

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(PCT Rule 71.1)

To:

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Date of mailing
(day/month/year)

09.10.2023

Applicant's or agent's file reference
P-PWU-836/WO

IMPORTANT NOTIFICATION

International application No.
PCT/EP2022/078607

International filing date (day/month/year)
14.10.2022

Priority date (day/month/year)
19.10.2021

Applicant
PAUL WURTH S.A.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary report on patentability and its annexes, if any, established on the international application.
2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.
3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary report on patentability. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed inventions is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the international
preliminary examining authority:



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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P-PWU-836/WO	FOR FURTHER ACTION		See Form PCT/IPEA/416
International application No. PCT/EP2022/078607	International filing date (day/month/year) 14.10.2022	Priority date (day/month/year) 19.10.2021	
International Patent Classification (IPC) or national classification and IPC INV. C21B11/02			
Applicant PAUL WURTH S.A.			
1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36. 2. This REPORT consists of a total of <u>6</u> sheets, including this cover sheet. 3. This report is also accompanied by ANNEXES, comprising: a. ☒ a total of <u>7</u> sheets, as follows: ☒ sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions). ☐ sheets containing rectifications, where the decision was made by this Authority not to take them into account because they were not authorized by or notified to this Authority at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4bis, 70.2(e), 70.16 and 91.2). ☐ superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)). b. ☐ a separate electronic file containing a sequence listing (<i>sent to the International Bureau only</i>)			
4. This report contains indications relating to the following items: ☒ Box No. I Basis of the report ☐ Box No. II Priority ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability ☐ Box No. IV Lack of unity of invention ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement ☐ Box No. VI Certain documents cited ☐ Box No. VII Certain defects in the international application ☐ Box No. VIII Certain observations on the international application			
Date of submission of the demand 04.08.2023		Date of completion of this report 09.10.2023	
Name and mailing address of the international preliminary examining authority:  European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Fax: +31 70 340 - 3016		Authorized officer Gimeno-Fabra, Lluís Telephone No. +31 70 340-2362	



Box No. I Basis of the report

1. With regard to the **language**, this report is based on
- ☒ the international application in the language in which it was filed
 - ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of:
 - ☐ international search (under Rules 12.3(a) and 23.1(b))
 - ☐ publication of the international application (under Rule 12.4(a))
 - ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a) and (b))
2. With regard to the **elements*** of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):

Description, Pages

1-17 as originally filed

Claims, Numbers

1-16 filed in electronic form on 04-08-2023

Drawings, Sheets

1/1 as originally filed

- ☐ a sequence listing - see Supplemental Box Relating to Sequence Listing.
3. ☐ The amendments have resulted in the cancellation of:
- ☐ the description, pages
 - ☐ the claims, Nos.
 - ☐ the drawings, sheets/figs
 - ☐ the sequence listing (*specify*):
4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (c-bis)):
- ☐ the description, pages
 - ☐ the claims, Nos.
 - ☐ the drawings, sheets/figs
 - ☐ the sequence listing (*specify*):
5. ☐ This report has been established:
- ☐ taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-bis) and 70.2(e)).
 - ☐ without taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91(Rules 66.4bis and 70.2(e)).

**INTERNATIONAL PRELIMINARY REPORT
ON PATENTABILITY**

International application No.
PCT/EP2022/078607

6. ☒ With regard to top-up searches (Rules 66.1 *ter* and 70.2(f)):
- ☒ A top-up search was carried out by this Authority on 26.09.2023 (all discovered documents are listed in the Supplemental Box Relating to Top-up Search).
 - ☐ Additional relevant documents have been discovered during the top-up search.
 - ☐ No top-up search was carried out by this Authority because it would serve no useful purpose.
7. ☐ Supplementary international search report(s) from Authority(ies) has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

* If item 4 applies, some or all of those sheets may be marked "superseded".

