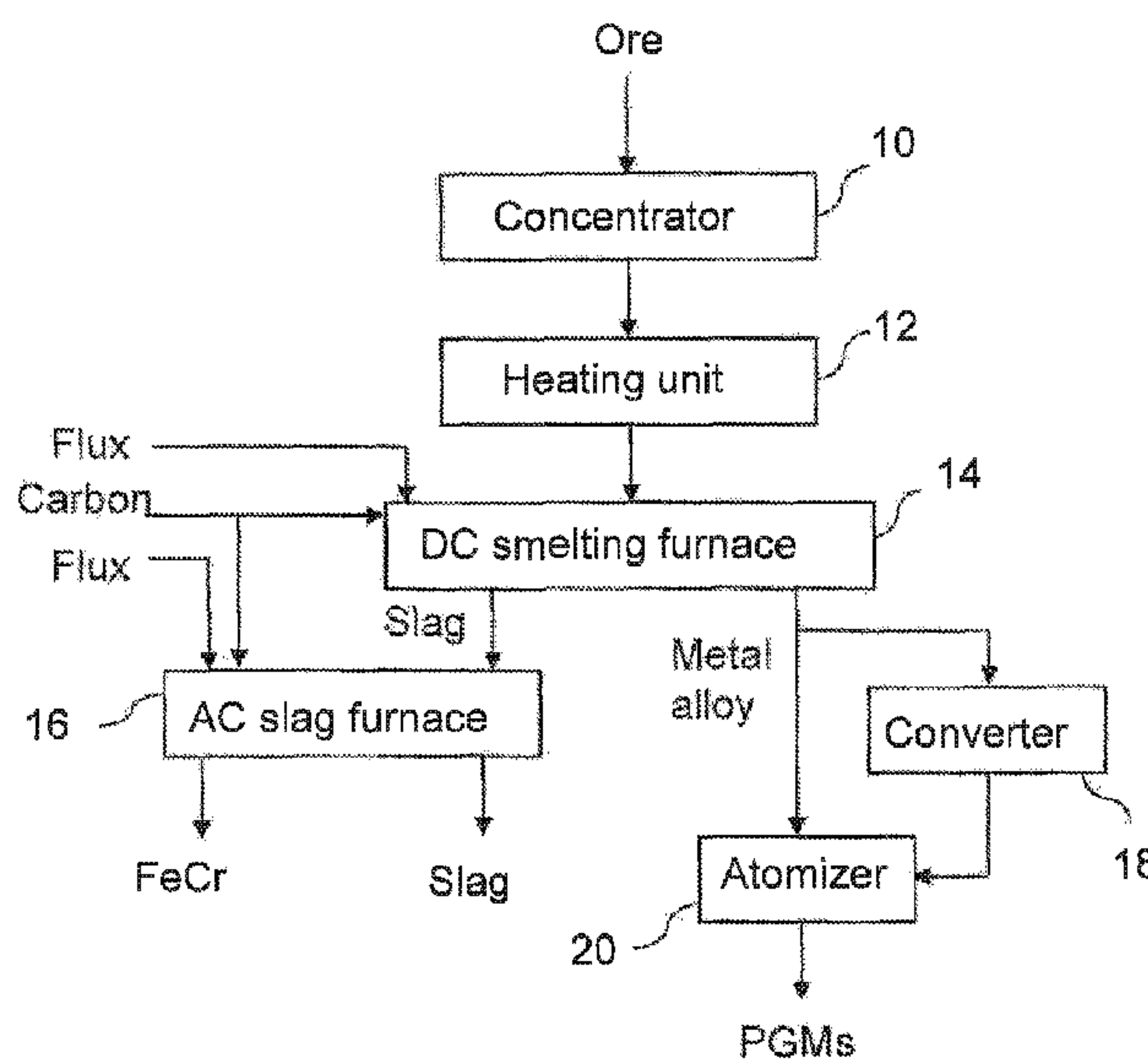




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(54) Titre : PROCÉDE ET APPAREIL POUR LA RECUPERATION DE PGM ET FERROCHROME A PARTIR DE MINÉRAIS DE CHROMITE PORTEURS DE PGM
 (54) Title: METHOD AND APPARATUS FOR RECOVERING PGM AND FERRO-CHROME FROM PGM BEARING CHROMITE ORE



