Aug. 10, 1943. R. L. PATTERSON 2,326,163

HEAT TREATMENT APPARATUS

Original Filed Nov. 3, 1941 3 Sheets-Sheet 1

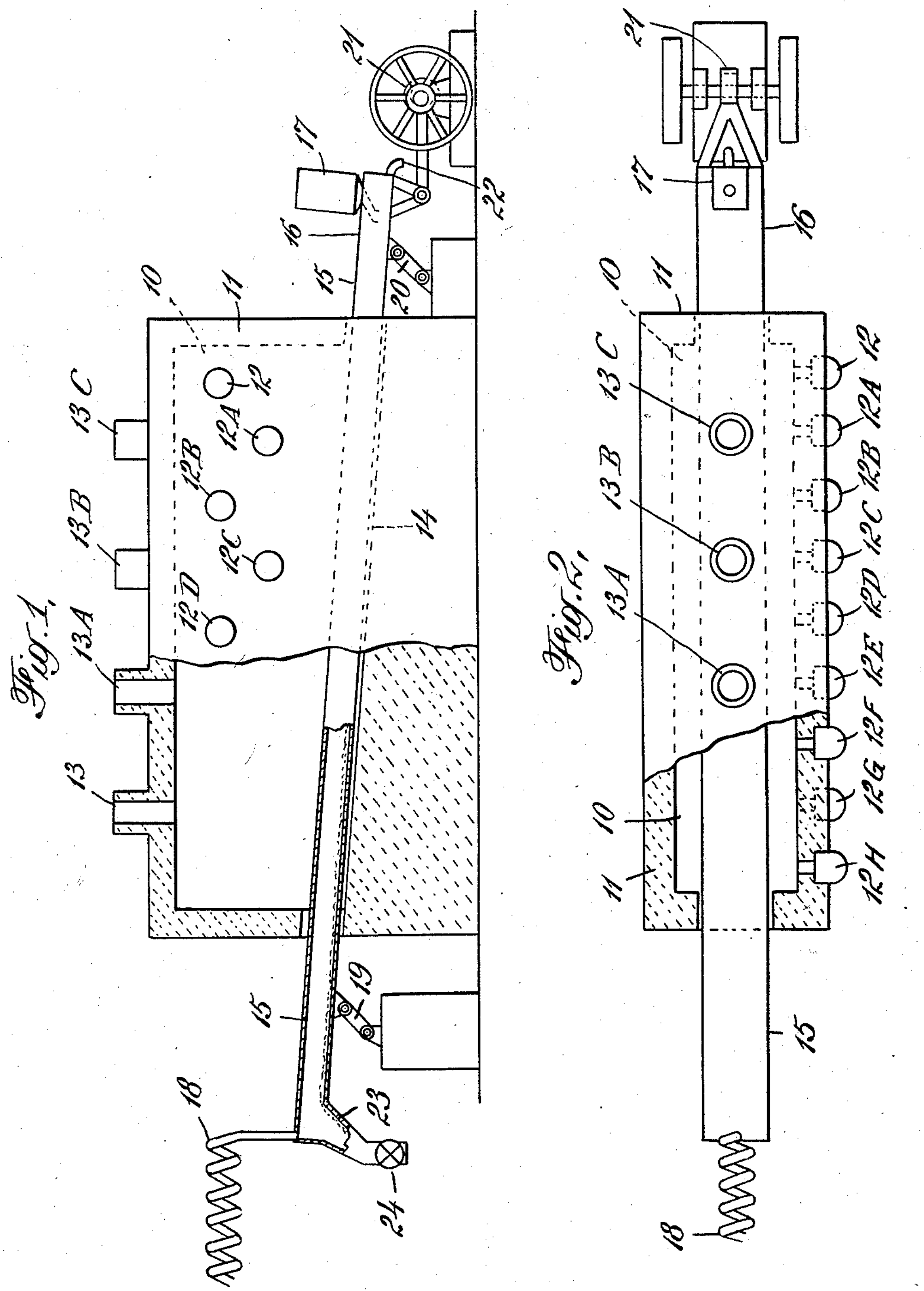

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Fig. 3,

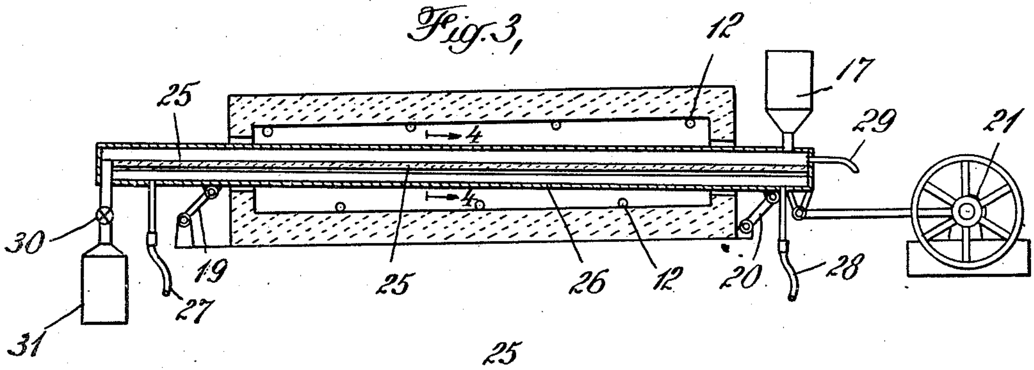

Fig. 4,

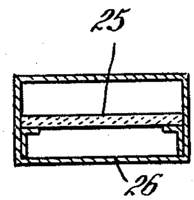

Fig. 5,

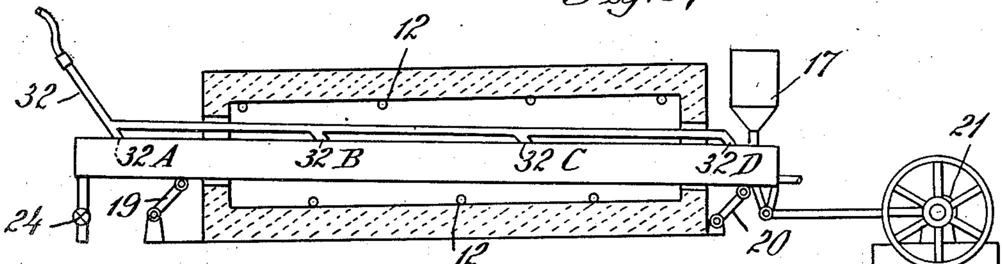

Fig. 6,

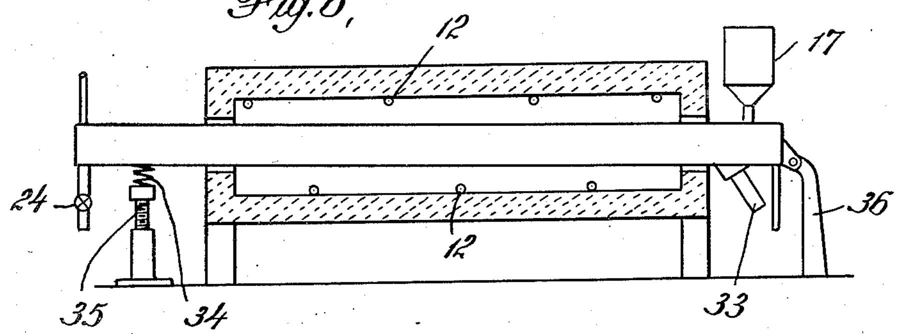

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Fig. 7,

