We, ASEA BROWN BOVERI AG being the person(s) identified below as the Applicant, request the grant of a standard patent to the person identified below as the Nominated Person, for an invention described in the accompanying complete specification.

Full application details follow.

Applicant and Nominated Person: ASEA BROWN BOVERI AG

Address: Baden, Switzerland

Invention Title: Method of operating an arc furnace, and an arc furnace

Name(s) of Actual Inventor(s): Andreas LOEBNEK, Jan ÖLSCHER, Sven-Einar STENKVIST

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Attorney Code: RI

<table>
<thead>
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<th>Application No</th>
<th>Country</th>
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<tr>
<td>19612383.6</td>
<td>Germany</td>
<td>DE</td>
<td>28 March 1996</td>
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Drawing number recommended to accompany the abstract: Fig 6.

Dated this twenty-first day of March 1997

By: PAUL WHENMAN
Registered Patent Attorney
Australia Patents Act 1990

Notice of Entitlement
(to be filed before acceptance)

I, Herbert Rzehak
being authorised by ASEA BROWN BOVERI AG
of Baden Switzerland

the applicant in respect of an application for a patent for an invention entitled

Method of operating an arc furnace, and an arc furnace

filed under Australian Application No. , state the following:

**Part 1 - Must be completed for all applications.**

The person(s) nominated for the grant of the patent:

- [ ] is/are the actual inventor(s) -

- [ ] has, for the following reasons, gained entitlement from the actual inventor(s):
  
  The nominated person is a person who would if a patent were
  granted upon an application made by the actual inventor(s)
  be entitled to have the patent assigned to it.

**Part 2 - Must be completed if the application is a Convention application.**

The person(s) nominated for the grant of the patent is/are:

- [ ] the applicant(s) of the basic application(s) listed on the patent request form

- [ ] entitled to rely on the basic application(s) listed on the patent request form by reason of the following:

The basic application(s) listed on the request form is/are the first application(s) made in a Convention country in respect of the invention.

**Part 3 - must be completed if the application was made under the PCT and claims priority.**

The person(s) nominated for the grant of the patent is/are:

- [ ] the applicant(s) of the application(s) listed in the declaration under Article 8 of the PCT

- [ ] entitled to rely on the applicant(s) listed in the declaration under Article 8 of the PCT by reason of the following:

The basic application(s) listed in the declaration made under Article 8 of the PCT is/are the first application(s) made in a Convention country in respect of the invention.

Signed: [Signature]

Date: 1997-02-12

Herbert Rzehak

Status: Authorized representative
In order to avoid damage to the inner walls of the arc furnace (1) and a reduction of the electric power when material (5) to be melted has been partly burned down in an arc furnace (1), additives (10) are fed to the filling opening of a hollow electrode (7) by means of a loose-material conveyor (25) during this critical melting phase. An arc (6) between the hollow electrode (7) and a melt (4) in the arc furnace (1) is thereby shortened. A loose-material container (9) is arranged at the end of the loose-material conveyor (25) at a distance from the electrode and can easily be separated from the hollow electrode (7) in order to permit the tilting of the arc furnace (1) to empty out the melt (4). Problematic waste materials which are to be disposed of, such as for example filter dust, can be added to the additives (10).
Invention Title:

Method of operating an arc furnace, and an arc furnace

The following statement is a full description of this invention including the best method of performing it known to us:
BACKGROUND OF THE INVENTION

Field of the Invention

The starting point of the invention is a method of operating an arc furnace, particularly for steelmaking, and an arc furnace for carrying out the method, according to the preamble of patent claims 1 and 4.

