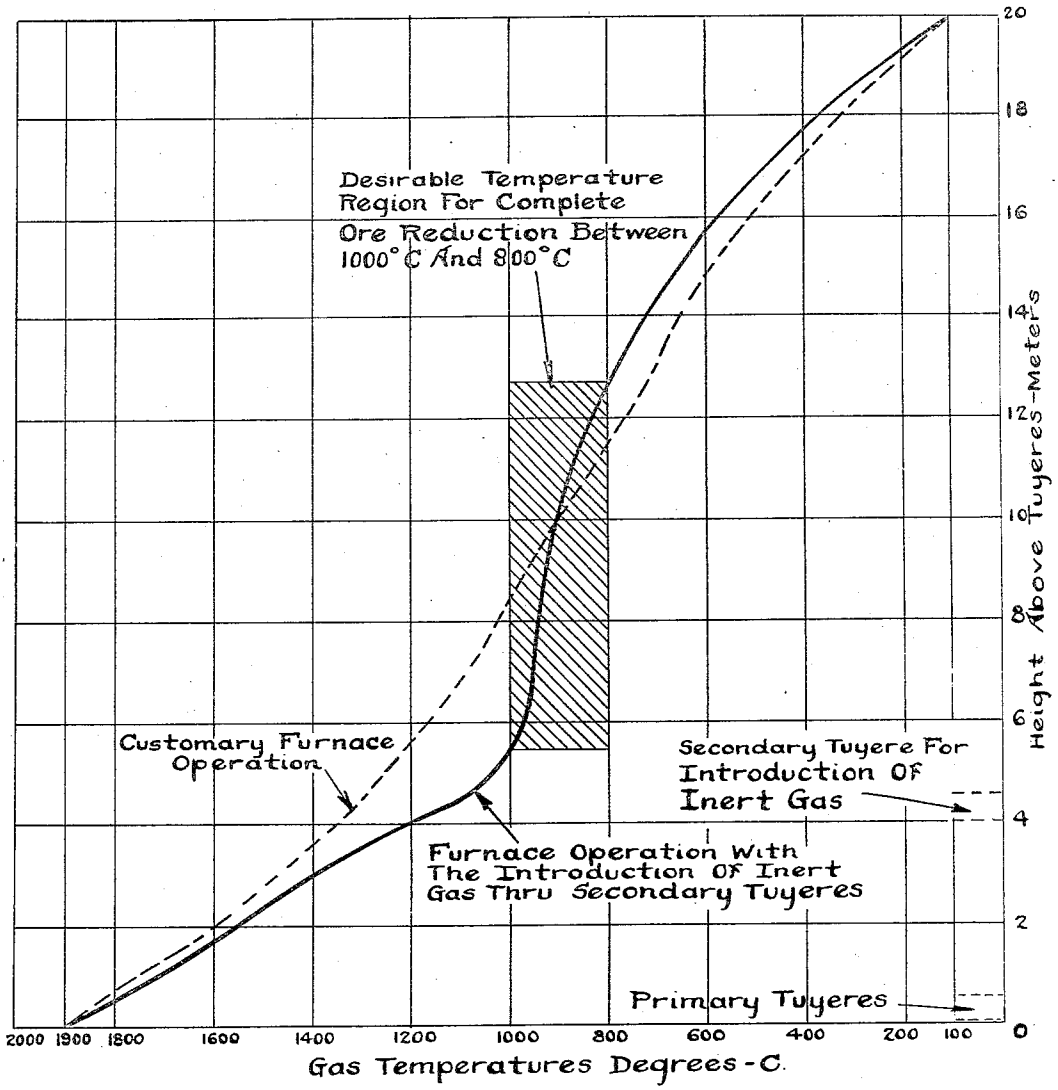
July 11, 1933. C. C. FURNAS 1,917,642

PROCESS OF CONTROLLING THE TEMPERATURE GRADIENT UP THE SHAFT OF A FURNACE

Filed June 23, 1930 2 Sheets-Sheet 1

Fig.-1



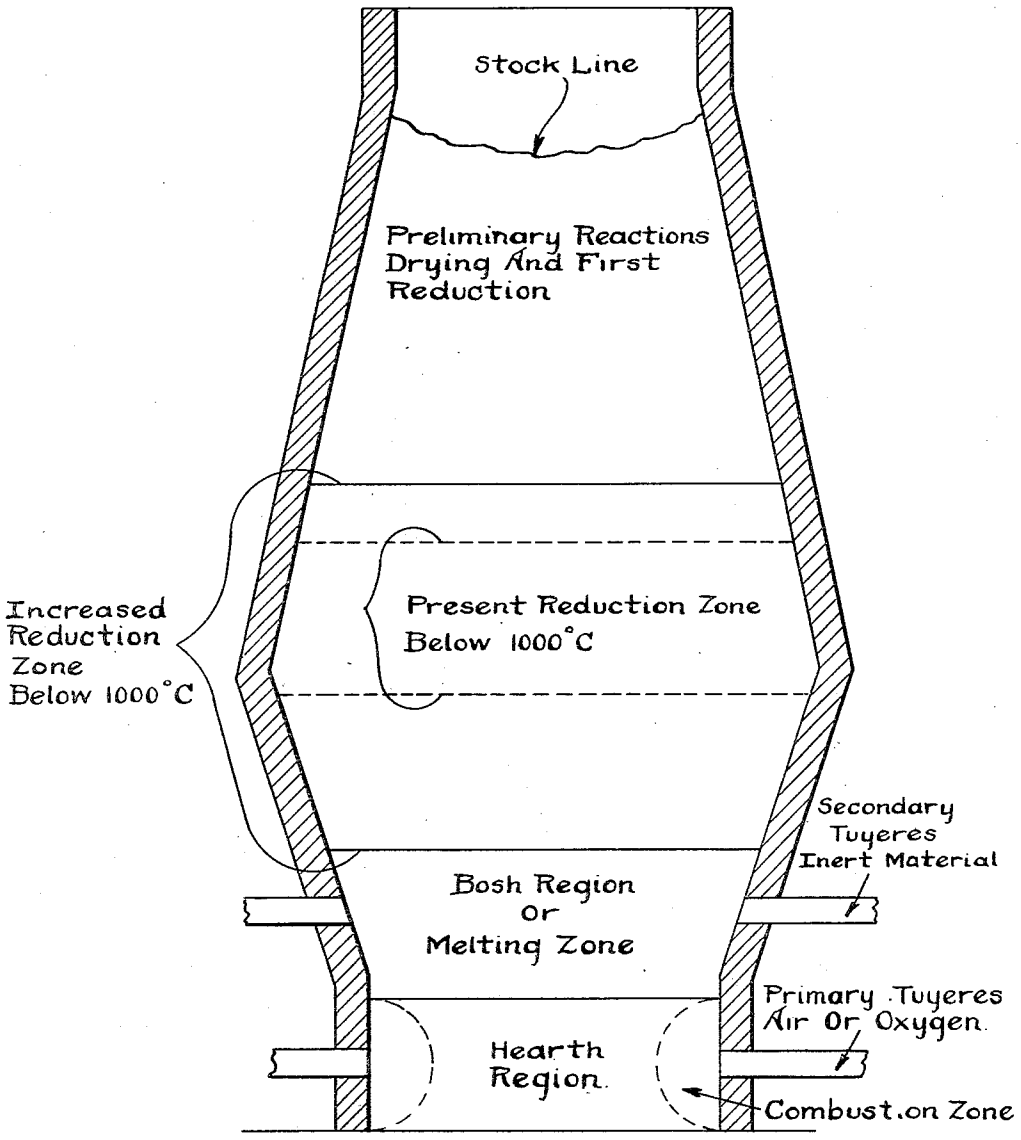
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PROCESS OF CONTROLLING THE TEMPERATURE GRADIENT UP THE SHAFT OF A FURNACE

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Fig-2



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UNITED STATES PATENT OFFICE

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PROCESS OF CONTROLLING THE TEMPERATURE GRADIENT UP THE SHAFT OF A FURNACE

Application filed June 23, 1930. Serial No. 463,094.

My invention relates to a process of controlling the temperature gradient up the shaft of a furnace, such, for example, as a blast furnace used for the reduction of ores of iron, copper, lead, manganese, silicon, chromium and ores of like character.

It is the object of this invention to produce in the furnace and along the length of the same a materially increased area of temperature particularly suitable for the purpose of reducing the ore and by that means of increasing the efficiency of the furnace. I obtain the objects of this invention by introducing into the furnace at a point not far above the combustion portion thereof a stream or streams of chemically inert material which has not been preheated and preferably an inert fluid such as nitrogen. The effect of this is to take up heat from the very hot material and gases in the melting zone above the combustion area and greatly increase the fluid stream of hot gases or hot material moving upwardly through the furnace shaft which will result in producing a temperature area suitable for the more important reducing action, which is greatly lengthened over the area which can be produced from the use of the combustion gases alone.

In blast furnaces which are used for smelting metals from their ores there is a shaft which may be of any size or shape but which in practice, for iron at least, is usually about twenty feet in diameter and sixty-five feet high. Ore, fluxing materials and solid fuel are fed in at the top of this shaft. At the bottom of the shaft air is blown in under more or less high pressure through tuyères. This blast of air impacts on the solid fuel and causes its combustion with the production of a large amount of heat. The residual air (nitrogen) and gases of combustion pass up through the shaft while the column of solid material therein moves in counterdirection downwardly. At the point of combustion this fluid stream will have substantially the heat of combustion and it will give up its heat to the descending solids, and by this means melt the ore and flux in the zone immediately above the combustion zone; and further up the column it will effect various reductions of the ore, that is, the carbon monoxide (CO) in the hot upwardly-moving fluid stream will take oxygen from the iron ore, finally reducing the ore from the form of an oxide to a pure metal. Considering the downward moving charge of solid particles as equivalent to a fluid stream, just as the upward moving gas forms a fluid stream, the whole system is a simple countercurrent heat exchanger. In normal operation of blast furnace practice, the entire furnace will be in a so-called "steady state". That is, the average temperature of either the gas or the solid at any point in the furnace does not substantially increase or decrease from time to time. That means that transverse sections of the furnace will remain at substantially constant temperatures, but the average temperature of these transverse sections will vary from the maximum heat of the combustion zone at the bottom to fairly moderate temperatures where the solid material is being introduced into the furnace shaft at the top. This variation may be represented by a line which will probably be slightly curved but which may approximate a nearly straight line, as indicated in the graph forming one of the sheets of drawings filed herewith and designated as "Figure 1".

In this graph temperature variations are shown running from 1900° C. at the bottom of the furnace in the combustion area to something less than 200° C. at the extreme top of the stock line.

Figure 2 of the drawings is a diagrammatic view of a blast furnace in section showing the several zones of heat up the shaft.

Applying this process to iron ore reduction, which is more or less typical of ore reduction generally, the solid stream moves from the point designated as stock line down through the various zones until it finally descends as molten material below the combustion zone. Similarly, the fluid gas stream moves upwardly from the combustion zone to the stack above the stock line, where it discharges. The three common forms in which iron ore exists are all oxides designated by the chemical symbols Fe_2O_3, Fe_3O_4 and FeO. Fe_2O_3 reduces very easily to

Fe_3O_4, and Fe_3O_4 reduces fairly easily to FeO. These reductions may, and do, take place at moderate temperatures below 800° C. But the important part of the blast furnace process is the reduction of the last oxide FeO to metallic iron, and this will not occur at temperatures materially below 800° C.

The air blown through the tuyères into the bottom of the furnace strikes hot solid fuel (usually coke which is almost pure carbon). Combustion takes place with the reaction.

$$C+O_2=CO_2$$

But this occurs in the presence of excess carbon, so that there immediately follows the reaction—

$$CO_2+C=2CO$$

This last reaction is usually completed within one meter of the nose of the tuyères in iron ore blast furnaces of the commercial type. The hot stream of gas moving upwardly from that point will consist of the residual nitrogen from the air introduced through the tuyères mixed with carbon monoxide or CO, all very hot. These gases go up the shaft unchanged until the carbon monoxide strikes unreduced iron oxide. Then, if the temperature conditions are right there occurs the reaction

$$FeO+CO=Fe+CO_2$$

If this reaction takes place up the stack in a zone where the temperature is at or below 1000° C. then the carbon dioxide (CO_2) then formed passes on out of the furnace unchanged. However, if the reaction takes place in a lower zone where the temperature is above 1000° C., then the CO_2 formed by the reaction may be reconverted into CO, and there is relatively small chance that the iron reduction reaction will be repeated before the gas gets out of the furnace. From this it will be seen that there is a loss of fuel efficiency in reduction of the iron ore where it takes place in the hotter zone. This is commonly called "solution loss", for by it the CO_2 gas acquires and takes out of the furnace an equal molecular quantity of carbon which is not effective in reducing the ferrous oxide of the iron ore to metallic iron. If, however, all of the iron ore is reduced to metallic iron before it reaches the hotter zone below the 1000° zone, the last reaction cannot take place and this solution loss would be avoided. There is, therefore, a distinct advantage in completing the iron ore reduction as far up the shaft as possible, and, if possible, before any of the oxide reaches the zone of heat above 1000° C. It follows that if by any means the most effective reducing zone at a temperature of between 1000 and 800 degrees can be materially extended along the shaft, this effect will be more certainly achieved and greater efficiency will result.