(57) **Abrégé/Abstract:**

In a method for recovering PGMs and ferrochrome from platinum group metals bearing chromite ore, a concentrate is prepared that contains most of PGMs and chromite of the ore and the concentrate is subjected to a heating step to dry and/or preheat the concentrate, after which the preheated concentrate is smelted under reducing conditions in a DC smelting furnace (14) to produce molten metal alloy containing the PGMs of the feed and molten slag containing the chromium of the feed. The molten slag is tapped from the smelting furnace (14) into an AC slag furnace (16), where iron and chromium are reduced to produce a ferrochrome alloy. PGMs are recovered from the metal alloy tapped from the smelting furnace (14) utilizing hydro-metallurgical processes.

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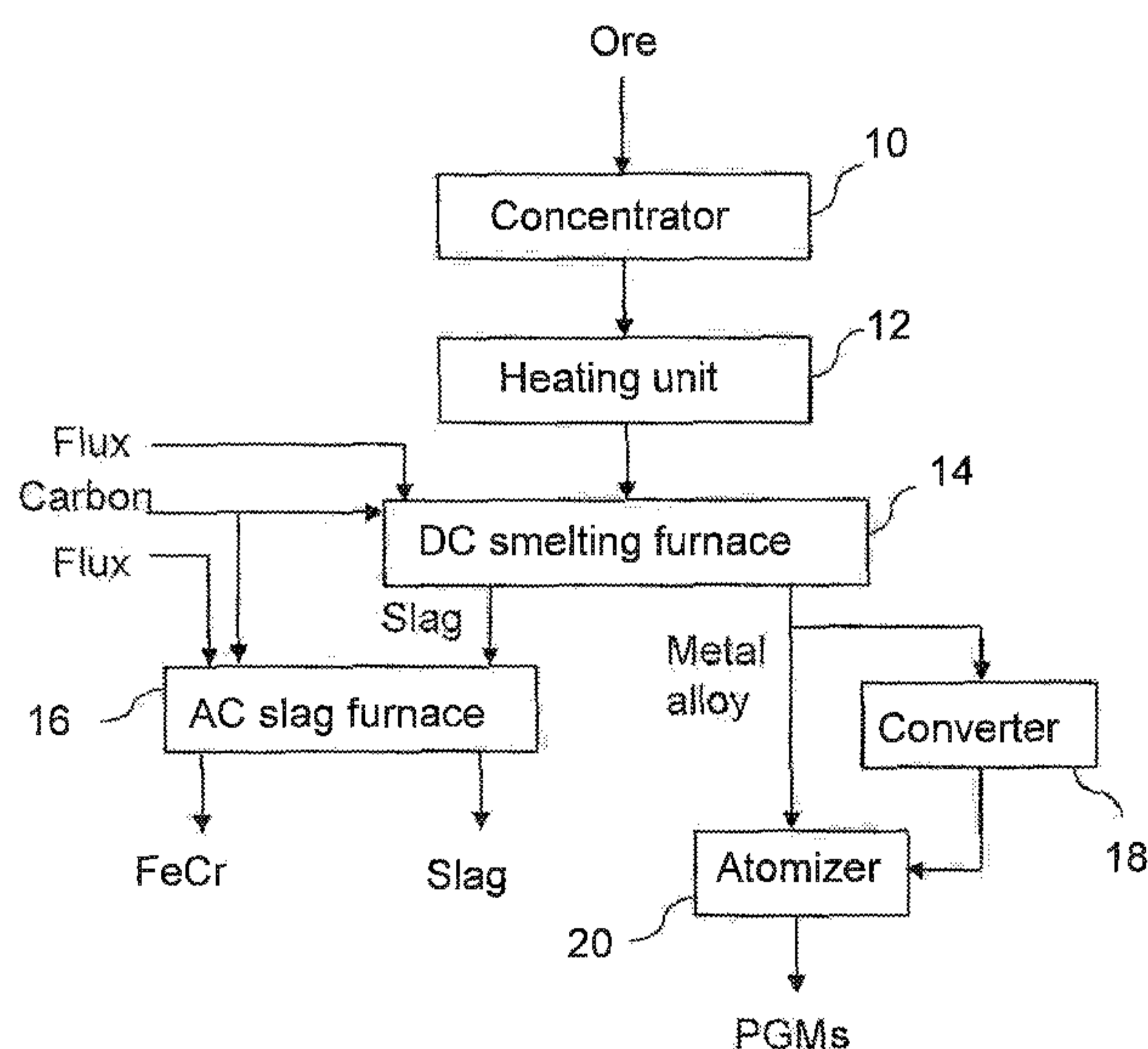


