DC sources during the metallurgical processes (oxidation, alloying, refining, etc.) and maintain constant electric contact with the molten steel, are called "metallic water-cooled process anodes."

The arc furnace to carry out the method of this invention consists of a bottom, walls and a roof. One or more movable carbon cathodes, each fitted with a moving device, are inserted in holes in the roof. The cathodes are connected by means of switches with the negative poles of the DC sources.

In holes situated above the furnace door sole, one or more movable melting anodes are inserted into the furnace space, which are fitted with a device to press them against the iron materials. These anodes are connected by means of switches with the positive poles of the DC sources.

In respect of material and design, the melting anodes can be made in conventional ways (carbon electrodes, metallic water-cooled electrodes, or metallic water-cooled electrodes with suitable electroconductive caps).

The furnace is equipped with metallic water-cooled process anodes to contact the molten steel, which are connected with the positive poles of the DC sources. The metallic water-cooled process anodes are immovable and are built into the walls in such manner that their front part is below the level of the door sole and their water-cooled part is inside the walls.

It is worthwhile to use an arc furnace, the metallic water-cooled process anodes of which are movable. They are inserted into the furnace space through holes situated above the door sole and are fitted with an operating mechanism to make them move forth until their front part reaches a level below the door sole. They can be moved back at least till their front part is hidden in the openings in the furnace walls.

The movable melting anodes and the metallic water-cooled process anodes are electrically insulated from the furnace shell or are in parallel therewith and thus are connected with the furnace shell. The movable carbon cathodes, as well as the movable melting anodes made of carbon material have a protective coating to prevent oxidation of their side surface.

A considerable advantage of the method of this invention is the substantial reduction of electrode consumption, the consumption of carbon material at the cathode being considerably smaller than that of an electrode in the AC arc and many times smaller than that at the anode. Moreover, as a result of the generation of the greater part of the heat in the molten steel, the temperatures of the walls and of the roof can be much lower than that of the metal, which makes their endurance longer and cuts down the covering materials investments. The more beneficial distribution of heat in the DC arc compensates for the electric losses in the rectifiers and saves electric power.

In the DC arc furnace the electromagnetic asymmetry of the system, available in the three-phase AC Heroult furnaces, are avoided. In the arc furnaces, based on the method of the present invention, one cathode gives completely symmetrical heat (thermal) loading of the walls. An important advantage of this invention is the fact that the electrical regime of the DC arc is much steadier than that of the AC arc, the burning of the DC arc being accompanied by considerably less noise, which is within acceptable limits.

BRIEF DESCRIPTION OF THE DRAWING

The furnace, according to the invention, is illustrated in the accompanying drawing. In the drawing:

FIG. **1** is a vertical cross-sectional view along the line A—A of an arc furnace with one movable melting anode, inserted into the furnace space through the furnace roof during the melting of iron materials;

FIG. **2** is a horizontal cross-sectional view along the line B—B of the arc furnace in FIG. **1**;

FIG. **3** is a vertical cross-sectional view along the line A—A of the furnace in FIG. **1** after melting of the iron materials during the metallurgical processes;

FIG. **4** is a vertical cross-sectional view along the line A—A of an arc furnace with two movable melting anodes, inserted in the furnace space through openings situated in the furnace walls and four metallic water-cooled process anodes built horizontally into in the furnace wall;

FIG. **5** is a top view of the furnace of FIG. **4** during the melting;

FIG. **6** is a vertical cross-sectional view along the line A—A of the furnace in FIG. **4** during the metallurgical processes;

FIG. **7** is a cross-sectional view along the line A—A of an arc furnace with three movable melting anodes and three metallic water-cooled process anodes;

FIG. **8** is a top view of the furnace in FIG. **7**;

FIG. **9** is a cross-sectional view along the line A—A of the furnace in FIG. **7** during the metallurgical processes;

FIG. **10** shows an arc furnace with three movable carbon cathodes inserted through the furnace roof and three movable metallic water-cooled process anodes during the metallurgical processes;

FIG. **11** is a top view of the furnace in FIG. **10**; and

FIG. **12** shows a circuit of connecting the cathodes and anodes to the DC sources.

SPECIFIC DESCRIPTION

The DC arc furnace for steelmaking, shown in FIG. **1**, has one movable carbon cathode **3**, inserted in the furnace space **7** through the roof **6**. By means of an actuating mechanism **19**, the movable carbon cathode can be moved up- and downwards. Into the furnace space **7**, through the roof **6** is inserted one melting anode **2**, too, which is connected with device **12** to move it up- and downwards, as well as to press it to the iron materials **13** with a constant force. Into the walls **5** water-cooled process anodes **1** are built, situated at an angle, so that their front part is at a level below the door sole **8** and above the bottom **4** of the furnace. The outer part of the process anodes **1**, situated in the walls **5** of the furnace, is water-cooled. Besides, at the entrance of the process anodes **1** into the furnace body water-cooled jackets **15** are installed.