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	<u>1-16</u>
	No: Claims	
Inventive step (IS)	Yes: Claims	<u>1-16</u>
	No: Claims	
Industrial applicability (IA)	Yes: Claims	<u>1-16</u>
	No: Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

- D1 US 8 926 728 B2 (NEPPER JEAN-PAUL [DE]; STEFAN TOBIAS [DE];
 OUTOTEC OYJ [FI]) 6 January 2015 (2015-01-06)
- D2 WO 2013/029119 A1 (ILUKA RESOURCES LTD [AU]; BERNARD
 NICHOLAS GLEN [AU] ET AL.) 7 March 2013 (2013-03-07)
- D3 CN 110 317 917 B (UNIV NORTHEASTERN) 1 January 2021 (2021-01-01)

D1 may be regarded as being the prior art closest to the subject-matter of claim 1, and discloses

A multi-step method for producing pig iron (P), the method comprising the steps of and being schematically depicted by the features of Fig. 1:

- a) pre-heating iron ore fines pre-heater to a temperature above 600 °C to obtain pre-heated iron ore fines (9);
- b) partially reducing the pre-heated iron ore fines in one or more fluidized bed reactors in presence of a hot reducing gas to obtain partially reduced iron (13);
- c) feeding the partially reduced iron to a submerged arc furnace comprising a bath of molten metal with a top slag layer (31) and,
- d) further reducing and melting the partially reduced iron within the submerged arc furnace in the presence of a carbonaceous material to obtain molten pig iron (Pig Iron, Figure 1);

Also in D1, in step a) the material is preheated to 300°C-500°C and in step b) the hot reducing gas has a temperature above 550 °C (roughly 800°C); and wherein, in step b), the partially reduced iron has a metallization degree of preferably 70 % (see D1, col. 5, l. 35-60).

Claim 1 further defines that the reducing gas of step b) comprises hydrogen, syngas, off-gas of the submerged arc furnace, other off-gases from the metallurgical plant, or mixtures thereof, wherein said syngas is produced from natural gas or biomethane, blast furnace gas, or mixtures thereof in the presence of air or oxygen-enriched air in one or more catalytic partial oxidation reactors.

The subject-matter of claim 1 therefore differs from this known D1, in that in claim 1:

- the pre-heater is electric or by microwaves -hence without solid-gas interaction-
- the reducing gas is the only reductant in the process

Claim 1 is novel in the sense of Art. 33(2) PCT.

Reference is made to claim 10, that in the present case is considered novel, because it seems intrinsic that the device of claim 10 would be constructionally different to the device of D1, as the reductant used in claim 10 is only in gaseous form.

Correspondingly the same applies to the nature of the pre-heater. Hence claim 10 is also considered novel in the sense of Art. 33(2) PCT.

The differences provide a combined technical effect: The electric preheating of the charge (only fine ore) in claims 1 and 10, enables the relatively high reduction degree of the ore in the pre-reduction stage without use of solid carbonaceous materials redundant, hence reducing CO₂ emissions.

The problem to be solved is therefore to provide an alternative pre-heating system to the charge, enabling the elimination of solid carbonaceous reductant.

While electrical pre-heating is a known solution in the field, that would be considered as applicable to preheating of ores, from for example D2 (p. 8, l. 5-13), it is emphasised that in the present case, the pre heating specifically enables the elimination of solid carbonaceous reductant, which is usually rendered necessary in the usual pre-reduction stages in the area.

Hence claim 1 and mutatis mutandis corresponding device claim 10, as well as their dependent claims are inventive in the sense of Art. 33(3) PCT.

D3 is cited herein as related general art (see Fig. 1).

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OFFICE FREYLINGER S.A.
RCS LUX B 65 192
VAT-No. LU 17560609

Strassen, 2 August 2023

International Patent application (PCT-Application)

Title: Method for reducing carbon footprint in operating a metallurgical plant for producing pig iron
Application Data: No. PCT/EP2022/078607 of 14 October 2022
Applicant(s): PAUL WURTH S.A.
Our reference: P-PWU-836/WO

Dear Sirs,

The present letter is in response to the Written Opinion of the International Searching Authority, issued with regard to the above-identified PCT application.

Amendments

The Applicant respectfully submits an amended set of claims, now comprising 16 claims.

Claim 1 is amended to specify that at step b), the hot reducing gas (J) is the sole reductant, based on [0008] and [0009] of the description of the application as filed.