Fig. 1

(57) Abstract: In a method for recovering PGMs and ferrochrome from platinum group metals bearing chromite ore, a concentrate is prepared that contains most of PGMs and chromite of the ore and the concentrate is subjected to a heating step to dry and/or preheat the concentrate, after which the preheated concentrate is smelted under reducing conditions in a DC smelting furnace (14) to produce molten metal alloy containing the PGMs of the feed and molten slag containing the chromium of the feed. The molten slag is tapped from the smelting furnace (14) into an AC slag furnace (16), where iron and chromium are reduced to produce a ferrochrome alloy. PGMs are recovered from the metal alloy tapped from the smelting furnace (14) utilizing hydro-metallurgical processes.

**METHOD AND APPARATUS FOR RECOVERING PGM AND FERRO-
CHROME FROM PGM BEARING CHROMITE ORE**

FIELD OF THE INVENTION

5 The invention relates to a method and an apparatus for recovering platinum group metals and ferrochrome from PGM bearing chromite ore.

BACKGROUND OF THE INVENTION

10 Most of the world's known platinum reserves are located in South Africa, which produces most of the world's platinum. South Africa is also the world's largest single producer of ferrochrome. Platinum group metals, or PGMs, include platinum, rhodium, palladium,
15 ruthenium, iridium, osmium. PGMs frequently occur together with chromites. The platinum industry in South Africa is increasingly moving from traditional Merensky reef to UG2 reef as a raw material. The UG2 reef contains most of the world's known PGM reserves, and
20 it also has high chromite content.

 There are some challenges in using UG2 based raw material with current PGM recovery processes. One of the challenges is that traditional smelting furnaces cannot use a concentrate that contains over 2.5%
25 Cr. If the chromium content is too high, Cr tends to create crust in the smelting furnace and the explosion risk is high. Traditional six-in-line smelting furnaces are susceptible to build-ups of high-melting chromite spinels if the Cr_2O_3 content of the feed is too
30 high. Also the furnace control is very challenging. Furthermore, concentration process is rather complicated when the target is to separate the chromite from the PGMs. Traditionally, UG2 ore has been concentrated by removing chromite from the ore as far as possible
35 to reach low chromite content in the PGM smelting furnace feed. It is very difficult to totally remove

chromite from the concentrate by flotation. Chrome melts at temperatures above 1600°C, whereas PGM smelting furnaces operate at 1400-1500°C. The presence of chromium in the feed leads to lower furnace reduction efficiency and chromite can also damage the smelting furnace.

The UG2 concentration process used by the platinum industry in South Africa produces lots of chromite-containing tailings. Ferrochrome producers can use these tailings as raw material. South Africa suffers from shortage of electricity, which is why local producers cannot use all chromite-containing tailings of platinum industry but tailings are exported to China. The Chinese are building a lot of ferrochrome capacity now, which is worrying for the South African producers. One of the targets of the present invention is to provide a process that allows the South Africans to use their UG2 reserves more completely in their own country.

