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(54) METHOD FOR INCREASING THE TEMPERATURE HOMOGENEITY IN A PIT FURNACE

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(57) ABSTRACT

A method for increasing temperature homogeneity in a pit furnace wherein at least two ingots to be heated lean against a respective one of first and second opposite inner walls of the pit furnace to form an elongated space having a V-shaped cross-section between them includes arranging at least one lance for an oxidant with an oxygen content of at least 85 percent by weight and at least one lance for fuel in a furnace wall with their orifices opening into the furnace at a distance from each other for supplying the oxidant and fuel to said V-shaped space to be combustible therein, wherein the orifice of the oxidant lance is arranged above the orifice of the fuel lance and is directed for the oxidant to flow obliquely downwards and along a longitudinal direction of said V-shaped space.

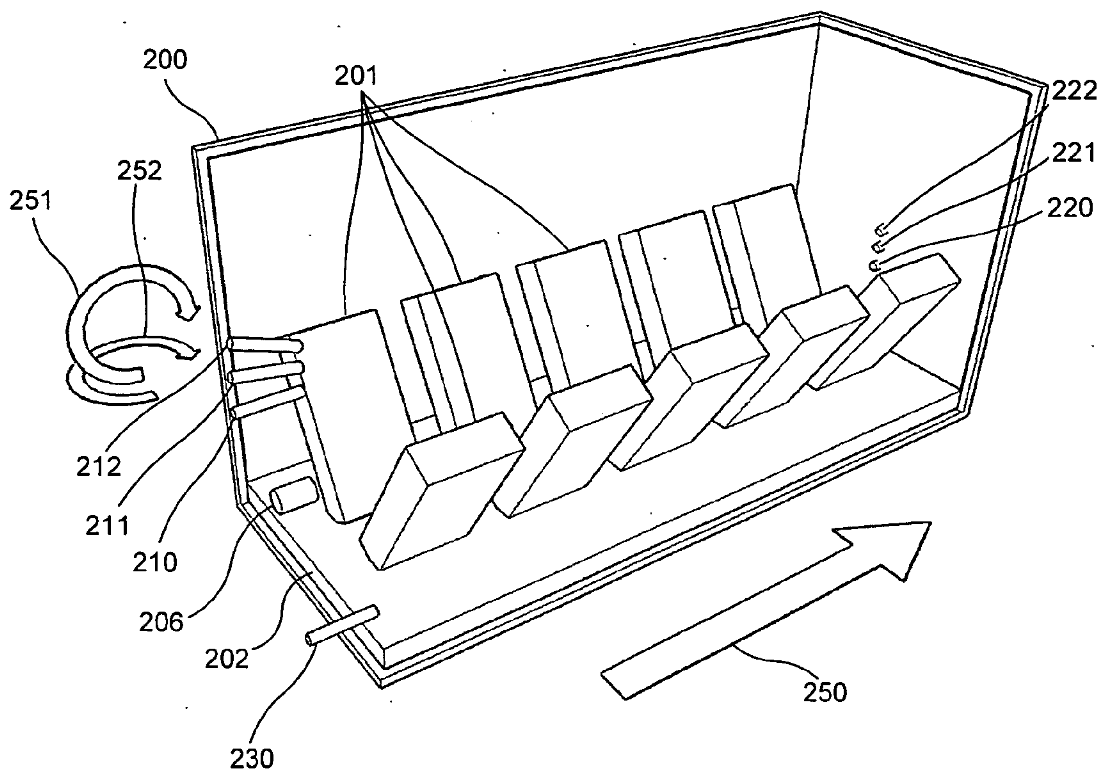


Fig. 1 (prior art)

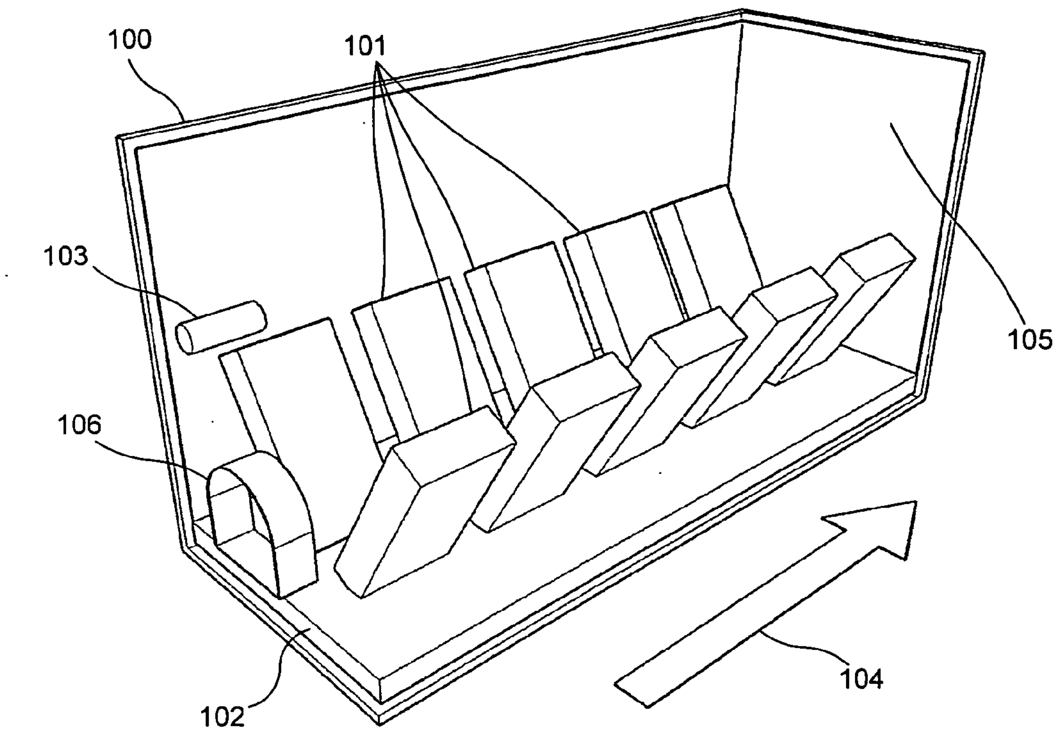


Fig. 2 (prior art)

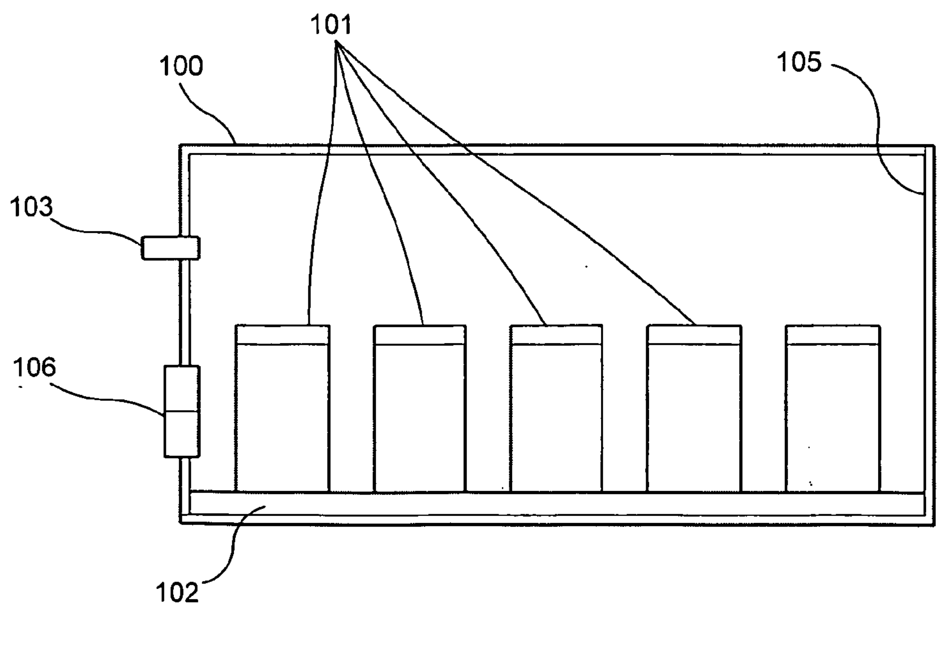


Fig. 3 (prior art)

