(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 May 2012 (10.05.2012)

PCT

(10) International Publication Number
WO 2012/058717 A1

(51) International Patent Classification:
C21B 13/00 (2006.01) *C22B 5/12* (2006.01)
C21B 5/00 (2006.01)

(21) International Application Number:
PCT/AU2011/001404

(22) International Filing Date:
3 November 2011 (03.11.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2010904887 3 November 2010 (03.11.2010) AU

(71) Applicant *(for all designated States except US)*: **TECHNOLOGICAL RESOURCES PTY. LIMITED** [AU/AU]; 120 Collins Street, Melbourne, Victoria 3000 (AU).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **EVANS, Timothy, James** [AU/AU]; 48 North Scenic Rd, Forresters Beach, New South Wales 2260 (AU).

(74) Agent: **GRIFFITH HACK**; Level 3, 509 St Kilda Road, Melbourne, Victoria 3004 (AU).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title**: PRODUCTION OF IRON

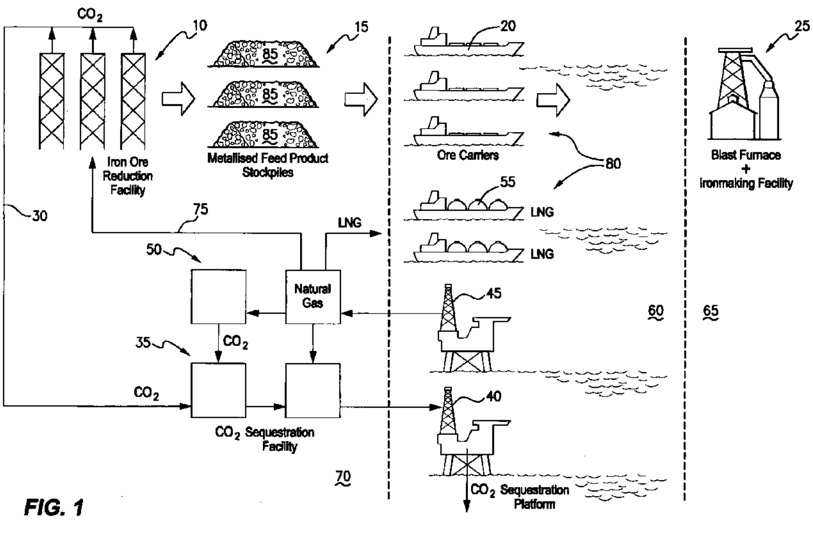

FIG. 1

(57) **Abstract**: A two stage ironmaking process is disclosed. A first stage includes solid state reduction of iron ore and producing a partially-reduced iron-containing feed material and an off-gas containing CO_2 at a location that is in close proximity to a site for sequestering $C0_2$. A second stage includes transporting the feed material to an ironmaking facility iron at another location and producing iron from the feed material.

WO 2012/058717 A1

PRODUCTION OF IRON

The present invention relates to producing iron from iron ore.

The term "iron ore" is understood herein to mean mined material that includes iron oxides. The term also covers mined material that contains other valuable metals. For example, the term covers mined material that contains iron oxides and titanium oxides.

The present invention relates particularly, although by no means exclusively, to producing iron from iron ore having a gangue content of at least 5% by weight on a dry basis.

The present invention relates more particularly, although by no means exclusively, to producing iron from iron ore with minimal CO_2 emissions.

Blast furnaces are the most widely-used option for producing iron from iron ore. Ironmaking and downstream steelmaking processes make a substantial contribution to CO_2 emissions in the world.

At present there is no readily available substitute to carbon for the production of iron from iron ore. For example, there is no commercially-available ironmaking process that can utilise electric current in the reduction process. This means that nuclear and hydro power cannot be used as an alternate source of energy for the reduction of iron oxides to iron. As a result, sequestration of CO_2 emissions is presently the most promising process for reducing CO_2 emissions from the ironmaking process.