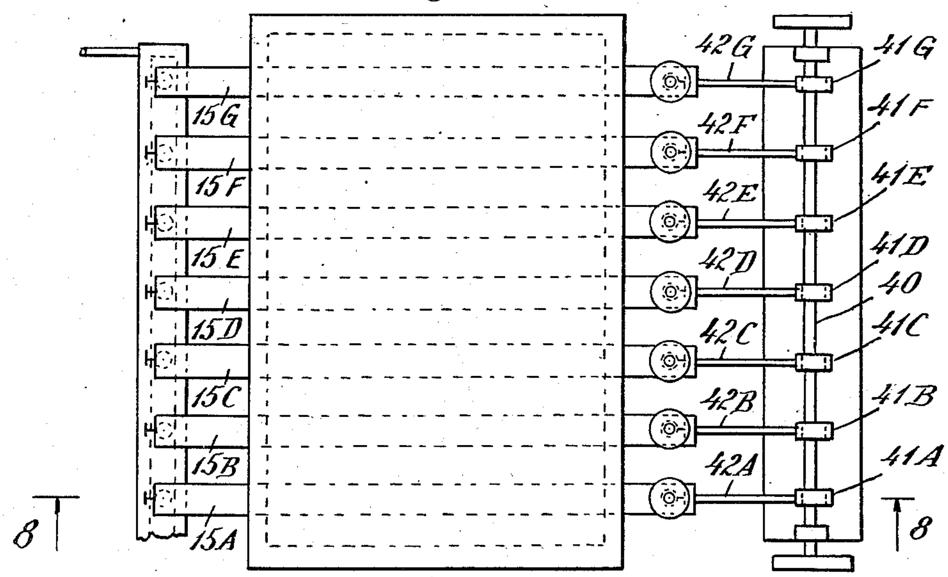


Fig. 8,

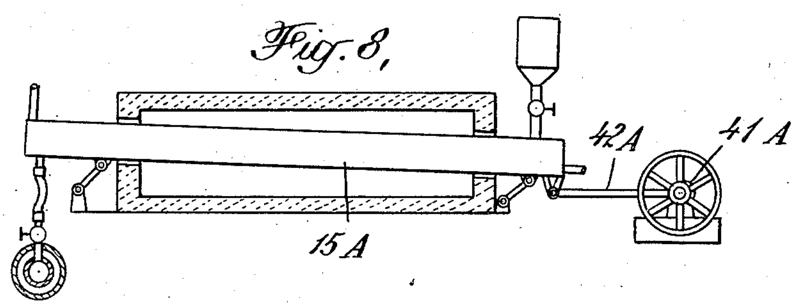
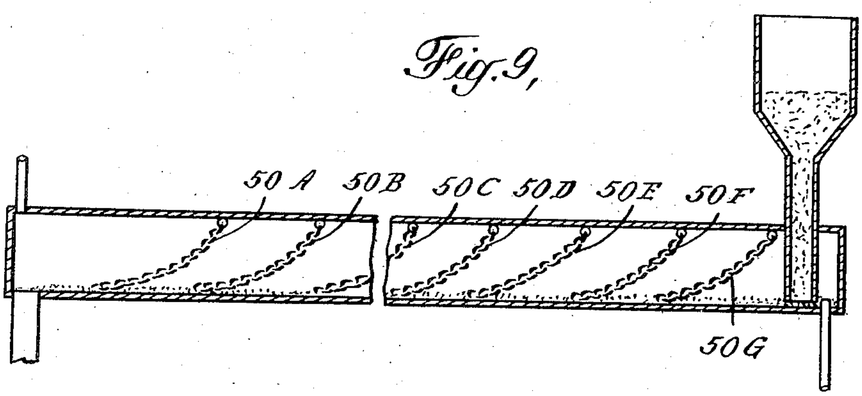


Fig. 9,



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UNITED STATES PATENT OFFICE

2,326,163

HEAT-TREATMENT APPARATUS

Raymond L. Patterson, New York, N. Y., assignor to Powder Metals and Alloys, Inc., New York, N. Y., a corporation of Delaware

Original application November 3, 1941, Serial No. 417,607. Divided and this application March 19, 1942, Serial No. 435,312

5 Claims. (Cl. 263—21)

This invention is concerned with furnace treatment and particularly with furnaces adapted to the treatment of finely divided material in the solid state with various gaseous treating agents. The invention is particularly adapted to the reduction of finely divided metal oxides and the like with hydrogen gas, but may be employed in the treatment of many finely divided solids with a variety of gaseous treating agents.

