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PRODUCTION OF FERRO-ALLOYS

The present invention relates to a method and an apparatus for producing ferro-alloys (such as steel) in an electric arc furnace or other suitable metallurgical furnace.

International Publication WO 2006/024069 in the name of New South Innovations Pty Ltd, hereinafter referred to as the "International Publication" discloses a method for producing a ferro-alloy in an electric arc furnace that is characterised by supplying an unagglomerated carbon-containing polymer that functions as a slag foaming agent to the furnace.

The International Publication defines the term "unagglomerated carbon-containing polymer" as covering "both fine and coarse granulated and particulate polymers and is intended to exclude such polymers as formed together with EAF waste dust or steel dust". The International Publication describes that such agglomerated solids comprising polymers and EAF waste dust or steel dust do not function as a slag foaming agent.

The International Publication describes that, typically, the unagglomerated carbon-containing polymer is charged into an electric arc furnace such that it at least partially combusts and produces a carbonaceous residue. The International Publication also describes that the carbonaceous residue then oxidises to cause slag foaming and may additionally function as a reducing agent or a recarburiser.

The International Publication describes that, typically, the carbon-containing polymer comprises the atoms C, H and optionally O only and that, whilst other elements may be present in the polymer (e.g. N, S, P, Si,

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halogens etc.) these other elements may interfere with ferro-alloy production and/or produce contaminants, pollutants, noxious gases etc. The International Publication describes that, by judiciously selecting the carbon-containing polymer, the formation of noxious gases and other detrimental or harmful products can be avoided. The International Publication describes that one suitable carbon-containing polymer is polyethylene but other plastics such as polypropylene, polystyrene, polybutadiene styrene, APS etc. may also be used.

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

The disclosure in the International publication is incorporated herein by cross-reference.

The applicant has carried out trials on the method of producing ferro-alloys in the form of steel at the electric arc furnace facilities of the applicant in Melbourne and Sydney.

As a consequence, the applicant has identified parameters that are important to the successful use of unagglomerated carbon-containing polymers in the production of steel.

In addition, as a consequence of the trials, the applicant has developed a particular method of producing steel (and other ferro-alloys). The method includes the use of unagglomerated and agglomerated carbon-containing polymers.

Furthermore, as a consequence of the trials, the applicant has developed technology for successfully

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supplying unagglomerated and agglomerated carbon-containing polymers to an electric arc furnace, or other suitable metallurgical furnace, to carry out the above-mentioned method of producing steel in the furnace.

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In particular, the technology developed by the applicant focuses on areas such as, but not limited to, (a) mixing of unagglomerated and agglomerated carbon-containing polymers and other materials, (b) supplying the mixture to a furnace including flowrate of material into the furnace, (c) materials handling of the mixture upstream of the furnace, and (d) temperature pick-up and overall heat control in the furnace.

According to the present invention there is provided a method for producing a ferro-alloy, such as steel, in an electric arc furnace or other suitable metallurgical furnace that comprises supplying a mixture of (a) a carbon-containing polymer that is capable of acting as a slag foaming agent and (b) another source of carbon into the furnace during at least a part of a power-on phase of the method.

More specifically, the present invention provides a method for producing a ferro-alloy, such as steel, in an electric arc furnace or other suitable metallurgical furnace that comprises supplying a mixture of (a) a carbon-containing polymer that is capable of acting as a slag foaming agent and (b) another source of carbon into the furnace during at least a part of a first power-on phase of the method and supplying a further mixture of the carbon-containing polymer and another source of carbon into the electric arc furnace during a second power-on phase of the method.