Pellets can be used in blast furnaces as a substitute for lump and sintered iron ore. Typical blast furnace pellets have less than 5% by weight of gangue. They are manufactured from low grade iron ore (i.e. iron ore with a gangue content greater than 5% by weight) that has been finely ground in order to separate the gangue material from the iron oxides. Low gangue pellets have lower coking coal consumption in blast furnaces compared with the use of higher gangue content pellets in blast furnaces. However, the use of pellets with less than 5% by weight gangue does not appreciably reduce the overall CO_2 emissions of the ironmaking process due to the energy involved in grinding and producing the pellets. It should however be noted that, overall, the use of pellets as a feed stock for a blast furnace can be economic where low cost energy and low cost (high gangue) iron ores are available.

Electric arc steelmaking processes are designed to convert scrap steel to molten metal and do not offer significant opportunities for reducing CO_2 emissions from the conversion of iron ores to iron in the ironmaking process. Electric arc furnaces can receive some raw materials, which typically are provided to dilute the impurities present in the scrap metal (such as copper and zinc). These raw materials must be of very low gangue content (typically less than 2% on a dry weight basis) so as not to affect the productivity of electric arc furnaces or significantly increase the electricity consumed by the furnaces (due to the increased need to heat gangue materials to the molten state).

One proposal to reduce the CO_2 emissions from blast furnaces is to capture the CO_2 emissions at the blast furnaces and to sequester these emissions in underground reservoirs. However, blast furnaces are fired using heated air (hot blast) and, as a result, the off-gas of a blast furnace has a high percentage of N_2 which has to be stripped from the off-gas using large volume gas handling equipment before the CO_2 can be sequestered. Such large volume gas handling equipment is expensive, and it is likely that it will be necessary to develop oxygen-fired blast furnaces (as alternatives to air-fired blast furnaces) before sequestration of CO_2 from blast furnaces will be economically viable.

A further difficulty with sequestration of CO_2 from blast furnaces arises where a blast furnace is not situated in close proximity to a suitable sequestration site. In this situation, there may be a requirement to transport the captured CO_2 over thousands of kilometres of pipe line. Such pipe lines will need to be specially installed and may represent a cost to the ironmaking process that means that it is no longer economically viable.

The cost of replicating existing iron and steelmaking facilities adjacent suitable sequestration sites could, in many cases, equal or exceed the cost of installing CO_2 pipelines. Moreover, simply replicating blast furnaces at suitable sequestration sites will not result in a maximum of CO_2 savings as it will be necessary to solidify the molten iron to pig iron before transporting it to steelmaking facilities in other locations. This will result in additional CO_2 emissions at the steelmaking facilities when the pig iron is reheated to its molten state for conversion to steel.

The above difficulties mean that an economically viable ironmaking/steelmaking process with CO_2 sequestration may be difficult to achieve in practice notwithstanding that CO_2

sequestration of blast furnace off-gas may itself be technically feasible.

The above description is not to be taken as an admission of the common general knowledge in Australia or elsewhere.

The present invention is based on a realisation that CO_2 sequestration in an ironmaking process may be economically viable if the ironmaking process is split into two stages, where a first stage includes solid state reduction of iron ore and producing a partially-reduced iron-containing feed material and an off-gas containing CO_2 at a location that is in close proximity to a site for sequestration of CO_2, and a second stage includes transporting the feed material to an ironmaking facility iron at another location and producing iron from the feed material.

More particularly, the present invention provides an ironmaking process that includes:

(a) a first stage which includes:

(i) reducing iron ore in a solid state in a solid state reduction facility and producing a partially-reduced iron-containing feed material and an off-gas containing CO_2, with the solid state reduction facility being situated at a location that is in close proximity to a site for sequestering CO_2,

(ii) collecting CO_2 gas produced during the solid state reduction of iron ore; and

(iii) sequestering the CO_2 gas; and

(b) a second stage which includes transporting the feed material from the first stage to an ironmaking facility and producing iron.

The first stage may include reducing iron ore in the solid state reduction facility and producing the feed material with a metallisation of at least 50%.

The term " metallisation" of an iron ore feed is understood herein to mean the percentage of the iron oxides in the iron ore feed that is reduced to metallic iron.

The first stage may include reducing iron ore and producing the feed material with a metallisation of at least 50%.

The first stage may include reducing iron ore and producing the feed material with a metallisation of at least 55%.

