Feb. 15, 1966 L. PÉRAS 3,234,608

CONTINUOUS-CASTING METHOD OF MELTING METALS IN A SLAG MEDIUM BY USING CONSUMABLE ELECTRODES

Filed Sept. 3, 1964 4 Sheets-Sheet 1

Fig. 1

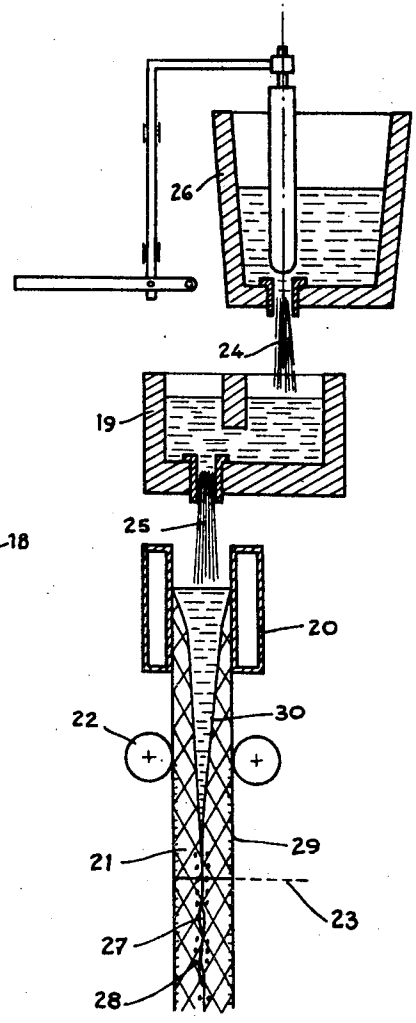
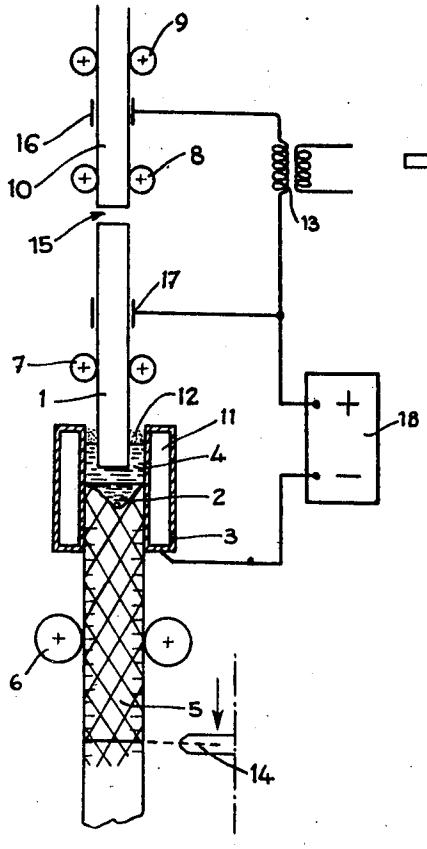


Fig. 2



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Fig. 3

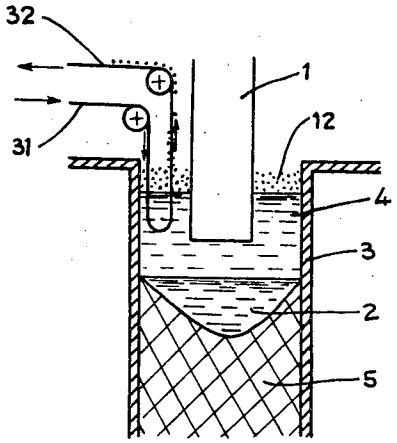
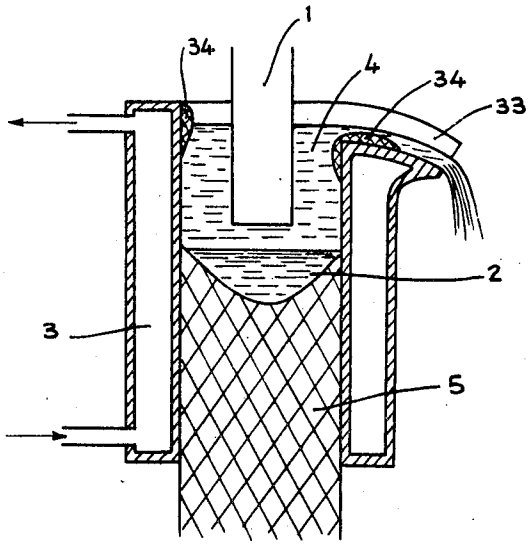