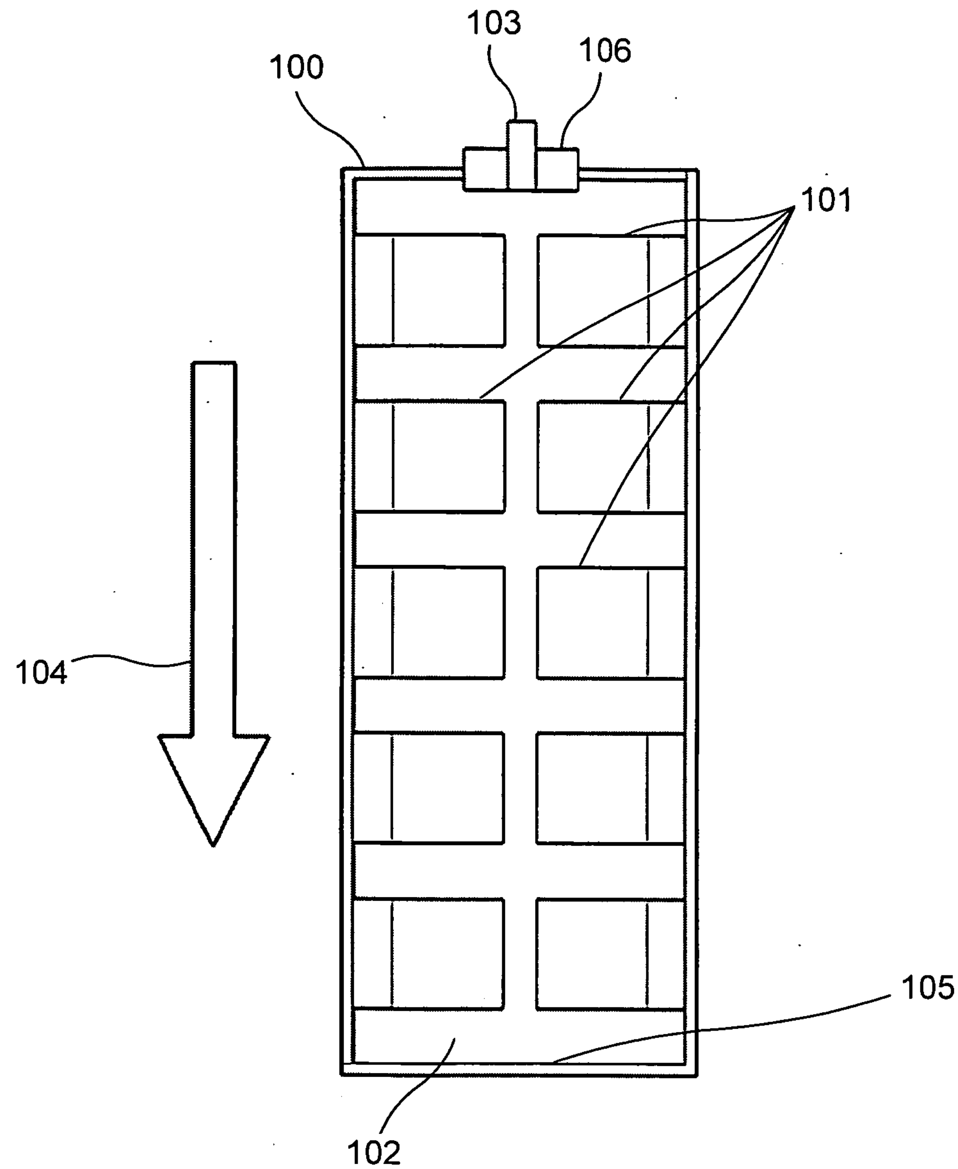
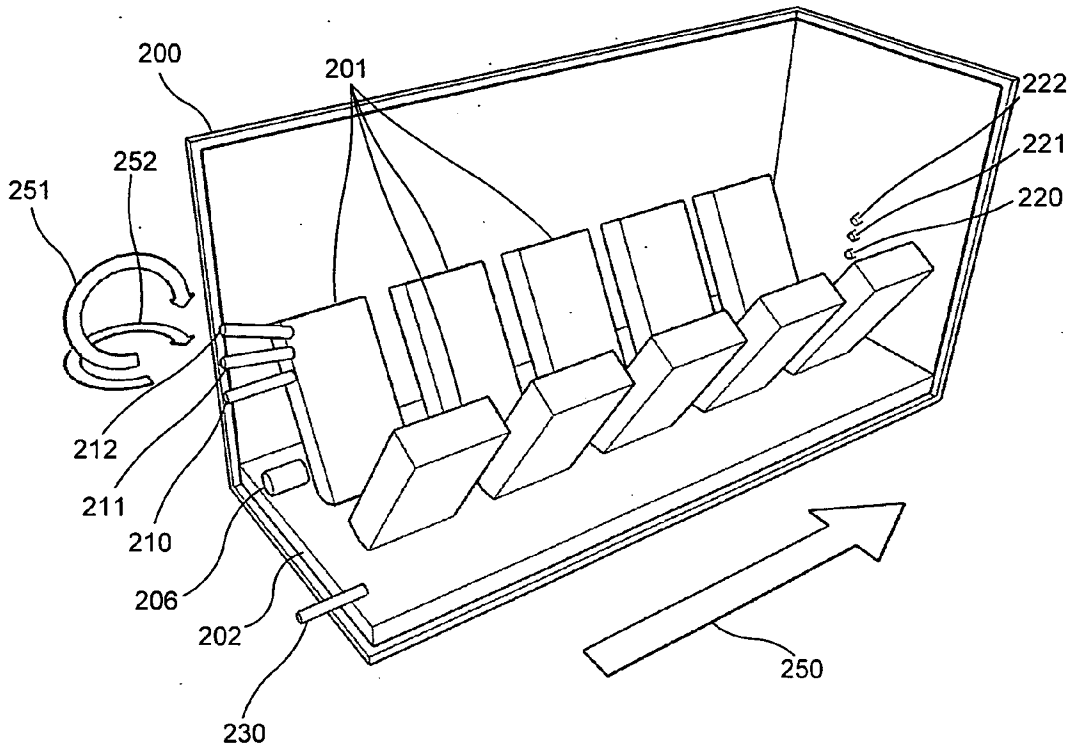