The first stage may include reducing iron ore and producing the feed material with a metallisation of at least 60%.

The first stage may include reducing iron ore and producing the feed material with a metallisation of between 60% and 85%.

The first stage may include producing the feed material with a metallisation of between 60% and 85% and a gangue content of greater than 5% by weight.

The gangue content may be greater than 6% by weight.

The gangue content may be greater than 7% by weight.

The first stage may include producing the feed material from iron ore in the form of iron ore fines having a gangue content of 6% or greater on a dry weight basis and the feed material having a metallisation of between 60% and 85%.

The first stage may include forming the partially-reduced iron ore fines produced by the solid state reduction into feed material particles of a size of at least 4 cm^3.

The gangue content of the particles may be greater than 7% by weight.

The gangue content of the particles may be greater than 8% by weight.

The solid state reduction facility used in the first stage may be situated at a location remote from the ironmaking facility used in the second stage.

The first stage may include treating off-gas produced in the solid state reduction facility and producing a CO_2 off-gas.

The CO_2 content of the CO_2 off-gas may exceed 90% by volume of the off-gas.

The CO_2 content of the CO_2 off-gas may exceed 95% by volume of the off-gas.

The CO_2 content of the CO_2 off-gas may exceed 99% by volume of the off-gas.

The CO_2 off-gas may have less than 10 % N_2 by volume.

The CO_2 off-gas may have less than 5% N_2 by volume.

The CO_2 off-gas may have less than 2% N_2 by volume.

The CO_2 off-gas may have less than 1% N_2 by volume.

The CO_2 off-gas may have greater than 90% by volume of CO_2 and less than 10% N_2.

The CO_2 off-gas may have greater than 95% by volume CO_2 and less than 5% by volume N_2.

The CO_2 off-gas may have greater than 99% by volume CO_2 and less than 1% by volume N_2.

The first and the second stages may be carried out at locations that are separated by a considerable distance.

The solid state reduction facility used in the first stage may be more than 1000 km from the ironmaking facility used in the second stage.

The solid state reduction facility may be located in close proximity to a facility for producing a gas from natural gas, and the first stage may include using the natural gas from the gas production facility as a reductant for reducing iron ore in the first stage.

The solid state reduction facility may be less than 1000 km from a sequestration facility for sequestering the CO_2 off-gas produced in the first stage.

The solid state reduction facility may be less than 700 km from the sequestration facility.

The solid state reduction facility may be less than 1000 km from the sequestration facility and more than 1000 km from the ironmaking facility.

The gangue content of the iron ore for the first stage may be at least 7% by weight on a dry basis.

The gangue content of the iron ore for the first stage may be at least 8% by weight on a dry basis.

The first stage may be a fluid bed process.

In that event, typically, the iron ore for the first stage is in the form of fines and a reductant for the first stage is a reducing gas.

The reducing gas may be natural gas or a syngas.

The term "fines" is understood herein to mean iron ore particles of a size that are typically fed to sinter plants at a blast furnace facility and typically are particles of iron ore that are less than 8 mm and typically 6.3 mm or less.

In addition, the first stage may include forming briquettes or other forms of agglomerates of partially-reduced iron ore fines produced in the solid state reduction facility in the first stage and supplying the briquettes or other agglomerates to the ironmaking facility used in the second stage.

The briquetting or agglomeration step may produce briquettes or agglomerates having a volume that is greater than 4 cm^3.

The briquetting or agglomeration step may produce briquettes or agglomerates having a volume that is greater than 6 cm^3.

The briquetting or agglomerating step may produce briquettes or agglomerates having a volume that is greater than 4 cm^3 and less than 8 cm^3.

The first stage may be a shaft furnace-based process for lump iron ore.

The volume of the lump iron ore may be greater than 4 cm^3.

The volume of the lump iron ore may be greater than 6 cm^3.

The volume of the lump iron ore may be in a range greater than 4 cm^3 and less than 8 cm^3.

A reductant for the first stage may be a solid or a gas reductant.

The solid reductant may be coal.

The gas reductant may natural gas or a syngas.

