

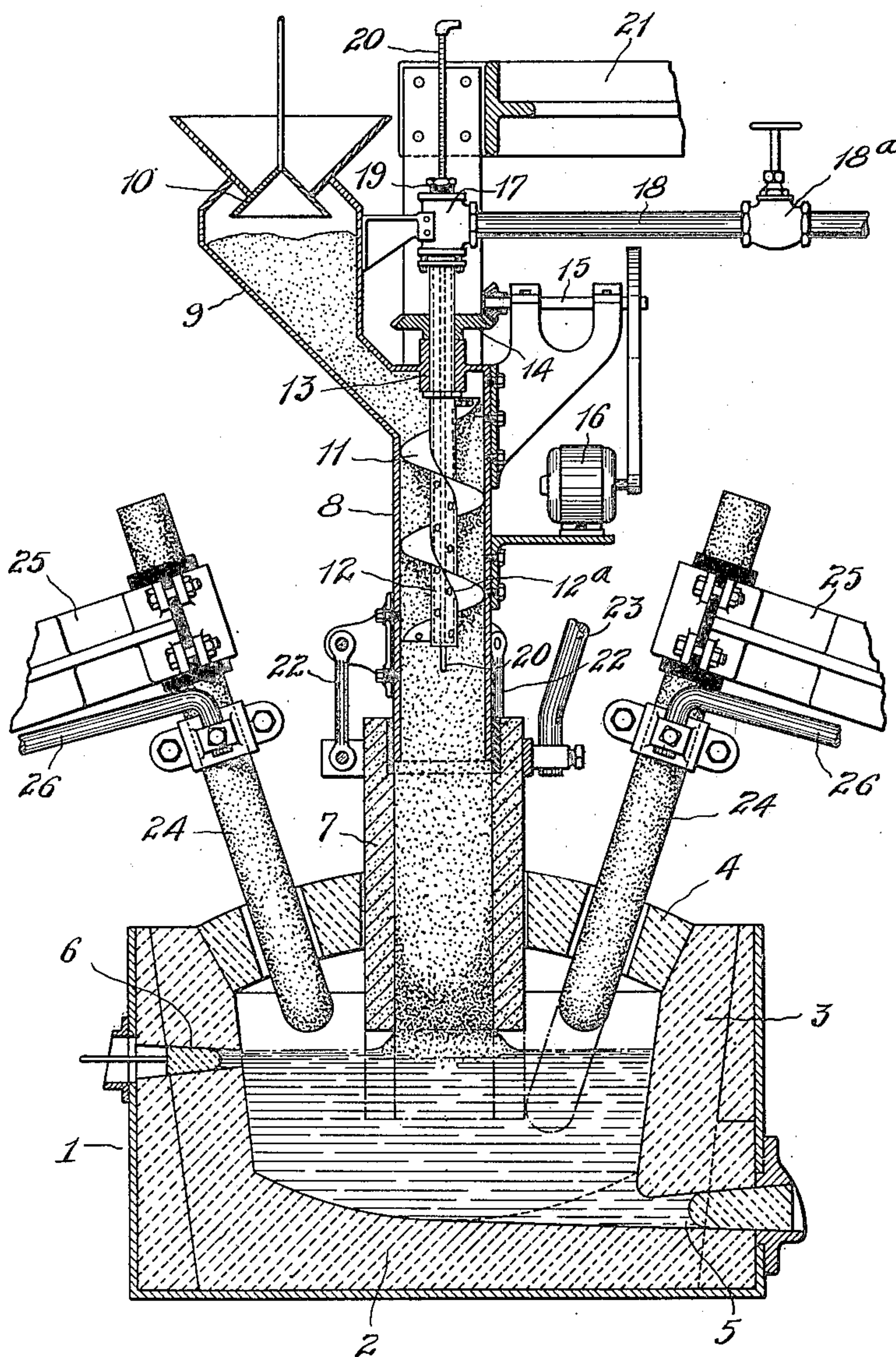
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PROCESS OF REDUCING METALLIC OXIDES

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PROCESS OF REDUCING METALLIC OXIDES.