Discussion of Background

In a preamble of patent claims 1 and 4 reference is made to a prior art known from Swiss house journal ABB Technik, 10/1992, pp. 3 - 10. For the melting-down of scrap, use is made of a solid graphite electrode in a direct-current arc furnace, in which the furnace cover is movable and the furnace vessel tiltable in order to tip out the slag and the finished melt. If the direct-current arc furnace is used as a reduction furnace for the continuous charging and processing of fine charges, it is fed either through a central opening in the electrode, directly into the arc furnace plasma, or through one or more charging doors next to the electrode. If a premixed fine-grained charge is fed through the hollow electrode, the charging mass flow is controlled so that equilibrium with the arc power can always be maintained. The two-part charging tube has a quick-release coupling and is electrically insulated from a filling hopper of the hollow electrode. The charging apparatus can be swung aside in order to uncouple the bottom part of the charging tube. This furnace has a fixed cover and a stationary shell. The metal and the slag are run off through tap holes at different heights. The furnace transformer is designed to supply
the rated power over a wide voltage and current range, so that the arc furnace can be operated at full load. The current supply system must therefore be made sufficiently flexible to enable this optimum to be adjusted in practical operation. As a rule four or five taps are provided on the transformer in order to enable this range to be covered.

Arc furnaces for reduction processes are not tiltable and have a rigidly mounted cover.

In connection with the relevant prior art, reference is also made to EP 0 058 774 B1, from which a tiltable arc furnace having a plurality of solid electrodes for steelmaking is already known, in which loose material is likewise introduced into the arc furnace from a loose-material container via a loose-material conveyor. The loose-material container is here arranged on the loose-material conveyor at a distance from the electrode.

From EP 0 637 634 A1 a method of producing a steel melt in an arc furnace is known, wherein fine-grained solids and/or gases pass through a hollow electrode directly into the arc in order to obtain an arc enclosed in a foamed slag over the flat bath period. In order to form the foamed slag it is also possible for filter dust to be fed in.

SUMMARY OF THE INVENTION

Accordingly, one object of the invention, as defined in patent claims 1 and 4, is to provide a novel method of operating an arc furnace, particularly for steelmaking, and to develop further an arc furnace of the type initially mentioned above in such a manner that an improvement of the efficiency of the arc furnace is achieved.

Advantageous developments of the invention are defined in the dependent patent claims.
The main advantage of the invention consists of a higher power density of the arc furnace as the result of a shorter arc.

Since the additives have a deionizing action on the plasma zone in which the arc burns, the arc is shortened with the same voltage and the same current. Depending on particle size, rate of feed and type of material of the additives, lateral heat radiation is thus reduced in comparison with heat radiation in the direction of the melt.

With the same length of arc, it is thus possible to work with a higher voltage. The arc furnace can therefore be operated with a higher electrical power for the same electrode diameter (same current). Hot spots are thus made less harmful.

Another advantage of the invention is that a reduced load on the hollow electrode and on the lining of the arc furnace is achieved. Thinner electrodes permit an extremely high saving of costs.

The additives required for the metallurgical processes are fed in at the optimal point. Since for example carbon does not have to be unnecessarily dispersed, waste gases are reduced.

If at least a part of the substances which have to be introduced in any case, such as for example lime and coal, are used as additives, they are utilized particularly effectively.

A way of processing problematic waste at almost zero cost is made possible. Steelworks waste, such as for example filter dust, can be added to the additives and can thus be disposed of without causing problems.

According to an advantageous development of the invention it is possible to prevent gas from passing out of the hollow electrode.

The tilting of the arc furnace into its end positions and the swiveling of the hollow electrode and
the furnace cover do not entail any additional operating costs. Additives can be introduced into the hollow electrode in all tilted positions of the arc furnace during melting operations.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 shows an arc furnace filled with scrap and provided with a conventional conveyor device for additives and a conveyor device which conveys additives into a hollow electrode of the arc furnace.

Figure 2 shows a tiltable arc furnace provided with two storage silos for additives which are connected by means of a hose.

Figure 3 shows the arc furnace of Figure 2 with an electrode adjustment device and a loose-material conveyor pivoted thereon.

Figure 4 shows in detail a loose-material conveyor according to Figure 3.