The present invention also provides a first stage of a two stage process for producing molten iron with minimal CO_2 emissions, with the first stage including:

(a) reducing iron ore having a gangue content of greater than 6% by weight on a dry basis in a solid state and producing a partially-reduced iron-containing feed material having a metallisation degree of 85% or less and an off-gas containing CO_2 in a solid state reduction facility at a location in the vicinity of a CO_2 sequestration facility;

(b) capturing CO_2 released from the solid state reduction facility and transporting the CO_2 to the CO_2 sequestration facility and sequestering the CO_2;

(c) stockpiling the partially-reduced iron-containing feed material produced in the solid state reduction facility;

(d) reclaiming the stockpiled partially-reduced iron-containing feed material for transportation to an ironmaking facility such as a blast furnace located remotely from the solid state reduction facility.

The iron ore may be lump ore or fines, as described above.

In the event that the iron ore is in the form of fines, the first stage may include forming briquettes or other forms of agglomerates of partially-reduced iron ore fines produced in the solid state reduction facility in the first stage and then stockpiling the briquettes or other agglomerates and ultimately transporting the briquettes to the ironmaking facility.

The present invention also provides a process for producing a metallised iron product in a solid state reduction facility for transportation to an ironmaking facility such as a blast furnace located remotely from the solid state reduction facility, the process including:

(a) supplying lump iron ore with gangue of at least 6% on a dry weight basis to the solid state reduction facility, the lump iron ore having a nominal volume of 4 cm^3 or greater;

(b) reducing the iron ore to greater than 60% and equal to or less than 85% metallisation in the solid state reduction facility and producing a metallised lump iron product and an off-gas having greater than 90% CO_2; and

(c) stockpiling the metallised lump iron product for transportation to the ironmaking facility.

The process may include transporting the off-gas to a CO_2 sequestration facility and sequestering CO_2 in the facility.

The present invention also provides an apparatus for producing iron from iron ore with minimal CO_2 emissions including, a solid state reduction facility for reducing iron ore having a gangue content of at least 6% by weight on a dry basis to less than 80% metallisation, and an ironmaking facility for completing reduction of partially reduced iron ore from the solid state reduction facility and producing molten iron.

The solid state reduction facility and the ironmaking facility may be at locations that are separated by a considerable distance.

The solid state reduction facility may be more than 1000 km from the ironmaking facility.

The solid state reduction facility may be located in close proximity to a facility for producing a gas from natural gas for use as a reductant in the solid state reduction facility.

The solid state reduction facility may be less than 1000 km from a sequestration facility for sequestering CO_2 produced in the solid state reduction facility.

The solid state reduction facility may be less than 700 km from the sequestration facility.

The solid state reduction facility may be less than 1000 km from the sequestration facility and more than 1000 km from the ironmaking facility.

The ironmaking facility may include a blast furnace.

The ironmaking facility may be a part of an integrated steelmaking facility.

The present invention may also include a steelmaking process comprising making steel from iron produced in the above-described ironmaking process.

The present invention is described in more detail hereinafter by way of example only with reference to the accompanying drawing which is a diagram of one embodiment of a two stage process and apparatus for producing molten iron from fines iron ore in accordance with the present invention.

The following description is in the context of reducing fines iron ore having a gangue content of at least 5% by weight on a dry basis, more typically at least 6% by weight on a dry basis. It is noted that the present invention is not so limited and also extends to producing iron from lump iron ore.

In the embodiment, iron ore fines and natural gas 75 (or coal) are supplied to a solid state reduction facility 10, typically in the form of a fluidised bed facility, such as a Circored and Circofer (available from Outotec) or Finmet furnace (available from Siemens VAI of Germany).

The facility 10 is operated under standard conditions and the iron ore is partially reduced to a metallisation of greater than 65 % and less than 85%.

The natural gas 75 is produced in a gas processing plant 50 that treats natural gas from onshore or offshore production wells 45.

The facility 10 discharges a partially metallised fines product 15 which is subsequently agglomerated or compacted to form a lump product 15 suitable for use as a feed material for an ironmaking facility in the form of a blast furnace 25.

The partially metallised lump product 15 is stored in stockpiles 85 that are proximate a port facility 80. Ore carriers 20 located at the port 80 transport the partially metallised feed material 15 to a port proximate the blast furnace 25.