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To all whom it may concern:

Be it known that I, EMIL BRUCE PRATT, a citizen of the United States, residing at East Cleveland, in the county of Cuyahoga and State of Ohio, have invented certain new and useful Improvements in Processes of Reducing Metallic Oxides, of which the following is a specification, reference being had therein to the accompanying drawings.

10 This invention relates to an improved process of reducing metallic oxides, such as ores of iron, by the use of hydrocarbons as reducing agents, and the present application is, in part, a continuation of my earlier application Serial No. 30,198, filed May 24, 1915.

One of the objects of the invention is to provide a process which is especially adapted for the reduction of ores in a finely divided state, such for example as the so-called flue dust.

Another object of the invention is the provision of a process of reducing metallic oxides in which electricity may be used to supply the requisite heat.

Another object of the invention is the provision of a process such as last referred to which will be substantially continuous in operation.

30 A further object of the invention is the attainment in a process of the character in question of the utmost efficiency and economy as to the amounts both of the reducing agent and the electric current required for a given quantity of ore.

Although it has been known for a long time that hydrocarbons can be used as reducing agents for metallic oxides, such as iron ores, and processes have been proposed which are chemically and theoretically correct, yet few, if any, of these processes have been used commercially because of the mechanical difficulties encountered. These mechanical difficulties arise from the fact that in order to act as a reducing agent, any hydrocarbon must first be decomposed into its elements, hydrogen and carbon. And then the hydrogen or the carbon, or both, must be brought into intimate contact with the ore when both are at the proper temperatures. Now, before a hydrocarbon is completely decomposed it is wholly or partially volatilized. Therefore, in all the processes heretofore proposed, the reducing

agent either escaped from the furnace before being decomposed or the decomposed hydrocarbon could not be brought into sufficiently intimate contact with the ore.

In the case of my improved process, one of the essential features is that the hydrocarbon is confined and kept in intimate contact with the ore until after decomposition of the ore has taken place, thus enabling all or nearly all of the reducing elements to perform their function and thereby effecting an economic use of both the reducing agent and the heat.

In so far as this principle of confinement is concerned, my invention can be practised in any one of a variety of ways which provide for the confinement of the hydrocarbon in intimate mixture and contact with the finely divided ore while said materials are subjected to a temperature high enough to decompose the hydrocarbon into hydrogen and carbon and, preferably, high enough to reduce the ore. However, to attain all the objects of my invention I prefer to introduce the hydrocarbon reducing agent, alone or mixed with the ore or with both the ore and flux, into an electrically heated furnace through a heated refractory tube or conduit that is almost or entirely non-porous. This tube is preferably a resistor tube made of carbon or graphite. It is placed in the electric circuit and may be heated to any desired degree, up to the volatilization point of carbon.

In case the ore is not mixed with the hydrocarbon before the latter is put through the tube, it becomes necessary that the exit end of the tube shall emerge at a point sufficiently low within the crucible of the furnace, that the hydrogen shall pass up through the charge of iron, flux, etc. in the crucible. If, on the other hand, the ore and the hydrocarbon are mixed before being forced through the resistor tube, the tube may constitute the chief part of the furnace, inasmuch as the decomposition, reduction and melting could all be accomplished within the tube. In this case, the chief purpose of the additional crucible is to let the metal settle and separate from the slag.

Inasmuch as it is possible to determine in advance with considerable accuracy the temperatures at which a resistor tube of given

cross section and length can be heated with a given current, it therefore is possible to so regulate the size of the tube, the rate of feed of the charge and the amount of current that any charge, containing a hydrocarbon, which may be put into one end of the tube and forced through, shall be heated to such a temperature that when it issues from the other end the hydrocarbon shall have been decomposed into carbon and hydrogen. At any rate this result can readily be attained by experimental trial.

In order that my invention may be quite clearly understood, I will now describe in further detail a preferred way of working the process, having reference to the accompanying drawing which shows in central vertical section the main features of a furnace suitable for the purpose.

In the drawing, 1 is the crucible part of an electric furnace having a bottom 2, side wall 3 and roof 4 formed of suitable refractory material such as is used for lining metallurgical furnaces. The furnace is provided at its bottom with a tap hole 5 for drawing off the metal, and at a higher level is provided with a tap hole 6 for drawing off slag.