The negative pole of the DC source **10** is connected through switch **18** with the movable carbon cathode **3**, and the positive pole of the DC source can be connected through switch **16** with the movable melting anode **2** and through switch **17** with the three water-cooled metallic process anodes; the latter are situated at an angle of 120° one to the other (FIG. **2**).

The method of this invention is performed in the following manner. The furnace is charged with iron materials **13**. The switches **16** and **18** are turned on, switch **17** remains turned off. The melting anode **2** is moved downwards by means of an actuating mechanism **12** and is pressed with a constant force against the iron materials **13**. Then begins the downward movement of the carbon electrode **3** until it reaches the iron materials **13** and an electric arc **9** is ignited. Roughly, the melting is carried out in the conventional way — the movable carbon cathode **3** forms a hole in the iron materials **13** and comes near the furnace bottom **4**. In the meantime melted steel **14** has been formed below it. As the melting proceeds, the quantity of melted steel **14** increases at the same time the iron materials **13** gradually get lower and lower. By means of the actuating mechanism **12** the movable melting anode **2** follows the lowering of the iron materials **13** and is constantly in an effective electric contact with them. A burning of long duration of the arc at the melting anode **2** is not at all admissible. Under the action of the "electromagnetic wind" the arc is curved to the opposite direction of the place of contact of the melting anode. As can be seen from FIG. **1** and FIG. **2**, more iron materials **13** are melted at the door and less at the melting anode **2**.

Depending on the particular conditions, the furnace can be loaded (charged) with iron materials **13** one, two or more times.

The melting is performed in described manner until there is enough melted steel **14** in the furnace, so that its level is higher than the contacting front part of the process anodes **1**. Then the electric connection between the positive pole of the DC source **10** and the melting anode **2** breaks up and by means of actuating mechanism **12** the melting anode **2** is lifted above the furnace roof **6**, the holes in the roof being closed in an appropriate way (FIG. **3**).

By means of switch **17** the positive pole of the DC source **90** is connected with the three process anodes **1**, which are in parallel. Due to the symmetrical disposition of the process anodes **1**, the ignited arc **9** is now burning perpendicularly to the melted steel **14**, whereupon the heat loading of the walls **5** is uniform.

The required metallurgical processes being performed and having attained the desired chemical composition and the necessary temperature of the steel **14**, the current is switched off and the steel **14** is tapped.

The furnace in FIG. **4** has two movable melting anodes **2**, which are inserted into the furnace space **7** through openings situated in the walls at a level higher than the door sole. The melting anodes **2** are outfitted with an actuating mechanism **12** to move them inwardly and outwardly, as well as to press them with a constant force against the iron materials **13**. The furnace has four metallic water-cooled process anodes **1**, which are horizontally built into the furnace walls **5**.

The two melting anodes **2** are situated symmetrically at an angle of 180° and are at the same time inclined (see FIG. **5**). As shown in FIG. **6** the anodes are situated at a level, higher than the door sole **8**. The process anodes are situated symmetrically at an angle of 90° one to the other. Each melting anode **2** can be connected with the positive pole of the DC source **10** by means of a separate switch **16**, and each process anode **1** — by means of a separate switch **17**.

The system operates in a manner similar to that described above. During the melting the movable carbon cathode **8** and the two movable melting anodes **2** are connected with the DC source. At this stage the four process anodes **1** shouldn't be connected with the DC source. Towards the end of the melting the current in the melting anodes **2** is turned off by means of the switches **16**, the melting anodes **2** are lifted up at least until they are hidden in the furnace wall **5**. Then the four process anodes **1** are connected with the positive pole of the DC source **10** by means of the switches **17**, after which the metallurgical processes are performed.

All anodes (melting anodes **2** and process anodes **1**) have their own separate switches **16** and **17**, which makes it possible, by switching on and off of particular anodes, to direct the electric arc **9** in the desired direction. This direction is contrary to the connection of the positive pole of the DC source **10** with the iron materials **13** or the melted steel **14**.

The furnace shown in FIG. **7** has one movable carbon cathode **3**, three movable melting anodes **2**, fitted with actuating mechanisms **12** and three metallic water-cooled process anodes **11**, fitted with actuating mechanisms **20**. The melting anodes **2** and the process anodes **11** are situated into the furnace space **7** through one and the same openings. These three openings are situated in the furnace walls **5** at a level higher than the door sole **8**.

FIGS. **7** and **8** show the connection of the melting anodes **2** with the positive pole of the DC source **10** by means of switch **16**. In the same Figures the process anodes **11** and the switch **17** are not shown.

Towards the end of the melting the current is turned off, the melting anodes **2** are driven out of the furnace shell; through the same openings the three movable metallic water-cooled process anodes **11** are inserted into the furnace space **7** by means of actuating mechanism **20** to such an extent, that their front end **15** is below the level of the door sole **8** and they are sufficiently immersed into the melted steel **14**. Then the process anodes **11** are connected with the DC source **10** by means of switch **17** after which the metallurgical processes are performed.