The facility 10 also produces an off-gas 30 that contains CO_2. The off-gas 30 is transferred to a CO_2

sequestration facility 35. The CO_2 in the off-gas is sequestered by CO_2 sequestration platform 40.

Together, the solid state metallisation process and the CO_2 sequestration process form a first stage of on one embodiment of a two stage ironmaking process in accordance with the present invention.

The second stage of the process includes at least a blast furnace or another ironmaking facility located remotely from the first stage. The ironmaking facility may be a part of an integrated ironmaking and steelmaking facility.

The gas processing plant 50 may also produce a CO_2-containing off-gas and this off-gas may also be transferred to the CO_2 sequestration platform 40.

In accordance with this embodiment of the present invention, the location for facility 10 is selected to be proximate a suitable CO_2 sequestration facility 35. Typically, the facility 10 and the sequestration facility may be within 500 km of each other. Such a sequestration facility may be proximate to and/or part of a fuel gas production plant 50. This selection of the location of the facility 10 facilitates sequestering CO_2 30 produced in the facility 10 so as to reduce emissions of CO_2 from the two stage ironmaking process.

The partially metallised feed material is transferred from the stockpile 15 to a blast furnace 25 and processed in the blast furnace to complete metallisation and melting of the feed product 15 and production of molten iron.

The blast furnace 25 is located remotely from the facility 10 and the stockpile 15 used in the first stage. Typically, the blast furnace 25 is located at least 1000 km from the facility 10 and the stockpile 15. Hence, it is necessary to transport the partially metallised feed material typically by train and/or ship 20 to the blast furnace 25.

As is indicated above, the selection of the location of the facility 10 to be close to the CO_2 sequestration facility facilitates processing and sequestration of CO_2 produced in the facility 10. This reduces CO_2 emissions from the overall iron making process.

Many modifications may be made to the embodiment of the process and the apparatus of the present invention described in relation to the diagram without departing from the spirit and scope of the invention.

Whilst the embodiment is described in the context of producing iron from fines iron ore, the present invention is not so limited and extends to producing iron from lump iron ore.

Whilst the embodiment includes using natural gas as the reductant in the first stage, the present invention is not so limited and extends to the use of other gases as the reductant and to the use of coal or other forms of solid carbonaceous material as the reductant in the first stage.

Whilst the embodiment includes sequestering CO_2 in the off-gas produced in the solid state reduction facility 10, the present invention is not so limited and extends generally to treating off-gas from the facility 10 to remove CO_2 from the off-gas. The treatment may include removing CO_2 from the off-gas, for example by an amine scrubber treatment or the use of a vacuum-pressure swing adsorption system.

The off-gas treatment may be more extensive than being focussed on CO_2. For example, the off-gas treatment may include converting CO to H_2 in the off-gas via a water gas shift reaction and using the H_2 as a reduction gas in the shaft furnace.

CLAIMS

1. An ironmaking process that includes:

(a) a first stage which includes:

(i) reducing iron ore in a solid state in a solid state reduction facility and producing a partially-reduced iron-containing feed material and an off-gas containing CO_2, with the solid state reduction facility being situated at a location that is in close proximity to a site for sequestering CO_2,

(ii) collecting CO_2 gas produced during the solid state reduction of iron ore; and

(iii) sequestering the CO_2 gas; and

(b) a second stage which includes transporting the feed material from the first stage to an ironmaking facility and producing iron.

2. The process defined in claim 1 wherein the first stage includes reducing iron ore and producing the feed material with a metallisation of at least 50%.

3. The process defined in claim 1 wherein the first stage includes reducing iron ore and producing the feed material with a metallisation of at least 55%.

4. The process defined in claim 1 wherein the first stage includes reducing iron ore and producing the feed material with a metallisation of at least 60%.

5. The process defined in claim 1 wherein the first stage includes reducing iron ore and producing the feed material with a metallisation of between 60% and 85%.

6. The process defined in claim 1 wherein the first stage includes producing the feed material with a metallisation of between 60% and 85% and a gangue content of greater than 5% by weight.