In the furnace treatment of many finely divided metal oxides and the like with hydrogen, the reaction products are finely divided metal and water vapor. If the water vapor is permitted to remain in contact with the freshly formed metal powder, it tends to react therewith, so that the reaction is reversed and the freshly formed metal powder is oxidized, at least on the surface. This tendency has caused difficulty in many heretofore customary processes for the manufacture of metal powder by reduction of oxides.

As the result of my investigations, I have developed an improvement that is applicable to the above-described and analogous processes in which a first finely divided material is treated with a gaseous reagent to produce a second finely divided solid material and a gaseous reaction product that is heavier than the gaseous reagent. The improvement involves bringing the gaseous reagent into contact with the first solid material while the latter is travelling upward through a reaction zone, withdrawing the resulting second material substantially continuously from an upper portion of the zone and withdrawing the gaseous reaction product substantially continuously from a lower portion of the zone. Preferably the solid material undergoing treatment travels upwardly on an incline, its motion being a pulsating one, with the gaseous reagent and the material passing in countercurrent. As indicated above, the process is particularly suitable for the treatment of a metal compound (say iron oxide) to form a metal (iron), the gaseous reagent being hydrogen with water as a gaseous reaction product, but the process is applicable to other materials.

The foregoing process, described and claimed in my copending application Serial No. 417,607, filed November 3, 1941 (of which this application is a division), preferably is conducted in an apparatus of my invention comprising a furnace chamber, an inclined hearth (preferably enclosed in a muffle) passing through the furnace or heating chamber, means for feeding finely divided solids onto the lower end of the hearth, means for bringing a gaseous treating agent into contact with the solids on the hearth, means for imparting oscillations to the hearth to cause the solid material to move upwardly thereon, means for withdrawing a gaseous reaction product from the lower end of the hearth, and means for discharging the treated solid material from the upper end of the hearth.

In my preferred furnace structure, hydrogen or other gaseous reducing agent is introduced at the upper end of an inclined muffle or trough, finely divided metal oxides or other material to be reduced being introduced at the other end of the muffle. The finely divided metal oxide or the like is caused to travel upwardly in the trough countercurrent to the hydrogen gas. The resulting water vapor is removed from the lower end of the trough while the resulting metallic particles are removed from the upper end. In this way, the water vapor is kept out of contact with the metal powder and the danger of reaction reversal is obviated. The muffle or trough in which the gas and metal compound are reacted passes through the heating chamber and the finely divided solids are caused to move upwardly in the muffle by imparting oscillations thereto. The muffle is movably mounted and is oscillated in a longitudinal direction by means of a cam mechanism, vibrator, or the like.

These and other features of my invention will be more thoroughly understood in the light of the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a longitudinal elevation, partly in section, through one form of the furnace of my invention;

Fig. 2 is a plan, partly in section, of the apparatus of Fig. 1;

Fig. 3 illustrates a modified form of the furnace structure of Figs. 1 and 2 provided with a muffle having a porous hearth;

Fig. 4 is a section taken through the muffle of the apparatus of Fig. 3 along the line 4—4;

Figs. 5 and 6 are diagrammatic longitudinal elevations illustrating further modifications of the apparatus of Figs. 1 and 2;

Fig. 7 is a plan view showing a furnace structure of my invention including a plurality of parallel muffles in which metal compounds to be reduced and the reducing gas may be moved in countercurrent with each other;

Fig. 8 is an elevation, partly in section, of the apparatus of Fig. 7 taken along the line 8—8; and

Fig. 9 is a longitudinal section of an upwardly inclined muffle constructed in accordance with my invention and equipped with a device for maintaining the material passing up the muffle in an unconsolidated and free condition.