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More specifically, the present invention provides a method of producing a ferro-alloy in an electric arc

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furnace or other suitable metallurgical furnace which comprises:

5 (a) supplying an initial charge of a feedstock for the ferro-alloy to the furnace;

(b) operating in a first power-on phase and establishing an arc between an electrode or electrodes of the furnace and the solid feedstock charge and generating
10 heat in the furnace and melting the solid feedstock charge;

(c) after a first period of time into the first power-on phase, commencing supply of a mixture of (i) a
15 carbon-containing polymer that is capable of acting as a slag foaming agent and (ii) an another source of carbon into the furnace;

(d) at the end of the first power-on phase, supplying
20 a further charge of the ferro-alloy feedstock to the furnace;

(e) operating in a second power-on phase by re-establishing the arc;

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(f) after a first period of time into the second power-on phase, commencing injection of a mixture of (i) a carbon-containing polymer that is capable of acting as a slag foaming agent and (ii) an another source of carbon
30 into the furnace; and

(g) at the end of the second power-on phase, tapping molten ferro-alloy from the furnace.

35 The method may include injecting the mixture of the carbon-containing polymer and the other source of carbon during non-power-on phases of the method.

The carbon-containing polymer may be an unagglomerated polymer described herein.

5 Typically, the unagglomerated carbon-containing polymer is as described in the International Publication.

The unagglomerated carbon-containing polymer may comprise any one or more of rubber (synthetic or natural)
10 and other polymers such as polypropylene, polystyrene, polybutadiene styrene, and APS. Typically, the polymer has a secondary function as an energy source.

The carbon-containing polymer may be an agglomerated
15 carbon-containing polymer. Examples of such agglomerates include agglomerates of carbon-containing polymers and any one or more of fluxes, iron oxides (such as mill scale), and bag house solids.

20 Typically, the further carbon source is as described in the International Publication and, by way of example, may act as a fuel and, in addition, may contribute to slag foaming, and act as a reducing agent or recarburizer.

25 The other source of carbon may comprise any one or more of coke, carbon char, charcoal and graphite.

A furnace operator may use any suitable parameter to assess the time to commence supply of the mixture of the
30 carbon-containing polymer and the other carbon source during the power-on phase or phases.

By way of example, the operator may time the commencement of such supply based on any one or more of
35 the power consumption of the furnace, the composition of the melt in the furnace, and the melt temperature.

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The power-on time during the power-on phase or phases may also be used as an indicator of the times to commence supply of the carbon-containing source and the other carbon source.

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The preferred ratio of the carbon-containing source and the other carbon source in the above-mentioned mixture of these materials may vary with particular furnaces.

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The ratio of the carbon-containing source and the other carbon source in the above-mentioned mixture of these materials may be varied during the time period or periods of supply of the mixture to the furnace.

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The flowrate of the mixture of the carbon-containing source and the other carbon source may be constant or may be varied during the time period or periods of supply of the mixture to the furnace.

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There may be continuous or periodic supply of the mixture of the carbon-containing source and the other carbon source during the power-on phase or phases.

The carbon-containing polymer may comprise 20-60 wt.% of the total weight of the mixture.

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More typically, the carbon-containing polymer comprises 20-50 wt.% of the total weight of the mixture.

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Typically, the carbon-containing polymer comprises 20-40 wt.% of the total weight of the mixture.

Preferably the carbon-containing polymer comprises 25-35 wt.% of the total weight of the mixture.

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The mixture of the carbon-containing source and the other carbon source supplied to the furnace during the

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first power-on phase may be the same as the mixture supplied during the second power-on phase.

Alternatively, the mixtures may be different in terms
5 of the materials and/or the ratios of the materials.

Typically, the sizes and the densities of each of the components of the mixture of the carbon-containing source and the other carbon source are selected having regard to
10 the materials handling requirements for mixing and transporting the mixture to the furnace. Components may be pre-mixed remotely from the furnace and stored as a mixture proximate the furnace and supplied via a pipeline to the furnace as required during the operation of the
15 method. Alternatively, the components may be stored separately proximate the furnace and mixed as required and transported to the furnace. The materials handling considerations including forming the mixture as a
homogeneous mixture, i.e. a mixture that has a
20 substantially uniform density with minimum segregation of the components, and being able to transport the mixture to the furnace efficiently, i.e. by avoiding blockages in pipes.

25 Typically, the size of the carbon-containing source is selected to be less than 6 mm and preferably less than 4 mm.

Typically, the method comprises injecting an oxygen-
30 containing gas, such as oxygen, into the furnace during the power-on phase or phases.