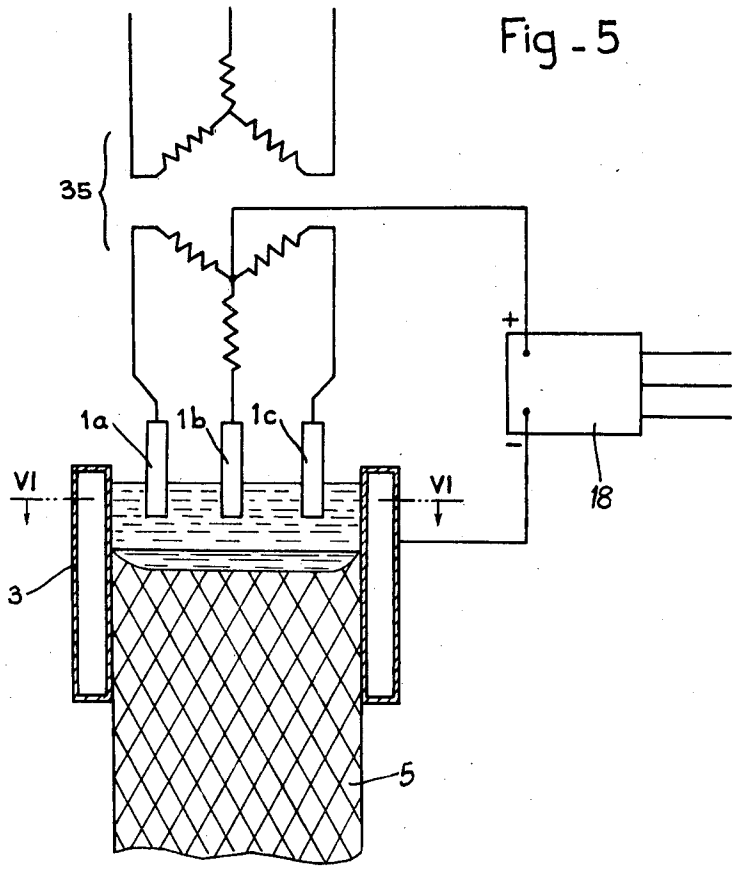
Fig. 4



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Fig. 5



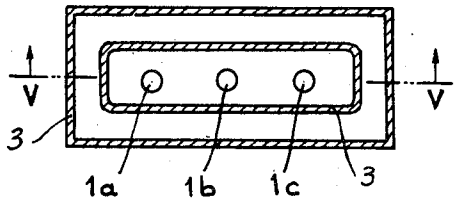


Fig. 6

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CONTINUOUS-CASTING METHOD OF MELTING METALS IN A SLAG MEDIUM BY USING CONSUMABLE ELECTRODES

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Fig_7

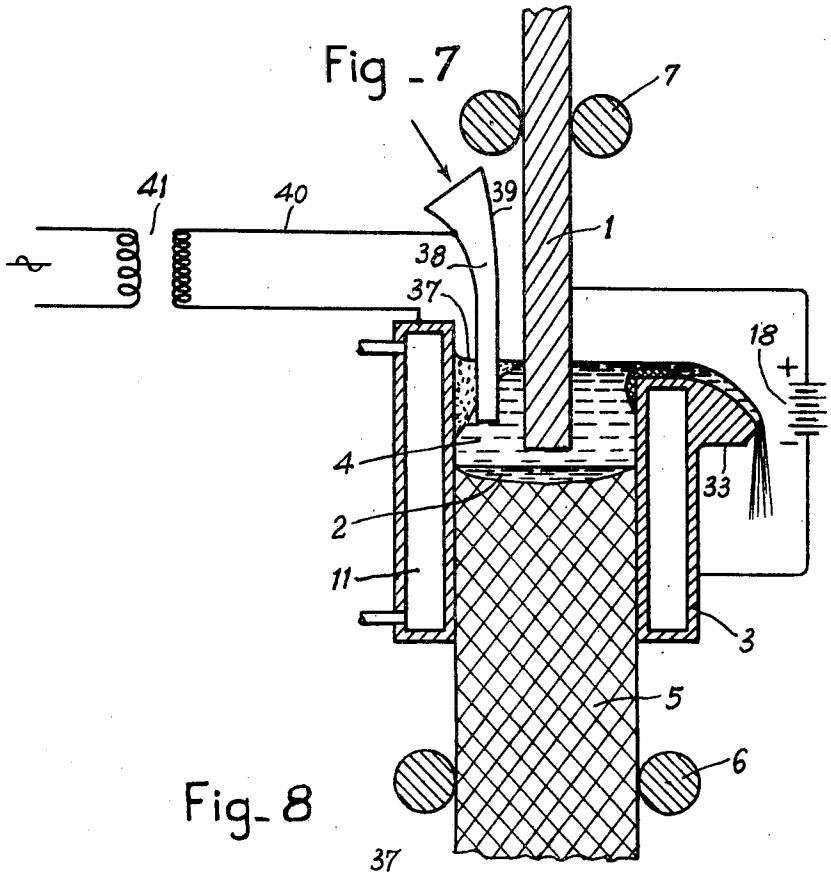
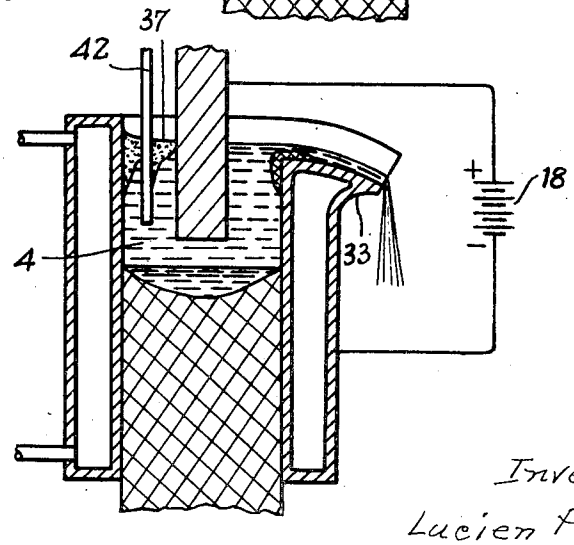