Referring now to Figs. 1 and 2, the apparatus comprises a heating chamber 10 of rectangular section enclosed by refractory walls 11. Heating means, for example, a plurality of burners 12, 12A, 12B, et seq. to 12H are provided within the heating chamber. Gaseous products of combustion from the burners may be withdrawn from the heating chamber through a plurality of flues 13, 13A, 13B, 13C.

The heating chamber is provided with a longitudinally sloping bottom 14 over which is supported a sloping trough or muffle 15 of heat conductive material. The trough slopes upwardly from right to left as shown in Fig. 1. The material to be reduced while it is maintained in the solid state (for example, finely divided iron oxide) is admitted into the lower end 16 of the trough from a hopper 17. Reducing gas, for example, hydrogen, is admitted into the upper end of the trough through a conduit 18. The trough passes completely through the heating chamber and is supported at both ends by hinged members 19, 20. A conventional cam mechanism 21 is fastened to the lower end of the tube and imparts longitudinal oscillations to the trough.

In the furnace, the hot hydrogen flows in counter-current to the finely divided metallic compound to be reduced. The oscillations imparted to the muffle cause the finely divided iron oxide to travel upward along the bottom of the muffle, which is sloped at a slight angle, say 5° from the horizontal. As the hydrogen gas reacts with the iron oxide, water vapor is formed. This water vapor is heavier than the hydrogen so that it tends to sink in the trough and is withdrawn through an outlet 22 at the lower end of the trough. The finely divided iron formed by reduction passes to the upper end of the trough and thence into a hopper 23 from which it may be withdrawn through a valve 24 into a conventional cooler, not shown. The freshly formed iron powder is pyrophoric and should be cooled to about room temperature in the absence of any oxidizing influences including water vapor.

It will be observed that in the apparatus of Figs. 1 and 2, the water vapor formed tends to flow by gravity into the lower portion of the trough and thus is prevented from coming into contact with the completely reduced metal powder.

The muffle may be made of any convenient material. For example, it may be made of heat resisting steel, provided that the temperature of treatment does not rise too high, say, in excess of about 1000° C.

The apparatus of Fig. 3 is, in general, similar to that of Figs. 1 and 2, like elements being designated by like numbers. However, in the apparatus of Fig. 3 the burners 12 are positioned both above and below the muffle in the heating chamber and the muffle is provided with an interior porous hearth 25. Hydrogen gas or other gaseous reducing agent to be reacted with the finely divided metallic compound (say iron oxide) in the furnace is introduced into a vapor space 26 underneath the porous hearth under pressure. Thus, hydrogen may be introduced into the vapor space underlying the porous hearth in the muffle through conduits 27, 28 at both ends of the furnace. As in the case of the furnace shown in Figs. 1 and 3, the muffle slopes upwardly to the left. Finely divided solids are caused to travel upwardly along the porous hearth by oscillation of the muffle. The hydrogen gas is brought into intimate contact with the iron oxide in its passage up the hearth by being forced through the hearth. Water vapor formed by reaction between the oxide and the hydrogen flows downwardly by gravity toward the lower end of the hearth and is withdrawn through an outlet conduit 29. The metallic iron resulting from reaction of the iron oxide and the hydrogen passes to the upper end of the hearth and is withdrawn through a valve 30 into a conventional cooler 31.

In the apparatus of Fig. 3, the flow of hydrogen and iron oxide is generally countercurrent, although not completely so. In any event, the fact that one end of the muffle is lower than the other end prevents the freshly reduced iron from coming in contact with the other product of reaction, i. e. the water vapor.

As indicated above, Fig. 4 is a transverse section taken through the muffle and shows the porous hearth 25, which may be of a suitable refractory, located within the muffle and overlying the vapor space 26 into which the reducing gas is introduced.