Attempts have been made to develop pyrometallurgical processes that tolerate higher chromite contents in the PGM concentrate. US 6,699,302 B1 discloses a method for processing metal sulfide concentrate that contains at least one metal selected from the group consisting of the PGMs, nickel, cobalt and zinc. The method comprises dead-roasting the metal sulfide concentrate, smelting the dead-roasted concentrate under reducing conditions in an electrically stabilized open-arc furnace, and collecting the metals from the smelting step in the form of an alloy or vapor. Chrome is an unwanted element and it is removed from the metal alloy in a converter.

Although the process of US 6,699,302 B1 can use raw materials with high chromium content, chrome is finally discarded from the process. Furthermore, the process is designed only for use with sulfide raw materials.

The industry lacks a process that effectively combines the recovery of PGMs and ferrochrome from a PGM bearing chromite ore, such as UG2.

5 **PURPOSE OF THE INVENTION**

The purpose of the present invention is to eliminate or at least reduce the problems of the prior art.

10 A further purpose is to provide a new process for effective utilization of PGM bearing chromite ore.

SUMMARY

In one aspect, there is provided a method for recovering platinum group metals and ferrochrome from PGMs bearing chromite ore, comprising the steps of:

- preparing a concentrate that contains most of the PGMs and chromite of the ore,
- subjecting the concentrate to a heating step to dry and/or preheat the concentrate,
- 20 - smelting the concentrate under reducing conditions in a DC smelting furnace (14) to produce molten metal alloy containing the PGMs of the feed and molten slag containing the chromium of the feed,
- tapping the molten slag from the smelting
- 25 furnace (14) into an AC slag furnace (16),
- reducing oxides of iron and chromium contained in the slag in the AC slag furnace (16) to produce ferrochrome alloy.

In one aspect, there is provided an apparatus for recovering platinum group metals and ferrochrome from PGMs and chromite containing ore concentrate, comprising a DC smelting furnace (14) arranged to receive the PGMs and chromite containing ore concentrate as a feed, which DC smelting furnace (14) is arranged to produce a molten metal alloy containing the PGMs of the feed and a molten slag containing the chromium of

the feed, and an AC slag furnace (16) arranged to receive the molten slag tapped from the DC smelting furnace (14), which AC slag furnace (16) is arranged to produce a ferrochrome alloy from the molten slag
5 tapped from the DC smelting furnace (14).

The new method comprises preparing a concentrate that contains most of the PGMS and chromite of the ore, subjecting the concentrate to a heating step to dry and/or preheat the concentrate, and smelting
10 the concentrate under reducing conditions in a DC smelting furnace to produce molten metal alloy that contains the PGMS of the feed and molten slag that contains the chromium of the feed. The molten slag is tapped from the smelting furnace into an AC slag furnace,
15 where reduction of the oxides of iron and chromium contained in the slag takes place so that ferrochrome is produced.

According to one embodiment of the invention the heating step additionally comprises roasting the
20 concentrate to remove sulfur and/or volatiles contained in the concentrate.

According to one embodiment of the invention the slag properties are controlled with flux.

Advantageously the method comprises adding flux and/or reductant into the smelting furnace and/or into the slag furnace.

5 According to one embodiment of the invention the reducing conditions in the smelting furnace and/or in the slag furnace are controlled with the addition of reductant.

10 According to one embodiment of the invention the slag properties in the smelting furnace and/or in the slag furnace are controlled with the addition of flux.

15 Advantageously molten metal alloy is tapped from the smelting furnace, after which PGMs are recovered from the metal alloy by hydrometallurgical processes or a combination of pyrometallurgical and hydrometallurgical processes.

20 According to one embodiment of the invention molten metal alloy from the smelting furnace is tapped to a Peirce-Smith converter, after which the converted metal alloy is subjected to atomization and hydrometallurgical process steps.

25 According to another embodiment of the invention molten metal alloy is tapped from the smelting furnace directly to an atomizer, after which the atomized metal alloy is subjected to hydrometallurgical process steps.

30 The new apparatus comprises a DC smelting furnace for producing a molten metal alloy containing the PGMs of the feed and a molten slag containing the chromium of the feed, and an AC slag furnace for producing a ferrochrome alloy from the molten slag tapped from the DC smelting furnace.

