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Published:

- *with international search report (Art. 21(3))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

Method of producing steel with using steel scrap in electric arc furnace

The present invention relates to the production of steel with using steel scrap in an Electrical Arc Furnace (EAF).

5 Steel can be currently produced through two mains manufacturing routes. Nowadays, most used production route named "BF-BOF route" consists in producing hot metal in a Blast Furnace (BF), by use of a reducing agent, mainly coke, to reduce iron oxides and then transform hot metal into steel into a converter process or Basic Oxygen Furnace (BOF). This route, both in the production of coke from coal in a coking plant and in the
10 production of the hot metal, releases significant quantities of CO₂.

The second main route involves so-called "direct reduction methods" using Direct Reduced Iron (DRI). Among them are methods according to the brands MIDREX®, FINMET®, ENERGIRON®/HYL, COREX®, FINEX® etc., in which sponge iron is produced in the form of HDRI (hot direct reduced iron), CDRI (cold direct reduced iron), or HBI (hot
15 briquetted iron) from the direct reduction of iron oxide carriers. Sponge iron in the form of HDRI, CDRI, and HBI undergoes further processing in electric arc furnaces to produce steel. Such route is also referred to as "DRI-EAF route".

One of the main options chosen by steelmakers to reduce CO₂ emissions is therefore to switch from the BF-BOF route towards the DRI-EAF route. However, use of
20 DRI products in classical electrical arc furnaces together with ferrous scraps has some limitations. Indeed, scraps contain a lot of impurities and resulting liquid steel will need to be further processed to produce high quality steel grades. Moreover, electric arc furnaces were up to now used for production of specific grades, mostly for long products applications, which do not have the same constraints in terms of metallurgy as the grades used notably
25 for automotive products.

For example, the amount of sulphur in liquid steel affects the brittleness of the steel and reduces weldability and corrosion resistance. The sulphur content tends to increase in the liquid steel due to the lower quality of available iron ore used for the direct reduction process. With the BF-BOF route it was possible to use the blast furnace for most of the
30 desulphurization, which will not be the case with the DRI-EAF route.

As another example, liquid steel produced from a basic oxygen furnace contains 20 to 90 parts per million (ppm) of nitrogen, compared to 100 to 140 ppm of nitrogen in liquid steel produced in an electric arc furnace. The nitrogen content of current electric arc furnace steel (EAF steel) is thus much higher than that of basic oxygen furnace steel (BOF steel)
35 and cannot meet the requirements of high-grade steel. High nitrogen content can result in

inconsistent mechanical properties in hot rolled steels, embrittlement of the heat affected zone (HAZ) of welded steels, and poor cold formability.

One of the aims of the invention is to propose a method of producing steel with steel scrap using an EAF that allows controlling the composition of the steel in a satisfactory manner.

In this view, the invention proposes a method of producing steel using an EAF comprising electrodes, the method comprising successively:

- a loading step comprising loading a load in the EAF, the load containing steel scrap ;
- a melting step comprising energizing the electrodes of the EAF for melting the load and generating a melt ;
- a desulphurization step comprising introducing a desulphurizing agent in the EAF within the melt for collecting sulphur in a slag above the melt and then removing the slag from the EAF; and
- a decarburization step comprising injecting oxygen in the EAF for decarburizing the melt.

The desulphurizing agent is chosen for reacting with sulfur and thus for lowering the sulfur content in the melt.

The desulphurization step operated with introducing the desulphurizing agent in the melt before operating a decarburizing step by injecting oxygen in the EAF allows performing the desulphurization step when the carbon content of the melt is still relatively high and the oxygen content of the melt is still relatively low.

This promotes the efficiency of the desulphurization step, namely by removing sulfur from the melt before sulfur reacts with oxygen. This allows controlling the sulfur content in the melt, in particular in view of producing steel with a low sulfur content.

In some examples, the steel production method comprises on or several of the optional following features, taken individually or according to any technically feasible combination:

- the desulphurizing agent is introduced in the EAF during melting and/or after melting of the load ;
- the desulphurizing agent comprises or consists of CaC_2 or lime or Mg or a mix of at least two of them;
- the desulphurizing agent comprises or consists in a mix of CaC_2 and Mg;
- the desulphurizing agent is introduced in the EAF when the carbon content of the melt is above a reference carbon content and/or at its maximum value before decarburization;

- the desulphurizing agent is introduced in the EAF when the oxygen content of the melt is below a reference oxygen content and/or at its minimum value before decarburization;

- the steel production method further comprises a composition adjustment step comprising introducing a composition adjustment slagging agent for forming a composition adjustment slag in the EAF and then removing the composition adjustment slag;

- the steel production method further comprises a denitrogenation step comprising the injection of a denitrifying agent in the EAF;

- the denitrifying agent comprises or consists of carbon;

- the load comprises at least 40% by weight of steel scrap;

- load comprises at least 40% by weight of direct reduced iron;

- load comprises between 40% by weight and 60% by weight of direct reduced iron.

The invention and its advantages will be better understood upon reading the following description which is given solely by way of non-limiting example, and which is made with reference to the appended drawings, in which:

- Figure 1 – 6 illustrated an Electrical Arc Furnace (EAF) during successive steps of a method of producing steel using the EAF.

- Figure 7 is a bloc diagram illustrating successive steps of a method of producing steel using an EAF according to an example;

- Figure 8 is a bloc diagram illustrating successive steps of a method of producing steel using an EAF according to another example.

As illustrated on Figures 1 – 6, a EAF 2 is configured for melting a load L (Figure 1) by generating electrical arc for heating and melting the load L into a melt M (Figures 2 – 6).

The EAF 2 is configured for receiving a load L containing metal materials, in particular a load L containing steel scrap SC and, optionally, pig iron and/or direct reduced iron (DRI) in addition to the steel scrap SC.

The EAF 2 comprises for example a shell 4 and a roof 6 delimiting a chamber 8 for receiving the load (L). The shell 4 comprises a top opening 10 for loading the load L into the chamber 8. The roof 6 is removably attachable to the shell 4 such as to open the EAF 2 for loading the steel scrap SC and close the EAF 2 for melting the load L into a melt M.

The shell 4 comprises for example a bottom 12 and a lateral wall 14. The top opening 10 is delimited by an upper edge of the lateral wall 14.

The shell 4 comprises for example a melt outlet 16 for discharging the melt M from the shell 4. The melt outlet 16 is preferably located on the bottom 12 of the shell 4. The melt outlet 16 located on the bottom 12 of the shell 4 allows discharging the melt M by flowing by gravity via the melt outlet 12.