7. The process defined in claim 6 wherein the gangue content is greater than 6% by weight.

8. The process defined in claim 1 wherein the first stage includes producing the feed material from iron ore in the form of iron ore fines having a gangue content of 6% or greater on a dry weight basis and with the feed material having a metallisation of between 60% and 85%.

9. The process defined in claim 8 wherein the first stage includes forming the partially-reduced iron ore fines into feed material particles of a size of at least 4 cm^3.

10. The process defined in claim 8 or claim 9 wherein the gangue content of the particles is greater than 7% by weight.

11. The process defined in any one of the preceding claims wherein the first stage includes treating off-gas produced in the solid state reduction facility and producing a CO_2 off-gas.

12. The process defined in claim 11 wherein the CO_2 content of the CO_2 off-gas exceeds 90% by volume of the off-gas.

13. The process defined in claim 11 wherein the CO_2 content of the CO_2 off-gas exceeds 95% by volume of the off-gas.

14. The process defined in any one of claims 11 to 13 wherein the CO_2 off-gas has less than 10 % N_2 by volume.

15. The process defined in any one of claims 11 to 14 wherein the CO_2 off-gas has less than 5% N_2 by volume.

16. The process defined in any one of the preceding claims wherein the solid state reduction facility used in the first stage is more than 1000 km from the ironmaking facility used in the second stage.

17. The process defined in any one of the preceding claims wherein the solid state reduction facility is located in close proximity to a facility for producing a gas from natural gas, and the first stage includes using the natural gas from the gas production facility as a reductant for reducing iron ore in the first stage.

18. The process defined in any one of the preceding claims wherein the solid state reduction facility is less than 1000 km from a sequestration facility for sequestering the CO_2 off-gas produced in the first stage.

19. The process defined in claim 18 wherein the solid state reduction facility is less than 1000 km from the sequestration facility and more than 1000 km from the ironmaking facility.

20. The process defined in any one of the preceding claims wherein the gangue content of the iron ore for the first stage is at least 7% by weight on a dry basis.

21. The process defined in any one of the preceding claims wherein the first stage is a fluid bed process.

22. The process defined in claim 21 wherein the iron ore for the first stage is in the form of fines and a reductant for the first stage is a reducing gas.

23. The process defined in claim 21 or claim 22 wherein the first stage includes forming briquettes or other forms of agglomerates of partially-reduced iron ore fines as the feed material and supplying the briquettes or other agglomerates to the ironmaking facility used in the second stage.

24. The process defined in claim 23 wherein the briquetting or agglomeration step produces briquettes or agglomerates having a volume that is greater than 4 cm^3.

25. The process defined in any one of claims 1 to 20 wherein the first stage is a shaft furnace-based process for lump iron ore.

26. The process defined in claim 25 wherein the volume of the lumps of lump iron ore is greater than 4 cm^3.

27. A two-stage ironmaking process wherein a first stage includes solid state reduction of iron ore and producing a partially-reduced iron-containing feed material and an off-gas containing CO_2 at a location that is in close proximity to a site for sequestering CO_2, and a second stage includes transporting the feed material to an ironmaking facility iron at another location and producing iron from the feed material.

28. A first stage of a two stage process for producing molten iron with minimal CO_2 emissions, with the first stage including:

(a) reducing iron ore having a gangue content of greater than 6% by weight on a dry basis in a solid state and producing a partially-reduced iron-containing feed material having a metallisation degree of 85% or less and an off-gas containing CO_2 in a solid state reduction facility at a location in the vicinity of a CO_2 sequestration facility;

(b) capturing CO_2 released from the solid state reduction facility and transporting the CO_2 to the CO_2 sequestration facility and sequestering the CO_2;

(c) stockpiling the partially-reduced iron-containing feed material produced in the solid state reduction facility;

(d) reclaiming the stockpiled partially-reduced iron-containing feed material for transportation to an ironmaking facility such as a blast furnace located remotely from the solid state reduction facility.

29. The process defined in claim 28 wherein the first stage includes transporting the stockpiled partially-reduced iron-containing feed material to the ironmaking facility.