35 According to one embodiment of the invention the apparatus further comprises a heating unit for drying and/or preheating the concentrate before it is fed to the smelting furnace. The heating unit is preferably selected from a group comprising a fluidized

bed reactor, a rotary kiln, a drying tower, or similar.

The slag furnace can be an open bath alternative current furnace, or similar.

5 According to one embodiment of the invention the apparatus further comprises a Peirce-Smith converter for removing iron from the molten metal alloy tapped from the smelting furnace.

10 According to another embodiment of the invention the apparatus further comprises an atomizer for atomizing the molten metal alloy tapped from the smelting furnace or from the converter.

15 Instead of using tailings from a PGM concentrator, the present invention proposes using molten slag from a PGM smelter as a raw material in ferrochrome production. According to the new method both PGMs and ferrochrome are produced at the same time, which gives flexibility for the use of raw material and makes the concentration of PGM and chromite containing ore easier. The process also saves energy compared to current recovery processes. The ferrochrome containing slag fraction need not to be cooled and reheated before introduction into ferrochrome process.

20 The present invention allows adjusting the Cr/Fe ratio in the ferrochrome by controlling how much iron is reduced in the smelting furnace. Typical use of pure UG2 ore results in Cr/Fe ratio of around 1.35, which means that the Cr content in the ferrochrome is below 50%. Higher Cr contents are preferred by the end users of ferrochrome, i.e. stainless steel industry.

BRIEF DESCRIPTION OF THE DRAWINGS

35 The accompanying drawing, which is included to provide further understanding of the invention and constitutes a part of this specification, illustrates an embodiment of the invention and together with the

description helps to explain the principles of the invention.

The enclosed Figure 1 is a flow chart illustration of one embodiment of a process according to the present invention.

DETAILED DESCRIPTION OF AN EMBODIMENT

PGM bearing chromite ore is fine grinded to liberate the PGM particles. The fine grinded ore is concentrated in a concentrator 10, where the target is to remove gangue while keeping iron, chromium, base metals and PGMs in the concentrate. The process is simpler than the concentration processes currently used in PGM recovery, because there is no need to separate chrome and iron from the base metals and PGMs.

The concentrate is subjected to heat treatment in a heating unit 12, where the concentrate is dried, if necessary, and possibly preheated before it is fed to a smelting furnace 14. The heating unit 12 can be, for instance, a fluidized bed reactor, a rotary kiln, or a drying tower. If the raw material contains lots of sulfides and/or volatiles, roasting can be carried out in the heating unit 12 to oxidize the metal sulfides. CO gas generated in subsequent smelting and slag furnaces 14, 16 can be used as a heat source in the heating unit 12.

The preheated concentrate is charged as a feed into a DC smelting furnace 14. At the same time, carbonaceous reductant, such as anthracite or coke, is charged to the smelting furnace 14. Also some flux may be charged, if necessary.

In the DC smelting furnace 14 the concentrate is melted and the PGMs, base metals and part of the iron contained in the feed are reduced to elemental metal, which is separated as a molten metal alloy below the lighter slag phase. However, most of the feed goes into the slag phase. For instance, all Cr and

most of Fe, Al₂O₃, SiO₂, MgO and CaO of the feed go into the slag phase. Reduction in the smelting furnace 14 is limited by controlling the amount of carbon charged to the furnace 14. The target is only to get the PGMs into metal phase together with just a part of the iron. Iron droplets capture the PGMs and other base metals, forming molten metal alloy. Ni and Cu can also be present in the molten metal alloy produced in the smelting furnace 14.

10 In the direct current (DC) smelting furnace 14 the charged material is directly exposed to an electric arc, and the current between a cathode and an anode passes through the charged material. Energy is supplied by open plasma arc. The temperature in the
15 smelting furnace 14 is relatively high, which is why reactions are quick. The plasma arc agitates the slag phase and creates strong currents, which further improves reactions. A carbon monoxide atmosphere is created in the closed furnace. One more advantage of using a DC smelting furnace is that it allows charging
20 fine grinded material.