A new claim 7 is added, to specify that the carbonaceous material (M) is at least partially, preferably entirely, introduced into the briquetted partially reduced iron (L) during hot briquetting and fed to the electric smelter submerged arc furnace (70) in step d), based on e.g. [0028] and [0041] of the description of the application as filed.

Original claims 7-15 are renumbered and their dependencies revised accordingly.

Amended claim 10 (original claim 9) is amended correspondingly to claim 1 to specify that the hot reducing gas (J) is the sole reductant, based on [0008] and [0009] of the description of the application as filed.

It is believed that the amendments made do not extend beyond the scope of the patent application as originally filed. Thus, the subject matter of the amended set of claims is in compliance with Article 34(2)(b) PCT.

Novelty

The Examiner acknowledged the novelty of the subject-matter of claims 1 and 9 as filed. As currently amended claims 1 and 10, respectively, comprise all the features of original claims 1 and 9, their subject-matter is novel as well.

Current claims 2-9 comprising all the features of claim 1 and current claims 11-16 comprising all the features of claim 10, their subject-matter is also novel over the cited prior art.

The Applicant therefore submits that the application meets the requirements of Art. 33(1) and 33(2) PCT.

Inventive Step

The aim of the present invention is to propose a method for reducing carbon footprint in operating a metallurgical plant for producing pig iron, and a corresponding plant. As mentioned in the description, the core of the proposed method and metallurgical plant is based on a partial (pre-)reduction step in one or more fluidized bed reactors to a metallization degree of 55 to 75 %, preferably 60 to 70 %, based only on hot gaseous reductants, followed by an electric smelter of the submerged arc furnace (SAF) type, where smelting and the completion of the reduction take place (see [0008]).

Consequently, the invention takes advantage of a combination of findings, one of them being that the partial reduction can be obtained when effected with only hot reducing gas as a reductant, which moreover can be at least partially based on off-gases available on a metallurgical plant, such as the off-gas of the submerged arc furnace of the method itself or of other processes, but also other off-gases (see [0009]).

In other words, **according to the present invention, the hot reducing gas is the SOLE reductant involved in the pre-reduction of the iron ore fines and there is NO solid reductant.**

On the contrary, according to D1 (US 8,926,728 B2), the pre-reduction of the iron ore fines occurs through the use of a solid carbonaceous reducing agent e.g. in the form of coal or char (see column 5, lines 29-33 and lines 58-60).

Therefore, the present invention distinguishes over D1 not only by the fact that in the present invention the pre-heater is electric, as acknowledged by the Examiner in his Written Opinion, but also by the fact that the reducing gas is the sole reductant in the pre-reduction step.

The technical effect of such a difference is that the method and metallurgical plant are particularly adapted to make use of renewable resources as energy source and gaseous reducing agents, such as “green” hydrogen, and “green” electricity. Moreover, the method can be flexibly and gradually converted to a full green operation (zero carbon dioxide emission), depending on the resources’ availability. The method is also particularly aimed at allowing for a mixed operation with (varying proportions of) hydrogen, recirculated CO-containing metallurgical off-gas(es) and syngas, with an enhanced flexibility in conversion to “green” operation depending on sources availability and costs (see [0014]).

The problem solved by the present invention may therefore be regarded as how to further decrease the carbon footprint of pig iron production to turn it into a zero-CO₂-emission operation.

While it is hereby acknowledged that a skilled person considering the teachings of D1 might be prompted to use a gaseous reducing agent, he certainly would not be motivated to forego the use of a solid reductant, at least not without simply disregarding the gist and teaching of D1, which clearly and unambiguously mentions that “As reducing agent, a gas mixture containing CO/H₂, preferably a gas mixture of 60 to 80 vol-% CO and 20 to 40 vol-% H₂ preferably is used in combination with char” on column 5, lines 58-60.

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Accordingly, he would not find any incentive in D1 that could have prompted him to replace the solid reductant by using a reducing gas as the sole reductant.

If the skilled person were to consider the teachings of D2 (WO 2013/029119 A1), he also would not find any teachings therein that could have prompted him to partially reduce the pre-heated iron ore fines in presence of only hot reducing gas as a reductant.

First of all because D2 is not concerned with the pre-reduction of iron ore fines, but more importantly because D2 clearly and unambiguously mentions that the reductant is aluminium, and certainly not a hot gas (see e.g. page 5, lines 23-24).