Fig. 4


200
201
222
221
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252
251
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206
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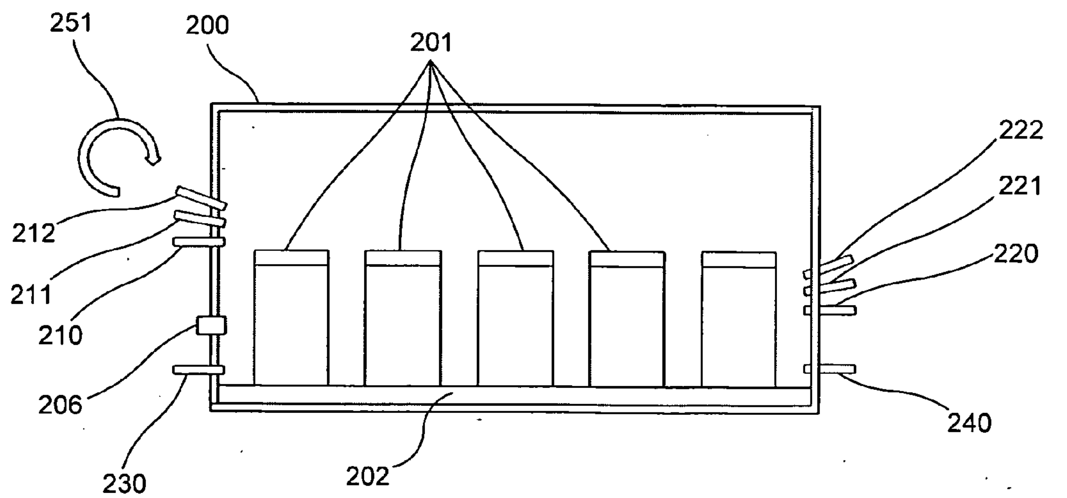
250

Fig. 5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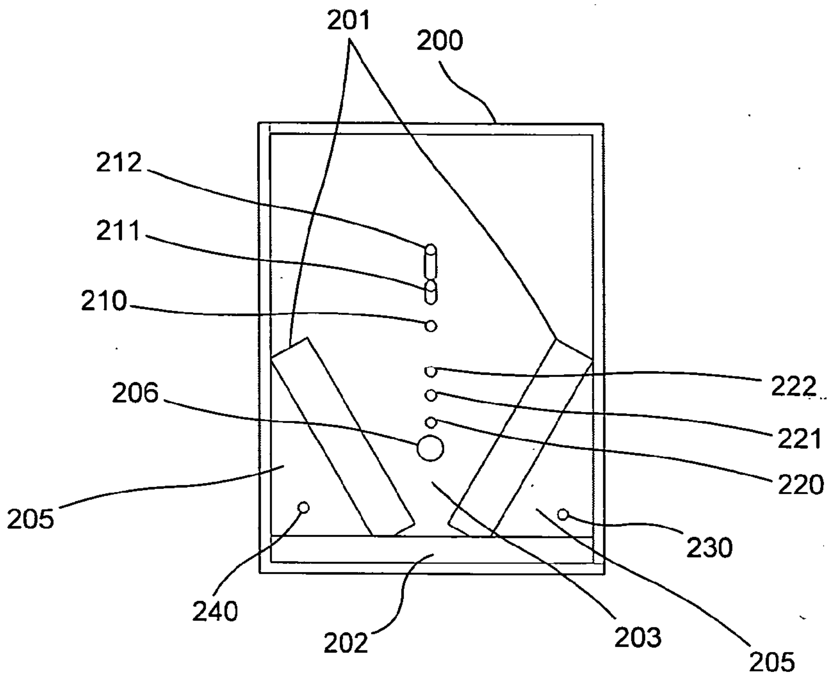
240

Fig. 6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200
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220
205
230
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202
203
205