The apparatus of Fig. 5 is, in general, similar to that of Figs. 1 and 2 (like elements being designated by the same characters as in Figs. 1 and 2). It differs from the apparatus of Figs. 1 and 2, however, in that the hydrogen is admitted into the muffle at a plurality of points along its length. Thus, the hydrogen gas is admitted into the muffle through a manifold 32 provided with a plurality of outlets 32A, 32B, 32C, 32D connected to the top of the muffle. A large portion of the manifold is actually within the heating chamber of the furnace structure so that the hydrogen or other reducing gas is pre-heated prior to its contact with the metallic compound to be reduced.

The apparatus of Fig. 6 differs from that of Figs. 1 and 5, inclusive, in that vibration or oscillation is imparted to the muffle by means of a vibrator 33 which bears against the outside of the lower end of the muffle. The upper end of the muffle is supported on a spring 34 which in turn is supported in a jack 35 so that the slope of the muffle can be adjusted slightly. The muffle is held in position in the heating chamber by means of a heavy anchor 36 attached to its lower end by a hinge or pivot. As in all of the previous cases hydrogen is introduced into the upper end of the muffle while the solid material is introduced into the lower end of the muffle. These two materials pass in countercurrent with each other through the muffle so that water vapor is withdrawn from an outlet conduit at the lower end of the conduit while freshly reduced metal powder is withdrawn from the upper end of the muffle.

To consider the apparatus of Figs. 7 and 8, it will be observed that it is in general like that of Figs. 1 and 2 except that it has a plurality of muffles, 15A, 15B, 15C, 15D, 15E, 15F, 15G connected in parallel within a single heating chamber. These muffles may be of any convenient cross-section, for example, they may be in the form of cylindrical tubes. The solid material to be reduced to metal powder or the like is introduced into each muffle from an individual hopper connected with its lower end. The metal compound so introduced passes in countercurrent with the reducing gas (say hydrogen) introduced into the upper end of each muffle through inlets which in turn are connected through valves to a hydrogen manifold. All of the muffles are oscillated by a single prime mover such as a motor-driven shaft **40**, provided with a plurality of eccentric cams, **41A, 41B, 41C, 41D, 41E, 41F, 41G** which are connected to the respective muffles by a plurality of rods **42A** et seq. to **42G**.

Fig. 9 illustrates a modification of the apparatus of my invention in which the muffle is provided with a plurality of loosely mounted scrapers in the form of interior chains **50A, 50B, 50C, 50D, 50E, 50F, 50G**. These chains are hung within the muffle in a longitudinal series and drag along the floor of the muffle. Vibrations or oscillations imparted to the muffle by a cam or vibrator mechanism cause the chains to move with respect to the floor of the muffle and tend to prevent caking and sticking of solid material thereon.

To consider the operation of all of the forms of the apparatus herein illustrated, it will be understood that the solid material to be treated is introduced at the lower end of the inclined hearth or muffle bottom and advanced upward to discharge at the upper end. The movement of the solid material up the hearth is accomplished by pulsating or oscillating the material. I prefer to employ a hearth that is enclosed in a muffle and to move the material up the hearth by oscillating the entire muffle structure. Thus, a series of longitudinal pulsations or oscillations imparted to the muffle will tend to move the material up a substantial incline, say an incline of 5° to 10° from the horizontal.

The muffle may be of any convenient cross-section and may have a hearth that is flat or in the form of a convex or concave trough. If there is no hazard of explosion the hearth is not necessarily enclosed (i. e. it may be the bottom of an open trough), but this is a preferred structure and it is almost essential when dealing with such reactive gases as hydrogen.

To consider a specific example of the operation of the apparatus of my invention, say, the apparatus of Figs. 1 and 2, iron oxide is introduced continuously into the lower end of the inclined muffle while hydrogen gas is introduced substantially continuously at the opposite end of the muffle. The iron oxide advances up the incline and is reduced by the hydrogen to metallic iron powder, the temperature within the muffle being maintained adequately high, say, in the neighborhood of 800° C., by means of the burners or other heating devices in the heating chamber. The metallic iron resulting from reaction of the iron oxide and the hydrogen is discharged in the finely divided state at the top of the incline. The water vapor resulting from the reaction is heavier than hydrogen and tends to sink into the lower end of the inclined tube or muffle, at which point it is removed. In this way, a zone of dry hydrogen is maintained at the upper end of the muffle so that re-oxidation of the iron powder is prevented.

The apparatus is useful with a variety of finely-divided reducible metal compounds and with a variety of gaseous agents. It is particularly applicable when the gaseous reaction product is considerably heavier than the original gas, an example being an operation in which hydrogen is converted into water vapor.

The operation of the apparatus of my invention may be continuous, particularly when a plurality of muffles in parallel is employed. Thus, the apparatus of Fig. 7 may be operated for indefinite periods. Should a muffle require cleaning, it may be withdrawn from service and cleaned without interrupting the operation of the other muffles in the structure.

The apparatus has a high capacity in terms of its volume and brings about a thorough reduction of a variety of metallic compounds, probably because the oscillations imparted to the muffle tend to roll the particles over so that no portion is permitted to pass through the furnace except after thorough contact with the hydrogen.

The modification illustrated in Fig. 9 may be employed advantageously whenever the solid material undergoing treatment is of such a nature that it tends to ball-up or stick to the sides or bottom of the muffle. Thus the apparatus is provided with loosely mounted scraper members, in this instance chains. The latter are a very effective mechanism for breaking up agglomerations of oxides and metal powders, although of course the chains do interfere to some degree with the passage of the material upwardly along the hearth.

I claim:

1. In a furnace structure, the combination which comprises a furnace chamber, an inclined hearth passing through the furnace chamber, means for feeding solid finely divided material onto the lower end of the hearth, means for feeding a gaseous treating agent into the upper end of the hearth, means for imparting oscillations to the hearth to cause the solid material to move upwardly thereon, means for discharging a gaseous reaction product that is heavier than the gaseous treating agent from the lower end of the hearth, and means for discharging the treated solid material from the upward portion of the hearth.

2. In a furnace structure, the combination which comprises a furnace chamber, an upwardly inclined muffle passing through the furnace chamber, means for feeding solid finely divided material into the lower end of the muffle, means for feeding a gaseous treating agent into the upper end of the muffle, means for imparting oscillations to the muffle to cause the solid material to move upwardly thereon, means for discharging a gaseous reaction product that is heavier than the gaseous treating agent from the lower end of the hearth, and means for discharging the treated solid material from the upward portion of the muffle.

3. In a furnace structure, the combination which comprises a heating chamber, an inclined muffle passing through the heating chamber, means for feeding solid finely divided material into the lower end of the muffle, means for feeding a gaseous treating agent into the muffle, means for imparting oscillations to the muffle to cause the solid material to move upwardly thereon, means for discharging a gaseous reaction product that is heavier than the gaseous treating agent from the lower end of the hearth, and means for discharging the treated solid material from the upward portion of the muffle.

4. In a furnace structure, the combination which comprises a furnace chamber, an upwardly inclined muffle passing through the furnace chamber and enclosing an inclined porous hearth, means for feeding solid finely-divided material onto the lower end of the hearth, means for feeding a gaseous treating agent into the muffle underneath the hearth, means for imparting oscillations to the muffle to cause the solid material to move upwardly on the hearth, means for withdrawing a gaseous reaction product that is heavier than the gaseous treating agent from the low-

er end of the hearth, and means for discharging the treated solid material from the upward portion of the muffle.

5. In a furnace structure, the combination which comprises a furnace chamber, an inclined muffle passing through the furnace chamber, means for feeding solid finely-divided material into the lower end of the muffle, means for feeding a gaseous treating agent into the muffle, means for imparting oscillations to the muffle to cause the solid material to move upwardly thereon, means for discharging the treated solid material from the upward portion of the muffle, means for withdrawing a gaseous reaction product from the lower portion of the muffle, and loosely mounted scraper members disposed within the muffle.

RAYMOND L. PATTERSON.