The method may include monitoring the slag profile, as described herein, during the course of the method and
35 controlling injection of the mixture of the carbon-containing polymer and the other source of carbon having regard to the monitored slag profile.

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The term "slag profile" is understood herein to mean characteristics, such as iron oxide levels, of the slag that provide an indication (directly or indirectly) of the operation of the method.

The slag profile may be monitored continuously or periodically.

The initial and the further charge of the feedstock may be solid charges. One or both charge may include at least some molten metal.

According to the present invention, there is also provided a metallurgical furnace such as an electric arc furnace that comprises a materials handling system for supplying a mixture of (i) a carbon-containing polymer that is capable of acting as a slag foaming agent and (ii) another source of carbon to the furnace during a method of producing a ferro-alloy in the furnace.

Typically, the materials handling system comprises separate hoppers for storing the carbon-containing polymer and the other carbon source, a pipeline for transporting the carbon-containing polymer and the other carbon source to the furnace, and control valves for controlling the flow of each of the carbon-containing polymer and the other carbon source into the supply line so that the mixture of these materials forms in the pipeline and is transported to and supplied to the furnace.

Typically, the materials handling system comprises a blower for entraining the mixture and transporting the mixture along the pipeline.

Typically, the materials handling system is arranged to supply the carbon-containing polymer to the pipeline

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upstream of the introduction point or points for the other carbon source.

5 The mixture of the carbon-containing polymer and the other carbon source may be supplied to the furnace by any suitable apparatus.

10 For example, the mixture may be injected into the furnace via a lance or lances extending into the furnace through an opening in a side or the roof of the furnace.

15 Other injection options include an intergrated burner/injector or intergrated burners/injectors extending through the side wall and/or the roof and consumable lances extending into the furnace.

20 The present invention is described further by way of example with reference to the accompanying drawing which is a timeline for one embodiment of a method of producing steel in an electric arc furnace in accordance with the present invention.

25 The following description of the timeline shown in the figure was developed during the course of trials at the Sydney electric arc facilities of the applicant.

30 In general terms, the technology developed by the applicant as a consequence of the trials, including the flowsheet, focuses on areas such as, but not limited to, mixing of unagglomerated carbon-containing polymers, as described herein, and other materials, supplying the mixture to a furnace, materials handling of the mixture upstream of the furnace, and temperature pick-up and overall heat control in the furnace.

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It can readily be appreciated that appropriate timelines for producing steel in other electric arc

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furnaces could readily be developed on a case-by-case basis.

5 With reference to the figure, a first solid feedstock for producing steel in the form of a scrap charge is supplied to the electric arc furnace in a two minute period of time.

10 After charging the furnace, power is supplied to the furnace electrodes and oxygen (or other suitable oxygen-containing gas) is injected into the furnace. Arcs are established between the electrodes and the solid feedstock, thereby generating heat that progressively melts the solid charge.

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After approximately 3MWh of power had been supplied to the furnace, which is typically a period of time of three minutes into this first power-on phase, injection of fluxes in the form of lime and magnesia into the furnace commences. These materials are supplied to form a slag on molten material forming in the furnace. The figure of 3MWh equates to the power required for the electrodes to "bore down" through the scrap and to be arcing on the heavy melt in the bottom of the furnace.

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After approximately 8MWh of power has been supplied to the furnace, which is typically a period of eight minutes into the first power-on phase, a mixture of an unagglomerated carbon-containing polymer in the form of rubber and another carbon source in the form of coke are injected into the furnace. The figure of 8MWh equates to when a flat bath of molten material and a liquid slag begin to form. The injection of the mixture continues at a constant flow rate for a period of four minutes to the end of the first power-on (and oxygen injection) phase. The mixture is injected via a lance extending into the furnace. The rubber/coke mixture acts as a fuel, with

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combustion of rubber/coke generating heat. The rubber/coke, including the combustion products, also act as a slag foaming agent, as described in the International Publication.

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A second charge of the feedstock for producing steel in the form of a scrap charge is supplied to the furnace during a two minute period following the end of the first power-on phase.