The shell 4 comprises for example a slag opening 18 for discharging a slag S1, S2 (Figures 2 – 5) formed on top of the melt M. The slag opening 18 is for example located on the lateral wall 14 of the shell 4.

The EAF 2 comprises for example a slag door 20 configured to be selectively closed (Figures 1, 2, 4 and 6) or opened (Figure 3 and 5). When closed, the slag door 20 closes the slag opening 18 and prevents slag or melt from flowing via the slag opening 18. When opened, the slag door 20 is moved away from the slag opening 16 and allows slag to flow via the slag opening 18. The slag opening 18 is preferably spaced from the bottom 12 of the shell 4 such that a slag S1, S2 on top of the melt M can flow via the slag opening 18 first, before the melt M.

Optionally, the EAF 2 is tiltable (as illustrated about arrow R on Figures 3 and 5) for pouring slag by gravity via the slag opening 16.

The EAF 2 comprises two or more electrodes 22 arranged for generating electrical arc between the electrodes 22 and metal scraps SC received in the chamber 8 when the electrodes 22 are powered with electrical energy. Each electrode 22 is for example made of graphite.

Each electrode 22 is for example mounted in the shell 4 or on the roof 6.

Each electrode 22 mounted on the roof 6 is preferably configured to project downwardly from the roof 6. This allows the electrode 22 to insert into a pile of metal scrap SC loaded in the chamber 8 before melting and to extend close to the melt M after melting.

Each electrode 22 mounted on the roof 6 is advantageously vertically slidable relative to the roof 6 such as to allow lowering the electrode 22 progressively in the chamber 8 during melting of the steel scrap SC.

The electrical energy is provided by an electrical source 24. Each electrode 22 is for example electrically connected to the electrical source 24.

The electrical source 24 is configured to provide direct current (DC) or alternative current (AC), in particular two-phase alternative current or three-phase alternative current.

The EAF 2 is for example configured for connection to an electrical source 24 providing three-phase alternative current (AC). In such case, the EAF 2 comprises three electrodes 22 each connected to one respective phase of the three phases of the electrical source 24. The three electrodes 22 are for example mounted on the roof 6 with projecting downwardly into the chamber 8, in particular towards the bottom 12 of the shell 4.

In another example (not illustrated), the EAF 2 is for example configured for connection to an electrical source 24 providing a direct current (DC). In such case, the EAF 2 comprises for example one electrode 22 mounted on the roof 6 with projecting

downwardly into the chamber 8, in particular towards the bottom 12 of the shell 4, and one electrode mounted on the shell 4, in particular on the bottom 12 of the shell 4.

The electrical source 24 comprises for example an electrical network and/or an electrical power plant using preferably one or several renewable energy sources.

5 The electrical power plant is preferably operated using CO₂ neutral electricity which includes notably electricity from renewable sources which is defined as energy that is produced from renewable resources, which are naturally replenished on a human timescale, including sources like sunlight, wind, rain, tides, waves, geothermal heat and biogas. In some embodiments, the use of electricity coming from nuclear sources can be used as it is
10 not emitting CO₂ to be produced.

A biogas is a renewable energy source that can be obtained by the breakdown of organic matter in the absence of oxygen inside a closed system called bioreactor. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste, food waste or any biodegradable materials.

15 The EAF 2 comprises a gas injection system 26 configured for injecting gas in the chamber 8 during operation of the EAF 2, in particular when the EAF 2 is closed, i.e. when the roof 6 is mounted in the shell 4 to close the EAF 2.

The gas injection system 26 is configured in particular for injecting gas into the EAF 2 during melting of the steel scrap SC and/or after melting of the steel scrap SC into a melt M.

20 The gas injection system 26 comprises one or several gas lances 28, each gas lance 28 opening inside the EAF 2 and a gas source 30 fluidly connected to each gas lance 28 for feeding said gas lance 28 with an injection gas. The gas source 30 is for example a reservoir, in particular a pressurized reservoir, or a gas distribution network.

25 Each gas lance 28 is for example oriented obliquely downwardly to inject a flux of gas, towards the surface of the melt M and/or into the melt M present in the EAF 2.

In a preferred embodiment, the gas injection system 26 is configured for injecting a gas containing or consisting of oxygen into the EAF 2.

The injection of oxygen into the EAF 2 allows reducing the carbon content of the melt M because the oxygen injected in the EAF 2 reacts with the carbon present in the melt, e.g. for forming carbon monoxide (CO).
30

The EAF 2 optionally comprises a desulphurizing agent feed system 32 configured for introducing a desulphurizing agent in the EAF 2, preferably during operation of the EAF 2, in particular when the EAF 2 is closed. The desulphurizing agent feed system 32 is for example configured for feeding a desulphurizing agent in solid state.

35 The desulphurizing agent is for example fed in the form of particles, in particular in the form of a powder, or even better as a submicronic powder.

The desulphurizing agent feed system 32 is for example configured for injecting the desulphurizing agent within the melt M, in particular below the surface of the melt M, for example at least 10 cm below the surface of the melt M, in particular at least 20 cm below the surface of the melt M, more in particular at least 30 cm below the surface of the melt M.

5 The deeper the injection is in the molten metal, the better.

The desulphurizing agent feed system 32 is for example configured for injecting the desulphurizing agent using a carrier gas, the carrier gas being an inert gas, such as argon (Ag).

10 The desulphurizing agent feed system 32 comprises for example a feed duct 34 opening in the chamber 8 of the EAF 2, within the melt M, and a slagging agent source 36 for storing the desulphurizing agent and providing the desulphurizing agent to the feed duct 34.

15 A method of producing steel from steel scrap SC using the EAF 2 will now be described with reference to Figures 1 – 6 illustrating the EAF 2 during successive steps of the production method and to Figure 7 which is a bloc diagram illustrating different steps of the production method.

The production method comprises a loading step E1 (Figure 1) comprising loading a load L in the EAF 2, more particularly in the chamber 8 of the EAF2.

20 The load L comprises steel scrap SC. In some examples, the steel scrap SC that is used is referred to, in the EU-21 Steel Scrap Specification, as old scraps (E1 or E3), new scraps (E8), shredded scraps (E40) or fragmentized scraps (E46).

Optionally, the load L comprises Direct Reduced Iron (DRI) and/or pig iron in addition to the steel scrap SC.

Preferably, the load L comprises at least 40% by weight of steel scrap SC.

25 In some examples, load L comprises at least 40% by weight of DRI, preferably from 40 to 60% by weight of DRI.

In other embodiments, the load may comprise from 40 to 60% by weight of steel scrap, up to 30% by weight of pig iron and from 10 to 60% by weight of DRI.

30 The percentage of DRI and/or of pig iron in the load L is highly dependent on the quality of the steel scrap SC which is used and of the steel grade to be produced. If the level of impurities, such as copper, chromium, molybdenum, nickel, tin, antimony, zinc and/or arsenic is low then the quantity of scrap to be charged may be increased and thus the quantity of DRI decreased. The amount of pig iron added depends also on energy availability, indeed by adding liquid pig iron the amount of energy needed to melt the DRI and the scrap is decreased due to the energy brought by the pig iron itself.

35

In view of loading the EAF 2, the EAF 2 is for example opened by removing the roof 6 from the shell 4 to load the steel scraps SC into the shell 4, e.g. using a crane, via the top opening 10, and the EAF 2 is then closed by attaching the roof 6 to the shell 4 and closing the top opening 10. If applicable, DRI and/or cold pig iron are for example charged into the shell 4, for example each via the top opening 10, together with steel scrap SC, or through a dedicated aperture provided in the roof 6 (not illustrated). Pig iron can be charged under solid form, as cold material or under liquid form. In that case, it is preferably charged after complete melting of the first batch of scrap.

The production method comprises a melting step E2 (Figure 2) comprising energizing the electrodes 22 with an electrical current such as to generate electrical arcs between the electrodes 22 and the load L in the EAF 2 and thus melt the load L.

Electrical arcs generate heat energy which melts the load L. The melting step E2 is performed until the load L is melted into a melt M which is then also called "bath".

Once the load L is melted, the electrodes 22 preferably continue to be energized with electrical current to generate electric arcs between the electrodes 22 and the melt M such as to target a desired temperature of the melt M.

The production method comprises a desulphurization step E3 (Figures 2 and 3) comprising introducing a desulphurizing agent in the EAF 2 for collecting sulphur in a slag S1 (Figure 3) forming a separate phase floating above the melt M and removing the slag S1 from the EAF 2 (Figure 3).

The desulphurizing agent is introduced in the EAF 2 for example during the melting step E2 and/or after the melting step E2. Preferably, the desulphurizing agent is introduced in the EAF 2 after the melting step E2.

The desulphurizing agent is for example introduced in the EAF 2 using the desulphurizing agent feed system 32. The desulphurizing agent feed system 32 is in particular used for introducing the desulphurizing agent in the EAF 2 during the melting step E2 and/or after the melting step E2, within the melt M.

The desulphurizing agent contains one or several chemical components, which exhibit chemical affinity with sulfur such as to react with sulfur present in the melt M and form sulfur-containing products, which tend to migrate from the melt M towards the slag S1, which collects the products of the reactions between sulfur and said chemical components.

The slag S1 is formed before injection of the desulphurizing agent and collects the sulfur-containing products generated by the reaction of the sulfur present in the melt M with the injected desulphurizing agent. The slag S1 is thus used for desulphurizing.

The slag S1 is for example generated during melting the load L, in particular by chemical components initially present in the load L, such as aluminum (Al), silicon (Si) metal oxides and/or organic residues.

The desulphurizing agent is introduced in the EAF 2 preferably when the carbon content of the melt M is above a reference carbon content and/or at its maximum value before decarburization. The reference carbon content is for example upper than 0.8% by weight of carbon in the melt, preferably upper than 1.5% by weight

The desulphurizing agent is introduced in the EAF 2 preferably when the oxygen content of the melt M is below a reference oxygen content and/or at its minimum value before decarburization. The reference oxygen content is below 50ppm by weight of oxygen in the melt, preferably below 25 ppm by weight.

The desulphurizing agent contains or consists of one or several chemical components chosen among calcium carbide (CaC_2), lime (CaO) and magnesium (Mg).

In particular, desulphurizing agent comprises or consists of one or at least two among calcium carbide, lime and/or manganese.

The reaction of calcium carbide with sulfur is $\text{CaC}_2 + \text{S} \rightarrow \text{CaS} + 2\text{C}$ where CaC_2 is calcium carbide, S is dissolved sulfur, CaS is calcium sulfide and C is dissolved carbon.

The reaction of lime with sulfur is $\text{CaO(s)} + [\text{S}]\text{Fe} = \text{CaS(s)} + [\text{O}]\text{Fe}$.

The reaction of sulfur with magnesium is $\text{FeS} + \text{Mg} = \text{MgS} + \text{Fe}$.

The slag S1 is for example evacuated via the slag opening 18. The slag removal comprises for example opening the slag door 20 to free the slag opening 18 and allow the slag S1 to flow out of the EAF 2. The slag opening 18 located vertically at a distance above the bottom 12 of the shell 4 allows the slag S1 formed on top of the melt M to flow out the EAF 2 via the slag opening 18 without the melt M flowing out of the EAF 2.

Optionally, if the EAF 2 is tiltable, the step of removing comprises tilting the EAF 2 to pour the slag S1 out of the shell 4 via the slag opening 18.

The production method comprises a decarburization step E4 (Figures 4 and 5) comprising injecting oxygen in the EAF for decarburizing the melt M, thus generating a decarburizing slag S2 (Figure 4) and removing the decarburizing slag S2 from the EAF 2 (Figure 5).

The decarburization step is performed after the desulphurization step.

The decarburization step is performed for example by injecting oxygen in the EAF 2, in particular using the gas injection system 26 for injecting a flux of gas containing or consisting of oxygen into the EAF 2 via each gas lance 28, as illustrated by arrow F on Figure 4.

The reaction of oxygen with dissolved carbon (i.e. carbon dissolved in the melt M) produces carbon monoxide. The reaction of oxygen with other elements or components present in the melt M form a decarburizing slag S2 which forms on top of the melt M.

Removal of the decarburizing slag S2 from the EAF 2 (Figure 5) is preferably performed with evacuating the decarburizing slag S2 via the slag opening 18.

The slag removal step comprises for example opening the slag door 20 to free the slag opening 18 and allow the decarburizing slag S2 to flow out of the EAF 2. The slag opening 18 located vertically at a distance above the bottom 12 of the shell 4 allows the decarburizing slag S2 formed on top of the melt M to flow out the EAF 2 via the slag opening 18 without the melt flowing out of the EAF 2.

Optionally, if the EAF 2 is tiltable, the removal of the decarburizing slag S2 comprises tilting the EAF 2 to pour the decarburizing slag S2 out of the shell 4 via the slag opening 18.

The production method comprises a collection step E5 comprising collecting the melt M from the EAF 2, preferably via the melt opening 16 of the shell 4.

Optionally, if the EAF 2 is tiltable, the step of collecting the melt M comprises tilting the EAF 2 to pour the melt M out of the shell 4 via the melt opening 16.

In a known manner, the melt M collected from the EAF 2 is for example further refined for adjusting the composition of the melt M. The further refinement, also called secondary metallurgy, is performed in a secondary metallurgy installation 36.

The secondary metallurgy installation 36 comprises one or more reactors, each reactor allowing reheating the melt, maintaining the melt into a low-pressure atmosphere, removing one or several elements or components from the melt for diminishing the content of said elements or components, and/or adding one or several elements or components into the melt for augmenting the content of said elements or components.

Secondary metallurgy reactors include for example a composition adjustment sealed device (or CAS), a cored wire injection device, a ladle furnace, a composition adjustment seal argon bubbling and oxygen blowing device (or CAS - OB), a Rheinstahl Heraeus reactor, optionally with oxygen blowing, with submerged lances and/or by lance with post-combustion, with powder injection and/or with oxygen injection by emerged sonic tuyeres, a vacuum tang degasser (VTD), vacuum oxygen decarburization (VOD), a vacuum ladle furnace or a vacuum arc decarburization.

In the production method, the desulphurization step operated with introducing the desulphurizing agent in the melt before operating a decarburization step by injecting oxygen in the EAF allows performing the desulphurization step when the carbon content of the melt is still relatively high and the oxygen content of the melt is still relatively low. This promotes the efficiency of the desulphurization step, namely by removing sulfur from the melt before

sulfur reacts with oxygen. Before the decarburization step, the carbon content is for example from 0.5 to 1% in weight and the oxygen content from 50 to 100 ppm in weight.

The subsequent decarburization step allows removing dissolved carbon, which is still present after the desulphurization step.

5 The production method thus allows controlling the sulfur content in the melt and the carbon content in the melt, in particular in view of producing steel with a low sulfur content and/or with a low carbon content.

10 At the exit of the EAF, the liquid steel preferably comprises less than 400 ppm in weight of carbon, preferably from 300 to 400 ppm in weight. The content of sulphur in the liquid steel at the exit of the EAF is preferably below 320ppm in weight, most preferably below 200 ppm in weight.

15 In other examples, the production method comprises one or several additional composition adjustment steps performed in the EAF, each additional composition adjustment step comprising introducing a composition adjustment slagging agent for forming a composition adjustment slag in the EAF and then removing the composition adjustment slag.

Each additional composition adjustment step is performed in the EAF before the desulphurization step, between the desulphurization step and the decarburization step or after the decarburization step.

20 The production method comprises one or several additional composition adjustment steps performed in the EAF before the desulphurization step and/or one or several additional composition adjustment steps performed in the EAF between the desulphurization step and the decarburization step and/or one or several additional composition adjustment steps performed in the EAF after the desulphurization step.

25 In some examples, the production method comprises an additional composition adjustment step which is a denitrogenation step.

The production method illustrated on Figure 8 differs from that of Figure 7 in that the production method comprises a denitrogenation step E3a performed in the EAF 2, which is performed preferably before the desulphurization step E3.

30 The denitrogenation step E3a comprises injecting a denitrifying agent comprising or consisting of carbon in the EAF 2, for example using the desulphurizing agent feed system 32.

35 Carbon injected during the denitrogenation step E3a reacts with oxygen and produces gaseous carbon monoxide in form of bubbles which will escape from the bath, taking with them the nitrogen contained in the molten metal.

The injected carbon may be biomass-based carbon, e.g. biochar, recycled-carbon including graphite refractory, by-products of graphite materials (breeze), coke breeze, petroleum coke. The injected carbon is preferentially biochar. By Biochar it is meant a charcoal that is produced by pyrolysis of biomass in the absence of oxygen. Biomass is renewable organic material that comes from plants and animals. Biomass sources for energy include wood and wood processing wastes—firewood, wood pellets, and wood chips, lumber and furniture mill sawdust and waste, and black liquor from pulp and paper mills, agricultural crops and waste materials—corn, soybeans, sugar cane, switchgrass, woody plants, and algae, and crop and food processing residues, biogenic materials in municipal solid wastepaper, cotton, and wool products, and food, yard, and wood wastes and animal manure and human sewage.

The denitrogenation step performed before the desulphurization step increases the carbon content of the melt before the desulphurization step. This allows to create reducing conditions which promote desulphurization.

This allows the production of a steel with low nitrogen content and low sulphur content. At the exit of the EAF, the liquid steel preferably comprises less than 30ppm of nitrogen.

Preferably, the decarburization step is the next composition adjustment step performed in the EAF 2 after the desulphurization step and/or, when a denitrogenation step is provided before the desulphurization step, the desulphurization step is the next composition adjustment step performed in the EAF 2 after the denitrogenation step.

The invention is not limited to the examples and variants as described above and illustrated on the Figures. Other examples and variants may be contemplated.

CLAIMS

1. Method of producing steel using an Electrical Arc Furnace (EAF) comprising electrodes, the method comprising successively:

5 - a loading step comprising loading a load (L) in the EAF, the load (L) containing steel scrap (SC) ;

 - a melting step comprising energizing the electrodes of the EAF for melting the load (L) and generating a melt (M);

10 - a desulphurization step comprising introducing a desulphurizing agent in the EAF within the melt (M) for collecting sulphur in a slag (S1) above the melt (M) and then removing the slag (S1) from the EAF; and

 - a decarburization step comprising injecting oxygen in the EAF for decarburizing the melt (M).

2. Method according to claim 1, wherein the desulphurizing agent is introduced in 15 the EAF during melting and/or after melting of the load (L).

3. Method according to claim 1 or 2, wherein the desulphurizing agent comprises or consists of CaC_2 or lime or Mg or a mix of at least two of them.

4. Method according to any one of the preceding claims, wherein the desulphurizing agent comprises or consists in a mix of CaC_2 and Mg.

20 5. Method according to any one of the preceding claims, wherein the desulphurizing agent is introduced in the EAF when the carbon content of the melt (M) is above a reference carbon content and/or at its maximum value before decarburization.

6. Method according to claim 5 wherein the reference carbon content is upper than 0.8% by weight of carbon in the melt (M), preferably upper than 1.5% by weight.

25 7. Method according to any one of the preceding claims, wherein the desulphurizing agent is introduced in the EAF when the oxygen content of the melt (M) is below a reference oxygen content and/or at its minimum value before decarburization.

8. Method according to claim 7 wherein the reference oxygen content is below 50ppm by weight of oxygen in the melt (M), preferably below 25 ppm by weight.

30 9. Method according to any one of the preceding claims, further comprising a composition adjustment step comprising introducing a composition adjustment slagging agent for forming a composition adjustment slag in the EAF and then removing the composition adjustment slag.

35 10. Method according to any one of the preceding claims, further comprising a denitrogenation step comprising the injection of a denitrating agent in the EAF.

11. Method according to claim 8, wherein the denitrifying agent comprises or consists of carbon.

12. Method according to any one of the preceding claims, wherein the load comprises at least 40% by weight of steel scrap (SC)

5 13. Method according to any one of the preceding claims, wherein the metal load (L) comprises at least 40% by weight of direct reduced iron (DRI).

14. Method according to any one of the preceding claims, wherein the metal load (L) comprises between 40% by weight and 60% by weight of direct reduced iron (DRI).

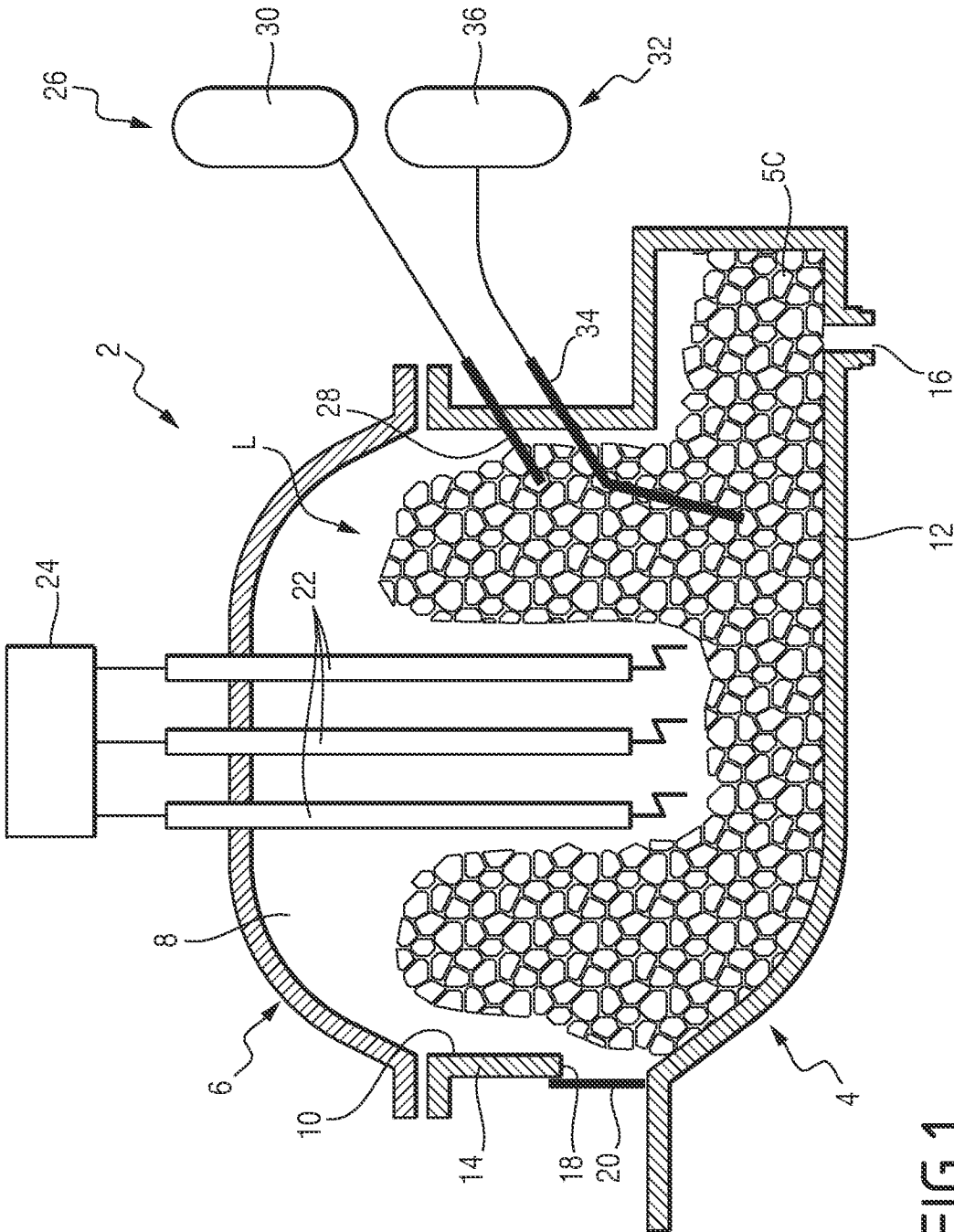


FIG.1

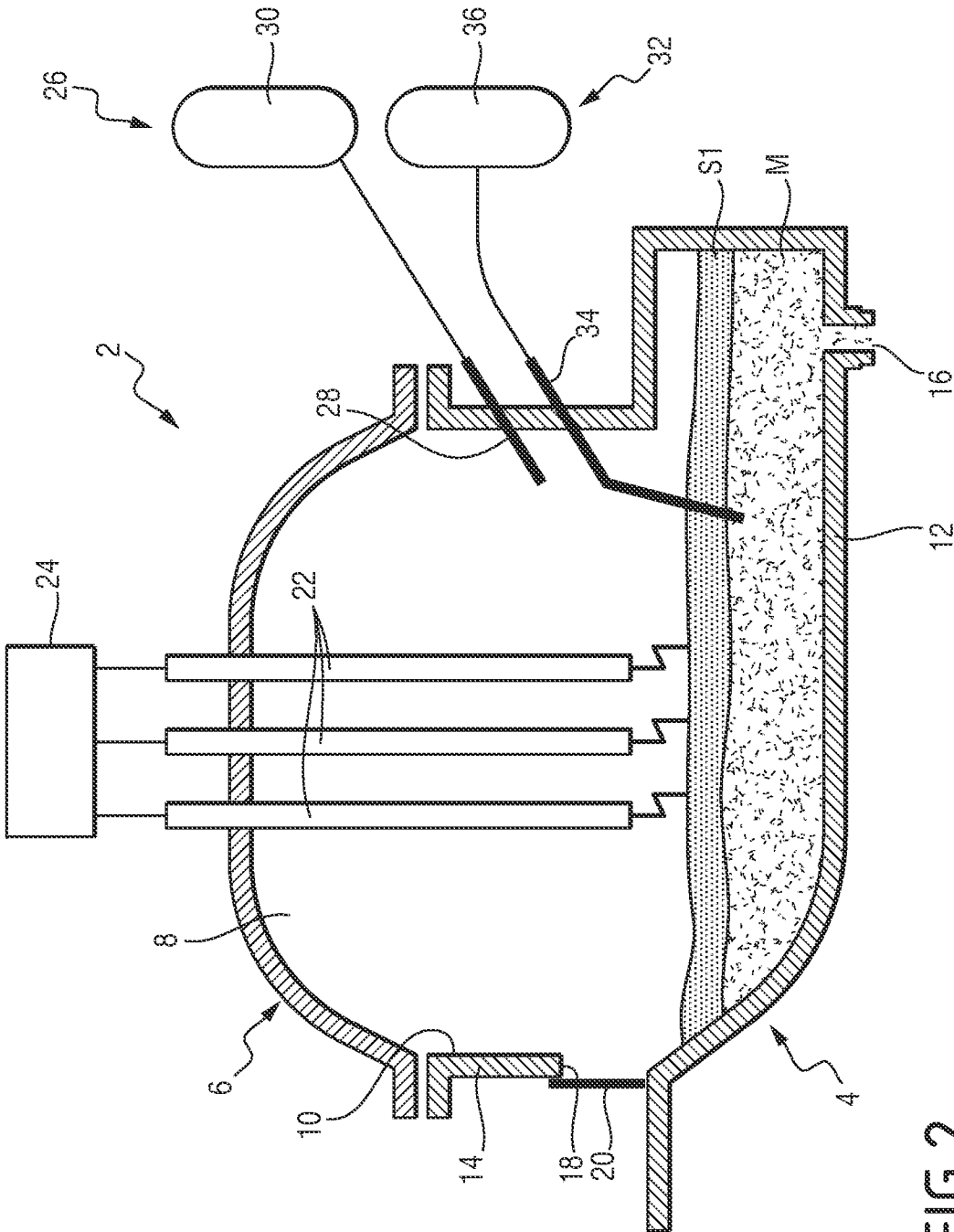
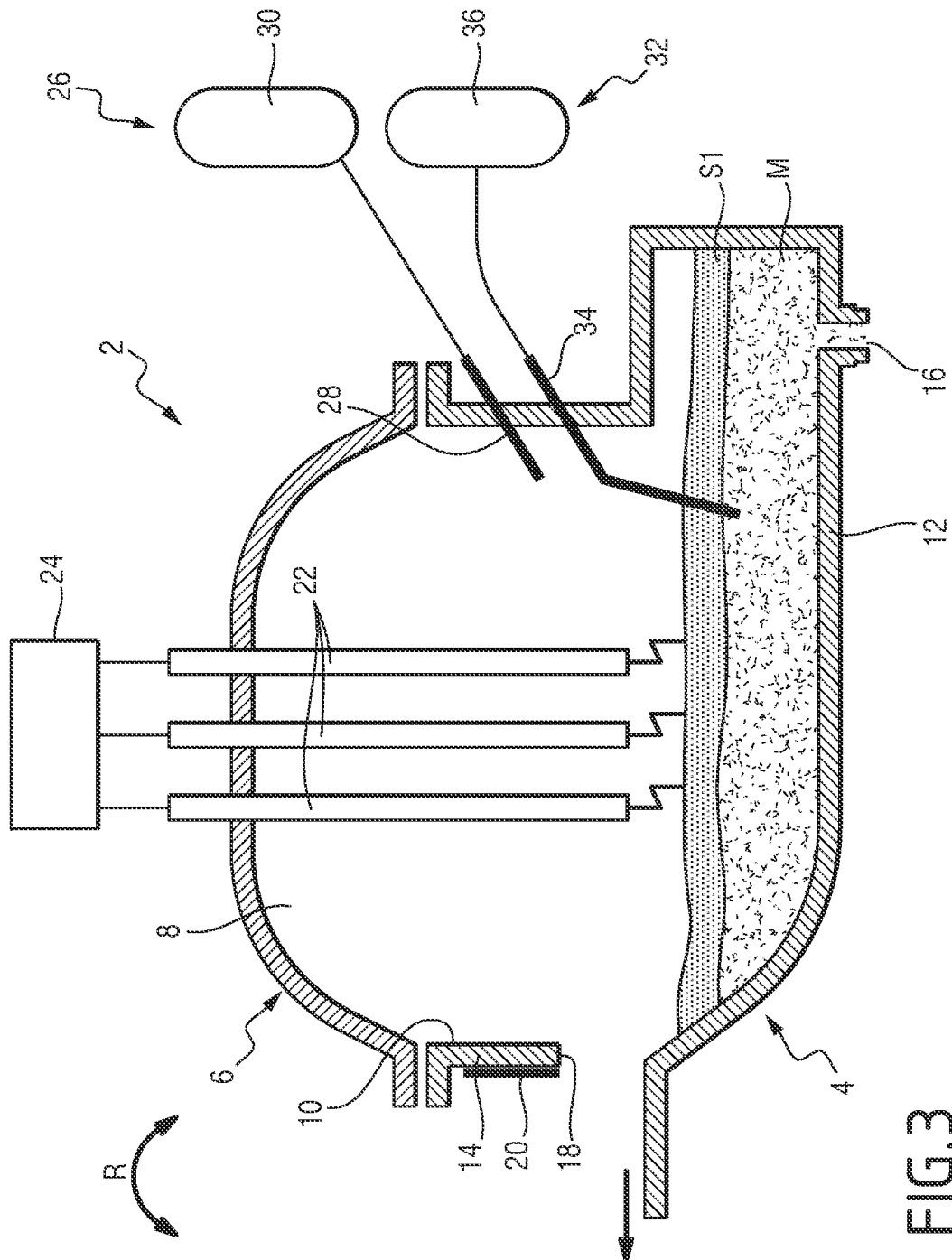
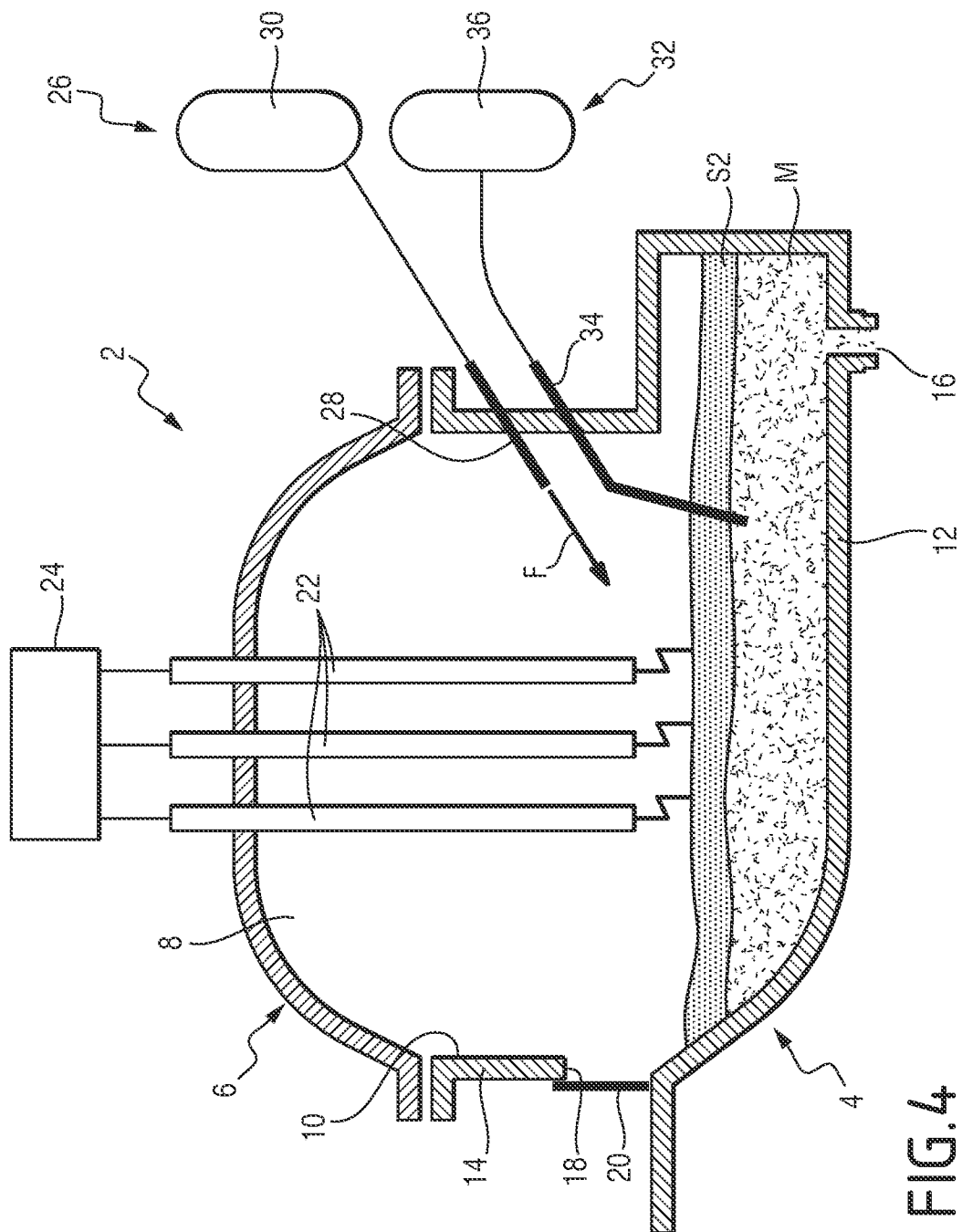


FIG. 2





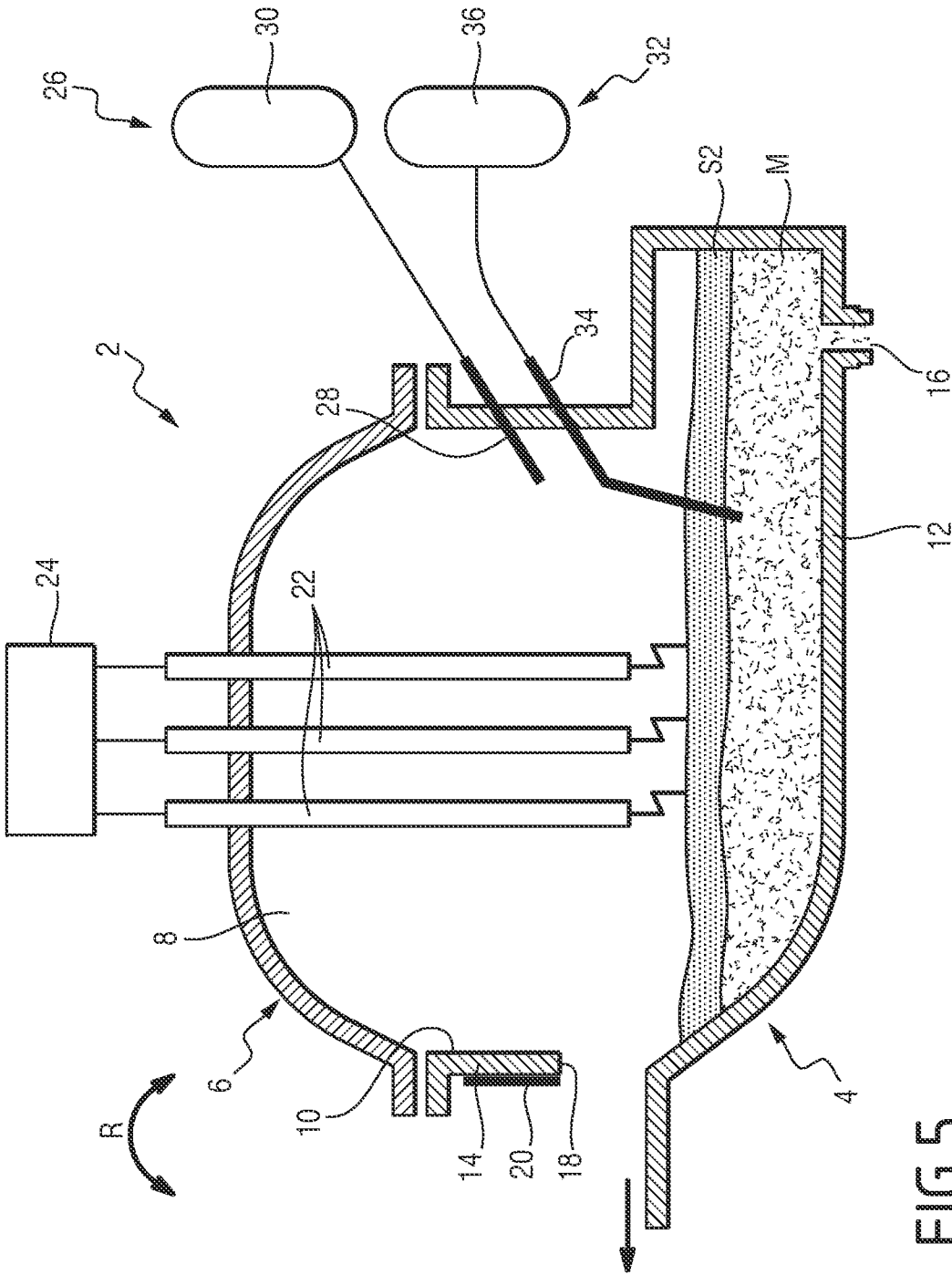
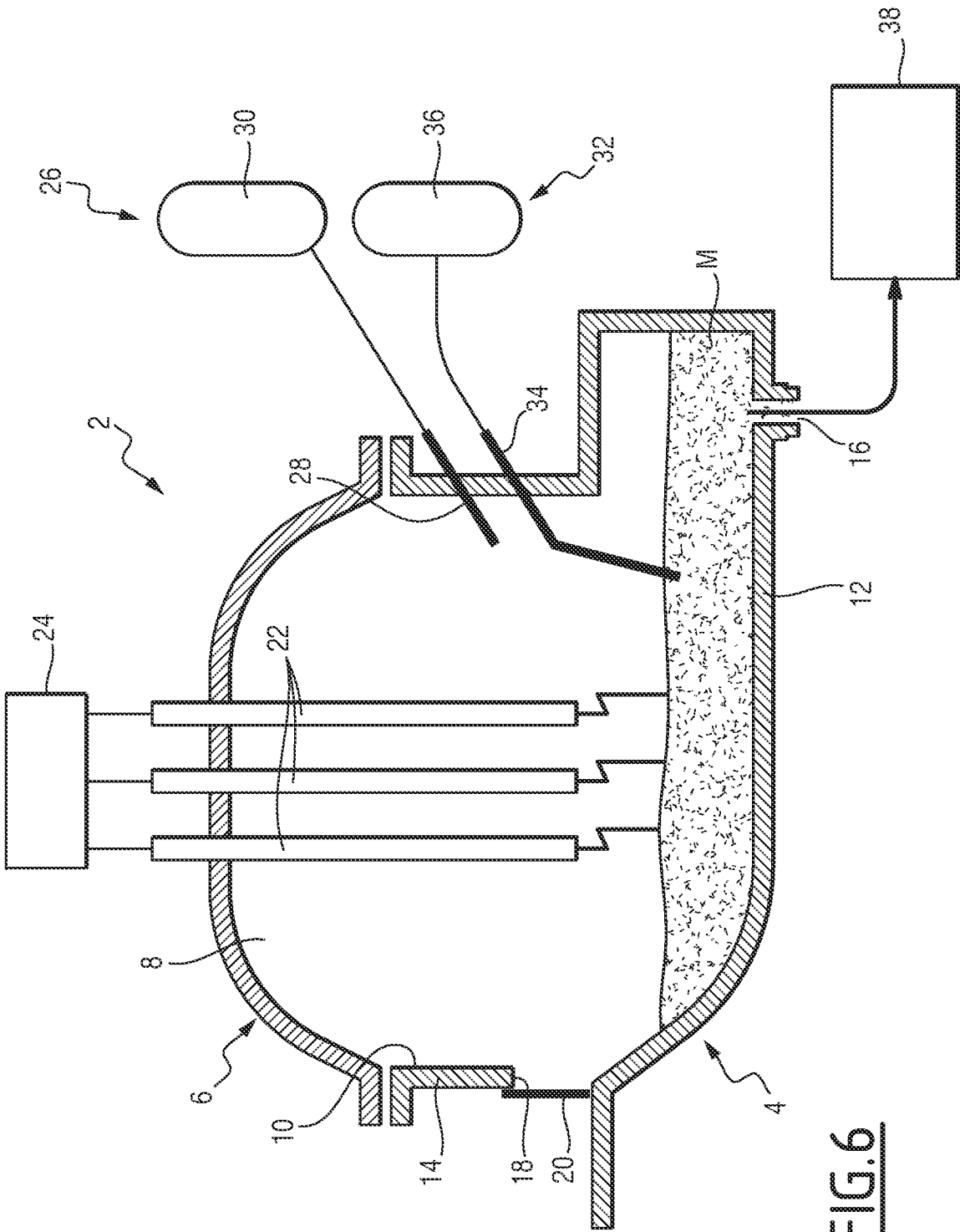


FIG. 5



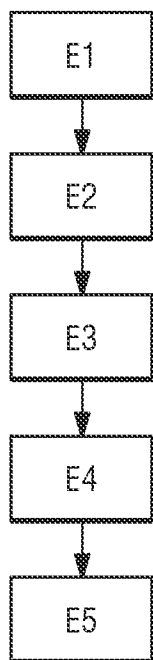
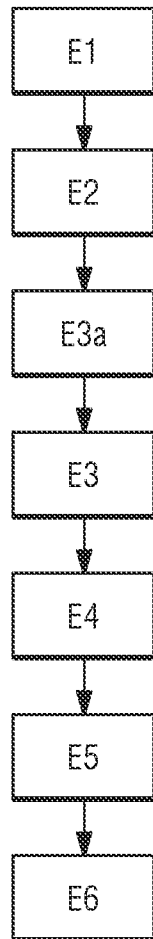


FIG.7

FIG.8

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2024/061392

A. CLASSIFICATION OF SUBJECT MATTER					
INV.	C21C5/54	C21C5/56	C21C7/06	C21C7/064	C21C7/072
	C21C7/076	C21C5/52			
ADD.					
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)					
C21C					
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)					
EPO-Internal, WPI Data					
C. DOCUMENTS CONSIDERED TO BE RELEVANT					
Category*	Citation of document, with indication, where appropriate, of the relevant passages				Relevant to claim No.
X	US 5 417 740 A (GALPERIN GRIGORI [RU] ET AL) 23 May 1995 (1995-05-23) figure 5 examples 1, 6 column 33, line 5 - line 64 column 13, line 8 - line 29 -----				1 - 14
X	US 5 654 976 A (COWX PETER [NO] ET AL) 5 August 1997 (1997-08-05) claims 1, 4, 6, 9, 19 -----				1 - 10, 12 - 14
X	US 3 816 100 A (RAMACHANDRAN S ET AL) 11 June 1974 (1974-06-11) claims 1, 2, 8, 14, 15 column 1, line 14 - line 30 column 2, line 44 - column 3, line 10 column 4 -----				1 - 14
☐ Further documents are listed in the continuation of Box C.					
☒ See patent family annex.					
* Special categories of cited documents :					
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"O" document referring to an oral disclosure, use, exhibition or other means			"Z" document member of the same patent family		
"P" document published prior to the international filing date but later than the priority date claimed					
Date of the actual completion of the international search			Date of mailing of the international search report		
24 January 2025			03/02/2025		
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016			Authorized officer Porté, Olivier		

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2024/061392

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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			US 5417740 A	23-05-1995
			WO 9535394 A1	28-12-1995

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US 3816100	A	11-06-1974	NONE	
