No. 882,517. PATENTED MAR. 17, 1908.

A. S. DWIGHT & R. L. LLOYD.

PROCESS OF TREATING ORES.

APPLICATION FILED MAR. 22, 1906.

Fig. 1.

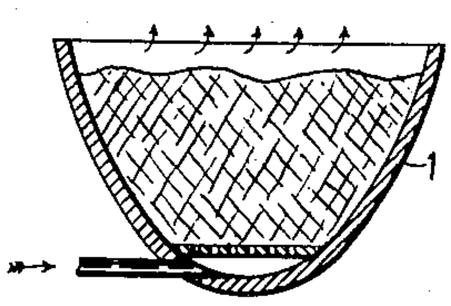


Fig. 2.

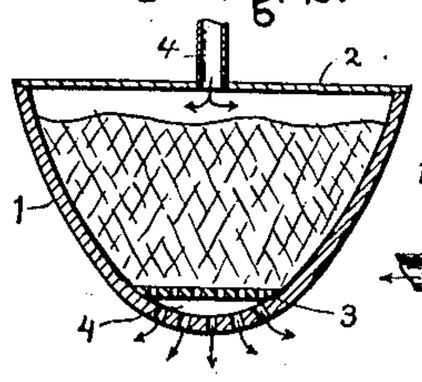


Fig. 3.

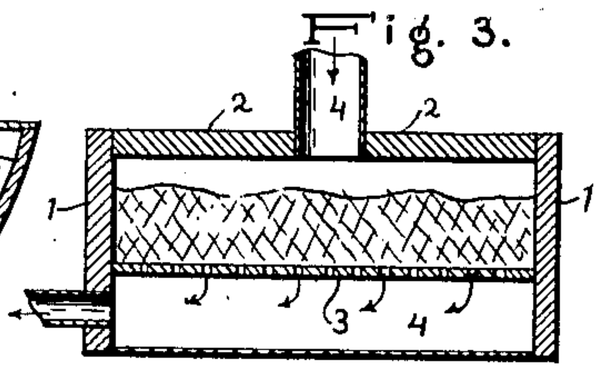


Fig. 4.

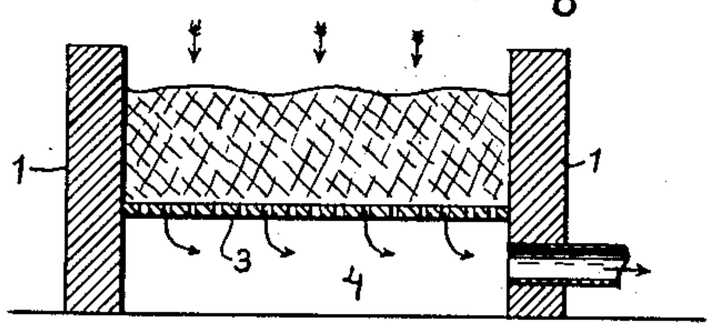
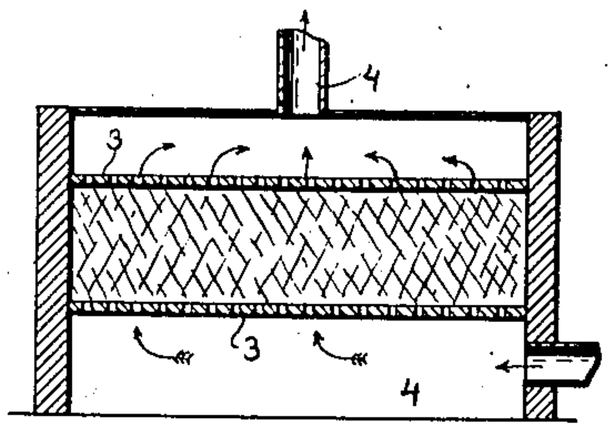


Fig. 5.



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PROCESS OF TREATING ORES.

No. 882,517. Specification of Letters Patent. Patented March 17, 1908.

Application filed March 22, 1906. Serial No. 307,431.

To all whom it may concern:

Be it known that we, ARTHUR S. DWIGHT and RICHARD L. LLOYD, citizens of the United States, residing at Cananea, in the State of Sonora and Republic of Mexico, have invented certain new and useful Improvements in Processes of Treating Ores, of which the following is a specification, reference being had therein to the accompanying drawing.

Our invention relates to improvements in the processes for treating metal bearing materials, and especially the processes for treating sulfid and analogous ores, the improvements being particularly, though not exclusively applicable to the treatment of ores and metallurgical products when they are in a finely divided condition.