In view of the above, the Applicant submits that a skilled person wishing to improve a method for reducing carbon footprint in operating a metallurgical plant for producing pig iron, and considering the teachings of D1 and D2, alone or in combination, would not find any incentive therein that could have prompted him to develop a method as claimed in the present application, and certainly not without inventive skills.

Any other conclusion must be based on hindsight after having full knowledge of the present invention.

From the above considerations, it must be concluded that the subject-matter of claim 1 involves an inventive step in view of the cited prior art.

The same reasoning applies mutatis mutandis to the subject matter of claim 10.

As claims 2 to 9 depend on claim 1 and claims 11 to 16 depend on claim 10, their subject-matter also involves an inventive step.

The Applicant therefore submits that the present application also meets the requirements of Art. 33(1) and 33(3) PCT.

In conclusion, we respectfully submit that the amended claims enclosed herewith meet the requirements of Article 33 PCT. Issuance of an International Preliminary Examination Report with a positive statement on novelty, inventive step and industrial applicability is requested.

In case the Examiner should disagree with the above reasoning and intend to issue an IPER with a negative statement on novelty and inventive step, we respectfully request that the undersigned be contacted for an informal interview by telephone (Rule 66.6 PCT) or that the Applicant is given an additional opportunity for submitting amendments or arguments (Rule 66.4(b) PCT).

Yours faithfully,

OFFICE FREYLINGER S.A.

Henri KIHN/FD23119550.doc/PT-I600WO/HKN
Professional Representative

Encl.: ✓ A set of amended claims
 ✓ Same with revision marks

Claims

1. A method for reducing carbon footprint in operating a metallurgical plant for producing pig iron (P), the method comprising the steps of:
 - a) pre-heating iron ore fines (A) in a first electric pre-heater (10) based on Joule effect and/or microwave heating to a temperature above 600 °C to obtain pre-heated iron ore fines (B);
 - b) partially reducing the pre-heated iron ore fines (B) in one or more fluidized bed reactors (50) in presence of only hot reducing gas (J) as a reductant to obtain partially reduced iron (K, L);
 - c) feeding the partially reduced iron (K, L) to a submerged arc furnace (70) comprising a bath of molten metal with a top slag layer;
 - d) further reducing and melting the partially reduced iron (K, L) within the submerged arc furnace (70) in the presence of a carbonaceous material (M) to obtain molten pig iron (P);

wherein, in step b), the hot reducing gas (J) comprises hydrogen (D), syngas (I), off-gas (O) of the submerged arc furnace, other off-gases (H) from the metallurgical plant, or mixtures of two or more thereof, wherein said syngas (I) is produced from natural gas or biomethane (F), blast furnace gas (G), off-gas (O) of the submerged arc furnace, other off-gases (H) from the metallurgical plant, or mixtures of two or more thereof in one or more reforming reactors (40) in the presence of air or oxygen-enriched air, steam or carbon dioxide (E);

wherein, in step b), the hot reducing gas (J) has a temperature above 550 °C;

and wherein, in step b), the partially reduced iron (K, L) has a metallization degree of 55 to 75 %, preferably 60 to 70 %.
2. The method according to claim 1, wherein the one or more fluidized bed reactors (50) is/are of a circulating type.
3. The method according to claim 1 or 2, wherein the hydrogen (D) is pre-heated in a second electric pre-heater (20) and off-gas (O) of the submerged arc furnace and optional other off-gases (H) from the metallurgical plant are pre-heated in a third electric pre-heater (30), both second and third pre-heaters being

independently based on Joule effect and/or microwave heating to a temperature above 700 °C.