Figures 5 to 7 show arc furnaces with different levels of scrap filling, and

Figures 8 and 9 show melting power diagrams for a melting cycle, without and with the supply of additives, in the melting state according to Figure 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, in Figure 1 is shown a direct current arc furnace or arc furnace (1)
comprising a bath electrode (2), a detachable furnace cover (3) having a central opening for the passage of a hollow electrode (7) and having a conventional feed opening (11) for supplying additives (10). An arc (6), which melts scrap (5), burns between the hollow electrode (7) and a steel melt or melt (4). The scrap (5) is fed into the arc furnace (1), with the furnace cover (3) open, before the melting process is started. From a first loose-material container (9) for additives (10), for example coal and lime, the latter are conveyed via a first conveyor device (8) into a filling opening (28) of the hollow electrode (7). It is important that the loose-material container (9) is arranged at a distance from the electrode and is thus subjected to only a low thermal load. Additives (10) are in addition conveyed from a container (13) to the feed opening (11) via another conveyor device (12).

Figure 2 shows an arc furnace (1) according to Figure 1, from which it can be seen that the additives (10) are conveyed by means of a pneumatic loose-material conveyor or forced-draft fan (15) from a loose-material store container or second loose-material container (16), via a hose connection or through a hose (17), into the first loose-material container (9). Instead of a forced-draft fan (15) it is for example also possible to use a suction conveyor as usually employed in conveying or an air-pressure conveyor. The loose-material container (9) is arranged, at right angles to the plane of the drawing, behind and at a distance from the hollow electrode (7), in accordance with Figure 1. (18) designates a rocker of the arc furnace (1), which enables the arc furnace (1) to be rolled on a flat support surface of a furnace foundation (19) and thus allows the arc furnace (1) to be tilted without additional operating expense.

Figure 3 shows a tiltable arc furnace (1) and an electrode adjustment device (22) which is arranged
in a furnace platform (21) for rotation and vertical adjustment. The electrode adjustment device (22) has a horizontal electrode carrier arm (23) which is mechanically and electrically connected on the one hand to a current supply (20) and on the other hand to the hollow electrode (7). At the same time, said adjustment device is connected, with electrical insulation, via a pivot joint (29) to a loose-material conveyor (25) which can be seen in greater detail in Figure 4. Said conveyor conveys the additives (10) from the loose-material container (9) by means of a motor (24), whose speed of rotation is adjustable, and of a worm drive connected thereto, to an electrode filler tube (26) connected at its end. Said filler tube is guided into a central opening in an electrically insulating hollow filler stopper (27), which is seated gastightly in the filling opening (28) of the hollow electrode (7) and can easily be separated from the hollow electrode (7) by turning the loose-material conveyor (25) about the pivot joint (29). The loose-material conveyor (25) can now easily be swung away, so that the replacement of a hollow electrode (7) is not hindered. Only a supporting bearing is situated on the hot hollow electrode while the sensitive parts [motor (24) and level sensors (not illustrated)] are attached at the cold end of the loose-material conveyor (25). The loose-material conveyor (25) can also be at the potential of the hollow electrode (7); in this case the hose (17) effects electrical separation from the loose-material conveyor (16).

It is important that the additives (10) are transported from a stationary loose-material store container (16) into an intermediate silo (9) which is attached at the rear end of the loose-material conveyor (25) which moves together with the electrode carrier arm (23).
It is obvious that instead of a forced-draft fan (13) a telescopic tubular chute or another conveyor plant, which either [lacuna] into an elongated silo or has joints at its ends, can be used (not illustrated).

Figures 5 to 7 show different filling states of the arc furnace (1) with scrap (5) - Figure 5 in the filled state with a length (11) of the arc (6) of approximately 60 cm, Figure 6 in a state in which over 50% has been burned away, with a length (12) of the arc (6) of approximately 30 cm, and Figure 7 in the completely burned-away state with a length (13) of the arc (6) of approximately 30 cm. Only in the partly burned-away filling state shown in Figure 6 are additives (10) conveyed through the hollow electrode (7), whereby the arc length (11) is shortened to (12).