7 is a refractory tube preferably formed of amorphous or graphitic carbon arranged to project through an opening in the roof 4. A vertical feed or conveyor tube 8 fits into the upper end of the tube 7, said tube 8 being provided at its upper end with a feed hopper 9, the mouth of which is normally closed by bell 10.

In the tube 8 is mounted a screw conveyor 11 having a hollow shaft 12 that is supported in bearing 13 and is fitted with a bevel gear 14 which is driven through the intermediate shaft 15 from the variable speed electric motor 16. The upper end of the tubular shaft 12 projects into and rotatably engages a T-coupling 17 which is supported from the hopper 9. One opening of the coupling 17 is fitted with a pipe 18 having a control valve 18^a through which the hydrocarbon reducing agent, which may be either gaseous, liquid or semi-solid, is conducted into the shaft 12. Said shaft 12 is provided with perforations 12^a as indicated, through which the hydrocarbon can issue and mix with the finely divided ore or mixture of the finely divided ore and fluxing material which is fed in through the hopper 9. The upper opening of the coupling 17 is provided with a stuffing box 19 through which passes the tube of a pyrometer 20 which extends down to project more or less below the lower end of said shaft so as to explore the temperature within the refractory tube 7.

The conveyor tube 8 is supported by a suitable crane 21 or the like by which said tube can be raised and lowered. The tube

7 in turn is supported, as by links 22, from the tube 8 so that the refractory tube 7 can be adjusted up and down by raising and lowering the tube 8 and its associated parts. As indicated, the refractory tube is electrically insulated from the supporting tube 8. 23 is an electric conductor suitably connected to the tube 7, so that the latter may serve as one of the furnace electrodes and function as a resistor tube. 24, 24 are electrodes which project through the roof 4 of the furnace, being adjustably supported by crane arms 25, 25 and electrically connected with conductors 26, 26. Any suitable number of electrodes 24 can be used.

In the use of the above described furnace in carrying out my process, there can be considerable variation with respect to the electrical connections and the location of the electric arcs. For example, with the electric connections as shown in the drawing the arcs are struck between the feed tube 7 and the electrodes 24, the tube 7 being of one polarity and the electrodes 24 of the opposite polarity. Again, the conductor 23 can be disconnected from the tube 7 and connected to one of the electrodes 24 in place of its conductor 26, in which case the arcs are struck from one of the electrodes 24 to one side of the tube 7 and from the opposite side of the tube 7 to the other electrode 24. In this case the tube 7 still acts as a resistor tube but the current passes circumferentially mainly through the lower part of the tube. In a third case the conductors can be connected as last described but the arcs struck from one electrode 24 to the molten bath and from the molten bath to the other electrode 24. In the first two cases it will be seen that the feed tube 7 is heated both by resistance and by radiation from the arcs and the molten bath, while in the third case the feed tube is heated entirely by radiation.

Assuming that the connections are made as shown in the drawing, the operation is as follows: Sufficient metal to start the furnace, either cold metal such as steel scrap, or molten metal from another furnace, is introduced into the crucible, the feeding tube 7 is lowered into position through the roof and the electrodes 24 are lowered far enough to contact with the tube 7 as indicated by the dotted lines in the drawing, whereupon both the tubes and the electrodes are adjusted upward to strike the arcs. Then, as soon as the furnace has come up to working temperature, or, in case the start is made with cold metal, as soon as said metal has become molten, the finely divided ore, preferably mixed with the necessary fluxing material which also is finely divided, is fed into the hopper 9, the conveyor 11 is started and the valve 18^a is opened to admit the hydrocarbon reducing agent. The charge of finely divided ore and flux finds its way

from the hopper into the conveyor tube 8 where it is gradually fed downward by the conveyor 11. As the charge gradually moves downward through the tube 8, the hydrocarbon reducing agent, such for example as fuel oil, is fed through the pipe 18 into the conveyor tube 12 and issues through the perforations of said tube and mixed with the finely divided ore and flux. As the charge thus completed moves downward into the resistor tube 7, it is subjected to the heat of said tube, and its temperature is gradually raised as it continues downward until decomposition of the hydrocarbon into hydrogen and carbon results. Then as the downward movement of the charge proceeds further its temperature is raised still higher until complete reduction of the metallic oxide is effected, and in this state the ore is discharged from the tube 7.