Liquid slag is tapped from the DC smelting furnace 14 to an AC slag furnace 16. Liquid metal alloy is tapped from the bottom of the DC smelting furnace 14 to further refining steps in pyrometallurgical and/or hydrometallurgical processes.

The slag furnace 16 is preferably an open bath alternative current furnace where electrodes are buried in a burden of lumpy materials comprised of molten slag received from DC smelting furnace. Carbonaceous reductant and flux are charged to the AC furnace to control the reduction reactions and to optimize the amount and quality of slag. Typical ferrochrome furnace operations comprise reduction of oxides
30 of iron and chromium into metal phase. The resulting slag mainly contains Al₂O₃, MgO, CaO and SiO₂. Metal alloy received from the slag furnace 16 contains Fe,

Cr, some C and Si. All the rest of the feed is retained in the slag. Products received from the slag furnace 16 are ferrochrome metal and slag. Typically, the temperature of the slag tapped from the AC slag furnace 16 is 1650-1750°C and the temperature of the ferrochrome tapped from the AC slag furnace 16 is 1550-1600°C.

PGM rich metal alloy tapped from the smelting furnace 14 can either be directly passed to hydrometallurgical treatment steps or it can be converted in a Peirce-Smith converter 18 before passing to hydrometallurgical treatment. The purpose of converting is to remove iron and other impurities from the metal alloy. The recovery of PGMs can comprise, for instance, atomization in an atomizer 20 and leaching.

The basic idea of the present innovation is to smelt the concentrate in a DC smelting furnace 14, where PGMs are reduced, and then to produce FeCr alloy from the slag of the DC smelting furnace in a separate AC slag furnace 16. This gives flexibility as regards the raw materials and simplifies the concentrating process 10.

Benefits of the new process comprise simplicity of the preceding concentration process as there is no need to remove chromite at an early stage. As FeCr and PGMs are produced at the same time, less concentration, cooling and melting is needed and the process is more energy efficient. The safety of the process is improved as there is no risk of crust formation or explosion. There are fewer restrictions for raw materials and no limits for the Cr content of the feed. Neither Cr nor PGMs are lost in the process.

It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not

limited to the examples described above; instead they may vary within the scope of the claims.

CLAIMS

1. A method for recovering platinum group metals and ferrochrome from PGMs bearing chromite ore, comprising the steps of:

- preparing a concentrate that contains most of the PGMs and chromite of the ore,
- subjecting the concentrate to a heating step to dry and/or preheat the concentrate,
- smelting the concentrate under reducing conditions in a DC smelting furnace (14) to produce molten metal alloy containing the PGMs of the feed and molten slag containing the chromium of the feed,
- tapping the molten slag from the smelting furnace (14) into an AC slag furnace (16),
- reducing oxides of iron and chromium contained in the slag in the AC slag furnace (16) to produce ferrochrome alloy.

2. The method according to claim 1, wherein the heating step also comprises roasting the concentrate to remove sulfur and/or volatiles contained in the concentrate.

3. The method according to claim 1 or 2, wherein the slag properties are controlled with flux.

4. The method according to any one of claims 1 to 3, comprising adding flux and/or reductant into the smelting furnace (14) and/or into the slag furnace (16).

5. The method according to claim 4, wherein the reducing conditions in the smelting furnace (14) and/or in the slag furnace (16) are controlled with the addition of reductant.

6. The method according to any one of claims 3 to 5, wherein the slag properties in the smelting furnace (14) and/or in the slag furnace (16) are controlled with the addition of flux.

7. The method according to any one of claims 1 to 6, comprising tapping molten metal alloy from the smelting furnace (14) and recovering PGMs from the metal alloy.

8. The method according to claim 7, wherein the tapped molten metal alloy is passed directly to hydrometallurgical treatment steps.

9. The method according to claim 7, comprising tapping molten metal alloy from the smelting furnace (14) to a Peirce-Smith converter (18) and subjecting the converted metal alloy to atomization and hydrometallurgical process steps.