30. A process for producing a metallised iron product in a solid state reduction facility for transportation to an ironmaking facility such as a blast furnace located remotely from the solid state reduction facility, the process including:

(a) supplying lump iron ore with gangue of at least 6% on a dry weight basis to the solid state reduction facility, the lump iron ore having a nominal volume of 4 cm^3 or greater;

(b) reducing the iron ore to greater than 60% and equal to or less than 85% metallisation in the solid state reduction facility and producing a metallised lump iron product and an off-gas having greater than 90% CO_2; and

(c) stockpiling the metallised lump iron product for transportation to the ironmaking facility.

31. The process defined in claim 30 includes transporting the off-gas to a CO_2 sequestration facility and sequestering CO_2 in the facility.

32. An apparatus for producing iron from iron ore with minimal CO_2 emissions including, a solid state reduction facility for reducing iron ore having a gangue content of at least 6% by weight on a dry basis to less than 80% metallisation, and an ironmaking facility for completing reduction of partially reduced iron ore from the solid state reduction facility and producing molten iron.

33. The apparatus defined in claim 32 wherein the solid state reduction facility and the ironmaking facility are at quite different locations separated by a considerable distance.

34. The apparatus defined in claim 33 wherein the solid state reduction facility is more than 1000 km from the ironmaking facility.

35. The apparatus defined in any one of claims 32 to 34 wherein the solid state reduction facility is located in close proximity to a plant for producing a gas from natural gas for use as a reductant in the solid state reduction facility.

36. The apparatus defined in any one of claims 32 to 35 wherein the solid state reduction facility is less than 1000 km from a sequestration facility for sequestering CO_2 produced in the solid state reduction facility.

37. The apparatus defined in claim 36 wherein the solid state reduction facility is less than 700 km from the sequestration facility.

38. The apparatus defined in claim 37 wherein the solid state reduction facility is less than 1000 km from the sequestration facility and more than 1000 km from the ironmaking facility.

39. The apparatus defined in any one of claims 32 to 38 wherein the ironmaking facility includes a blast furnace.

40. The apparatus defined in any one of claims 32 to 39 wherein the ironmaking facility is a part of an integrated steelmaking facility.

1/1

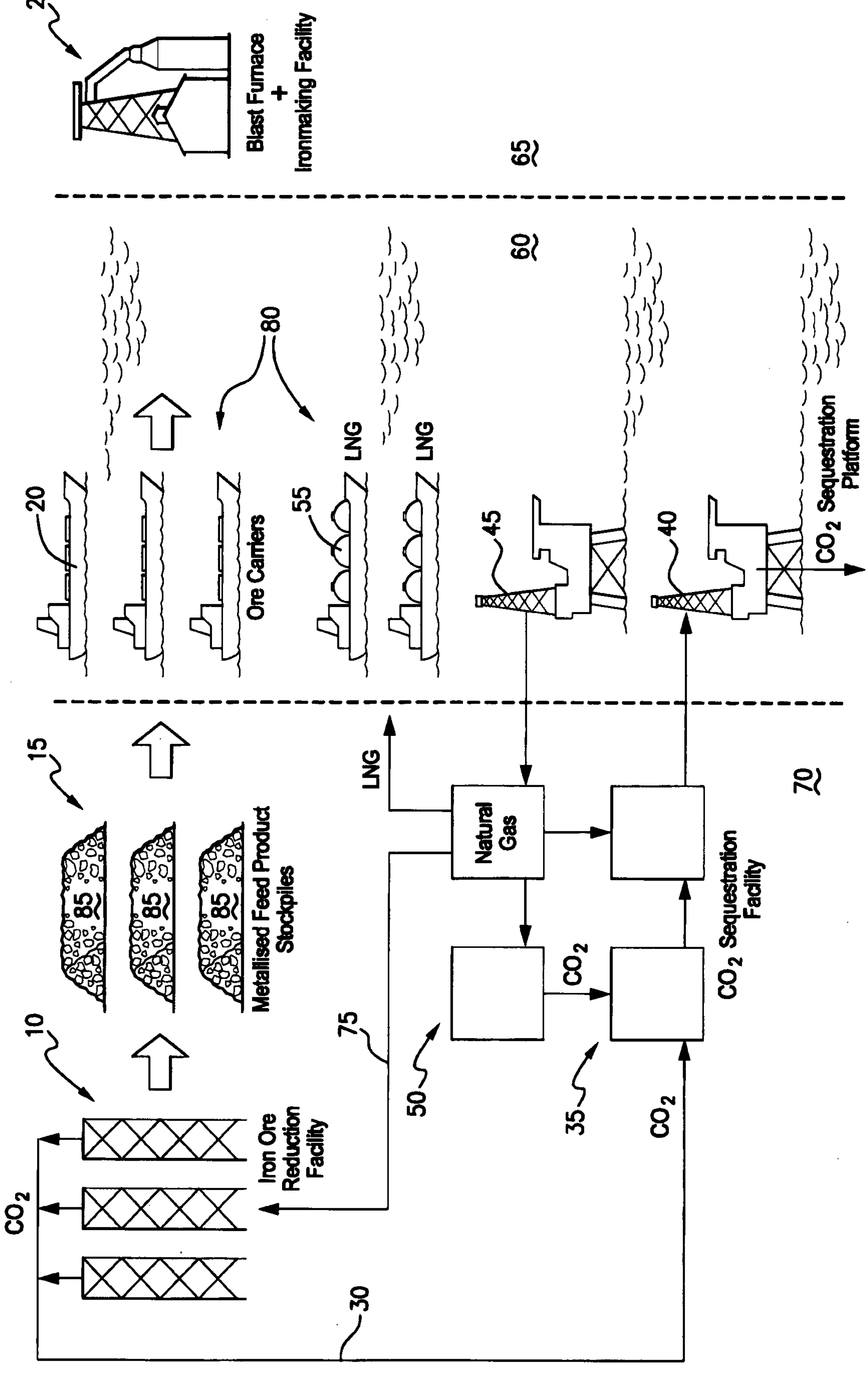
25
Blast Furnace
+
Ironmaking Facility
65
60
80
20
Ore Carriers
55
LNG
LNG
45
40
CO_2 Sequestration Platform
15
85
85
85
Metallised Feed Product Stockpiles
LNG
Natural Gas
70
CO_2 Sequestration Facility
CO_2
10
Iron Ore Reduction Facility
75
50
35
CO_2
CO_2
30