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After charging the second feedstock charge, power to the furnace and oxygen (or other suitable oxygen-containing gas) injection are re-established and the furnace commences operating a second power-on phase.

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After approximately 3MWh of power has been supplied to the furnace following the second feedstock charge, which is typically three minutes of the second power-on phase, fluxes in the form of lime and magnesia are supplied to the furnace to contribute to maintaining a required level of slag in the furnace.

After approximately 20 MWh of power has been supplied to the furnace since the first feedstock charge, which is typically a further five minute period of time in the second power-on phase, the mixture of rubber and coke is again injected into the furnace via the lance and injection of the mixture continues at a constant flow rate until the end of the second power-on (and oxygen injection) phase. Typically, the second power-on (and oxygen injection) phase runs for 24-28 minutes.

After the second power-on phase ends, the furnace is tapped to discharge molten steel and slag from the furnace during a two minute period.

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At the end of tapping, there is a two minute turnaround time before the method is repeated with a new charge of scrap is supplied to the furnace.

5 Based on the trials at the Sydney and the Melbourne electric arc furnace facilities of the applicant, results achieved to date indicate that the invention has the potential to:

10 (a) speed up the slag-foaming process;

(b) achieves a reduction in electricity consumption, meaning a fall in greenhouse gas emissions if produced by coal-fired power stations;

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(c) reduces total cost of production by reducing the quantity of injectant material required;

(d) improve furnace productivity by a reduction in "tap-to-tap" time - a measure of the time taken to produce one batch of molten steel.

20 In addition, the use of unagglomerated carbon-containing polymers has significant potential can potentially be diverted away from land fills.

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The above findings are significant outcomes.

30 Many modifications may be made to the embodiment of the method of the present invention described above without departing from the spirit and scope of the invention.

35 By way of example, whilst the embodiment is described in the context of producing steel, the present invention is not so limited and extends to the production of ferro-alloys generally.

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Furthermore, whilst the embodiment is described in the context of producing steel in an electric arc furnace, the present invention is not so limited and extends to the production of steel and ferro-alloys generally in any suitable metallurgical vessel.

In addition, whilst the embodiment includes the use of an unagglomerated carbon-containing polymer, the present invention is not so limited and extends to the use of agglomerated carbon-containing polymers.

In addition, whilst the embodiment includes the supply of the mixture of the unagglomerated carbon-containing polymer and the other carbon source by injecting the mixture through one of more than one lance extending into the furnace, the present invention is not so limited and extends to supplying the mixture into the furnace using any suitable apparatus.

In addition, whilst the embodiment includes particular time periods for charging the furnace, and supplying other materials to the furnace, the present invention is not limited to these time periods and extends to any suitable time periods. In addition, the present invention extends to situations in which there is continuous charging of materials to the furnace.

In addition, whilst the embodiment includes continuous injection of the mixture of the unagglomerated carbon-containing polymer and the other carbon source at constant flow rates during part of power-on phases, the present invention is not so limited and extends to periodic injection and/or variable flow rates of injection during power-on phases and, if required, other non-power-on phases of the method.

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In addition, whilst the embodiment includes the use of lime and magnesia as slag-forming agents, the present invention is not so limited and extends to the use of any suitable materials.

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In addition, whilst the embodiment includes supplying lime and magnesia during the first and second power-on phases, the present invention is not so limited and extends to adding these and other fluxes with the scrap, during power-on and after power on.

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In addition, whilst the embodiment includes operating the method with two power-on phases, the present invention is not so limited and extends to operating with one or any other suitable number of power-on phases.

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In addition, whilst the embodiment describes the supply of the mixture of the unagglomerated carbon-containing polymer and the other carbon source, the present invention also extends to embodiments in which there is supply of only one of the components at other times in the method.

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CLAIMS

1. A method for producing a ferro-alloy in an electric arc furnace that comprises supplying a mixture of (a) a carbon-containing polymer that is capable of acting as a slag foaming agent and (b) another source of carbon into the furnace during at least a part of a first power-on phase of the method and supplying a further mixture of the carbon-containing polymer and another source of carbon into the electric arc furnace during at least part of a second power-on phase of the method, wherein the carbon containing polymer is selected from one or more of rubber (synthetic or natural), polypropylene, polystyrene and polybutadiene styrene, and the other source of carbon is selected from one or more of coke, carbon char, charcoal and graphite.
2. A method of producing a ferro-alloy in an electric arc furnace or other suitable metallurgical furnace which comprises:
 - (a) supplying an initial charge of a feedstock for the ferro-alloy to the furnace;
 - (b) operating in a first power-on phase and establishing an arc between an electrode or electrodes of the furnace and the solid feedstock charge and generating heat in the furnace and melting the solid feedstock charge;
 - (c) after a first period of time into the first power-on phase, commencing supply of a mixture of (i) a carbon-containing polymer that is capable of acting as a slag foaming agent and (ii) an another source of carbon into the furnace, wherein the carbon containing polymer is selected from one or more of rubber (synthetic or natural), polypropylene, polystyrene and polybutadiene styrene, and the other source of carbon is selected from one or more of coke, carbon char, charcoal and graphite;
 - (d) at the end of the first power-on phase, supplying a further charge of the ferro-alloy feedstock to the furnace;
 - (e) operating in a second power-on phase by re-establishing the arc;

(f) after a first period of time into the second power-on phase, commencing injection of a mixture of (i) a carbon-containing polymer that is capable of acting as a slag foaming agent and (ii) an another source of carbon into the furnace, wherein the carbon containing polymer is selected from one or more of rubber (synthetic or natural), polypropylene, polystyrene and polybutadiene styrene, and the other source of carbon is selected from one or more of coke, carbon char, charcoal and graphite; and

(g) at the end of the second power-on phase, tapping molten ferro-alloy from the furnace.

3. The method defined in claim 1 or claim 2, further comprising assessing the time to commence supply of the mixture of the carbon-containing polymer and the other carbon source during the power-on phase or phases based on any one or more of the power consumption of the furnace, the composition of the melt in the furnace, and the melt temperature.

4. The method defined in any one of the preceding claims, wherein the ferro-alloy is steel.

5. The method defined in any one of the preceding claims comprises varying the ratio the carbon-containing polymer and the other carbon source in the mixture of these materials during the time period or periods of supply of the mixture to the furnace.

6. The method defined in any one of the preceding claims comprises maintaining the flowrate of the mixture of the carbon-containing polymer and the other carbon source constant during the time period or periods of supply of the mixture to the furnace.

7. The method defined in any one of claims 1 to 5 comprises varying the flowrate of the mixture of the carbon-containing source and other carbon source during the time period or periods of supply of the mixture of the furnace.

8. The method defined in any one of the preceding claims comprises maintaining a continuous supply of the mixture of the carbon-containing polymer and the other carbon source during the power-on phase or phases.

5 9. The method defined in any one of the preceding claims wherein the carbon-containing polymer comprises 20-60 wt.% of the total weight of the mixture.

10. The method defined in any one of the preceding claims wherein the carbon-containing polymer comprises 25-35 wt.% of the total weight of the mixture.

10 11. The method defined in any one of the preceding claims wherein the mixture of the carbon-containing polymer and the other carbon source supplied to the furnace during the first power-on phase is the same as the mixture supplied during the second power-on phase.

15 12. The method defined in any one of the preceding claims comprising injecting an oxygen-containing gas into the furnace during the power-on phase or phases.

13. The method defined in claim 12, wherein the oxygen-containing gas is oxygen.

20 14. An electric arc furnace when used to carry out the method for producing a ferro-alloy in the furnace defined in any one of the preceding claims, comprising a materials handling system for supplying a mixture of (i) the carbon-containing polymer that is capable of acting as a slag foaming agent and (ii) the other source of carbon to the furnace during the method of producing the ferro-alloy in the furnace, wherein the materials handling system comprises separate hoppers for storing the carbon-containing polymer and the other carbon source, a pipeline for transporting the carbon-containing polymer and the other carbon source to the furnace, and control valves for controlling the flow of each of the carbon-containing polymer and the other carbon source into the supply line so that the mixture of these materials forms in the pipeline and is transported to and supplied to the furnace.

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