10. The method according to claim 7, comprising tapping molten metal alloy from the smelting furnace (14) to an atomizer (20) and subjecting the atomized metal alloy to hydrometallurgical process steps.

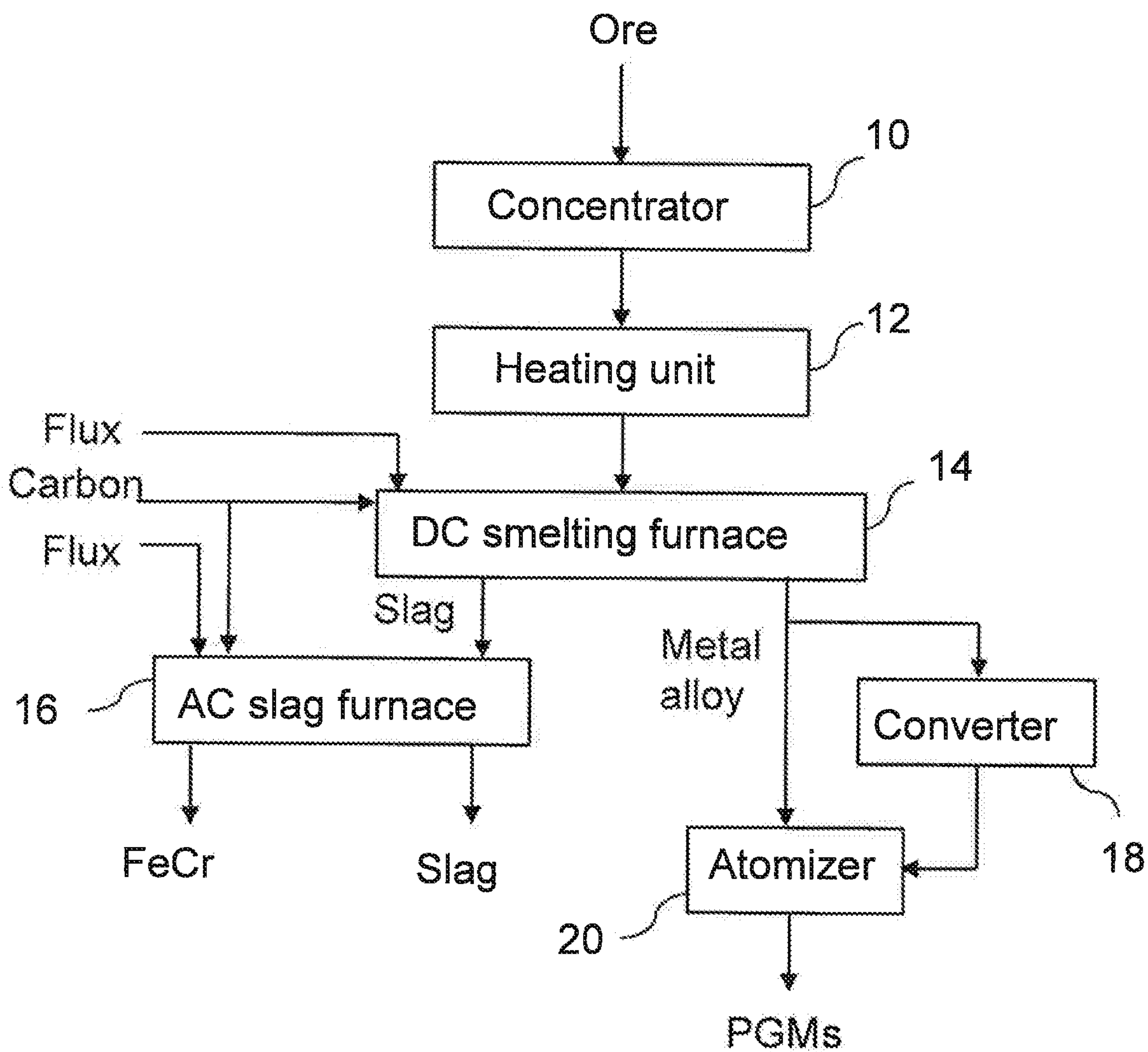


Fig. 1