Fig_8



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United States Patent Office 3,234,608 Patented Feb. 15, 1966

3,234,608

CONTINUOUS-CASTING METHOD OF MELTING METALS IN A SLAG MEDIUM BY USING CONSUMABLE ELECTRODES

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Filed Sept. 3, 1964, Ser. No. 394,270
Claims priority, application France, Nov. 19, 1959, 810,624, Patent 1,264,474; Nov. 20, 1959, 810,846, Patent 1,260,008; Feb. 13, 1960, 818,446, Patent 77,165

12 Claims. (Cl. 22—200.1)

This application is a continuation-in-part of my co-pending applications Ser. No. 68,751 and Ser. No. 68,772, filed November 14, 1960, now abandoned.

It is known to prepare metals and alloys purified to a high degree to free them from foreign substances such as nitrogen, oxygen, hydrogen and non-metallic inclusions, by melting the metal or alloy in vacuo in a direct-current electric arc furnace of which the anode consists of the metal to be remelted, in the form of a vertical rod, the cathode consisting of the surface of the liquid metal of the ingot solidifying in a cool copper crucible. Thus, the length of the ingot that may be obtained is compulsorily limited by the depth of the ingot mould which has its bottom necessarily closed to ensure the necessary vacuum seal and to balance the pressures.

In the conventional method of casting steel continuously the liquid steel from a casting ladle is gradually poured in the open atmosphere into a casting pool from which it flows out, still in the open atmosphere into a cooled copper ingot mould; the metal which has set on the side surfaces is extracted in the downward direction from the lower portion of this ingot mould under which it completes its solidification. The solid bar or rod is fed by means of a pair of driving rollers beneath which the bar is cut periodically into sections of proper length through any suitable method and then discharged.

In this procedure, the steel is first melted in a suitable furnace and then transferred to the pouring ladle.

Under these conditions, this known method provides an intermittent operation and the run is limited by the capacity of the furnace and/or of the ladle. Moreover, the jets of molten metal from the ladle and from the pool are subject to a certain oxidation of the metal which is detrimental to its final quality. Finally and more particularly, due to the reduction in temperature which takes place from the beginning to the end of the casting operation as a consequence of the ladle cooling, it is not possible to reduce the rate of flow of the metal into the ignot mould and therefore to reduce the depth of solidification to values more consistent with the desired steel quality.

It is the essential object of the present invention to provide a method of melting and casting metals which combines the advantages of the two known methods broadly set forth hereinabove while avoiding their drawbacks.

Further, as is well known, direct reduction of iron ores leads to products the nature of which will vary with the process used. Thus, in the fluidized bed method, the pulverized ore kept in suspension in the upwardly streaming hot reducing gas is brought to the condition of iron powder or very fine pieces. When reduced in a rotary furnace, the crushed ore produces small, porous grains of varying degrees of roundness known as sponge-iron. If this sponge iron, which includes large amounts of gangue, is crushed and subjected to magnetic separation, the iron obtained comes in the form of small pieces.

As a general rule, the granular iron obtained by direct reduction is contaminated to a varying degree by iron

protoxide, FeO, resulting from incomplete reactions and from gangue such as lime or magnesium silicate, aluminates, phosphates, etc. existing in the ore. Indeed it is common to find 1–15% of non-metallic impurities. The large area offered up to oxidation by iron which is in the granular form, in conjunction with the presence of the non-metallic contents referred to, makes it difficult to make direct use of such reduced ores, so much so in fact that in most cases the latter is used, after briquetting, in lieu of scrap iron for steel-work, open hearth or electric furnaces.

Another object of the invention is to overcome these drawbacks by providing a method which enables iron to be separated from the gangue and reduction of the last traces of iron protoxide to be completed, and which thereby permits the iron to be produced directly in marketable form, such as in billets, slabs or rounds.

This invention may essentially be defined as a method of melting and casting metal in the form of bars, slabs, billets, or sections which consists in effecting on the one hand in a single apparatus the electrical melting or consumable positive electrodes, the cathode being the metal bath during its solidification, and on the other hand the conventional casting in a cooled continuous casting mould, this method being characterized in that melting and casting take place within a slag medium at the atmospheric pressure without forming an electric arc, the slag composition being such that the slag has a purifying action and that the current flowing through the slag between the anode and cathode causes an electrolytic reduction of the slag which ensures a complete reduction of the metal, the casting of this metal being as slow as desired without any risk of oxidation, thus permitting the setting of the metal into parallel layers slightly inclined to the horizontal.

The method in accordance with the invention which permits the direct reduction of iron ore consists in first moulding into bar form the powder, or sponge-iron obtained from a direct iron-reducing method involving fluidization in a rotary or other type of furnace, such moulding if necessary including sintering at a moderate temperature to facilitate handling of the bars, then in using the bars as the electrodes for the above-mentioned melting and electrolytic process.

In addition, it may be emphasized that the new electrodes of this invention are abutted as the operation proceeds, for example by spark welding, that the solidified cast bar is cut into sections also as the operation proceeds, that the bath heating and the electrolytic effect may be ensured from a common direct-current supply (or from separate supplies of alternating current and direct-current, respectively), and that the correcting or make-up addition of slag as well as the removal of excess slag are accomplished either periodically or continuously.

Suitable material for the formation of slag is supplied in solid or preferably liquid form.

In the case of the reduction of iron ore, this method has shown that it possesses the great advantage of dissolving, in the slag the small quantity of gangue that the electrode contains. Each iron or steel droplet draining off the electrode is washed by the slag before it drops into the metal bath; thus, on its way through the slag, it gets rid of the gangue and the iron protoxide.

Furthermore, the phenomenon of electrolysis ensures reduction of this iron protoxide in conjunction with liberation of the iron on the surface of the fused metal constituting the cathode.

Since the gangue does not have the required composition to enable it to constitute the slag, its composition is improved, as explained, by mixing various reduced minerals and by incorporating suitable correcting additives.

More precisely, included among these correcting additives, are such oxygenated constituents as silica, alumina and calcium oxide used for the purpose of adjusting the basicity (such that the minimum index of basicity shall be 1) and the temperature of melting, such halogenic fluxes as fluor-spar and possibly sodium fluoride, barium chloride or cryolite, such oxygenated fluxes as sodium silicate and fluidifying agents such as titanium oxide, manganese oxide, and the like. The object sought is to regulate the fusibility, the fluidity, the electrolytic conductivity and the solubility of the iron oxide, and the basicity of the slag. The composition of the slag is determined according to the electrolysis reactions which will dictate the limits of oxygen, sulphur and phosphorus contents of the fused steel, and the suitable silicon, manganese and aluminum contents to be chosen according to the properties that are sought.

The molecular basicity index will be chosen greater than 1.

As an electrolysis phenomenon is incompatible with the formation of an electric spark or arc which can be considered as a short-circuit of the current in the fluid, this spark or arc must be prevented in the carrying into effect of the invention. Now, the formation of an electric spark or arc between an electrode to be melted and the metallic bath depends on the conductivity of the slag, and therefor on its composition and on the distance between the metallic bath and the electrode immersed in the layer of slag. For this reason it is necessary, in order to obtain the electrolysis effect according to the invention, to select a slag of such composition that is rather good electric conductive in such manner, that no electric spark or arc can be produced.

Compositions of slags suitable for the proposed object, that is to say which are favourable to elecrolysis, have good fusibiliy or electric conductivity and a thermal conductivity that are suitable in the molten state, are given in the following examples, in which the percentages given are by weight.

Example 1

CaO ---------- 20 to 30%.
$5CaO \cdot 3Al_2O_3$ ---------- Up to 30%.
CaF_2 ---------- The remainder, while remaining less than 80%.

Example 2

	Percent
CaO	20 to 30
CaF_2	70 to 80

Example 3

MgF_2	10 to 30
CaF_2	10 to 40
CaO	20 to 50
$3CaO \cdot 5Al_2O_3$	20 to 30

Example 4

SiO_2	About 28.66
CaO	About 29.33
MgO	About 12
CaF_2	About 30

The melting point of all the above slags is in the neighbourhood of 1400° C.

Example 5

In a case where electrodes are employed made from a reduced ore corresponding to the following percentage composition by weight: Fe=82%, Ca=0.6%, SiO_2=4.5%, MnO=0.4%, MgO=2.5%, Al_2O_3=0.8%, the remainder being FeO and traces of impurities, there is added 3.85% by weight of fluor-spar, CaF_2, for 100 parts by weight of reduced ore so as to give a suitable slag having the molecular compositions: CaO=4.28%, SiO_2=30%, MnO=22.4%, MgO=25%, Al_2O_3=3.2%, CaF_2=15.12%, this slag having a molecular basicity

index of about 2.

In fact, in this latter composition the molecular weights are: CaO=56, MnO=71, MgO=40 and SiO_2=60, the ratio is:

$$\frac{CaO+MnO+MgO}{SiO_2}=\frac{\frac{4.28}{56}+\frac{22.4}{71}+\frac{25}{40}}{\frac{30}{60}}=2.03$$

Speaking more generally, and again for the case in which the starting material is an ore, the gangue of the electrode or electrodes can advantageously be comprised within the following limits, expressed in percentage by weight: SiO_2=10 to 25%, Al_2O_3=2 to 10%, Mn_xO_y=0 to 10%, MgO=0 to 10%, CaO=20 to 50%, the remainder being iron oxide.

In view of the necessity of avoiding the formation of an electric spark or arc, it is obvious that if the slag contained more silica with respect to the other oxides, the process of electrolysis would not take place and an arc could be formed. It is for this reason that the siliceous ores are excluded. Experience has shown that the gangue of many Algerian ores is suitable and this is also the case with a large number of other rich ores: from Morocco, Guinea, Venezuela, Mexico, etc., but not all.

If the slag is richer in silica, the fluor-spar is destroyed and the slag is no longer a conductor of electricity; if the electric field between the electrodes is sufficient, a discharge is produced in the same way as if the voltage is sufficient between two electrodes separated by a sufficiently thin plate of glass, a spark can strike which pierces a hole through the glass plate. It is in this way that the breakdown and failure during use of condensers take place, since once the hole has been pierced the spark passes through easily.

Thus the amount of electrical insulators like silica and alumina in the slag must be maintained sufficiently low to avoid the formation of an electric arc or spark.

In fact, fluor-spar when mixed with silica SiO_2 gives the following reaction at high temperature:

$$3SiO_2+2CaF_2=2SiO_2 \cdot CaO+SiF_4$$

with the formation of silicate of lime, $SiO_2 \cdot CaO$ and silicon fluoride SiF_4, which is volatile and is eliminated. It is thus not possible to count on the electrolytic conductivity of the slag by CaF_2, which disappears if the slag contains too much silica and not enough lime. The silica is therefore all the more harmful in that silica and the silicates are electrical insulators which do not conduct the current, whereas lime, on the contrary, becomes electrically conductive at high temperatures.

According to the invention, the elimination of the FeO takes place by virtue of the electrolysis of the slag which supplies anions (in particular anions of calcium), which results in a reduction of FeO and the re-formation of oxides (lime or other substances, silica, alumina, etc.).

Molten fluor-spar CaF_2 is electrolytically dissociated into an anion Ca^{++} and two cations F^- which result in the medium being electrolytic and electrically conductive. This property is retained in the case of a molten mixture of quick-lime CaO and fluor-spar, and also if there is present manganese oxide MnO.

The ion F^- which is directed to the iron anode forms FeF_2, iron fluoride, which dissolves in the bath. It is also an electrolyte and is dissociated into Fe^{++} and two times F^-. The electric field directs the Fe^{++} ion towards the metallic bath cathode, in which the iron loses its electrical charge for the same reason as above, the fluor-spar lost its electric charge on the anode. The direct current is necessary in order to hold these electric charges.

De-oxidation takes place since, as Ca^{++} similarly tends to be carried to the cathode but remains on the surface

because it is not soluble in the steel, we have at the surface of the steel the reaction:

$$FeO+Ca=CaO+Fe$$

The iron is dissolved in the metallic bath and the lime is dissolved in the slag. In this way, the metallic bath is perfectly de-oxidized.

In the same way, all the manganese oxide MnO which can exist in the slag is reduced by the calcium at the surface of the steel bath, which recovers the manganese and thus improves the quality of the steel.

In the case where the starting material is reduced ore and calcium fluoride is subsequently added, this addition will advantageously be made in a proportion of 2 to 5% by weight of the reduced ore.

The voltage and intensity of the direct current which produces the electrolysis obviously depend on the slag to which the process is applied. For example, in the preceding cases the voltage will preferably be chosen between 20 and 30 volts, the current density being for example about 800 A. per sq. cm. of electrode, this being given by way of indication and without any implied limitation.

If account is taken of the possibility of applying the method of electrolysis according to the invention, to other metals of the group of Fe and ferrous alloys, the voltage will, generally speaking, be comprised between 10 and 35 volts.

This invention is applicable not only to steel melting processes but also to the melting of other metals or alloys. It is concerned not only with the method broadly set forth hereinabove but also with the apparatus constructed for carrying out this method, and with the products obtained therefrom.

The invention will now be described with specific reference to the forms of embodiment illustrated by way of example in the accompanying drawings which relate more particularly to the melting and casting of steel. In the drawings:

FIGURE 1 is a diagrammatical vertical section showing the conventional melting and casting method given for comparison purposes;

FIGURE 2 is a diagrammatical axial section showing the method of melting and casting metal according to this invention;

FIGURES 3 and 4 are fragmentary sections showing two different methods of eliminating the slag excess;

FIGURES 5 and 6 are a diagrammatical vertical section and a diagrammatical horizontal or cross section showing a device according to this invention wherein the bath of molten metal is heated by using an alternating current superimposed on a direct current, the electrolytic action resulting from the use of the superposed direct current;

FIGURES 7 and 8 are diagrammatical vertical sections showing two different methods of supplying the material for the formation of slag.

The conventional methods of melting and casting metals (see FIG. 1) cause the molten metal to be received into a pouring ladle **26** from which the metal jet **24** flows into a pouring pool **19** from which the metal flows again in the form of a jet **25** into the hollow open-bottom and cooled copper ingot mould **20** from which the solidified metal **21** in the form of bars, slabs, billets, or sections is extracted by driving rollers **22** and finally cut at **23** for example by means of an adequate blow-pipe to sections having the desired length.

In its simplest form (see FIG. 2) a device according to the present invention comprises an anode **1** consisting of a vertical rod of the metal to be melted which is connected through a clamp **17** to the positive terminal of a source of current **18**; a cathode consisting of the solidifying metal bath **2** in the copper ingot mould **3** cooled by a water circulation **11** and connected to the negative terminal of the source of current.

Overlying this metal bath **2** is a bath **4** of molten slag in which the anode is dipped, this slag insulating the bath

2 to avoid any contact thereof with the atmospheric air.

Thus, the free surface of the bath **2** is practically at the atmospheric pressure, fact which permits to avoid the use of packings. The ingot mold **3** is open at its bottom as in the conventional continuous-casting ingot mould, and the solidified bar **5** is driven in the downward direction by any suitable device, for example in the form of a pair of rollers **6**.

This bar **5** is then cut across its axis as in conventional continuous casting methods, for example by means of a flying blow pipe **14** fed in the downward direction at the same rate as the bar and rotated about a vertical axis by any suitable means.

In this device the electrolytic reactions originated in the slag ensure the reducing character of the surface reactions of the metal bath and a correct composition of the steel; with this treatment, the steel may be freed of any noxious elements such as nitrogen, oxygen, phosphorus, sulphur and non-metallic inclusions by properly adjusting the slag compositions. Thus this slag contains silica, lime magnesio, alumina, fluor-spar; titanium, manganese, barium oxides, as well as silicates and alcaline or alkaline-earth halides, etc.

Since the drops of metal which are formed at the anode and fall into the steel bath are also protected completely from any contact with the atmospheric air, the melting rate may be adjusted without any risk of oxidation at as low a value as desired to reduce the depth of the steel bath and ensure a solidification of the metal into parallel, nearly horizontal layers (see FIG. 2), so as to better eliminate the axial pipe **27**, the micropipes **28** and the peripheral cracks **29** generally observed in the conventional methods of casting steel continuously (FIG. 1) in which the metal solidifies in the form of substantially vertical layers **30** with pronounced anisothermies or temperature difference between the axis and the periphery of the cast bar.

In the method of this invention it is possible to maintain the slag composition either periodically or continuously by adding either slag granules of adequate composition, or suitable mineral or metallic correcting agents and by eliminating either periodically or continuously the deteriorated slag through any suitable means. Thus, for example, the used slag may be eliminated either by using a conventional stopper-rod or steel bars on which it solidifies, or (FIG. 3) by causing an iron wire or tape **31** to circulate continuously through the slag mass at a proper rate for carrying along on its surface a certain quantity of solidified slag **32**, or causing the slag to flow from the ingot mould over a discharge lip **33** provided to this end at the upper portion of the ingot mould (FIG. 4), provided that the deposits **34** formed on the periphery are scraped off at spaced time intervals.

It is also possible to alter the slag composition by covering it either with a suitable gaseous atmosphere, for example an atmosphere having reducing properties, or with an insulating powder **12** such as graphite, charcoal, ect. In any case, it is remarkable that as a consequence of the electrolytic effects a relatively limited mass of slag permits of casting a very large quantity of steel without displaying any noxious alteration.

Whereas the downward feed of the solidified bar and the electrical power are generally adjusted by the operator to the proper and desired values, with this invention the anode feed may be adjusted automatically to keep the electrode distance between the same and the body of molten metal at a constant value and the current voltage and strength at the requisite values.

As the feed of the consumable electrode as well as the forward and backward adjustments thereof are ensured by a lateral device comprising for example a pair of rollers **7** (FIG. 2), it is possible to feed the metal anodes continuously. The fresh electrodes **10** can be abutted either by means of screw threads such as the

nipples of the carbon electrodes of the Héroult Furnaces, or (FIG. 2) through the conventional spark welding process at 15, attended by a compression, by using a separate source 13 of alternating current and an additional connecting clamp 16. (The electrode to be abutted is guided and driven by two pairs of rollers 8 and 9.)

If desired, an alternating current may be superposed on the direct current (see FIGS. 5 and 6) to permit the separate adjustments of the heating and electrolysis. The principle of this invention also applies to the use of several consumable electrodes mounted in parallel to ensure the continuous casting of slabs 5 to be used in the manufacture of sheet metal stock. Thus, the diagrammatic FIGURE 5 illustrates a typical embodiment of this construction incorporating three electrodes 1*a*, 1*b*, 1*c*, wherein additional heating is effected by means of three-phase alternating current from a transformer 35, while electrolysis and heating is effected by a rectifier 18 connected for example in series. If desired, six electrodes may be arranged side by side either in two times three, or in six-phase relationship.

According to a preferred form of operation, it is possible to avoid:

(1) The abutting of the electrodes,

(2) The flying cutting of the cast ingot.

To this end, the aggregate mass of the electrode is equal to that of the ingot to be obtained as a continuous casting. For each electrode the casting is commenced or primed by using a dummy ingot bottom. Thus, the method may either include the step of rolling the dummy bottom together with the ingot and then cutting off the dummy bottom, or, better still, cutting the dummy bottom of the case ingot, before rolling and using the dummy bottom for the next operation.

If desired, electrodes consisting of moulded and sintered metal to be remelted may be used and several electrodes may be mounted in parallel so that the cross-sectional area of the ingot be as large as desired while limiting the cross-sectional area of each separate electrode, this being particularly advantageous in that it reduces the press power necessary for moulding the iron powder used for preparing the electrodes, or ensures a better distribution of the pressure throughout the moulded electrode prior to the sintering operation.

Thus, for example, six electrodes having the same cross-sectional shape, whether of round, square, rectangular, oval or other configuration, may be used in a parallel mounting on the same straight line to form a rectangular-sectioned elongated ingot, for example of the conventional slab shape, from extra-mild steel or pure iron for subsequent rolling into sheet plates in continuous rolling mills.

Furthermore, the arrangement may comprise two apparatus of any one of the types described hereinabove which are disposed in parallel, one apparatus being operated while the other is being prepared for the next run, the two apparatus being connected by turns to the same current generator.

When priming the apparatus the operator may pour into the ingot mould a suitable quantity of molten slag from a preceding run which has been remelted in a nearly small furnace. If desired, the operator may pour into the ingot mould a suitable quantity of slag from a preceding run which has been crushed into lumps or ground to form a fine powder beforehand. If desired, suitable reducing or fluxing agents may be added with a view to correct the nature of the slag, whether the latter be in molten, granular or powder form. Finally, the excess slag overflowing from the top edge of the ingot mould during the run may be converted directly into granules as it sets and cools in order to be ready for a subsequent partial re-use, for example for priming the next run.

Of course, the method contemplated for melting and casting iron and steel is also applicable to a large number of other metals and alloys.

Although the present invention has been described with reference to preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the scope of the invention, as those skilled in the art will readily understand.

Referring now to FIGURE 7, an iron bar 1 obtained by moulding iron particles, obtained through a direct reduction of the ore in conjunction with a sintering operation if necessary, is subjected to electrolytic melting in a copper continuous casting mould 3 provided with a cooling device 11. The bar serving as the anode is connected to the positive terminal of the current source 18 while the continuous casting mould is connected to the negtive terminal thereof.

The fused metal forms a bath 2 at the top of the ingot mould covered by the molten slag 4 and solidifies at the bottom into an ingot 5 which can be withdrawn in continuous fashion by appropriate means 6. The bar is fed in by components 7 in such a way that it is in continuous contact with the molten slag, and the metal drops which drain off are washed by the slag before they fall into the molten metal.

The gangue contained in the bar melts together with the metal and collects at the top of the fused metal. However, since this gangue does not have the required composition it must be provided with correcting additives in the form of elements such as those enumerated above.