Fig. 7

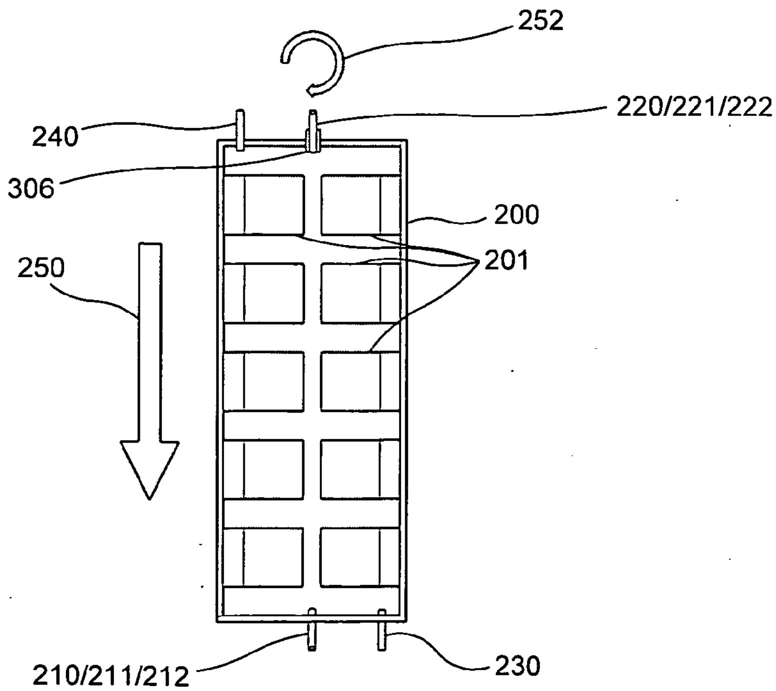

252
220/221/222
240
306
200
250
201
210/211/212
230

Fig. 8

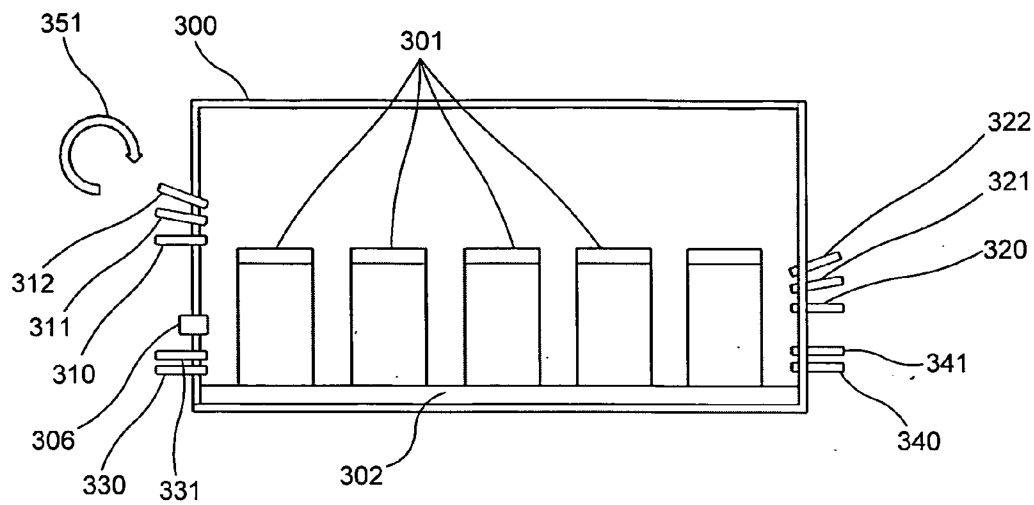

351
300
301
322
321
320
312
311
310
306
330
331
302
341
340

Fig. 9

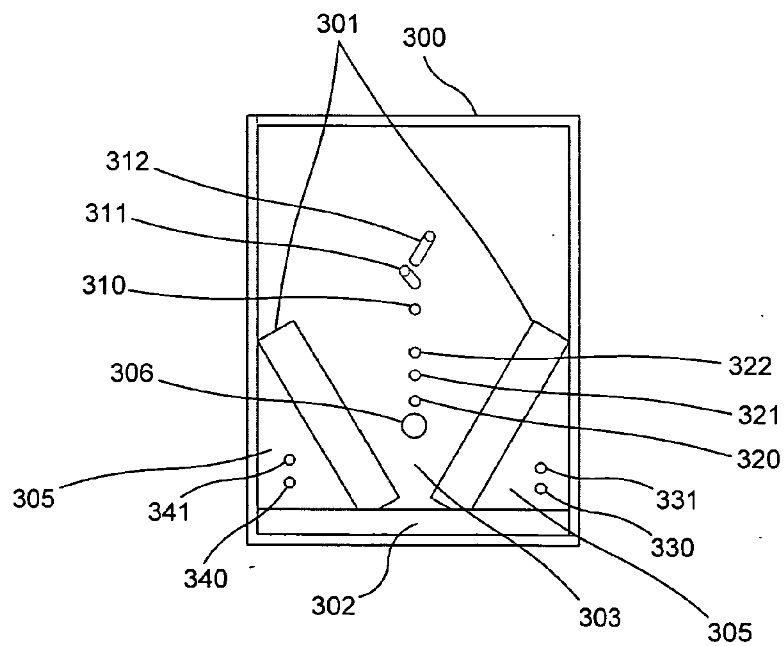
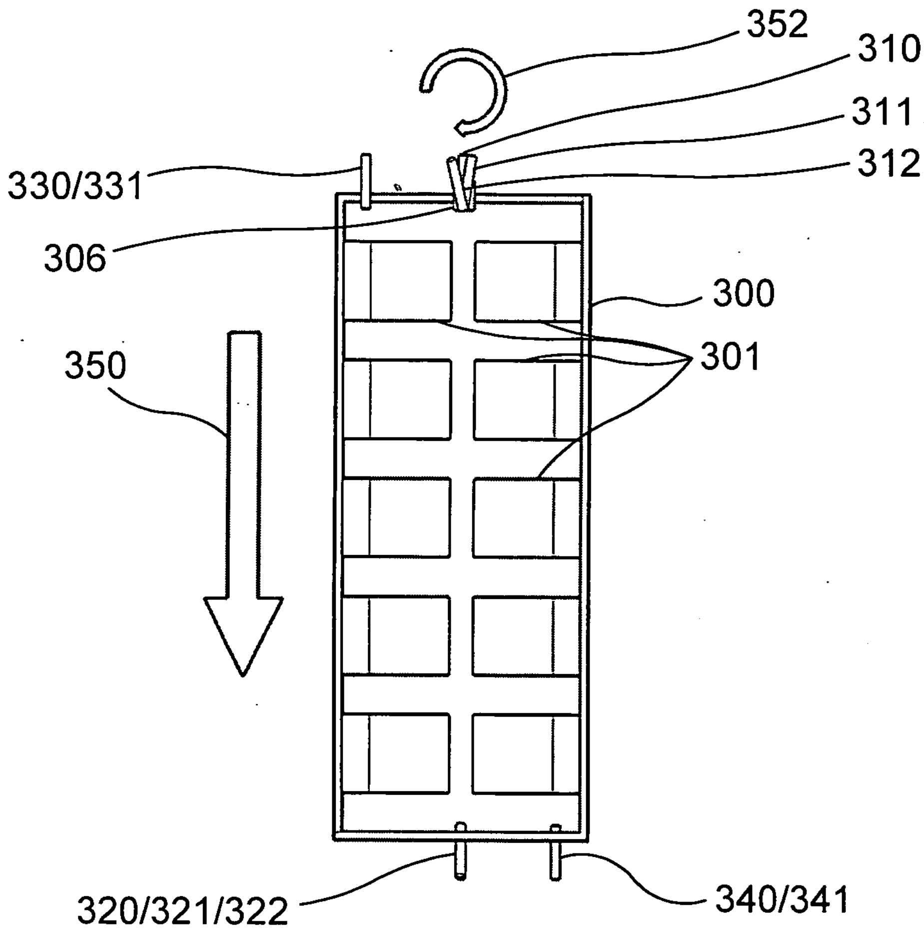

301
300
312
311
310
322
306
321
320
305
341
331
330
340
302
303
305

Fig. 10



METHOD FOR INCREASING THE TEMPERATURE HOMOGENEITY IN A PIT FURNACE

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a method for increasing the temperature homogeneity in a pit furnace.

[0002] During heating of ingots in pit furnaces, the ingots are normally positioned leaning against opposite inner walls in the pit furnace, and resting on the furnace floor, often on a layer of oxide scale from previous runs.

[0003] In such furnaces, it is desirable to achieve good temperature homogeneity, in other words to minimize temperature gradients inside the furnace. However, there are problems with the normally used furnace geometry in which the ingots are positioned leaning against the inner walls of the furnace.

[0004] In the conventional art, air burners are used to heat such pit furnaces. Such air burners turn over quite large volumes of air and fuel, leading to large volumes of hot combustion gases being circulated in the furnace. By, for example, arranging an air burner in one of the short sides of the furnace, and an exhaust port on the same short side but below or above the burner, lengthwise circulation along the whole furnace can be accomplished, whereby the gas volumes from the air burner can yield sufficient temperature homogeneity in the furnace.

[0005] However, in order to decrease the amount of formed CO and O_x, and in order to increase energy efficiency, more and more often oxyfuel combustion, i.e. where an oxidant with high oxygen content is used to combust a fuel, is used. Since such oxidants comprise considerably less ballast in the form of nitrogen than what is the case when air is used as the oxidant, smaller volumes of combustion gases arise, in many cases not more than ⅕ as compared to a corresponding air burner, and therefore it is more difficult to achieve a sufficient temperature homogeneity.

[0006] It is especially common that the upper parts of the ingots risk overheating at the same time as the lower parts become too cool.

[0007] There are limited possibilities to direct the combustion reaction to cooler parts of the furnace, because of the risk of local overheating close to the combustion location. In general, it is also not possible to compensate for the smaller amounts of combustion gases by increasing the power of the oxyfuel burners. To arrange a large number of oxyfuel burners in one and the same furnace is possible, but very costly. Moreover, the result will still not be adequate, since it is desirable to heat different numbers of ingots in the same furnace at different occasions.

SUMMARY OF THE INVENTION

[0008] The present invention solves the above problems.

[0009] Hence, the present invention relates to a method for increasing the temperature homogeneity in a pit furnace, in which at least two ingots to be heated are caused to lean against a respective one of first and second opposite inner walls of the pit furnace so that the ingots form an elongated space having a V-shaped cross-section between them as seen along the first and second walls, and is characterised in that at least one separate lance for an oxidant with an oxygen content of at least 85 percent by weight and at least one separate lance for fuel are caused to be arranged in a furnace wall with their orifices arranged opening out into the furnace at a distance from each other and so that oxidant and fuel, respectively, are caused to be suppliable to said V-shaped space and to be combustible therein, and in that the orifice of the lance for oxidant is caused to be arranged above the orifice of the fuel lance and to be directed so that the oxidant flows obliquely downwards and along the longitudinal direction of said V-shaped space.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] In the following, the invention will be described in detail, with reference to exemplifying embodiments of the invention and to the appended drawing figures, of which:

[0011] FIG. **1** is a partly cut away perspective view showing a conventional pit furnace;

[0012] FIG. **2** shows the pit furnace of FIG. **1** from a long side;

[0013] FIG. **3** shows the pit furnace of FIG. **1** from the top;

[0014] FIG. **4** is a partly cut-away perspective view showing a pit furnace according to a first preferred embodiment of the present invention;

[0015] FIG. **5** shows the pit furnace of FIG. **4** from a long side;

[0016] FIG. **6** shows the pit furnace of FIG. **4** from a short side;

[0017] FIG. **7** shows the pit furnace of FIG. **4** from the top;

[0018] FIG. **8** is a view corresponding to that in FIG. **5**, but which shows a pit furnace according to a second preferred embodiment of the present invention as seen from a long side;

[0019] FIG. **9** shows the pit furnace of FIG. **8** from a short side; and

[0020] FIG. **10** shows the pit furnace of FIG. **8** from the top.

DESCRIPTION OF THE INVENTION

[0021] FIGS. **1-3** illustrate, using a common set of reference numerals, a conventional pit furnace **100** in which ten ingots **101** are heated in two rows of five ingots each. The ingots rest upon a bed **102** of oxide scale from previous runs, and are standing leaning, over two rows, against the opposite inner walls of the respective long sides of the furnace **100**, along the longitudinal direction **104** of the furnace **100**.

[0022] The furnace **100** is heated using a conventional air burner **103**, directed along the longitudinal direction **104** of the furnace **100**. The air burner **103** is arranged in the wall in one of the short ends of the furnace **100**. Since the furnace is shown partly cut away in FIGS. **1-3**, said short end is not shown, together with the ceiling of the furnace **100** and one of its long sides. The hot combustion gases from the air burner **103** flow in the direction **104** along the rows of ingots **101**, and turns over at a distal short end **105** of the furnace to then again flow back to the short end in which the air burner **103** is arranged, and there be evacuated through an exhaust channel **106** for flue gases. Since the air burner **103** and the exhaust channel **106** are arranged in the same wall in the furnace **100** but at different heights, natural convection arises resulting in sufficient temperature homogeneity throughout the whole furnace chamber.

[0023] FIGS. **4-7** show, with common reference numerals, a pit furnace **200** in which a method according to the present invention for increasing the temperature homogeneity is applied. The furnace **200** is largely similar to the furnace **100** shown in FIGS. **1-3**. In the furnace **200** there is arranged a number of, at least two, ingots **201**. The ingots **201** are arranged along two rows along the main longitudinal direction **250** of the furnace **200**, each leaning against a respective first and second opposite inner walls of the pit furnace **200**, so that the ingots **201** form a space **203** having a V-shaped cross-section (see FIG. **6**) between and above them along said first and second inner walls. Said inner walls preferably constitute the inner walls of the long sides of the furnace **200**. In FIGS. **4-7**, which are partly cut away, one of said walls is not shown.

[0024] The ingots **201** rest upon a bed **202** of oxide scale similar to the bed **102**. Alternatively, the ingots **201** may rest directly upon the furnace floor.

[0025] An exhaust channel **206** for flue gases is arranged in one of the short sides of the furnace **200**.

[0026] It is preferred that at least one separate lance **211**, **212** for oxidant, and at least one separate lance **210** for fuel, are arranged in a furnace wall so that their orifices are arranged inside, opening out into, the furnace **200** at a distance from each other, and so that oxidant and fuel, respectively, can be supplied to the V-shaped space **203** between the ingots **201** and to react therein.

[0027] The lower fuel lance **210** and the two oxidant lances **211**, **212** arranged above the orifice of the fuel lance **210** together form a lance aggregate or group. The aggregate may also be designed with other configurations of lances for fuel and oxidant, as long as the orifice of at least one oxidant lance is arranged above at least one fuel lance.

[0028] It is preferred that the distance between each oxidant and fuel lance is at least 5 cm.

[0029] The oxidant being supplied via at least one, but preferably all, lances for oxidant has, according to the invention, an oxygen content of at least 85 percent by weight, preferably at least 95 percent by weight. The fuel may be any suitable, conventional, gaseous, liquid or solid fuel, such as oil or natural gas. It is preferred that the fuel is a gaseous or liquid fuel.

[0030] It is preferred that at least one of the lances **211**, **212** for oxidant, preferably all lances **211**, **212** for oxidant, is arranged with their orifice arranged above the orifice of at least one fuel lance **210**, and is directed so that the oxidant flows obliquely downwards and along the longitudinal direction of the V-shaped space **203**, essentially parallel to said first and second furnace walls. In other words, the oxidant is supplied to the V-shaped space **203** between the ingots **201**, so that the downwards inclined stream of oxidant runs in the longitudinal direction **250** of the furnace **200**. Moreover, it is preferred that the stream of oxidant from each of the oxidant lances **211**, **212** is arranged to cut through an area in the space **203** in which the fuel is supplied using the fuel lance **210**. Preferably, at least one stream of oxidant and at least one stream of fuel meet in the space **203**.

[0031] Since the oxidant has such high oxygen content, the amount of hot combustion gases originating from the fuel and the oxidant being supplied through lances **210**, **211**, **212** will be substantially smaller than the corresponding amount of combustion gases originating from the air burner **103** for the corresponding heating powers. As described above, operation with such oxidant conventionally gives rise to deteriorated temperature homogeneity. Notably, it has proven difficult to achieve sufficiently high temperatures towards the bottom of the V-shaped space **203** between the ingots **201**, i.e. in the vicinity of the oxide scale bed **202** at the bottom of the furnace **200**, as well as in the space **205** (see FIG. **6**) having a triangular cross-section being present under the ingots **201**, between each ingot **201** or row of ingots and the furnace wall against which the ingot or ingots **201** is leaning.

[0032] Thus, the oxidant flows out from lances **211**, **212**, and meets the fuel flowing out from the fuel lance **210** in the V-shaped space **203** between the ingots **201**. Since the oxidant is supplied this way, through a separate lance, the geometrical shape and the velocity of the oxidant stream may be controlled so that it may carry with it the resulting mixture of fuel and oxidant down towards the bottom of the V-shaped space **203**. Thereby, the temperature there can be increased without any increased risk of overheating, which had been the case if for example an air burner had been positioned closer to the bottom or if a separate oxidant lance had been positioned so that it opened out directly in close vicinity to the ingots **201**.

[0033] The fuel lance **210** may be arranged horizontally and so that the fuel stream is directed essentially straight along the main longitudinal direction of the V-shaped space. However, it is preferred that the fuel lance is somewhat inclined downwards as compared to the horizontal plane, at an angle of maximally 5°. The respective oxidant streams from lances **211**, **212** are in this case directed with the same or a larger angle of inclination as compared to the horizontal plane. Hereby, the downwards inclined oxidant stream can carry the combustion mixture with it downwards towards the bottom of the V-shaped space.

[0034] According to a preferred embodiment, at least one oxidant lance **211**, **212** opens out above all supply locations for fuel, in the present example thus the fuel lance **210**, which are arranged in the same furnace wall in which the orifice of the oxidant lance **211**, **212** in question is arranged. This results in all fuel being supplied via the lance **210**, **211**, **212** aggregate in question is conveyed downwards in the V-shaped space **203** using the oxidant stream from the lance in question.

[0035] According to an especially preferred embodiment, the oxidant is supplied through at least one oxidant lance **211**, **212**, preferably the oxidant lance **212** the orifice of which is arranged at the top position in each respective aggregate, at high velocity. This results in increased convection in the furnace chamber, which compensates for the smaller amounts of combustion gases as compared to if one or several air burners had been used instead of the oxyfuel burner which is embodied by the lance aggregate **210**, **211**, **212**.

[0036] It is preferred that the lancing velocity is at least 100 m/s, which in many applications results in sufficient convection in the furnace chamber. Furnace atmosphere gases are sucked into the combustion mixture, which lowers the combustion temperature and thereby leads to less formed NO_x. Then, in combination with the above described downwards inclined oxidant stream, the whole furnace chamber, including the bottom of the V-shaped space **203**, will be sufficiently warm without any risk for local overheating.

[0037] According to an especially preferred embodiment, oxidant is lanced through at least one oxidant lance **211**, **212** at a velocity which is at least the sonic velocity. This results in heavily increased convection and recirculation throughout the whole furnace chamber, with corresponding improved temperature homogeneity and decreased CO and NO_x rates. Such a method is especially preferred in larger furnaces.

[0038] Most preferred is to supply oxidant through at least one oxidant lance **211**, **212** at a velocity of at least Mach 1.5. Such high lancing velocity has been found to result in convection which increases as a function of the velocity in a non-linear manner. Above about Mach 1.5, combustion of flameless type can be achieved, in which the combustion can take place in the majority of the furnace chamber simultaneously, with no clearly distinguishable flame. Therefore, this results in very good temperature homogeneity even in difficult to access parts of the furnace chamber.

[0039] It is preferred that at least one oxidant lance **211**, **212**, more preferably each oxidant lance, is mounted so that the respective oxidant streams out into the furnace chamber at an angle of more than 0° and but more than 20°, most prefer between 3 and 5°, as compared to the horizontal plane. Thus, at least one oxidant lance **211**, **212** is inclined from a horizontal position in the direction denoted by the arrow **251**. This results, in a pit furnace **200** of normal size, in that the mixture of oxidant and fuel is conveyed sufficiently far towards the bottom of the V-shaped space **203** so that a desired temperature homogeneity can be achieved.

[0040] According to an especially preferred embodiment, more than one oxidant lance **211**, **212**, arranged with their respective orifices one above the other, is used as is illustrated in FIGS. **4-7**. In this case, it is preferred that the downwards inclined angle, in comparison to the horizontal plane, with which the resulting oxidant stream is directed, is equal to or larger for oxidant lances **212** having respective orifices arranged further up than for oxidant lances **211** having respective orifices arranged further down. In the present exemplifying case with two oxidant lances **211**, **212**, it is preferred that a lower oxidant lance **211** has an angle of more than 0° and not more than 10°, while an upper oxidant lance **212** has an angle of more than 0° and not more than 20°, however at least the same angle as the upper oxidant lance **212**. By arranging several oxidant lances this way, one above the other, the total flow of fuel and oxidant can be controlled such that a good spread of fuel and oxidant can be achieved in the space **203**.

[0041] In the exemplifying embodiment illustrated in FIGS. **4-7**, a first group or aggregate of lances, comprising a fuel lance **210** and two oxidant lances **211**, **212**, arranged in one of the short sides of the furnace **200**, and a second lance aggregate, comprising a fuel lance **220** and two oxidant lances **221**, **222**, is arranged in the other, opposite short side of the furnace **200**. Both lance aggregates hence comprise a respective fuel lance **210**, **220** above the orifice of which the orifices of two respective oxidant lances **211**, **212**, **221**, **222** are arranged. Each such aggregate may be designed having other configurations of lances for fuel and oxidant, as long as at least one downwards inclined oxidant lance for oxidant with more than 85 percent by weight oxygen has its orifice arranged above the level for at least one fuel lance in each aggregate.

[0042] As is clear from FIGS. **5** and **6**, the two lance aggregates are arranged at different heights in the furnace **200**. By such an arrangement, the temperature homogeneity can be further increased because of circulation effects arising in the furnace chamber. It is in this case preferred that the fuel lance **210** having its orifice arranged at the lowest height in the first aggregate of lances **210**, **211**, **212** is arranged with its orifice at a height above the furnace floor which is between 0.7 and 1.2 meters above the level above the furnace floor at which the orifice of the lance **220**, the orifice of which is arranged at the lowest height in a second aggregate of lances **220**, **221**, **222**, is arranged. It is furthermore preferred that all such aggregates of fuel and oxidant lances **210**, **211**, **212**, **220**, **221**, **222** the orifices of which are arranged so that the respective lance opens out into the V-shaped space **203** are arranged so that no lance orifice is arranged at a vertical level from the furnace floor so high so that overheating of the ingots **201** is risked as a direct consequence of the thermal energy being supplied locally as a result of the fuel or oxidant which is supplied through such a lance. What this vertical level is will depend upon the design of the furnace **200** as well as upon the positioning and shape of the ingots **201**, but it is preferred that no such lance has its orifice arranged at a level below 1.5 meters above the floor.

[0043] FIGS. **8-10**, the views of which correspond to the views of FIGS. **5-7**, illustrate an alternative embodiment, wherein a pit furnace **300**, in a way which is similar to the above described in connection to FIGS. **4-7**, comprises ingots **301** supported by an oxide scale bed **302** and heated by two opposite aggregates of lances **310**, **320** for fuel in combination with lances **311**, **312**, **321**, **322** for oxidant. The arrow **350** denotes the longitudinal direction of the furnace **300**. An exhaust channel **306** is for flue gases.

[0044] As most clearly can be seen in FIGS. **9** and **10**, the lances **311**, **312** for oxidant are not, however, only inclined in relation to the horizontal plane in the direction of rotation pointed out by the arrow **351**, similarly to the lances **211**, **212** in FIGS. **4-7**, but lances **311**, **312** are also inclined in the horizontal plane, in relation to a longitudinally arranged vertical plane and in a direction of rotation pointed out by the arrow **352**. As a consequence, the resulting mixture of oxidant and fuel in the V-shaped space **303** (see FIG. **9**) between ingots **301** can be spread more evenly than what is possible when only arranging the lances **311**, **312** at an angle in relation to the horizontal plane according to the above.

[0045] It is preferred to adjust the lance angles for each individual lance for oxidant depending on the actual application, so that the resulting temperature distribution in the V-shaped space **303** becomes as homogenous as possible. It is especially preferred that at least two lances **311**, **312** for oxidant are mounted with their orifices arranged in the furnace chamber one above the other and so that their respective oxidant can stream out into the furnace chamber at different angels either in the horizontal plane and/or in the vertical plane. This results in even spread of the fuel/oxidant mixture but while still retaining the possibility to keep a low risk for local overheating because of the supplied oxidant. It is preferred that the angle in the horizontal plane, in the direction of rotation **352**, between the oxidant stream from each individual oxidant lance and the main longitudinal direction of the V-shaped space **303**, is 10° or less in any direction.

[0046] It is especially preferred that at least one lance for oxidant **311**, **312**, **321**, **322**, preferably all such lances, are redirectable, so that it is possible to redirect their respective stream of oxidant in the horizontal plane and/or in the vertical plane. This will render the furnace **300** adjustable depending on changing operation prerequisites with for example different numbers of and/or differently sized ingots **301** to be heated.

[0047] According to a preferred embodiment, more than one lance for oxidant is used in the furnace, preferably in combination with one and the same lance for fuel, whereby the heating power in the furnace is controlled during operation by one or several lances being switched on or off, while the amount of supplied fuel is controlled so that it at each moment in time or at least over time stoichiometrically corresponds to the total oxygen supplied via the oxidant. In order to decrease the total heating power in the furnace from a certain higher power level to a certain lower power level, an oxidant lance may be operated in a pulsating manner, where the switched on and switched off time periods are controlled so that the mean emitted power becomes the desired power. Moreover or alternatively, one or several oxidant lances may be completely switched off.

[0048] In this context, it is preferred to commence the heating method with all oxidant lances switched on, whereby the total heating power is maximal. Once the furnace has reached a certain predetermined operating temperature, one or several oxidant lances may either be operated in a pulsating manner or alternatively be switched off. This decrease of the total heating power may be carried out in one or several steps, by altering the number of switched on oxidant lances and/or by altering the time periods for one or several oxidant lances being operated in a pulsating manner.

[0049] Thereafter, the total heating power can be successively decreased in the same manner, at the same time as the operating temperature is maintained in the furnace and until the ingots have reached a desired final temperature. Then, the total heating power can be further decreased, still in the same manner as described above, so that temperature equilibrium prevails during a holding time with constant ingot temperature.

[0050] During this whole procedure, it is preferred that at least one oxidant lance is operated with full power at each time. Moreover, it is preferred that at least one oxidant lance, being the oxidant lance having its orifice arranged furthest up in the furnace of the lances in an aggregate comprising at least a fuel lance and at least one oxidant lance, is operated at full power. It is especially preferred that this at least one oxidant lance is operated with the above described high lancing velocities. This way, it is possible to control the total heating power over a broad power interval and at all times ensure satisfactory convection and therewith temperature homogeneity in the whole furnace chamber, including the V-shaped space between the ingots.

[0051] If a total heating power is desired which is lower than that achieved when only one oxidant lance is operated at full power, it is preferred that only one oxidant lance is operated in a pulsating manner. This single oxidant lance is in this case preferably an oxidant lance which is the oxidant lance with its orifice arranged at the lowest height in an aggregate comprising at least one fuel lance and at least one oxidant lance, where the single lance has its orifice arranged above at least one fuel lance through which fuel is supplied.

[0052] In order to further increase the thermal homogeneity during the carrying out of a method according to the present invention, it is furthermore preferred that oxidant is supplied through different lances for oxidant, or through different constellations of lances for oxidant, in an alternating manner. Thus, one and the same total heating power can be maintained but using alternating oxidant lances. This leads to temperature homogenization over time, and decreases the risk of local overheating in so called “hot spots”.

[0053] It is especially preferred to convert an existing pit furnace operated with conventional air burners to instead being operated using oxyfuel combustion, by installing one or several fuel lances and one or several oxidant lances operated according to the above said. By such conversion followed by such operation, an existing pit furnace can cost-efficiently be converted into more environmentally friendly oxyfuel operation without running into problems with poor thermal homogeneity in the furnace as a consequence.

[0054] Again with reference to the pit furnace **200** illustrated in FIGS. **4-7**, it is furthermore preferred to increase the thermal homogeneity in the furnace **200** by arranging at least one lance **230** for an oxidant with an oxygen content of at least 85 percent by weight in an furnace wall so that the orifice of the lance is arranged inside the furnace **200** and so that oxidant can be supplied directly to the space **205** having a triangular cross-section (see FIG. **6**) which is present under at least one ingot **201** which in turn is leaning against an inner wall of the pit furnace **200**, between the ingot **201** and the wall. That the oxidant can be supplied directly to the space **205** is to be interpreted so that the stream of oxidant originating from the lance **230** streams into the space **205** without striking against any obstacles on its way. Preferably, the lance **230** opens out in the space **205** itself, but it may also open out some ways outside and shoot the oxidant stream into the space **205**.

[0055] In case several ingots **201** are arranged in the furnace **200** along the same furnace wall, this space **205** of triangular cross-section will in general constitute an elongated, substantially cylinder-shaped body having triangular cross-section and being partly separated from the heated part of the furnace **200**. In the case where oxyfuel is used to heat the furnace **200**, it is difficult to achieve sufficiently elevated temperatures also in the space **205**. This leads to problems both in case one or several ingots **201** lean along a row against the same inner wall and in case ingots lean against both opposite long sides, as is shown in FIGS. **4-7**.

[0056] The height of the bed **202** of oxide scale varies during operation, and also across time during several operating cycles. Since oxidant lances **230**, **240** the orifices of which are arranged opening out directly into the space **205** risk ending up below the level for the bed **202** when sufficient volumes of oxide scale are on the furnace floor, it is preferred to arrange all lances opening out into the space **205** under the ingots **201** at such height so that it is possible to surveil the oxide scale level and empty the furnace floor from oxide scale before it reaches the level for the orifices of installed lances.

[0057] It is especially preferred that the oxidant lances **230**, **240** are arranged with their orifices arranged at a height above the furnace floor which is above the maximum level for an oxide scale bed appearing in the furnace during operation. More specifically, it is preferred that they are arranged to be at a height above the furnace floor of 0.5-1.0 meters.

[0058] Furthermore, it is preferred that the oxidant supplied from the lance **230**, similarly to that supplied from lances **211**, **212**, is supplied at elevated velocities, preferably at least 100 m/s, more preferably at least sonic velocity, most preferably at least Mach 1.5. At such elevated lancing velocities, the above described advantages in terms of temperature homogeneity and low flame temperatures are achieved, in turn resulting in low CO and NO_x rates. This is of special importance to avoid local overheating in the comparatively narrow space **205** under the ingots **201**, and additionally leads to that the lance **230** can be positioned with its orifice arranged further up along the inner wall of the furnace **200** without the risk of it as a consequence giving rise to local overheating of ingots **201** at low oxide scale bed **202** depths. Moreover, the lanced high velocity oxidant stream will suck hot furnace gases into the space **205** from surrounding parts of the furnace **200**, which additionally increases the thermal homogeneity in the furnace **200** by distributing thermal energy to the space **205**.

[0059] The present inventors have surprisingly discovered that the formation of oxide scale during operation tends to consume large amounts of oxygen. It has been noted that this in some cases can lead to a lack of oxygen in the combustion reaction, whereby the concentration of CO in the furnace atmosphere very rapidly can be sharply increased. According to a preferred embodiment, use is made of this phenomenon in that the main combustion, in the main furnace chamber including those parts of the furnace **200** constituted by the space **205**, is continuously controlled so that they are under stoichiometric, by adjusting down the total amount of oxidant supplied through the oxidant lances **211**, **212** the orifices of which are arranged above the space **205**. Hence, this will lead to elevated levels of CO in the furnace atmosphere. This CO is then oxidized in the space **205** by aid of additionally supplied oxidant with at least 85 percent by weight oxygen, supplied through the oxidant lance **230** to the space **205**. As a result of this additional oxidant, global stoichiometric equilibrium is achieved in the furnace **200**.

[0060] In this case, no additional fuel is thus supplied to the space **205**. Instead, the oxidant supplied through the lance **230** is caused to react mainly with the CO formed during incomplete combustion of fuel in the furnace **200**, using oxidant supplied to a part of the furnace which is not constituted by the space under the ingot. Thereby, the combustion of the fuel takes place in two stages in the furnace **200**, namely in a first stage during which CO is formed and a subsequent stage during which complete combustion to CO_2 takes place.

[0061] An alternative embodiment is shown in FIGS. **8-10**, wherein a separate lance **331** for fuel supplies additional fuel, besides the fuel being supplied through lances **310**, **320** to the V-shaped space **203** and to the rest of the furnace chamber, to the space **305** (see FIG. **9**), with which fuel the oxidant supplied through the lance **330** is caused to react. In this case, no adjustment down of the amount of oxidant supplied to the rest of the furnace chamber is required to obtain under stoichiometric combustion.

[0062] According to a preferred embodiment, more than one lance for oxidant is arranged in the space **205**, **305**. Thus, in FIGS. **4-7** a corresponding lance **240** is also arranged in the opposite short end of the furnace **200**, in addition to the lance **230**, so that it opens out into the space **205** under the ingots **201** which are leaning against the opposite long side of the furnace. In this case, when at least two ingots **201** that are to be heated are leaned against one each of respective first and second opposite inner walls of the pit furnace **200**, so that a respective space **205** with triangular cross-section is formed under each respective ingot, it is in general preferred that at least one respective lance **230**, **240** for oxidant having an oxygen content of at least 85 percent by weight is arranged in one respective furnace wall, arranged with its orifice so that it opens out into the furnace **200** and so that oxidant can be supplied to the respective space **205**, and so that the lances **230**, **240** in addition are arranged with their orifices arranged to open out in one opposite furnace wall each, and directed so that the streams of oxidant together give rise to a circulating flow motion in the furnace **200**. Hence, in FIG. **7**, the circulating flow motion will, starting out from lance **240**, run in the direction **250** to the opposite short end, perpendicularly away from the orifice of the lance **230**, thereafter back to the first short side and finally perpendicularly back to the orifice of the lance **240**. Such an arrangement will result in good temperature homogeneity throughout the whole space **205** under all ingots arranged in the furnace **200**.

[0063] In FIGS. **8-10** a corresponding arrangement is illustrated, comprising oxidant lances **330** and **340**, respectively. In this case, the preferred but not required design with one respective fuel lance **331**, **341** used in combination with each oxidant lance **330**, **340** is also shown.

[0064] What has been said above regarding alternating operation with several different oxidant lances for increasing temperature homogeneity is also valid for operation of lances **230**, **240**, **330**, **340**. Hence, it is possible to operate for example lances **230**, **240** in an alternating manner, so that firstly one **230**, then the other **240**, thereafter again the first **230** lance is operated, while the lance which at each point in time is not operated is instead switched off. It is also possible and preferred to perform such alternating operation comprising both oxidant lances **230**, **240**, **330**, **340** opening out into the space **205**, **305** as well as oxidant lances **211**, **212**, **221**, **222**, **311**, **312**, **321**, **322** opening out into the space **203**, **303**. With such a mode of operation, the temperature homogeneity can be maximized over time, and local overheating can be avoided, in a way which easily can be adapted to current operating conditions.

[0065] According to a preferred embodiment, the temperature inside the furnace is measured using temperature sensors (not shown), which are conventional as such, at different locations where local overheating can be feared, and the alternating operation is controlled so that the heating power is decreased in places where the measured temperature is so high that overheating is risked, i.e. higher than a certain predetermined value which is dependent upon the heated material.

[0066] Because of the above said concerning the oxygen consumption of the oxide scale formation process, it is, in order to control the CO concentration in the furnace, also preferred to measure the oxygen level in the furnace during operation, for example using one or several conventional lambda sensors and, based upon this measurement value or these measurement values, control the supplied amount of oxygen through the oxidant lances **230**, **240**, **330**, **340**, **211**, **212**, **221**, **222**, **311**, **312**, **321**, **322** so that the oxygen concentration in the furnace is kept essentially constant. The control can for example take place by continuous control of the supply of oxidant through one or several oxidant lances or by operating one or several oxidant lances in a pulsating manner, with suitable relations between switched on time and switched off time. This results on the one hand in that the amount of CO in the flue gases can be controlled to desired low levels, on the other hand in that any afterburning in the space **205**, **305** can be optimized.

[0067] Above, preferred embodiments have been described. However, it is obvious to the skilled person that many modifications can be made to the described embodiments without departing from the idea of the invention.

[0068] For example, an oxyfuel combustion according to the present invention can be used as a complement to one or several existing air burners in a pit furnace, to increase the maximum capacity for the pit furnace or to decrease the power of the air burner with maintained capacity but smaller negative environmental impact.

[0069] Moreover, the lances for oxidant and fuel illustrated in FIGS. **4-10** and described above can be arranged in other constellations. More oxidant lances can for instance be arranged so as to heat especially difficult to get at spaces and/or to create additional turbulence inside the furnace, depending on the actual operating conditions. The lances opening out into the V-shaped space do not need to be centrally arranged in said space, but can for example be arranged with their respective orifices somewhat displaced in the horizontal plane. In this case, it is preferred that the resulting downwards inclined oxidant stream cuts through an area to which fuel is supplied in the V-shaped space. Also, more fuel lances may be used in each aggregate or group, alternatively in other places in the furnace so that fuel is supplied to a location being cut through by one or several high velocity streams of oxidant.

[0070] Finally, it is possible to arrange one oxidant lance at low height in each one of the corners in the furnace, so that oxidant is supplied from both directions into the space under the ingots along both long sides of the furnace.

[0071] Therefore, the invention shall not be limited to the described embodiments, but may be varied within the scope of the enclosed claims.

1-14. (canceled)

15. A method for increasing temperature homogeneity in a pit furnace, comprising:

leaning at least two ingots to be heated against a respective one of first and second opposite inner walls of the pit furnace for forming an elongated space having a V-shaped cross-section between the at least two ingots as viewed along the first and second walls;

arranging at least one lance for an oxidant having an oxygen content of at least 85 percent by weight, and at least one lance for fuel in a furnace wall such that orifices of the at least one oxidant lance and the at least one fuel lance open out into the furnace at a distance from each other;

supplying the oxidant and the fuel to said V-shaped space for being combustible therein;

arranging the orifice of the oxidant lance above the orifice of the fuel lance; and

directing the oxidant flow obliquely downwards and along a longitudinal direction of said V-shaped space.

16. The method of claim **1**, wherein the orifice of the oxidant lance is arranged above all supply locations for the fuel in the furnace wall where the orifice of the oxidant lance is arranged.

17. The method of claim **15**, wherein the supplying the oxidant is at a velocity of at least 100 m/s.

18. The method of claim **17**, wherein the supplying the oxidant is at sonic velocity or more.

19. The method of claim **15**, further comprising directing streams from the oxidant lance and the fuel lance to meet in the V-shaped space.

20. The method of claim **15**, wherein the arranging the at least one oxidant lance comprises mounting said lance for streaming oxidant into the furnace at an angle of between 0 and 20° in relation to a horizontal plane.

21. The method of claim **20**, wherein the arranging the at least one oxidant lance comprises mounting said lance for streaming oxidant into the furnace at an angle of between 3 and 5° in relation to the horizontal plane.

22. The method of claim **15**, further comprising directing the oxidant lance for controlling an angle of an oxidant stream in both horizontal and vertical planes depending upon operating conditions of the furnace.

23. The method of claim **15**, wherein the at least one oxidant lance comprises at least two oxidant lances having respective orifices and being mounted so that the respective orifices are arranged above each other in the furnace for streaming the oxidant from the lances into the furnace at different angles in the horizontal and/or vertical planes.

24. The method of claim **23**, wherein some of the at least two oxidant lances have orifices arranged relatively higher for the respective oxidant from said lances to stream into the furnace at an angle in relation to the horizontal plane which is at least equal to the oxidant streams from others of the plurality of the oxidant lances having orifices arranged at lower heights.

25. The method of claim **23**, further comprising controlling heating power in the furnace by the at least one or a plurality of the oxidant lances being switched on or off, and controlling an amount of the fuel supplied to stoichiometrically correspond to total oxygen supplied via the oxidant.

26. The method of claim **23**, wherein the temperature homogeneity in the furnace is increased during operation by supplying the oxidant through different lances for the oxidant or through at least one constellation of lances for the oxidant.

27. The method of claim **15**, further comprising measuring an oxygen level in the furnace with at least one lambda sensor, and controlling the oxygen supplied through the at least one oxidant lance for maintaining an oxygen concentration in the furnace to be substantially constant.

28. The method of claim **15**, further comprising:

providing a first group of lances having at least one oxidant lance with an oxygen content of at least 85 percent by weight and at least one fuel lance;

arranging orifices of said first group at a first short side of the furnace;

providing a second group of lances having at least one oxidant lance with an oxygen content of at least 85 percent by weight and at least one fuel lance;

and arranging orifices of said second group at a second short side of the furnace opposite to the first short side;

wherein the first group are arranged with their orifices at a height between 0.9 and 1.5 meters above a floor of the furnace and the second group is arranged with their orifices at a lower height.

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