A specific melting power (P), cf. Figure 9, can thereby be brought to high values without danger to furnace components.

In a starting phase (a) of the melting, according to Figure 5, in which the arc furnace (1) is completely filled with scrap (5), the energy of the arc (6) does not reach the furnace walls. In an end phase (c) of the melting, according to Figure 7, the scrap (5) has been completely melted down and the steel bath (4) is covered with a foaming slag (14), which also envelops the arc (6). In a critical phase (b) of the melting, according to Figure 6, in which the scrap (5) has been melted down to such an extent that the inner side walls of the arc furnace (1) are no longer completely covered with scrap (5) but sufficient melt (4) is not yet present to form a foaming slag (14), a large part of the energy of the arc (6) is lost or leads to damage to the inner side walls of the arc furnace (1) if steps are not taken to provide protection. In order to avoid such damage, the power of the arc (6) must be lowered, which reduces a specific electric melting power (P), cf. Figure 8.
In Figures 8 and 9 the relative specific electric melting power \( (P) \) per tonne of material \( (S) \) to be melted is plotted in \% on the ordinates against the time \( (t) \) in arbitrary units on the abscissa.

Figure 8 shows two successive identical power curves \((30)\), each with a starting phase \((a)\) of equal length in which the melting power \( (P) \) rises from 0 to 100\% and is kept approximately constant until a predeterminable energy limit value \( (W_G) \), which is represented in the starting phase \((a)\) by the hatched areas under the power curves \((30 - 33)\), is reached. In the critical phases \((b)\) of approximately equal length which respectively then follow, without the addition of additives \((10)\), the melting power \((P)\) is adjusted to a reduced power level, in order to protect the furnace walls, and finally to 0. The critical phases \((b)\) are followed in each case by a scrap refill phase \((e)\). A subsequent third power curve \((31)\) differs from the power curves \((30)\) in respect of the final end phase \((c)\), in which the melting power \((P)\) rises from the reduced power level to almost 100\% and is finally adjusted to 0. Then follows a melt discharge phase \((d)\) and thereupon once again a scrap refill phase \((e)\), which terminates a melting cycle \((g)\) with 3 scrap refill phases \((e)\).

Figure 9 shows a power diagram corresponding to Figure 8 in the case of the supply of additives \((10)\) during the reduced critical phases \((b')\), which replace the critical phases \((b)\) according to Figure 8, so that in all a reduced melting cycle time \((g')\) results, cf. power curves \((32) - (33)\) which correspond to the power curves \((30) - (31)\) according to Figure 8. The supply of additives \((10)\) is started as soon as the melting energy consumed reaches the predeterminable energy limit value \( (W_G) \), so that practically no power drop occurs. This energy limit value \( (W_G) \) lies in the range from 30\% to 90\%, preferably in the range from 60\% to
70% of the total melting energy per scrap filling. On the last scrap filling for each melting cycle the supply of additives (10) can be discontinued when the foaming slag phase is reached, which may be the case at approximately 90% of the total melting energy.

Example:
In the case of a melt with three scrap refill phases (e), it was possible to shorten the previous melting cycle time (g) of 60 minutes by 5 minutes, which with an arc furnace (1) with a scrap filling of 100 t and an operation lasting 320 working days gives a production increase of 8%, that is to say from 770 kt/a to 830 kt/a. Energy consumption fell by 40 kWh/t. The final consumption of hollow electrodes (7) fell by 0.2 kg/t of steel.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.
<table>
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<td>Bath electrode</td>
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<td>Arc</td>
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<tr>
<td>7</td>
<td>Hollow electrode</td>
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<tr>
<td>10</td>
<td>8, 12 Conveyor devices</td>
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<td>10</td>
<td>Loose material, additives</td>
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<td>11</td>
<td>Feed opening in 3</td>
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<tr>
<td>15</td>
<td>Container for additives</td>
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<tr>
<td>14</td>
<td>Foaming slag (14)</td>
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<tr>
<td>15</td>
<td>Forced-draft fan</td>
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<td>Second loose-material container, loose material store container</td>
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<td>18</td>
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<td>19</td>
<td>Current supply to 7</td>
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<td>Furnace platform</td>
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<td>25</td>
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<td>24</td>
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<td>Loose-material conveyor</td>
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<td>28</td>
<td>Pivot joint</td>
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<tr>
<td>30</td>
<td>- 33 Power curves</td>
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<tr>
<td>35</td>
<td>a Starting phase of melting</td>
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<tr>
<td>35</td>
<td>b Critical melting phase without feeding loose material</td>
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</table>
b' Melting phase with feeding of loose material, reduced critical phase