Among the objects aimed at are such as the following, namely, to effect a rapid and economical treatment of the materials; and, second, to insure that after treatment they shall be in such physical condition that they can be readily and cheaply manipulated during the subsequent stages of reduction.

In order that our invention may be clearly understood we will select an illustrative material, and will describe the important matters incident to its treatment at each stage, and set forth the qualities which characterize it at these different stages; wishing it to be understood however that we do not limit ourselves to such material, or class of materials selected for illustration, or to the details which will be set forth in conveying a clear understanding of the improvements which we have devised.

We will herein consider galena, or iron and copper pyrites, as typical of the many materials which may be treated by our process.

A mass of the crude ore may, for present purposes, be regarded as comprising two sub-masses, one including the pulverulent or finely divided particles and the other including the relatively larger aggregations or lumps.

In order to clearly apprehend the matters which characterize our invention attention may be directed, at present, to the first sub-mass just referred to as the one composed of the relatively fine, or sub-divided, particles.

As is well known to metallurgists, this portion of an ore mass which will be hereinafter referred to as the "fines", has been a source of great trouble and expense when attempts have been made to obtain therefrom the metal contained therein; and indeed much loss has been experienced because of these fines. The other portion of the initial ore, the sub-mass which includes the relatively larger lumps or aggregations (commencing, say, with particles of three eighths of an inch in diameter, and from there upward) has always been readily susceptible of successful treatment, because of its physical condition. The reason of this has been that because of the size of the particles or lumps they could be disposed in a furnace in such way that the oxygen or other smelting gases could readily percolate through the mass, traveling through the interstices naturally present in such a charge. But when below a certain diameter, the particles (such as the "fines" herein referred to) become so small that the interstices are inappreciable; and, in consequence, the passage of oxygen or other gas through a charge of these smaller particles in the furnace is impeded, and economical reduction of the metallic contents is prevented. Many mechanisms and methods of treatment have been proposed and experimented with in the attempt to economically handle these "fines" or finely divided parts of ore masses. And during recent years some have come into more or less extended use.

Having in mind ores of the classes above typified, such as the sulfid ores of lead, copper or iron, it may be said that in general, the desideratum at the preliminary stage of the treatment of the fines is, first, to eliminate the sulfur bodies or analogous bodies, and, secondly, to leave the desulfurized particles joined together, or agglomerated, in relatively large masses, blocks, or cakes, so that in the succeeding stages of treatment the desulfurized material can be readily disposed to insure that the largest possible percentage of the ultimate metal can be obtained.

Of the numerous methods that have been heretofore practiced or proposed, we will briefly refer to one or two in order that the characteristics of our improved method may stand forth more plainly by contrast.

One of the processes of late introduction was characterized by the mixing of lime with the sulfid, then highly heating the mixture, then partially cooling it and then blowing it from beneath. The intention was to desulfurize the metallic constituents, and

the expectation was that there would then be a sintering of the entire charge throughout. The following have been observed as the facts incident to carrying out that process. The ore is arranged in a vertically disposed charge over an air inlet. As the upper parts of the charge merely rest (by gravity) upon the lower parts, the superincumbent portions become lighter and lighter, upward, along any vertical line therethrough. The charge is ignited at the lower surface near the air inlet or inlets, and atmospheric air is caused to travel upward, by blast or suction, through the mass of fines toward the top surface. As it travels upward it advances upward the plane of the combustion which results from the oxidation of the sulfur or other combustible elements in the mass. The heat from this internal combustion of desulfurization (the desulfurizing being the first desideratum) is of a degree sufficient to cause the agglomerating of the desulfurized particles, that is to produce sinter therefrom. But we have found that this sintering (the second desideratum) demands more than mere heat, even of high degree; it requires quiescence of the desulfurized particles (each relative to its immediate neighbors) if they are to be agglomerated. If these particles are agitated or disturbed at this time the sintering is impeded and even entirely thwarted. In some of the portions of a charge, more or less nearly complete sintering will be found to have occurred, while in other portions of the same mass practically no sintering at all can be obtained even though the particles have been desulfurized. The agitating and disturbing of the particles which prevent the sintering may be caused either by mechanical devices or by currents of gas or air. When the earlier processes are followed, in which use is made of an upblast of air, considerable sintering is found to occur in the lower part of the charge, especially when the ore has been piled in a mass deep enough to insure that the particles in the lower parts thereof shall be held in quiescence by the superincumbent mass. The upward rising air currents (from blast or suction) tend to disturb this quiescence, but their action upon the lowermost particles is to some extent overcome by the gravity of those above. That is to say, the agitation, disturbance, and movements of the particles, tend to become greater and greater as there is approach to the top of the mass. Observation invariably discloses that in masses of ore treated in the way described by the application of up-drafts of air, the sintering or agglomerating action becomes less and less as the upper surface is approached; so that (as found by actual experience) a large percentage of the ore body in its upper regions remains pulverulent, or as "fines", even though approximately thoroughly desulfurized. This relatively large quantum of non-sintered desulfurized fines, for correct handling, requires further treatment to prepare it properly for blast furnace smelting. These facts have been recognized by metallurgists, and, in order to lessen the proportion of unsintered fines at the top of the charge to the sintered portion at the bottom, the latest practice has been to increase the depth of the charge and to correspondingly increase the size of the pots or ore holders. But this in turn has introduced, as is now well known, two serious and costly difficulties, namely; first, it requires a higher blast pressure, and, consequently, a greater consumption of power to force the air through the higher column of ore, and, second, the resulting cake is so large and tough that a serious expenditure of labor is required to break it into fragments of the proper size for subsequent smelting operations in the blast furnace. If the opposite course be taken, that is if the ore be treated in shallow charges or thin layers, power can be saved, the labor of manipulating the sintering product can be reduced and a greater output can be secured per square foot of hearth. But all attempts, known to us, to do this have failed, because, in the earlier processes, as above described, the blast or draft of air is carried toward an unconfined or unrestrained portion of the ore mass, that is the stratum adjacent to the surface of gas exit, and the fine particles in that portion of the ore are kept in agitation by the air and gas currents and prevented from sintering together. Consequently, shallow charges, or thin layers have not been available. For example, in a layer six inches thick, with a blast pressure of five ounces per square inch, as much as one third or one half of the layer will escape sintering, to wit, that part which is adjacent to the gas exit surface.