In FIG. **9** the melting anodes **2** and the switch **16** are not shown.

The furnace shown in FIG. **10** has three movable carbon cathodes **3**, which are inserted into the furnace space **7** through three holes in the roof **6**. In the furnace walls there are three openings at a level higher than that of the door sole **8**, through which the movable melting anodes **2** and the movable water-cooled process anodes **11** are inserted in succession. The DC sources **10** are used, each of them supplying one carbon cathode **3** and one melting anode **2** until melted steel is produced, after which they are connected with a process anode **11** each as well.

FIG. **11** shows the connection of cathodes **3** and anodes **11**. Cathode **3** and anode **11**, which are supplied by one and the same DC source **10**, are situated one opposite the other. In this case the electric arcs **9** curve to the center of the furnace, as shown in FIG. **10**.

The melting is performed as with the furnace in FIG. **7**.

FIG. **12** shows a circuit for connecting the cathodes and the anodes. The furnace has three movable carbon cathodes **3**, three melting anodes **2** and three process anodes **1**, **11**. In the Figure anodes **1**, **2** and **11** are used singly and the three types of anodes are not used simultaneously.

It is evident from FIG. **12** that every negative pole of the DC sources **10** can be connected with every one or several of the cathodes. The same applies to the positive poles of the DC source **10** and to the anodes **1**, **2**, **11** as well.

As the diagram shows, there are several possibilities for directing one or more electric arc **10** in the required direction. With the conventional DC sources, which have a dropping voltage-amperage characteristics, to connect more cathodes to one DC source is not worthwhile as one DC source of this type cannot keep more than one arc burning. This doesn't apply to the anodes where every combination of their inclusion in circuit is acceptable.

With some DC sources (those with constant characteristics, for example) it is possible to connect the negative pole of a DC source to one, two or more cathodes. In order to perform the melting, the switches **18*a***, **18*e***, **18*i*** and the switches **16*a***, **16*b***, . . . **16*i*** are turned on. The electric arcs at all cathodes (**3*a***, **3*b***, **3*c***) are directed vertically. After the iron materials in the centre of the furnace have been melted, switches **16*a***, **16*c***, **16*e***, **16*f***, **16*g*** and **16*h*** are turned off. Then the electric arcs are directed towards the furnace walls so that melting is intensified in those areas.

At the end of the melting, switches **16*b***, **16*d*** and **16*g*** are turned off the melting anodes **2*a***, **2*b***, **2*c*** are drawn out of the furnace, the process anodes **11*a***, **11*b***, **11*c*** being immersed in the molten steel. Switches **17*a***, **17*e***, **17*i*** are turned on and the arcs are directed towards the centre of the furnace. In this way burning of the walls during the metallurgical processes is prevented.

What we claim is:

1. An apparatus for making steel by an arc process, comprising:
   a furnace having a hearth and a substantially closed top provided with at least one opening;

a carbon cathode extending through said opening and provided with means enabling displacement of said carbon cathode relative to said hearth;

a water-cooled process anode received in said furnace at a level above the bottom of said hearth and adapted to contact a melt of steel upon the formation thereof;

at least one melting anode movably extending into said furnace and provided with means for pressing said melting anode against a mass of ferrous material in said furnace on said hearth and enabling said melting anode to follow the decrease in level of said material upon the smelting thereof;

a direct-current source having a negative terminal connected to said cathode;

first switch means between the positive terminal of said source and said melting anode for initially connecting said melting anode with said source whereby electric current flows through said material between said cathode and said melting anode to smelt said material and form a pool of molten steel on said hearth; and

second switch means between said positive terminal and said process anode and operable alternately with said first switch means for connecting said process anode to said source to enable an electric current to pass through the pool of molten steel between said process anode and said cathode.

2. The apparatus defined in claim **1** wherein said furnace has a door with a sill and said process electrode is built into a wall of said furnace at a location below said sill and is fixed in said wall.

3. The apparatus defined in claim **1** wherein said process anode has a water-cooled portion received in a wall of said furnace.

4. The apparatus defined in claim **1** wherein said furnace has a door with a sill, said process anode being movably mounted in a wall of said furnace and having a lower end disposed below said sill in a fully inserted position of said process anode.

5. The apparatus defined in claim **1** wherein said furnace has a shell, further comprising means for electrically insulating said anodes from said shell.

6. The apparatus defined in claim **1** wherein said furnace has a shell and said anodes are connected in parallel and are electrically connected with said shell.

7. The apparatus defined in claim **1** wherein said cathode has a protective coating preventing oxidation of its flanks.

8. The apparatus defined in claim **1** wherein said melting anode is composed of carbon and has a protective coating along its flanks.

* * * * *