As the decomposition of the hydrocarbon occurs when it is thoroughly distributed through and in intimate contact with the finely divided ore and flux, it is obvious that the minute particles of carbon will be deposited directly on the particles of ore throughout the mass thereof, and at the same time the hydrogen will also be uniformly distributed and in intimate contact with the ore throughout the mass thereof, and this thorough distribution and intimate contact of the carbon and hydrogen with respect to the finely divided ore continues until the reaction between the metallic oxides and the carbon and hydrogen results in the reduction of the ore. In the case of fuel oil and most other hydrocarbons, volatilization occurs at a temperature below the temperature of decomposition, but inasmuch as all the materials are closely confined and the only outlet for the gaseous hydrogen is downward through the resistor tube, it is insured that the hydrogen shall be maintained in intimate contact with the ore until it reaches the reduction temperature. Obviously this result is secured whether the hydrocarbon used is solid, liquid or gaseous.

By means of the pyrometer 20, the temperature of the charge within the resistor tube 7 can be determined and the speed of the conveyor 11 can then be controlled to secure a rate of feed through the resistor tube such that decomposition of the hydrocarbon and, preferably, as above described, a reduction of the ore, shall occur before the charge emerges from the resistor tube and falls into the molten bath. In addition to varying the speed of the conveyor 11, the electric current can be regulated to assist in securing the desired temperature of the charge before it emerges from the resistor tube.

The reduced ore discharged from the lower end of the resistor tube 7, drops into the molten bath of the furnace where the smelt-

ing operation is completed. The level of the molten bath will, of course, gradually rise and the resistor tube 7 and electrodes 24 are correspondingly adjusted upward either manually, or automatically in a well known manner, to properly maintain the electric arcs. From time to time, molten metal can be tapped off from the bottom of the furnace so that there will be no undue rise and fall of the level of the bath. Also, some of the slag can be drawn off from time to time through the tap hole 6. Thus a continuous operation of the furnace can be maintained.

Since the charge of reduced ore, as it falls from the end of the tube 7 into the molten bath, will be more or less supported by the bath, by vertical adjustment of the tube 7 this resistance to the discharge therefrom of the ore can be varied so that any premature and sudden discharge of a considerable mass of the ore before it has passed gradually through the reduction zone, is effectively prevented.

The apertures in the furnace roof through which the tube 7 and the electrodes 24 project afford exits for the gaseous products of reduction but, as will readily be understood, other exits can be provided for this purpose. As these gaseous products of reduction are non-oxidizing, the carbon electrodes do not rapidly deteriorate.

In case a liquid, semi-solid or solid hydrocarbon is used as a reducing agent, it can obviously be mixed with the finely divided ore and flux before the latter is charged into the hopper 9. However, when either gaseous or liquid hydrocarbons are used I prefer to feed the reducing agent through the hollow conveyor shaft as above described.

The operation of the furnace in carrying out my process, when the other forms of electrical connection above described are used, is much the same as that just described. When the conductor 23 is led to one of the electrode 24 instead of to the resistor tube 7 and the arcs are struck between said tube and electrodes 24, the application of heat to the said tube tends to be more localized at its lower end and this may affect slightly the rate at which the charge should be fed. When with the last mentioned connection the arcs are struck from one electrode 24 to the bath and from the bath to another electrode 24, since no current is passed through the tube 7 and the latter is heated entirely by radiation, the electrodes 24 should be adjustably supported in such a manner that the positions of the arcs can be varied in relation to the tube 7 so that the temperature of said tube can to a certain extent be varied and controlled. The temperature of said tube can further be varied by adjusting it vertically in relation to the bath so long as such adjustment does

not interfere with the maintenance of suitable resistance to the discharge of the ore into the molten bath to insure the uniform feed of the ore through the tube 7 in the manner previously described.

From the foregoing description it will be seen that by reason of the thorough mixing and intimate contact of all materials of the charge until reduction has taken place, my improved process is highly economical in the utilization both of the reducing agent and of the necessary heat.

I have made especial reference to iron ore but it will be understood that the process is applicable to various other metallic oxides. Indeed, it is to be understood that the foregoing description and the accompanying drawings are presented only for purposes of explanation and illustration, the scope of the invention being indicated by the appended claims.

What I claim is:

1. The process of reducing metallic oxides, such as iron ores and the like, to the metallic state, which consists in charging materials comprising the oxides and a hydrocarbon reducing agent into a refractory container so as to substantially fill the same and with the oxides and reducing agent mixed, heating the said container and the mixed oxides and hydrocarbon therein until said hydrocarbon is decomposed into carbon and hydrogen and meanwhile maintaining the reducing agent, whether it is in a solid, liquid, vapor or gaseous state, in intimate contact with the metallic oxides throughout the mass thereof, and continuing to heat the said mixture while still in said container and while the hydrogen and carbon are in intimate mixture and contact with the metallic oxides until the metallic oxides are reduced to the metallic state by the action of the decomposed hydrocarbon.

2. The process of reducing metallic oxides, such as iron ores and the like, to the metallic state, which consists in charging materials comprising the oxides and a hydrocarbon reducing agent into a refractory container with the oxides and reducing agent mixed and without any free space above the charge, heating the said container and the mixed oxides and hydrocarbon therein until the latter is decomposed into carbon and hydrogen and meanwhile maintaining the reducing agent, whether it is in a solid, liquid, vapor or gaseous state, in intimate contact with the metallic oxides throughout the mass thereof, and thereafter continuing to heat said materials while the hydrogen and carbon are in intimate mixture and contact with the metallic oxides until the said oxides while still in the said container are reduced by the action of the hydrogen and carbon.

3. In the process of reducing metallic oxides, such as iron ores and the like, to the me-

tallic state, the steps which consist in introducing materials comprising the oxides and a hydrocarbon reducing agent into a refractory tube so as to substantially fill the bore of the same and with the oxides and reducing agent mixed, advancing the mixture of oxides and hydrocarbon through the tube and simultaneously applying heat to the oxides and hydrocarbon, and controlling the amount of heat so applied to the oxides and hydrocarbon in relation to the rate of feed thereof so as to insure decomposition of the hydrocarbon into hydrogen and carbon while the oxides and hydrocarbon are maintained in intimate contact throughout the mass of said oxides.

4. The process of reducing metallic oxides, such as iron ores and the like, to the metallic state, which consists in charging materials comprising the oxides and a hydrocarbon reducing agent into a refractory feeding tube so as to substantially fill the bore of the same and with the oxides and hydrocarbon mixed, advancing the oxides and hydrocarbon through the said tube and simultaneously heating said oxides and hydrocarbon in the tube at such a rate in relation to the rate of feed of the materials that the hydrocarbon is decomposed into hydrogen and carbon while it is maintained, whether in a solid, liquid, vapor or gaseous state, in intimate contact with the oxides throughout the mass thereof and further heating the mixture while still confined in said tube until the oxides are reduced to the metallic state by the action of the decomposed hydrocarbon.

5. The process of reducing metallic oxides, such as iron ores and the like, to the metallic state, which consists in charging materials comprising the oxides and a hydrocarbon reducing agent into a refractory feeding tube so as to substantially fill the bore of the same and with the oxides and hydrocarbon mixed, advancing the oxides and hydrocarbon through the said tube and simultaneously heating said oxides and hydrocarbon in the tube at such a rate in relation to the rate of feed of the materials that the hydrocarbon is decomposed into hydrogen and carbon while it is maintained, whether in a solid, liquid, vapor or gaseous state, in intimate contact with the oxides throughout the mass thereof, further heating the mixture while still confined in said tube until the oxides are reduced to the metallic state by the action of the decomposed hydrocarbon, and delivering the reduced ore directly into an electrically heated crucible.

6. The continuous process of reducing metallic oxides, such as iron ores and the like, to the metallic state, which comprises mixing the finely divided oxides and suitable fluxing material with a hydrocarbon reducing agent, advancing said mixture substantially continuously through a refractory

feeding tube, simultaneously applying heat to said tube and its contained charge to effect therein the decomposition of the hydrocarbon and reduction of the ore, delivering the reduced ore from the tube directly into an electrically heated crucible, drawing molten slag from the top of the molten bath in the crucible and drawing metal from the molten bath at a level below that of the molten slag. 10

In testimony whereof, I hereunto affix my signature.

EMIL BRUCE PRATT.