The purpose of our present invention is to provide a method of treating such ores as are referred to, and in the conditions described, in such way that both the desulfurizing and the sintering shall be complete throughout the entire charge, and uniform, and shall be practically simultaneous, requiring but a single manipulation of each charge; whereby there shall be an avoidance entirely of a residue of unsintered, desulfurized fines; whereby the ore can be successfully treated in shallow charges or thin layers, with a minimum expenditure of power, and a maximum output per unit of capacity; and whereby there is secured as the final product, a sinter cake or "biscuit" of superior character, that is a sinter which is porous and spongy, with strength enough to resist ordinary handling, but still friable enough to be cheaply broken to the size required in subsequent operations.

Among the other processes heretofore proposed for desulfurizing ores of the class

herein contemplated, which may be here referred to by way of contrast with our method, were, first, one similar to that last above described, the exception being that instead of calcium oxid use was made of calcium sulfate or calcium sulfid, and, second, a method in which a mixture of the sulfid ore, and calcium carbonate was used. But inasmuch as these and other proposed methods of treatment, may for present purposes, be regarded as similar to the one more fully described above it is not necessary to contrast them severally, or in detail, with the method we have devised. In each of these also the igniting has been started at the bottom of the mass, and the combustion has been maintained by forcing currents of air upward from the bottom toward an unrestrained and unconfined mass of fines at the top. And in all cases the result has been such as above described, namely incomplete and imperfect sintering of the unrestrained part of the mass, the upwardly traveling air currents so agitating, disturbing or moving the particles of the mass that the agglomerating action of sintering cannot take place.

The characteristics of our novel process will be understood from the description given below, taken in connection with the accompanying drawings, wherein:

Figure 1 is a sectional diagrammatic view showing an ore holder or receptacle which typifies the devices used in the earlier processes of the recent class to which we have above referred, and which illustrates also the manner of using these devices, the arrows indicating the directions of travel of the air and of the gases of combustion. Fig. 2 is a sectional view, also diagrammatic in character, showing the manner in which ore receptacles of this kind can be used when following our method of treatment. Fig. 3 is a sectional view, also diagrammatic, illustrating a modified apparatus for operating our process, the devices here shown being suitable either for plenum or vacuum draft. Fig. 4 is a section of a more or less similar apparatus, this one however being adapted for vacuum draft only. Fig. 5 is a diagrammatic sectional view illustrating how our process can be carried on when an up-draft of air is employed.

Referring to Fig. 1, which, as aforesaid, typifies the essential features of construction and the mode of operation of a class of devices that have been heretofore used in desulfurizing and sintering ores, 1 indicates the approximately vertical walls of the ore holder or receptacle. 3 indicates means for confining or retaining the mass of ore on one of its sides, in this case being at the bottom. 4 indicates a duct through which can be supplied oxygen or other agent for supporting combustion or maintaining the chemical reaction which is desired in the interior of the ore mass. This supply duct is shown as communicating with a distributing chamber 7 below the ore supporting or retaining wall or floor 3.