Now, while iron ore can be completely reduced in the temperature zone or region of from 800° C. to 1000° C., the reaction there is relatively slow. It follows that if complete reduction is to be effected at these temperatures it will be necessary to hold the material in such temperature zone for a considerable length of time, which is the same thing as stating that the temperature zone 800° to 1000° for the downwardly-moving stream of solid particles must be increased in length. My process herein described provides a means of doing this, which will thus materially increase the efficiency of the furnace. As shown in Figure 2, the combustion temperature of the gases in the region of the tuyères in a blast furnace for reducing iron ore must be maintained at from 1700° C. to 1900° C. in order to melt the iron and carry on the "hearth reactions", that is, the reactions of melting the uncombustible materials and causing separation of metal and slag. For the reasons above given, it is desirable to reduce the temperature of the gases after they leave the hearth region to 1000° C. as quickly as possible, provided the reduction can be followed by maintaining temperatures from 1000° C. to 800° C. for a considerable distance up the shaft. Normally, as shown in Figure 2, the hearth region will be extended some 10 meters above the combustion zone and the reduction zone between 800° C. and 1000° C. will be only some 2 meters long. Above that zone the counter-moving gas and material streams will be reduced in temperature to a point where reduction of FeO will take place, with the result that much unreduced FeO will pass down into the hotter parts above and into the hearth region and melting zone and the solution losses above described will take place.

I accomplish at the same time reduction in length of the hotter than 1000° C. region and the melting zone and an increase in length of the reduction zone by introducing inert material into the furnace by secondary tuyères entering the furnace a suitable distance up the shaft above the combustion zone. This may be accompanied by forcing less air into the furnace through the primary tuyères, and would be particularly effective were oxygen enrichment of the air forced in to be practiced.

The inert material may be any type of chemically inert material, such as a gas, a spray of liquid, a vapor or finely divided solid. A very desirable inert material is nitrogen. In the practice of this invention it is primarily designed as a heat carrier, the effect of its introduction being to lower the temperature of the part of the furnace where the inert material is introduced by the absorption of heat into said inert material in that portion

of the furnace, from which it carries such absorbed heat up the furnace, or along the shaft or chamber where the hot fluid stream is moving. And because the volume of heat carrier is thus artificially increased it will transfer heat to the oppositely-moving stream of solids through a much longer length of the shaft or room and produce the lengthened reduction zone between 1000° C. and 800° C., which is so important for efficient operation. That is, applied to iron ore reduction, the furnace will reduce a larger quantity of ore with the consumption of less fuel.

Although I have shown and described this process as applicable to an iron ore smelting furnace, its applicability is general, not only to all types of smelting furnaces, but in any use where a stream of heated fluid is caused to move through a shaft or room (vertically or horizontally, or in any desired direction) and it is desirable to control the temperature gradient of that stream in such shaft or room. For example, the process may be employed where it is desirable to carry the heat of the gas to greater distances from the combustion point, such as in reheating furnaces used for heating steel bars, in still columns where it is desired to carry the heat for vaporization higher up to the reflux column; in foundry cupolas; in fuel beds, such as gas producers and water gas producers, and in any situation wherever it is desirable to increase the heat-carrying capacity of the heated fluid stream.

In any of these uses the introduction of inert material at any point in the fluid stream must result in a change of the character of the temperature gradient. That is, in a sudden lowering of temperature in the region where the (cold) inert material is introduced, and an extension in the fluid stream of the region of lower temperature beyond the point of introduction of the inert material, and this control of the temperature gradient in the manner described, will increase efficiency of the apparatus and process with which the control is associated, as, for example, in the smelting of iron ore and other ores, and will reduce fuel consumption for a given amount of ore reduction.

I claim:

1. The step in the process of smelting iron ore in blast furnaces which consists in effecting a lowering of temperature of the hot fluid stream at a point above the hearth region and melting zone, and maintaining within the furnace shaft an increased length of region where the counter-moving solid stream is held at temperatures between 1000° C. and 800° C.

2. The step in the process of smelting iron ores in blast furnaces which consists in forcing cold nitrogen into the hot fluid stream moving upwardly in the shaft of the furnace through the descending stream of solid particles at a point above the hearth region whereby an increased length of said counter-moving solid stream is held at reducing temperatures between 1000° C. and 800° C.

3. The process of smelting iron ores in blast furnaces which consists in forcing a reduced amount of air enriched with oxygen through primary tuyères into the combustion zone at the bottom of the furnace shaft, and forcing into the hot fluid stream above said primary tuyères through secondary tuyères cold nitrogen in quantities such as to reduce at that point the temperature of the upwardly-moving hot fluid stream, and carrying said reduced temperature a great distance up the shaft of the furnace whereby the counter-moving solid stream is held for a materially extended part of its length at temperatures between 1000° C. and 800° C.

In testimony whereof I hereunto affix my signature.

CLIFFORD C. FURNAS.