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2011/001404

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

C21B 13/00 (2006.01) ***C21B 5/00*** (2006.01) ***C22B 5/12*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC: IC/EC (C21B 13/-, C21B 3/-, C21B 5/-, C21B 11/-, C22B 5/02/LOW) & Keywords (IRON, REDUCTION, OFF, GAS, CO2, SEQUESTER) and like terms

ESPACENET, USPTO, GOOGLE PATENTS & Keywords (IRON, ORE, REDUCTION, STAGES, SOLID, DIRECT, SHAFT, CARBON, DIOXIDE) and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 5238487 A (HAUK et al) 24 August 1993	
X	see abstract; column 1, lines 13 – 43; column 2, line 45 – column 3, line 14; claim 1; figures 1 – 2	1 – 20, 25 – 40
Y	see abstract; column 1, lines 13 – 43; column 2, line 45 – column 3, line 14; claim 1; figures 1 – 2	21 – 24
	WO 2005 / 116275 A2 (OUT-OKUMPU TECHNOLOGY OY [FI]) 8 December 2005	
Y	see abstract; page 29, lines 24 – 30; claims 17, 26	21 – 24

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 November 2011	28/11/2011

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	**VIJAYA MATHE** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : (02) 6225 6162

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 4202534 A (DAVIS, Jr.) 13 May 1980	
A	see abstract	
	US 4897113 A (BECERRA – NOVOA et al) 30 January 1990	
A	see abstract	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2011/001404

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5238487	AU	74198/94	AU	85841/91	BR	9105177
		CA	2052659	CS	9103631	DE	4037977
		EP	0487856	JP	4268008	PT	99638
		TR	25745	ZA	9107786		
WO	2005116275	AU	2005248041	BR	PI0511680	CA	2566320
		CN	1961083	EA	200601978	EP	1766099
		JP	2008501098	NZ	551517	US	2008210055
		US	7824603	US	2010269636	US	7947107
		ZA	200609569				
US	4202534	NONE					
US	4897113	US	4734128				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX