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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 May 2025 (22.05.2025)

WIPO | PCT

(10) International Publication Number
WO 2025/104632 A1

(51) International Patent Classification:
F27B 9/06 (2006.01) *F23D 14/66* (2006.01)
F27B 9/20 (2006.01) *F27B 9/30* (2006.01)
F27D 11/02 (2006.01) *F27B 9/36* (2006.01)
F27D 99/00 (2010.01)

(21) International Application Number:
PCT/IB2024/061320

(22) International Filing Date:
14 November 2024 (14.11.2024)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
102023000024282 16 November 2023 (16.11.2023) IT

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(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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY,

(54) Title: HYBRID-POWERED HEAT TREATMENT PLANT AND PROCESS FOR HEAT TREATMENT OF METAL PRODUCTS, IN PARTICULAR STEEL PRODUCTS

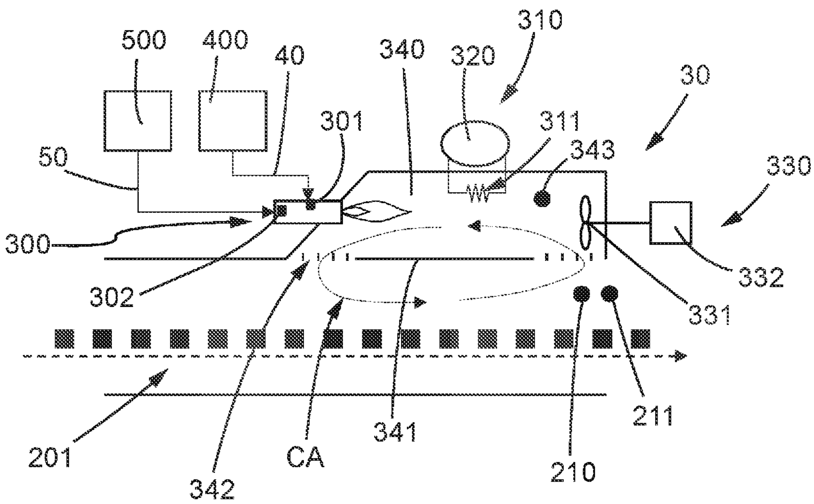

Fig. 2

(57) Abstract: Plant (10) for heat treatment of metal products (PM), comprising : a furnace (20) for heat treatment of metal products (PM), comprising: - a working chamber (201) with at least one opening for entering and/or exiting metal products (PM), at least one conditioning assembly (30) of the atmosphere inside the working chamber (201), which is coupled to the furnace (20) and is in fluid communication with the working chamber (201) and comprises: at least one combustion unit (300) of a combustible fluid and a comburent fluid in a combustion chamber which is defined by the working chamber (201) or is in fluid communication with it; at least one first supply duct (40) and at least one second supply duct (50) for supplying respectively a combustible fluid and a comburent fluid, and adapted to be coupled at the inlet respectively to a respective source of a combustible fluid and a comburent fluid (400, 500), - at least one suction duct (60) for suctioning at least a fraction of the atmosphere inside the working chamber (201), and at least one heat-generating electric unit (310) configured to heat the atmosphere inside the working chamber (201), wherein the electric unit (310) is

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MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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*

adapted to be coupled to an electric energy source (320) and is configured to transform the electric energy into thermal energy.

HYBRID-POWERED HEAT TREATMENT PLANT AND PROCESS FOR HEAT TREATMENT OF METAL PRODUCTS, IN PARTICULAR STEEL PRODUCTS

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The present invention relates to a heat treatment plant and process for heat treatment of metal products, in particular steel products, with hybrid power, i.e., both combustible and electric power.

The present invention relates to the field of heat treatment furnaces used, in particular in the steel industry, to submit metal products to controlled temperature variation processes, in particular heating followed by cooling, so as to obtain variations in the physical features of the treated metal products.

As known, such furnaces are divided into various typologies; in particular, reference will be made to continuous or batch-type furnaces, generally consisting of a longitudinally developing working chamber, with a first opening for entering the metal products to be treated and a second opening for exiting the treated metal products. Inside the working chamber, mechanical systems are present for supporting and moving the metal products to be treated from the inlet opening to the outlet opening.

In order to heat the metal products, free-flame burners are typically used, supplied by combustibles which can be for example of fossil origin (natural gas), or for example produced from renewable sources (biogas, hydrogen from water electrolysis), or for example recovered from other processes (coke oven gas), or mixtures thereof.

The furnace is typically divided into at least two areas:

- a first area in which the metal products are heated to the treatment temperature; this first area is typically divided into a passive preheating section and an active heating section provided with burners;
- a second area where the temperature is maintained constant (maintaining or soaking section) to achieve uniform temperature conditions inside the metal products to be treated.

Given the decarbonization and energy transition policies of the industrial processes and, in particular in the steel industry, there is the problem of reducing the overall carbon dioxide emissions (carbon footprint) of the known heat treatment furnaces.

To this end, the use of combustible gases produced from renewable sources was proposed. In particular, the use of hydrogen produced by water electrolysis in electrolytic cells supplied by electric energy from renewable sources was proposed and tested, even industrially: when used in pure form, such combustible allows to virtually reduce CO_2 emissions to zero. This solution has the advantage of being applicable to an existing furnace without major structural modifications, but has the disadvantage of a suboptimal use of electric energy. Indeed, the overall performance, i.e., the ratio of the energy absorbed by the material to the electric energy which supplies the electrolyser to produce all the hydrogen required for combustion, is determined as the efficiency of the electrolyser multiplied by that of combustion: considering that the electrolysis process currently has a performance of about 60-75%, while the performance of a modern heat treatment furnace can reach

60-80%, it can be deduced that only 35-60% of the electric energy used to produce the hydrogen is effectively conferred to the metal products in the form of thermal energy.

Thus, there is a need for a plant and process that overcome the problems of the prior art described above, allowing to reduce the carbon dioxide emissions from fossil combustibles, maintaining at the same time a good heat treatment process quality and with a high efficiency in the use of the energy sources.

These objects, according to the present invention, are achieved by making a heat treatment plant and process for heat treatment of metal products, in particular steel products, as set forth in the independent claims.

Further features are provided in the dependent claims.

The features and advantages of a heat treatment plant and process for heat treatment of metal products, in particular steel products, according to the present invention, will be more apparent from the following exemplary and non-limiting description referred to the attached schematic drawings, in which:

Figure 1 is a schematic figure of a possible embodiment of a plant according to the present invention;

Figure 2 is a schematic figure of a conditioning assembly of the plant according to Figure 1;

Figure 3 is a block diagram of a process according to the present invention.

With reference to the attached figures, a heat treatment plant 10 for heat treatment of metal products PM, in particular steel products, is schematically shown.

"Heat treatment" means to indicate a thermal cycle conducted under predetermined atmospheric conditions which provides steps of heating the metal pieces to predetermined treatment temperatures, with the aim of imparting desired crystalline, mechanical, or technological features to the metal or metal alloy (in particular steel) by which the pieces are made. Examples of heat treatments include annealing, normalizing, tempering, hardening, quenching, and similar treatments.

The plant 10 comprises a heat treatment metallurgical furnace 20 for heat treatment of metal products PM.

The furnace 20 comprises a working chamber 201 with at least one opening for entering and/or exiting metal products PM, respectively to be treated and treated, wherein a heat treatment atmosphere is present inside the working chamber 201.

The furnace 20 can be of the continuous or batch type.

In one possible embodiment, the working chamber 201 comprises at least one inlet opening 202 for the metal products PM to be treated and at least one outlet opening 203 for the treated metal products PM. In the working chamber 201, at least one advancing assembly 204 is present, configured to advance the metal products along it in the advancing direction, not necessarily linear, from the inlet opening 202 to the outlet opening 203. The advancing assembly 204 is configured to support the metal products PM advancing them along an advancing direction and it can be of the movable skid type, roller type, or other types known in the field, and thus not further described.

A heat treatment atmosphere is present inside the working chamber 201, said heat treatment atmosphere being divided into a plurality of areas distributed along the working chamber 201. From the inlet opening 202 to the outlet opening 203, at least two areas can follow one another:

- a first heating area 2011 for heating the metal pieces PM to a treatment temperature Tt;
- a second area 2012 for maintaining the heated metal pieces PM at the treatment temperature Tt.

The first heating area 2011 can optionally be divided into two or more sections:

- a first passive preheating section, i.e., wherein no active heat generating units are present, and the metal pieces being preheated by convection and/or irradiation from the atmosphere circulating in such first section;
- a second active heating section, i.e., wherein at least one active heat generating unit is present, configured to provide heat to the atmosphere present in the working chamber 201, heating it, heat being then transferred by convection and/or irradiation to the metal pieces PM.

In the first area 2011, the metal pieces PM are heated until reaching the treatment temperature Tt.

In the second area 2012, a substantially uniform temperature is maintained so as to reduce the temperature gradient inside the heated metal pieces PM.

The plant 10 further comprises at least one conditioning assembly 30 of the atmosphere inside the working chamber 201, which is coupled to the furnace 20 and is in fluid communication with the working chamber 201.

At least one conditioning assembly 30 is coupled to the furnace 20 at at least one of the areas into which the atmosphere inside the working chamber 201 is divided.

In a preferred embodiment, at least one conditioning assembly 30 is coupled to the furnace 20 at the first heating area 2011 and/or at the second maintaining area 2012.

At the first heating area 2011, one or more conditioning assemblies 30 are arranged at the possible second active heating section thereof.

In a preferred embodiment, one or more conditioning assemblies 30, not necessarily identical to each other, are coupled to the furnace 20 at the first heating area 2011 and at the second maintaining area 2012.

Each conditioning assembly 30 comprises at least one combustion unit 300 of a combustible fluid and a comburent fluid in a combustion chamber, wherein the combustion chamber is defined by the working chamber 201 or is in fluid communication with it.

In one possible embodiment, the combustion unit 300 is provided with at least one outflow nozzle 301 of a combustible fluid in fluid communication with a combustion chamber and at least one outflow opening 302 of a comburent fluid in fluid communication with the combustion chamber, the combustion chamber being defined by the working chamber 201 or being in fluid communication with the working chamber 201.

The outflow nozzle 301 and the outflow opening 302 can be in direct communication with the combustion chamber if the combustible fluid and comburent fluid are not pre-mixed to each other.

Alternatively, the combustion unit 300 is provided with at least one outflow nozzle of a mixture of a combustible fluid and a comburent fluid in fluid communication with the combustion chamber, the combustion chamber being defined by the working chamber 201 or being in fluid communication with the working chamber 201.

The combustion unit 300 comprises, for example, a burner of a type known to the skilled person and thus not further described.

The plant 10 therefore comprises:

- at least one first supply duct 40 for supplying a combustible fluid, directly or indirectly, to the combustion unit 300 and adapted to be coupled at the inlet to a source of combustible fluid 400,
- at least one second supply duct 50 for supplying a comburent fluid, directly or indirectly, to the combustion unit 300 and adapted to be coupled at the inlet to a source of comburent fluid 500.

In one possible embodiment, the first supply duct 40 and the second supply duct 50 are in fluid communication with a device for mixing the combustible fluid and the comburent fluid, local to the combustion unit 300 or central, which is in fluid communication with the outflow nozzle of the combustion unit 300, for outflowing the mixture thus formed therethrough.

In a possible alternative embodiment:

- the first supply duct 40 is in fluid communication with the outflow nozzle 301 of the combustion unit 300, and
- the second supply duct 50 is in fluid communication with the outflow opening 302 of the combustion unit 300.

In the following, reference will be made to the latter embodiment.

In the case where two or more conditioning assemblies 30 are provided, the first supply duct 40 and the second duct 50, and the respective combustible fluid source 400 and comburent fluid source 500, can be common to their combustion units 300 or local to each of them.

The first supply duct 40 comprises the set of ducts and shut-off and/or control valves along which a fluid current of combustible flows, which, starting from the combustible source 400, is supplied to the combustion unit 300. The first supply duct 40 connects the combustible source 400 to the outflow nozzle 301 and can be at least partially formed in the combustion unit 300 (burner).

Combustible fluid means a combustible, typically a gaseous combustible of the type of natural gas, biogas, coke oven gas, hydrogen, or other combustible gases, alone or in mixtures.

The second supply duct 50 comprises the set of ducts and shut-off and/or control valves along which a fluid current of comburent fluid flows, which, starting from the comburent source 500, is supplied to the combustion unit 300. The second supply duct 50 connects the comburent source 500 to the outflow opening 302. The second supply duct 50 can be at least partially formed in the combustion unit 300 (burner).

Comburent fluid means a fluid adapted to chemically react with the combustible by oxidizing (burning) it; the comburent can be, for example, air, oxygen-enriched air, or other oxidizing gases, alone or in mixtures. In the case where the comburent is air, the comburent source 500 consists of the environment outside the furnace 20.

The combustion chamber can consist of a tubular compartment formed in the combustion unit 300 and in fluid communication with the working chamber 201, or it can consist of the working chamber 201 itself.

The plant 10 further comprises at least one suction duct 60 for suctioning at least one fraction of the atmosphere inside the working chamber 201, wherein the suction duct 60 is in fluid communication, at the inlet, with the working chamber 201 and, at the exit, with a suction unit 600 of at least one fraction of said atmosphere. The suction duct 60 comprises the set of ducts and shut-off and/or control valves, schematically represented by the valve assembly 601, along which a fluid current flows formed by at least one fraction of the atmosphere inside the working chamber 201 which is suctioned along it. The suction unit 600 can comprise a chimney and/or a possible suction fan (exhauster). The flow rate of the suctioned fraction of atmosphere can be adjusted between a minimum and a maximum; preferably, the minimum value corresponds to a null value of the flow rate, i.e., wherein the atmosphere inside the working chamber 201 is entirely maintained inside the latter. Generally, the working chamber 201 is maintained at a slight overpressure with respect to the environment outside the furnace 20.

The suction duct 60 and the suction unit 600 are advantageously arranged and configured to suction a fraction of the atmosphere inside the working chamber 201 at the first heating area 2011 and/or the second maintaining area 2012. They are in particular arranged and configured to suction a fraction of the atmosphere inside the working chamber 201 in countercurrent to the advancing direction of the metal products PM.

According to the invention, the conditioning assembly 30 further comprises:

- at least one heat-generating electric unit 310 configured to heat the atmosphere inside the working chamber 201, wherein the electric unit 310 is adapted to be coupled to an electric energy source 320 and is configured to transform the electric energy supplied thereto into thermal energy.

The electric unit 310 is a unit configured to be supplied by electric energy from an electric energy source 320 and to transform the electric energy supplied thereto into thermal energy to generate heat for heating the atmosphere inside the working chamber 201.

The electric unit 310 comprises one or more electric heaters, which can be of the one or more electric resistor type, or electric arc type or plasma type. Preferably, the electric unit 310 comprises one or more electric resistors 311, and the electric energy provided thereto is transformed into thermal energy by Joule effect. The electric resistors 311 can directly contact the atmosphere inside the working chamber 201 or can be in thermal communication with conduits in which a fraction of the atmosphere inside the working chamber 201 is circulated.

In the case where two or more conditioning assemblies 30 are present, the electric energy source 320 can be common or local to the respective electric units 310.

Each conditioning assembly 30 thus comprises at least one combustion unit 300 and at least one electric unit 310.

If two or more conditioning assemblies 30 are provided, they are placed in series with respect to each other. Only by way of example, the plant 10 of Figure 1 comprises a conditioning assembly 30 at the first area 2011 and a conditioning assembly 30 at the second area 2012.

If two or more conditioning assemblies 30 are provided, they can be equal to or different from each other, in particular their respective combustion units 300 and/or the respective electric units 310 can be equal to or different from each other.

In a preferred embodiment, at least one, and advantageously each, conditioning assembly 30 further comprises at least one forced circulation unit 330 for the forced circulation of the atmosphere inside the working chamber 201.

The forced circulation unit 330 can comprise at least one fan 331 driven by a respective motor 332.

In a further preferred embodiment, at least one, and advantageously each, conditioning assembly 30 further comprises at least one recirculation chamber 340 in fluid communication with the working chamber 201 for recirculating the atmosphere between the recirculation chamber 340 itself and the working chamber 201.

The recirculation chamber 340 is advantageously arranged or formed at the top of the working chamber 201, i.e., at the ceiling of the latter.

The recirculation chamber 340 can consist of a compartment at least partially separated from the working chamber 201 by means of at least one partitioning wall 341 provided with one or more passage openings 342, through which an atmospheric current CA flows from the working chamber 201 to the recirculation chamber 340 and vice versa from the recirculation chamber 340 to the working chamber 201.

The recirculation chamber 340 can be made as an integral part of the working chamber 201 or can consist of a component made as a part separate from the working chamber 201 to which it is subsequently coupled.

If two or more conditioning assemblies 30 are provided, they can be equal to or different from each other, in particular the possible respective forced circulation units 330 and/or possible recirculation chambers 340 can be equal to or different from each other.

One or more combustion units 300 can be arranged at the recirculation chamber 340 or at the working chamber 201, so as to be in fluid communication directly with the recirculation chamber 340 or directly with the working chamber 201.

One or more electric units 310 can be arranged in the recirculation chamber 340 or in the working chamber 201.

One or more forced circulation units 330 can be arranged at the recirculation chamber 340 or at the working chamber 201. The motors 332 which drive the forced circulation units 330 are advantageously arranged outside the working chamber 201 and outside the recirculation chamber 340.

In a preferred embodiment, as exemplified in Figure 2, the conditioning assembly 30 comprises at least one combustion unit 300, at least one electric unit 310, and at least one forced circulation unit 330, each of which is arranged in the recirculation chamber 340.

Generally, the forced circulation unit 330 is configured and arranged to the forced circulation of the atmosphere between the working chamber 201 and the electric unit 310 and/or the recirculation chamber 340.

According to a further aspect of the present invention, the plant 10 comprises, for at least one and advantageously for each conditioning assembly 30:

- a measuring device 210 arranged to measure at least the oxygen concentration (content) present in the atmosphere inside the working chamber 201, and
- at least one temperature sensor arranged to detect the temperature of at least one atmospheric current circulating in the working chamber 201 and/or through the conditioning assembly 30. The detecting device 210 is, for example, an oxygen probe of a type known to the skilled person.

The temperature sensor is, for example, a thermocouple of a type known to the skilled person.

The measuring device 210 and the temperature sensor are connected to a control and/or processing electronic unit 100, local or central, which is configured and/or programmed to control at least one and advantageously each conditioning assembly 30 and/or the suction unit 600 depending on the measured oxygen content and/or temperature, as described below.

In a preferred embodiment, the plant 10 comprises, at least for one of the conditioning assemblies 30:

- at least a first temperature sensor 211 arranged to measure the temperature of the atmospheric current inside the working chamber 201 and connected to the control and/or processing electronic unit 100, and/or
- at least a second temperature sensor 343 arranged to measure the temperature of the atmospheric current

present in the recirculation chamber 340 and connected to the control and/or processing electronic unit 100.

The first temperature sensor 211 is arranged in the working chamber 201. The second temperature sensor 343 is arranged in the recirculation chamber 340. Preferably, the electric unit 310 and, preferably also the combustion unit 300, are arranged in the recirculation chamber 340.

If multiple conditioning assemblies 30 are present, each provided with its own recirculation chamber 340, it can be provided a first temperature sensor 211 common to two or more of them or a first temperature sensor 211 local to each of them. If multiple conditioning assemblies 30 are present, each provided with its own recirculation chamber 340, each of them is provided with at least one, advantageously two or more, second sensors 343 arranged in the corresponding recirculation chamber 340.

If multiple conditioning assemblies 30 are present, it can be provided a measuring device 210 common to two or more of them or a measuring device 210 local to each of them.

According to one aspect of the present invention, the control and/or processing electronic unit 100 is configured and/or programmed for:

- Controlling the power of the electric resistors 311 forming the electric unit 310 to maintain or reach a set temperature in the recirculation chamber 340. Such control will be based on the temperature present in the recirculation chamber 340 measured by the second temperature sensor 343.
- Controlling the rotation speed of the fans 331 forming

the forced circulation unit 330 to maintain or reach the set temperature in the recirculation chamber 340. Such control will be based on the temperature present in the working chamber 201 measured by the first temperature sensor 211.

- Controlling the turning on or off of the burners forming the combustion unit 300, which will operate with such a combustion ratio to generate a minimum residual oxygen content. Such control will be based on the oxygen concentration value measured by the measuring device 210 and will be based on the fact that if the measured oxygen concentration will be below a certain threshold, the burners will be turned off or controlled so as to generate fewer fumes than those recirculated. If the measured oxygen concentration will be higher than the fixed threshold, the burners will be turned on or controlled so as to generate a number of low-oxygen-content fumes, to reduce the overall value thereof.

According to the present invention, the control and/or processing electronic unit 100 is therefore configured and/or programmed for:

- reducing or zeroing the flow rate of combustible fluid and comburent fluid supplied to the combustion unit 300, reducing or zeroing the thermal power delivered by the combustion unit 300, and/or reducing or zeroing the flow rate of the fraction of atmosphere suctioned by the suction unit 600 by means of the valve assembly 601, if the measured oxygen concentration is lower than a fixed threshold value,

- increasing or restoring the flow rate of the combustible fluid and comburent fluid supplied to the combustion unit 300, by increasing or restoring the thermal power delivered by the combustion unit 300, and/or by increasing or restoring the flow rate of the fraction of atmosphere suctioned by the suction unit 600 by means of the valve assembly 601, if the measured oxygen concentration is higher than a fixed threshold value.

The threshold value is, for example, between 1% and 3%, depending on the applications. The threshold value can depend on the maximum set heat treatment temperature and/or the features of the material of the products to be treated and/or other technical aspects. Such threshold value is related to the need to avoid or limit the formation of surface oxides on the metal pieces PM to be treated.

The control and/or processing electronic unit 100 is further configured and/or programmed for:

- controlling the electric power delivered by the electric unit 310 depending on the temperature measured by the second temperature sensor 343, and/or
- controlling the forced circulation unit 330 depending on the temperature measured by the first temperature sensor 211.

Preferably, the furnace 20 is made so as to limit the outside air entering the working chamber 201, in order to maintain a substantially constant composition of the atmosphere inside the working chamber 201, with precautions (e.g., sealing devices) which can relate to various components of the furnace 20, such as, for example, the inlet 202 and outlet openings 203, the advancing assembly 204, etc.

A plant 10 as described above can be used to operate as described hereinbelow.

In a first starting step, the atmosphere inside the working chamber 201 is composed of room temperature air.

The conditioning assemblies 30 are activated:

- the electric units 310 and forced circulation units 330 are turned on, and

- the combustion units 300 are activated.

Progressively, the oxygen percentage of the atmosphere inside the working chamber 201, measured by the measuring devices 210, decreases until falling below the prefixed threshold value (acceptability threshold).

In a second steady-state step, when the oxygen concentration present in the atmosphere inside the working chamber 201 measured by the measuring devices 210 has fallen below the prefixed threshold value, the thermal power delivered by the combustion units 300 (e.g., burners) is reduced compared to the first starting step down to be ideally zeroed.

In this second steady-state step, employing the combustion units 300 (e.g., burners) is limited solely to restoring the desired conditions of the atmosphere inside the combustion chamber 201, in particular restoring and maintaining the oxygen concentration at values lower than the acceptability threshold.

By reducing or zeroing the thermal power generated by the combustion units 300, indeed, the oxygen concentration present in the atmosphere inside the working chamber 201 tends to increase due to air from the environment outside the furnace 20 entering the latter. This happens, for example, during the passage of metal products PM at the inlet and outlet of the working chamber 201 and due to the inevitable entering false air. Under ideal conditions, i.e., in the absence of entering ambient air, once an acceptable oxygen concentration is reached, the combustion units 300 are maintained off (inactive).

In more detail, during this second steady-state step, the oxygen concentration present in the atmosphere inside the working chamber 201 is measured and monitored by the measuring devices 210.

When the measured value is lower than the prefixed threshold value, the thermal power delivered by the combustion units 300 (e.g., burners) is reduced or zeroed. This results in a corresponding reduction or zeroing of the flow rate of fumes produced by combustion. At the same time, therefore, the flow rate of the fraction of atmosphere suctioned by the suction unit 600 is reduced or zeroed.

Due to air from the environment outside the furnace 20 inevitably entering the working chamber 201, the oxygen concentration present in the atmosphere inside the working chamber 201 increases. When the oxygen concentration measured by the measuring devices 210 exceeds the prefixed threshold value, the thermal power delivered by the combustion units 300 is increased or restored. This results in a corresponding increase in the flow rate of fumes produced by combustion. At the same time, therefore, the flow rate of the fraction of atmosphere suctioned by the suction unit 600 is increased or restored. The oxygen concentration present in the atmosphere inside the working chamber 201 consequently decreases, and when the oxygen concentration measured by the measuring devices 210 falls below the prefixed threshold value, the thermal power delivered by the combustion units 300 (e.g., burners) is reduced or zeroed and, at the same time, the flow rate of the fraction of atmosphere suctioned by the suction unit 600 is reduced or zeroed.

In the second steady-state step, therefore, the plant 10 operates cyclically as described above.

During the operation of the plant 10, both during the first starting step and during the second steady-state step, in one or each of the conditioning assemblies 30, the atmosphere inside the working chamber 201, into which combustion fumes were released, is recirculated by the forced circulation units 330 (e.g., fans 331).

The electric units 310 are turned on, and the respective electric heaters (electric resistors 311) are hit by the atmospheric current CA, heating it to the useful temperature for the heat treatment process based on the temperature measured in the recirculation chamber 340 by the corresponding second temperature sensors 343. The atmospheric current CA, thus heated and recirculated, is directed towards the metal products PM, ceding heat to them by convection and irradiation, thereby cooling. The cooled atmospheric current CA is suctioned again by the forced circulation units 330 towards the electric units 310 to be heated again by them. The operation of the forced circulation units 330 (fans 331) is controlled based on the temperature measured in the working chamber 201 by the first temperature sensors 211. Such steps are repeated cyclically.

The control of the plant 10, and in particular the control of the thermal power delivered by the combustion units 300 and the electric units 310, therefore, takes place based on the measured values of the oxygen concentration and the temperature of the atmosphere inside the working chamber 201 by the measuring devices 210 and the first temperature sensors 211, and the temperature inside the recirculation chambers 340 by the second temperature sensors 343.

As readily understandable by a skilled person, the combustion units 300 affect both the temperature (by delivering thermal power) and the oxygen concentration (by introducing combustion fumes into the atmosphere inside the working chamber 201). The electric units 310, on the other hand, affect the temperature of the atmosphere circulating in the working chamber 201.

Therefore, another object of the present invention is a control method for controlling a plant 10 as described above, comprising the steps of:

- measuring the oxygen concentration present in the atmosphere inside the working chamber 201,
- measuring the temperature of at least one atmospheric current circulating in the working chamber 201 and/or through the conditioning assembly 30,
- reducing or zeroing the flow rate of the combustible fluid and the comburent fluid supplied to at least one or each of the combustion units 300, reducing or zeroing the thermal power delivered therefrom, and/or reducing or zeroing the flow rate of the fraction of atmosphere suctioned by the suction unit 600, if the measured oxygen concentration is lower than a fixed threshold value,
- increasing or restoring the flow rate of the combustible fluid and comburent fluid supplied to at least one or each of the combustion units 300, increasing or restoring the thermal power delivered therefrom, and/or increasing or restoring the flow rate of the

fraction of atmosphere suctioned by the suction unit 600, if the measured oxygen concentration is higher than a fixed threshold value.

Such a control method further provides for:
- controlling the thermal power delivered by at least one or each electric unit 310 depending on the measured temperature.

In a preferred embodiment, the conditioning assembly 30 comprises at least one forced circulation unit 330 for the forced circulation of the atmosphere inside the working chamber 201, and at least one recirculation chamber 340 in fluid communication with the working chamber 201 for recirculating the atmosphere between the recirculation chamber 340 and the working chamber 201, in this case the control method comprises the steps of:
- measuring the temperature of the atmospheric current inside the working chamber 201 with at least one first temperature sensor 211 arranged here, and
- controlling the forced circulation unit 330 depending on the atmospheric current temperature inside the working chamber 201 thus measured,
and/or
- measuring the temperature of the atmospheric current in the recirculation chamber 340 with at least one second temperature sensor 343 arranged here, and
- controlling the electric power delivered by the electric unit 310 depending on the atmospheric current temperature in the recirculation chamber 340 thus measured.

The present invention further relates to a heat treatment process 1000 for heat treatment of metal products PM, in particular steel products, comprising:

a) supplying 1001 metal products PM to be submitted to heat treatment to the working chamber 201 of a heat treatment metallurgical furnace 20;

b) supplying 1002 a combustible current and a comburent current or a mixture thereof to at least one combustion unit 300 coupled to the furnace 20, causing their combustion to take place with generation of hot combustion products, releasing the hot combustion products thus produced into the atmosphere inside the working chamber 201;

c) providing 1003 the atmosphere inside the working chamber 201 with heat obtained from an electric energy source 320 by an electric unit 310 configured to transform the electric energy into thermal energy,

d) heating and/or maintaining 1004 the metal products PM by means of at least one fraction of the sensible heat of the atmosphere inside the working chamber 201, obtaining hot metal products PM at a treatment temperature Tt;

e) suctioning 1005 at least one fraction of the atmosphere inside the working chamber 201 by means of a suction unit 600 in fluid communication with the working chamber 201,

f) extracting 1006 the treated metal products PM from the working chamber 201.

Two or more of steps a) to f) indicated above can take place simultaneously at the same area or at different areas of a plurality of areas into which the atmosphere inside the working chamber 201 is divided and along which the metal products PM are advanced.

In particular, two or more of steps b) to e) can take place simultaneously at a first heating area 2011, or a section thereof, and/or a second maintaining area 2012, into which the atmosphere inside the working chamber 201 is divided and along which the metal products PM are advanced.

In a preferred embodiment, simultaneously with one or more of steps b), c), d), and e), the step of recirculating 1008 an atmospheric current CA of the atmosphere inside the working chamber 201 between the electric unit 310 and the metal products PM by at least one forced circulation unit 330 through at least one recirculation chamber 340 is provided. The recirculated atmospheric current CA is thus cyclically subjected to a heating step by the heat generated by the electric unit 310 and a cooling phase in which it releases heat to the metal products PM.

According to one aspect of the present invention, the process 1000 further comprises:

- measuring the oxygen concentration present in the atmosphere inside the working chamber 201,
- measuring the temperature of at least one atmospheric current circulating in the working chamber 201 and/or through the conditioning assembly 30, and
- controlling 1007 one or more of steps b), c), d), and e) depending on the measured oxygen concentration and temperature.

In particular, the controlling step 1007 comprises at least the steps of:

- reducing or suspending 1070 step b), reducing or zeroing the thermal power delivered by the combustion unit 300 if the measured oxygen concentration is lower than a prefixed threshold value;

- increasing or restoring 1071 step b), increasing or restoring the thermal power delivered by the combustion unit 300 if the measured oxygen concentration is higher than a prefixed threshold value.

Step 1070 of reducing or suspending step b) results in a reduction of the flow rate of the combustion products (combustion fumes) released into the atmosphere inside the working chamber. Similarly, step 1071 of increasing or restoring step b) results in an increase in the flow rate of the combustion products (combustion fumes) released into the atmosphere inside the working chamber.

Simultaneously with step 1070 of reducing or suspending step b), therefore, step e) of suctioning 1005 is reduced or suspended, reducing or zeroing the flow rate of the suctioned fraction of atmosphere inside the working chamber 201.

Simultaneously with step 1071 of increasing or restoring step b), instead, step e) of suctioning 1005 is increased or reset, increasing or restoring the flow rate of the suctioned fraction of atmosphere inside the working chamber 201.

In steady-state conditions, steps 1070 and 1071 are repeated cyclically.

Step 1008 of recirculating an atmospheric current CA of the atmosphere inside the working chamber 201 between the electric unit 310 and the metal products PM is advantageously simultaneous with steps 1070 and 1071, respectively of reducing or suspending and increasing or resetting step b).

The controlling step 1007 further comprises step 1072 of controlling the thermal power delivered by the electric unit 310 depending on the measured atmospheric current temperature.

In particular, the process 1000 comprises:

- measuring the temperature of the atmospheric current inside the working chamber 201 with at least one first temperature sensor 211 arranged in the working chamber 201, and/or
- measuring the temperature of the atmospheric current present in the recirculation chamber 340 with at least one second temperature sensor 343 arranged in the recirculation chamber 340,

wherein the controlling step 1007 comprises at least one of the steps of:

- controlling 1073 the recirculating step 1008 depending on the temperature of the atmospheric current inside the working chamber 201 measured by the first temperature sensor 211,

and/or

- controlling 1072 the electric power delivered by the electric unit 310 depending on the temperature of the atmospheric current in the recirculation chamber 340 measured by the second temperature sensor 343.

Controlling 1073 the recirculating step 1008 comprises controlling the rotation speed of the fans 331 forming the forced circulation unit 330, depending on the temperature of the atmospheric current inside the working chamber 201 measured by the first temperature sensor 211 to maintain or reach a set temperature in the working chamber 201.

Controlling 1072 the electric power delivered by the electric unit 310 comprises controlling the power of the electric resistors 311 forming the electric unit 310 to maintain or reach a set temperature in the recirculation chamber 340.

The threshold value of the oxygen concentration is, for example, between 1% and 3%, depending on the applications. The threshold value can depend on the maximum set heat treatment temperature and/or the features of the material of the products to be treated and/or other technical aspects. Such threshold value is related to the need to avoid or limit the formation of surface oxides on the metal pieces PM to be treated.

The treatment temperature Tt is determined depending on the heat treatment, the metal or metal alloy by which the metal products PM are made, and their features.

As readily understandable by a skilled person, the procedure 1000 according to the present invention is implementable or implemented by a plant 10 according to the present invention, whose description above is to be intended as integrally incorporated here.

From the description above, it is apparent that one of the technical advantages of the present invention lies in that, after combustion products (combustion fumes) are released into the atmosphere inside the working chamber of the furnace, such that the atmosphere inside the chamber reaches a desired chemical composition, in particular with regard to the oxygen content present therein (tenor which must be lower than a predefined threshold value), the atmosphere inside the working chamber is at least partially, and preferably entirely, recirculated, being maintained hot using predominantly or exclusively heat obtained from electric energy, possibly produced by renewable sources, and with high heating efficiency by Joule effect (95 – 98%), thereby reducing net CO_2 emissions.

If the furnace 20 was ideally airtight, with no entering ambient air or exiting combustion fumes, once achieved the desired chemical composition, the atmosphere inside the working chamber 201 could be maintained and used an indefinite number of times, drastically reducing, until ideally zeroing, the consumption of combustible in the combustion units. The latter would indeed be used only during the starting step until reaching the desired chemical composition of the atmosphere inside the working chamber 201.

For the same process specifications, due to the presence of the electric units 310 (electric resistors 311), combustion units 300 (burners) with lower power than those adopted in known plants can be installed. The latter would indeed be used only to create and restore a desired chemical composition of the atmosphere inside the working chamber 201, in particular in terms of oxygen content.

Similarly, for the same process specifications, the sizing of the suction plant (suction unit 600 and suction duct 60) is proportionally reduced compared to that of known plants.

Overall, therefore, this results in savings in the construction, maintenance, and operation costs of the plant according to the present invention. The plant and process for heat treatment of metal products according to the present invention allow to effectively combine the thermal energy generated by combustion of a combustible with the thermal energy generated from electric energy.

The plant and process for heat treatment of metal products according to the present invention are based on at least partial, ideally total, replacement of the chemical energy released by combustion in combustion units (burners) with the electric energy by which electric units for transforming electric energy into thermal energy (electric heating means, advantageously in the form of electric resistors) are supplied, thus firstly directly obtaining lower combustible consumption compared to plants of the prior art.

Considering that the performance of these electric heating means can reach 95-98%, the advantage is further apparent, for example, when compared to solutions which provide the use of hydrogen obtained from water electrolysis as a combustible. Furthermore, the presence of combustion units inside the furnace, together with the electric heating means, allows to control the composition of the atmosphere inside the working chamber, maintaining the non-oxidizing features thereof required to prevent the formation of oxides on the surface of the treated metal products. It should be noted that the plant 10 and the process 1000 according to the present invention are also makeable and implementable following the modernization (revamping) of existing heat treatment plants by installing along the working chamber one or more conditioning assemblies 30 as described above and schematized in the attached figures, or even just electric units, measuring devices arranged to measure the oxygen concentration, temperature sensors, and processing and control units or programs as described above.

Each conditioning assembly 30, in particular, comprises, as noted above:

- at least one combustion unit 300 configured to be connected in fluid communication with a first supply duct for a combustible fluid and a second supply duct for a comburent fluid, or with a supply duct of a mixture of a combustible fluid and a comburent fluid of a metallurgical heat treatment plant;
- at least one electric unit 310 configured to transform electric energy into thermal energy, for example, by means of electric resistors, and to be connected to an electric energy source.

In a preferred embodiment, each conditioning assembly 30 further comprises:

- at least one recirculation chamber 340, configured to be arranged in fluid communication with the working chamber of a heat treatment metallurgical furnace of such a plant; and/or
- at least one forced circulation unit 330, configured to recirculate an atmospheric current of the atmosphere inside the working chamber of the furnace between the working chamber and the electric unit.

In a preferred embodiment, one or more of the combustion units 300, electric unit 310, and forced circulation unit 330 are arranged in the recirculation chamber 340.

In a preferred embodiment, each conditioning assembly 30 is configured to be connected to or also comprises:

- a measuring device 210 arranged to measure at least the oxygen concentration present in the atmosphere inside the working chamber of the furnace,
- at least a first temperature sensor 211 arranged to

measure the temperature of the atmosphere inside the working chamber of the furnace, and

- at least a second temperature sensor 343 arranged to measure the temperature in the recirculation chamber 340, wherein

- the measuring device 210 and the first and second temperature sensors 211, 343 are connected or configured to be connected to a control and/or processing electronic unit 100, local or central, which is configured and/or programmed to control at least one and advantageously each conditioning assembly 30 and/or the suction unit of the plant depending on the measured oxygen content and temperature, as described above.

The description of each conditioning assembly mentioned above in the context of the plant 10 and the operation thereof is hereby referenced.

The plant and process thus conceived are susceptible of numerous modifications and variants, all falling within the invention; furthermore, all details are replaceable by technically equivalent elements. In practice, the materials used, as well as the dimensions, can be any depending on the technical requirements.

CLAIMS

1) Heat treatment plant (10) for heat treatment of metal products (PM), in particular steel products, comprising:

- a heat treatment metallurgical furnace (20) for heat treatment of metal products (PM), wherein said furnace (20) comprises:

  - a working chamber (201) with at least one opening for entering and/or exiting metal products (PM) to be treated or treated, respectively,

  - wherein an heat treatment atmosphere is present inside said working chamber (201);

- at least one conditioning assembly (30) of said atmosphere which is coupled to said furnace (20) and which is in fluid communication with said working chamber (201), wherein said conditioning assembly (30) comprises:

  - at least one combustion unit (300) of a combustible fluid and a comburent fluid in a combustion chamber, said combustion chamber being defined by said working chamber (201) or being in fluid communication with said working chamber (201);

- at least one first supply duct (40) for supplying a combustible fluid, said first supply duct being adapted to be coupled at the inlet to a source of said combustible fluid (400),

- at least one second supply duct (50) for supplying a comburent fluid, said second supply duct being adapted to be coupled at the inlet to a source of a comburent fluid (500),

- at least one suction duct (60) for suctioning at least one fraction of said atmosphere, wherein said suction duct (60) is in fluid communication, at the inlet, with said working chamber (201) and in fluid communication, at the exit, with a suction unit (600) of at least one fraction of said atmosphere,

characterized in that said at least one conditioning assembly (30) further comprises:

- at least one heat-generating electric unit (310) configured to heat said atmosphere, wherein said electric unit (310) is adapted to be coupled to an electric energy source (320) and is configured to transform said electric energy into thermal energy.

2) Plant (10) according to claim 1, wherein said at least one conditioning assembly (30) comprises at least one forced circulation unit (330) for the forced circulation of the atmosphere inside said working chamber (201).

3) Plant (10) according to claim 1 or 2, wherein said at least one conditioning assembly (30) comprises at least one recirculation chamber (340) in fluid communication with said working chamber (201) for recirculating said atmosphere between said recirculation chamber (340) and said working chamber (201).

4) Plant (10) according to claim 3, wherein said recirculation chamber (340) comprises a compartment at least partially separated from the working chamber (201) by means of at least one partitioning wall (341) provided with one or more passage openings (342) for the flow through them of an atmospheric current (CA).

5) Plant (10) according to claim 3 or 4, wherein at least one between said combustion unit (300) and said electric unit (310) is arranged in said recirculation chamber (340).

6) Plant (10) according to claim 2 and any one of claims 3 to 5, wherein said forced circulation unit (330) is

arranged to recirculate said atmosphere between said working chamber (201) and said electric unit (310) and/or said recirculation chamber (340).

7) Plant (19) according to claim 2 and any one of claims 3 to 6, wherein said combustion unit (300), said electric unit (310) and said forced circulation unit (330) are arranged in said recirculation chamber (340).

8) Plant (10) according to one or more of the preceding claims, wherein said electric unit (310) comprises one or more electric heaters of the electric resistor type (311) or electric arc type or plasma type.

9) Plant (10) according to one or more of the preceding claims, comprising, at least for said conditioning assembly (30), a measuring device (210) arranged to measure at least the oxygen concentration present in the atmosphere inside said working chamber (201) and at least one temperature sensor arranged to measure the temperature of at least one atmospheric current circulating in said working chamber (201) and/or through said conditioning assembly (30), wherein said measuring device (210) and said temperature sensor are connected to a control and/or processing electronic unit (100), wherein said control and/or processing electronic unit (100) is configured and/or programmed to control said at least one conditioning assembly (30) and/or said suction unit (600) depending on the measured oxygen content and/or temperature.

10) Plant (10) according to claim 9, wherein said control and/or processing electronic unit (100) is configured and/or programmed for:

- reducing or zeroing the flow rate of said combustible fluid and/or said comburent fluid or mixture thereof supplied to said combustion unit (300), reducing or zeroing the thermal power delivered by said combustion unit (300), and/or reducing or zeroing the flow rate of the fraction of atmosphere suctioned by said suction unit (600), if the measured oxygen concentration is lower than a fixed threshold value,

- increasing or restoring the flow rate of said combustible fluid and said comburent fluid or mixture thereof supplied to said combustion unit (300), increasing or restoring the thermal power delivered by said combustion unit (300), and/or increasing or restoring the flow rate of the fraction of atmosphere suctioned by said suction unit (600), if the measured oxygen concentration is higher than a fixed threshold value, and

- controlling the thermal power delivered by said electric unit (310) depending on the measured temperature.

11) Plant (10) according to claim 9 or 10 when dependent from claim 6, comprising, at least for said conditioning assembly (30),

- at least a first temperature sensor (211) arranged to measure the temperature of the atmospheric current inside said working chamber (201) and connected to said control and/or processing electronic unit (100), and/or

- at least a second temperature sensor (343) arranged to measure the temperature of the atmospheric current present in said recirculation chamber (340) and connected to said control and/or processing electronic unit (100).

12) Plant (10) according to claim 11, wherein said control and/or processing electronic unit (100) is

configured or programmed for:

- controlling the electric power delivered by said electric unit (310) depending on the temperature measured by said second temperature sensor (343), and/or
- controlling said forced circulation unit (330) depending on the temperature measured by said first temperature sensor (211).

13) Plant (10) according to one or more of the preceding claims, wherein:

- said working chamber (201) comprises at least one inlet opening (202) for the metal products (PM) to be treated and at least one outlet opening (203) for the treated metal products (PM), said furnace (20) comprising an advancing assembly (204) configured to advance said metal products (PM) along said working chamber (201) from said inlet opening (202) to said outlet opening (203), and wherein
- a heat treatment atmosphere is present inside said working chamber (201), said heat treatment atmosphere being divided into a plurality of areas distributed along said working chamber (201),
- wherein at least one said conditioning assembly (30) is coupled to said furnace (20) at at least one of said areas.

14) Plant (10) according to claim 13, wherein said plurality of areas comprises in succession to each other at least: a first heating area (2011) for heating said metal products (PM) to a treatment temperature (Tt) and a second area (2012) for maintaining the heated metal products (PM) at the treatment temperature (Tt), wherein at least one of said conditioning assemblies (30) is coupled to said furnace (20) at at least one of said

first area (2011) and said second area (2012).

15) Control method for controlling a plant (10) according to one or more of the preceding claims, comprising the steps of:

- measuring the oxygen concentration present in the atmosphere inside said working chamber (201),
- measuring the temperature of at least one atmospheric current circulating in said working chamber (201) and/or through said conditioning assembly (30),
- reducing or zeroing the flow rate of said combustible fluid and said comburent fluid or mixture thereof supplied to said combustion unit (300), reducing or zeroing the thermal power delivered by said combustion unit (300), and/or reducing or zeroing the flow rate of the fraction of atmosphere suctioned by said suction unit (600), if the measured oxygen concentration is lower than a fixed threshold value,
- increasing or restoring the flow rate of said combustible fluid and said comburent fluid or mixture thereof supplied to said combustion unit (300), increasing or restoring the thermal power delivered by said combustion unit (300), and/or increasing or restoring the flow rate of the fraction of atmosphere suctioned by said suction unit (600), if the measured oxygen concentration is higher than a fixed threshold value, and
- controlling the thermal power delivered by said electric unit (310) depending on the measured temperature.

16) Control method according to claim 15, wherein said at least one conditioning assembly (30) comprises at least one forced circulation unit (330) for the forced

circulation of the atmosphere inside said working chamber (201) and at least one recirculation chamber (340) in fluid communication with said working chamber (201) for recirculating said atmosphere between said recirculation chamber (340) and said working chamber (201), the method comprising the steps of:

- measuring the temperature of the atmospheric current inside said working chamber (201), and
- controlling said forced circulation unit (330) depending on the measured atmospheric current temperature inside said working chamber (201),

and/or

- measuring the temperature of the atmospheric current present in said recirculation chamber (340), and
- controlling the electric power delivered by said electric unit (310) depending on the measured atmospheric current temperature present in said recirculation chamber (340).

17) Heat treatment process (1000) for heat treatment of metal products (PM), particularly steel products, comprising:

a) suppling (1001) metal products (PM) to be submitted to a heat treatment to the working chamber (201) of a heat treatment metallurgical furnace (20);

b) suppling (1002) a combustible current and a comburent current or a current of a mixture thereof to a combustion unit (300) coupled to said furnace (20) to cause their combustion to take place with generation of hot combustion products, releasing said hot combustion products into the atmosphere inside said working chamber (201);

c) providing (1003) said atmosphere inside said working chamber (201) with heat obtained from an electric energy source (320) by an electric unit (310) configured to transform said electric energy into thermal energy,

d) heating and/or maintaining (1004) said metal products (PM) by means of at least one fraction of the sensible heat of said atmosphere inside said working chamber (201), obtaining hot metal products (PM) at a treatment temperature (Tt);

e) suctioning (1005) at least one fraction of the atmosphere inside said working chamber (201) by means of a suction unit (600) in fluid communication with said working chamber (201),

f) extracting the treated metal products (PM) from said working chamber (201).

18) Process (1000) according to claim 17, wherein simultaneously to at least one of said steps b), c), d) and e), the step of recirculating (1008) an atmospheric current (CA) of the atmosphere inside said working chamber (201) between said electric unit (310) and said metal products (PM) with at least one forced circulation unit (330) by at least one recirculation chamber (340) is provided.

19) Process (1000) according to claim 17 or 18, comprising:

- measuring the oxygen concentration present in the atmosphere inside said working chamber (201),
- measuring the temperature of at least one atmospheric current circulating in said working chamber (201) and/or through said conditioning group (30),
- controlling (1007) one or more of steps b), c), d) and e) depending on the measured oxygen concentration and temperature.

20) Process (1000) according to claim 19, wherein said controlling (1007) comprises the steps of:

- if the measured oxygen concentration is lower than a prefixed threshold value, reducing or suspending (1070) step b) and, at the same time, reducing or suspending step e);

- if the measured oxygen concentration is higher than a prefixed threshold value, increasing or resetting (1071) step b) and, at the same time, increasing or resetting step e).

21) Process (1000) according to claim 18 and claim 19 or 20, comprising

- measuring the temperature of the atmospheric current inside said working chamber (201) with at least a first temperature sensor (211), and/or

- measuring the temperature of the atmospheric current present in said recirculation chamber (340) with at least a second temperature sensor (343),

wherein said controlling (1007) comprises at least one of the steps of:

- controlling the recirculation step (1008) depending on the measured atmospheric current temperature inside said working chamber (201),

and/or

- controlling the electric power delivered by said electric unit (310) depending on the measured atmospheric current temperature present in said recirculation chamber (340).

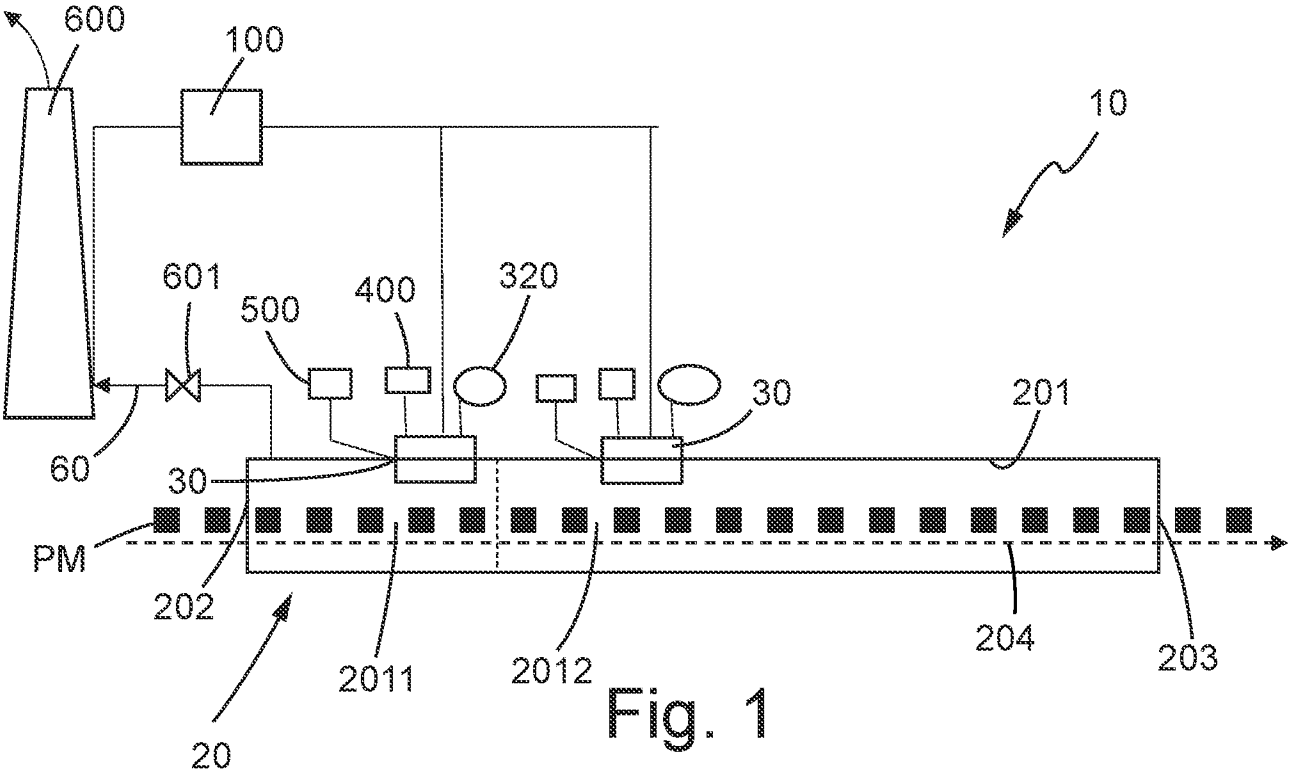
600
100
10
601
500
400
320
30
201
60
30
PM
202
2011
2012
204
203
20

Fig. 1

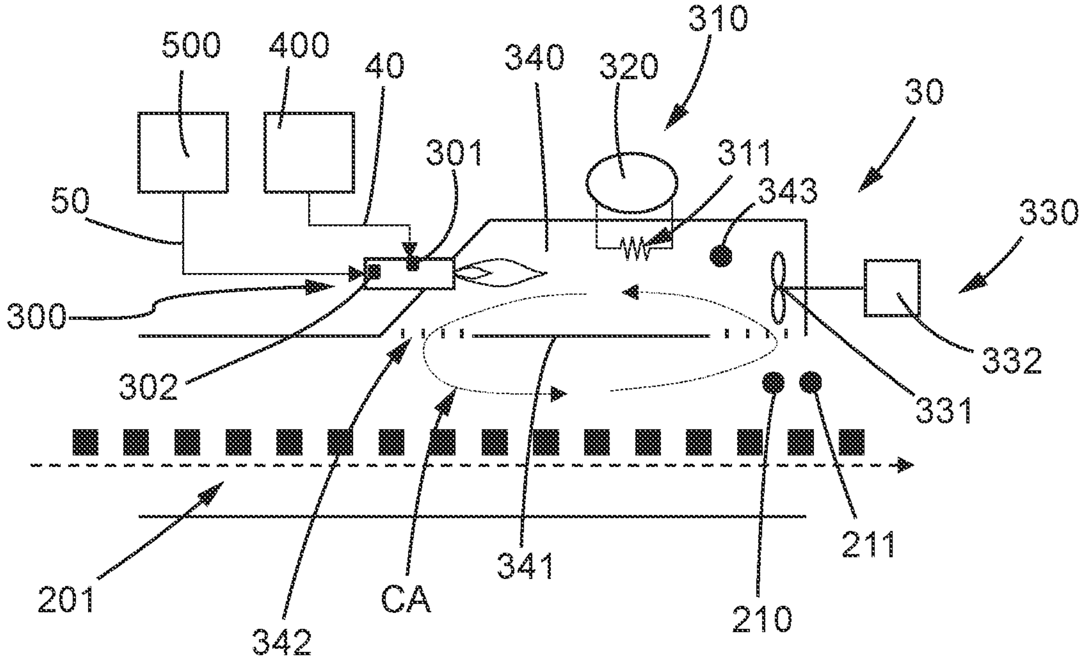
500
400
40
340
320
310
30
301
311
343
330
50
300
302
332
331
201
342
CA
341
210
211

Fig. 2

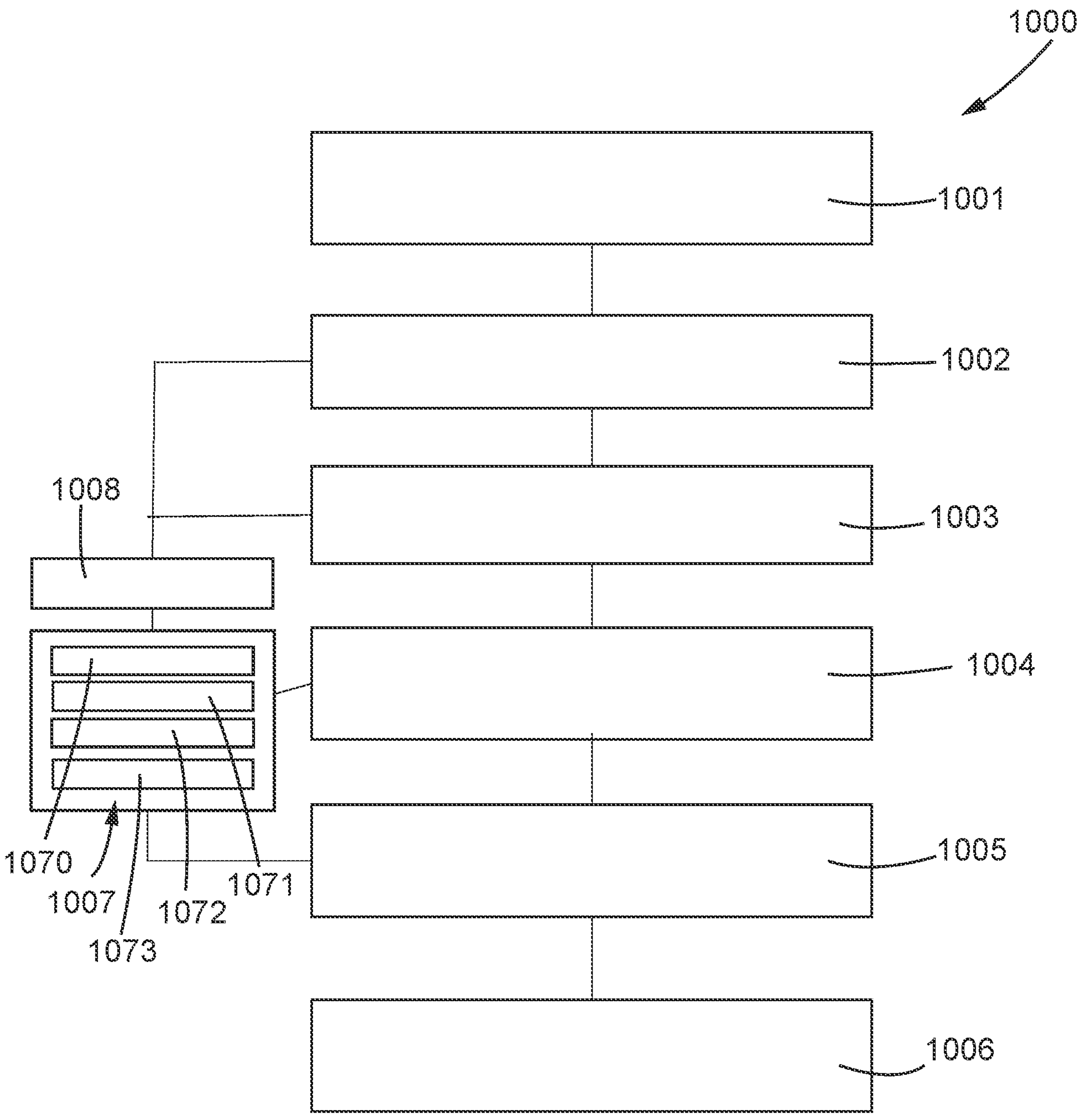
1000
1001
1002
1003
1004
1005
1006
1007
1008
1070
1071
1072
1073

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/061320

A. CLASSIFICATION OF SUBJECT MATTER
INV. F27B9/06 F27B9/20 F27D11/02 F27D99/00 F23D14/66
ADD. F27B9/30 F27B9/36

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)
F27B F27D

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2019/119777 A1 (ANDRITZ TECH & ASSET MAN GMBH [AT]) 25 April 2019 (2019-04-25) paragraph [0001] - paragraph [0027]; figures 1, 2	1-21
A	US 2023/304740 A1 (MOZZI ENRICO [IT] ET AL) 28 September 2023 (2023-09-28) abstract paragraph [0001] - paragraph [0004] paragraph [0026] - paragraph [0030] paragraph [0033] - paragraph [0055] paragraph [0160] - paragraph [0171]	1-21
A	JP S58 16112 A (MATSUSHITA ELECTRIC IND CO LTD) 29 January 1983 (1983-01-29) abstract; figure 1	1-21

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[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
23 December 2024	03/02/2025

Name and mailing address of the ISA/	Authorized officer
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1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Van Veen B. M.: "Electric Preheating of Combustion Air", , 9 July 2021 (2021-07-09), XP093185483, Delft University of Technology Retrieved from the Internet: URL:https://repository.tudelft.nl/file/File_3cf071bd-44f7-4f75-bb4d-e6218a0485ce?preview=1 [retrieved on 2024-07-13] page 37 - page 74 -----	1-21

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2024/061320

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