c Final phase of melting

d Melt discharge phase

e Scrap refill phase

g, g' Melting cycle times

5 - 13 Arc lengths

P Specific electric melting power per tonne of material to be melted

t Time

Wg Energy limit value
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of operating an arc furnace, particularly for steelmaking,
a) in which solid material to be melted and at least one additive are melted by means of an arc of at least one hollow electrode to a liquid melt.

b) during a critical melting phase (b'), in which the material to be melted is partly melted down in the arc furnace, at least one additive is conveyed through the hollow electrode into the melt.

2. The method as claimed in claim 1, wherein the feeding of the at least one additive begins after a predeterminable electric melting energy (Wg) in the range from 30% to 90% of the total melting energy per scrap filling has been reached.

3. The method as claimed in claim 2, wherein the feeding of the at least one additive begins after a predeterminable electric melting energy (Wg) in the range from 60% to 70% of the total melting energy per scrap filling has been reached.

4. An arc furnace particularly for steelmaking,
a) comprising a hollow electrode and a first loose-material conveyor for feeding loose material from a first loose-material container to a filling opening of the hollow electrode,

b) the first loose-material conveyor being arranged at a distance from the electrode, wherein

c) the first loose-material container is attached at the rear end of the first loose-material conveyor

moving together with an electrode arm.
5. The arc furnace as claimed in claim 4, wherein the first loose-material conveyor is pivotally connected to a vertically adjustable and rotatable or tiltable electrode adjustment device for the hollow electrode.

6. The arc furnace as claimed in claim 4 or 5, wherein the first loose-material conveyor is gastightly and detachably connected to the filling opening of the hollow electrode via an electrically insulating, hollow filler stopper.

7. The arc furnace as claimed in one of claims 4 to 6, wherein the first loose-material conveyor is connected to a second loose-material container via a conveyor device.

8. The arc furnace as claimed in one of claims 4 to 7, wherein the first loose-material conveyor is connected to a second loose-material container via an electrically insulating hose.

9. The arc furnace as claimed in one of claims 4 to 8, wherein the loose material contains at least one additive.

10. The arc furnace as claimed in one of claims 4 to 9, wherein the arc furnace is tiltable or rotatable.

DATED THIS 21 DAY OF MARCH 1997

ASEA BROWN BOVERI AG
Patent Attorneys for the
Applicant:
F.B.RICE & CO.
ABSTRACT OF THE DISCLOSURE

In order to avoid damage to the inner walls of the arc furnace (1) and a reduction of the electric power when material (5) to be melted has been partly burned down in an arc furnace (1), additives (10) are fed to the filling opening of a hollow electrode (7) by means of a loose-material conveyor (25) during this critical melting phase. An arc (6) between the hollow electrode (7) and a melt (4) in the arc furnace (1) is thereby shortened. A loose-material container (9) is arranged at the end of the loose-material conveyor (25) at a distance from the electrode and can easily be separated from the hollow electrode (7) in order to permit the tilting of the arc furnace (1) to empty out the melt (4). Problematic waste materials which are to be disposed of, such as for example filter dust, can be added to the additives (10).

(Figure 6)
The furnace transformer is used...