4. The method according to any one of the preceding claims, wherein the carbonaceous material (M) in step d) comprises or consists of bio-char produced by biomass, optionally including demolition wood, such as up to 40 wt.-%, and/or waste plastics, such as up to 20 wt.-%.
5. The method according to any one of preceding claims, wherein the iron ore fines (A) have a grainsize distribution in the range 0,1 – 1 mm.
6. The method according to any one of the preceding claims, wherein step b) further comprises hot briquetting partially reduced iron ore fines (K) to obtain briquetted partially reduced iron (L).
7. The method according to claim 6, wherein the carbonaceous material (M) is at least partially, preferably entirely, introduced into the briquetted partially reduced iron (L) during hot briquetting and fed to submerged arc furnace (70) in step d).
8. The method according to any one of the preceding claims, wherein the other off-gases (H) of the metallurgical plant comprise one or more of off-gases from a coke oven plant, a Direct Reduced Iron plant and basic oxygen furnace.
9. The method according to any one of the preceding claims, wherein all electrical energy needed in the pre-heater(s) and the submerged arc furnace, preferably in all of the steps of the method is renewable electricity.
10. A metallurgical plant for producing pig iron (P) with a reduced carbon footprint, preferably by implementing the method according any of claims 1 to 8, the metallurgical plant comprising:
 - a first electric pre-heater (10) configured for pre-heating iron ore fines (A) based on Joule effect and/or microwave heating into pre-heated iron ore fines (B) at a temperature above 600 °C;
 - one or more fluidized bed reactors (50) configured for partially reducing the pre-heated iron ore fines (B) in the presence of only hot reducing gas (J) as a reductant into partially reduced iron (K, L) to a metallization degree of 55 to 75 %, preferably 60 to 70 %;

- a submerged arc furnace (70) comprising a bath of molten metal with a top slag layer, configured for receiving the partially reduced iron (K, L) and further reducing and melting the partially reduced iron (K, L) in the presence of a carbonaceous material (M) to obtain molten pig iron (P);

wherein the metallurgical plant further comprises one or more reforming reactors (40) configured for producing a syngas (I) from a feed of natural gas or biomethane (F), a feed of blast furnace gas (G), one or more feeds of off-gas (O) of the submerged arc furnace and other off-gases (H) from the metallurgical plant, or a feed of mixtures of two or more thereof, and a feed of air or oxygen-enriched air, steam or carbon dioxide (E); wherein the metallurgical plant further comprises a feed of hydrogen (D); a hot reducing gas mixing device fluidly connected upstream to the one or more reforming reactors (40) and to the feed of hydrogen (D), and optionally to one or more of said feeds of an off-gas (O) of the submerged arc furnace and of other off-gases (H) of the metallurgical plant, or a feed of mixtures of two or more thereof, and downstream to an inlet of the one or more fluidized bed reactors (50), said hot reducing gas mixing device being configured for providing hot reducing gas (J) at a temperature above 550 °C comprising hydrogen (D), syngas (I), off-gas (O) of the submerged arc furnace, other off-gases (H) of the metallurgical plant, or mixtures of two or more thereof.

11. The metallurgical plant according to claim 10, wherein the one or more fluidized bed reactors (50) is/are of a circulating type.
12. The metallurgical plant according to claim 10 or 11, comprising a second electric pre-heater (20) based on Joule effect and/or microwave heating fluidly connected between said feed of hydrogen (D) and the hot reducing gas mixing device, and a third electric pre-heater (30) based on Joule effect and/or microwave heating fluidly connected between said one or more feeds of off-gas (O) of the submerged arc furnace and optionally other off-gases (H) of the metallurgical plant and the hot reducing gas mixing device, said second and third electric pre-heaters (20, 30) being configured for pre-heating the relevant off-gas(es) and syngas to a temperature above 700 °C.

13. The metallurgical plant according to any of claims 10 to 12, wherein the carbonaceous material (M) is provided from a source comprising or consisting of bio-char produced by biomass, optionally including demolition wood, such as up to 40 wt.-%, and/or waste plastics, such as up to 20 wt.-%.
14. The metallurgical plant according to any one of claims 10 to 13, further comprising a hot briquetting apparatus configured for briquetting partially reduced iron ore fines (K) into briquetted partially reduced iron (L).
15. The metallurgical plant according to any one of claims 10 to 14, wherein the metallurgical plant comprises one or more among, a coke oven plant, a Direct Reduced Iron plant, a blast furnace and basic oxygen furnace, providing said other off-gases (H) of the metallurgical plant.
16. The metallurgical plant according to any one of claims 10 to 15, wherein all electrical energy needed in the pre-heater(s) and the submerged arc furnace, preferably the electrical energy needed for all electric devices of the metallurgical plant, is renewable electricity.