These elements can be introduced directly into the molten slag either in the form of lumps or powder, or better still in the form of a liquid. In the latter case, the additives to be mixed in are first melted together in an auxiliary furnace. They must then be introduced through the non-conducting, pasty surface layer 37 right into the conducting, fluid part lying close to the surface of the fused metal. To this end (see FIGURE 7), provision can be made for a refractory tube 38 of suitable height equipped with a funnel 39 at its top. This funnel may be heat-insulated if the rate at which liquid is added is sufficient to prevent congealing; otherwise provision must be made for, say, a resistance heating system 40 capable of preventing solidification. To this end, the current may be caused to flow directly through the slag if the latter is a good conductor of electricity; otherwise, the tube may be an electrical conductor made of tungsten or graphite which is heated by the resistance heating, preferably using alternating current through the medium of a transformer 41. The additives themselves can be supplied in the form of rods obtained by melting and subsequently moulding their constituents, or by moulding the latter in powder form and then sintering them; alternately, the additives can take the form of agglomerates obtained by means of a water-bearing binding agent such as kaolin, clay, sodium silicate, aluminous cement, etc., with or without subsequent baking for the purpose of eliminating the water while retaining cohesion by sintering. If the additives are used in the form of a rod 42 (FIG. 8), then the latter is made to pass through the layer of gangue 37 and to penetrate into the fluid slag 4 where it gradually dissolves. The rate of feed of the rod 42 is made proportionate to the mean rate of feed of the electrode 1, in order to ensure consistency in the composition of the slag.

In accordance with a modification, the additives can be added directly to the ore reduced to powder form or lumps before moulding of the electrode. Thus when the electrode melts and the drops of iron fall into the bath of metal, the correcting additives of the slag and the gangue of the reduced mineral pass into the slag simultaneously, so that the latter retains a constant composition throughout the operation. Finally, some additives can be incorporated into the powdered iron as and when the electrode is being formed, other additives being incorporated directly into the molten slag.

Since the formation of slag is proportional to the formation of the iron, the slag which forms must be evacuated.

This can be performed by the use of a spillway 33, for example.

An endless-type electrode feed can be ensured without interrupting operation, by any one of the methods mentioned above, for instance by drawing or sparking followed by compression. However, in the case of compressed iron having sustained only slight pre-sintering so that the metal remains malleable and porous, the sparkling method followed by compression can be replaced by a method whereby direct contact with axial pressure and resistance heating is resorted to, since this method ensures adequate welding of the new electrode to the stub of the old.

Depending on the size and shape of the continuous casting mould, continuous casting obtained by this method leads to the direct obtainment of steel billets, rounds or slabs having excellent properties, without the need to resort to intermittent stages such as open-hearth furnaces, casting-ladle, ingot mould and blooming, with all the drawbacks these entail from the point of view of stoppages, heating costs, successive operations, losses of material at the various stages, etc.

What I claim is:

1. The method of refining and casting ferrous metals comprising continuously feeding a consumable electrode of said metal containing impurities including iron oxide to a molten body of said metal in a bath of basic slag having an index of basicity greater than 1, applying a direct current potential to said electrode as the anode and to said body of molten metal as the cathode, the composition of said slag, the tension of said direct current, and the separation of said body and the bottom of said electrode being such that current flows between said electrode and said body through said slag without arcing and said oxide is reduced electrolytically while the end of said electrode is progressively melted, continuously withdrawing molten metal from said body as said electrode is consumed, passing said withdrawn metal into and through a cooled continuous casting mold thereby producing a continuous casting of refined metal.

2. The process as set out in claim 1 in which the fluidity and conductivity of the slag are maintained by the addition thereto of at least one compound from the group consisting of silica, alumina, calcium oxide, sodium silicate, calcium fluoride, sodium fluoride, barium chloride, sodium fluoaluminate, titanium oxide, and manganese oxide.

3. The process as set out in claim 2 in which the additive compound is incorporated in the consumable electrode.

4. The method as set forth in claim 2 in which the added compound is calcium fluoride in an amount of between 2 and 5% of the electrode.

5. The method as set forth in claim 1 in which the consumable electrode included gangue materials comprising by weight:

	Percent
CaO	20–50
Al_2O_3	2–10
SiO_2	10–25
MgO	Up to 10
Mn_xO_y	Up to 10

6. The method according to claim 1, wherein an alternating current is superimposed on the direct current.

7. The method according to claim 1, wherein the composition of said slag is by weight:

CaO	20 to 30%.
$5CaO3Al_2O_3$	Up to 30%.
CaF_2	The rest and up to 80%.

8. The method according to claim 1, wherein the composition of said slag is by weight:

	Percent
CaO	20 to 30
CaF_2	70 to 80

9. The method according to claim 1, wherein the composition of said slag is by weight:

	Percent
CaO	20 to 50
$5Al_2O_33CaO$	20 to 30
CaF_2	10 to 40
MgF_2	10 to 30

10. The method according to claim 1, wherein the composition of said slag is by weight:

	Percent
CaO	About 29.33
CaF_2	About 30
SiO_2	About 28.66
MgO	About 12

11. The method according to claim 3, wherein the molecular composition of the slag is:

	Percent
CaO	About 4.28
Al_2O_3	About 3.2
CaF_2	About 15.12
SiO_2	About 30
MgO	About 25
MnO	About 22.4

12. The method according to claim 1, wherein the tension of said direct current is 10 to 35 v.

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