As indicated by the arrows, the gas, or other reagent, is delivered through the duct 4 into the distributing chamber 7 below the mass, and is forced upward through the supporting wall or floor 3 and through the lower surface of the ore mass.

In operation the ore is ignited, in any suitable way, at the bottom. With an apparatus such as shown in Fig. 1 the disturbing or agitating action on the particles in the bottom of the mass caused by the up-blast of air can, to some extent, be balanced or overcome by the weight of the superincumbent parts of the mass as above explained; and throughout such lower parts more or less complete sintering can be attained. The sinter so formed in the lower part of the mass is, generally, relatively highly porous or cellular and more freely permeable (than the original mass of pulverulent fines) by the currents or jets of air. Consequently as the combustion, and the sintering, advance upward the lifting efficiency of the air blast becomes relatively greater, and the particles of the ore in the upper regions of the mass become more and more liable to agitation, displacement and disturbance. The forcing of the air upward through the more or less pulverulent mass results in the formation at the upper surface of "blow holes" or "craters", these extending to a greater or less depth from that surface, and furnishing not only centers of violent disturbance, but also channels of least resistance for the escape of air. Consequently there is throughout the top stratum of the mass a lack of uniformity in the reaction of the oxygen and the combustible parts of the ore. Highly seared lines of particles forming craters are left surrounded by regions of fine non-agglomerated material.

Turning to Fig. 2, it illustrates an apparatus and also the mode of operation which we have devised and which can be easily contrasted with the older method and devices. In Fig. 2 also we have an ore receptacle or holder, the vertical walls of which are indicated by 1. A retainer is shown at 3, which here also is below the mass. But in this case the parts are so constructed and arranged that the air travels in a direction exactly opposite to that followed in the mechanism in Fig. 1. That is to say, it is allowed to enter through the top surface of the ore mass, whence it travels downward to and through the bottom thereof. The place of igniting, also, is diametrically opposite in this instance, the initial firing taking place at the top. As shown in Fig. 2 the air, or other reagent gas, is delivered to and distributed over the top surface under pressure by a duct 4 leading from any suitable pressure or supplying device. In this case the combustion

which starts at the top advances downward following the downward moving gas supply. The products of the interior reactions escape through the exit passages in the retainer or support below the ore, either directly into the open air, or into a suitable collecting chamber or duct, from which latter they may be taken to any place preferred or may be discharged into the atmosphere.

It will be seen that there is no uplifting action, whatever, to agitate, disturb or displace any of the particles of the ore mass. The down-moving currents of air tend to compact the particles at the top at the instant of firing, and immediately thereafter there begins to form a layer of agglomerated material, at first approximately viscous in character, but soon solid and relatively hard. The plane of combustion and of sintering advances downward, the travel of the air continuing as above described. When the lower part of the mass is reached perfect quiescence of the particles is maintained because of the retaining devices at the bottom, on the one hand, and the downward pressure and travel of the air and the settling of the upper part of the mass, on the other hand, which prevent agitation or disturbance. Finally, if the operation be properly conducted, the entire mass is converted into one desulfurized sinter.

With devices such as those shown in Fig. 2 the cover element 2 is readily removable and the sinter cake can be easily removed without affecting any of the apparatus of the ore holder.

In Fig. 4 we present a similar apparatus, wherein a substantially similar process can be carried out, the only difference being that in this case the air is caused to enter the top surface of the mass and travel downward through it by suction, or by an exhaust device of suitable character which draws it from the duct or chamber 7 below the ore retainer at 3. Here there is a conventional illustration also of a fixed ore holder having approximately vertical walls 1, from which, however, the sinter can be readily removed, the top being left entirely open. Or, if preferred, we may combine in one apparatus the cover device shown in Fig. 2 with the ore holder in Fig. 4. This we illustrate in Fig. 3. In such case provision is made for causing the draft either by suction, through one duct, or by pressure through that at 4; or both may be used. The cover 2 in the construction in Fig. 3, like that in Fig. 2, is to be understood as detachable so that the sinter cake can be readily removed when desired.

We do not wish it to be understood that all of the advantageous features incident to our process depend upon carrying the air through the ore mass in a downward direction. For, as illustrated in Fig. 5, an ore holder of suitable character can be used with its parts so constructed and related that the air can be introduced otherwise than at the top, as for instance at the bottom, and the air, the combustion, and the sintering, can be caused to advance away from the surface where the air enters, provided the other features of our invention are retained; that is, if provision be made for maintaining acquiescence, as perfect as possible, of the particles of the mass lying at, or in the region of, the gas exit surface opposite the surface where the air enters. In Fig. 5 there is provision of this sort, use being here made of an ore retaining or confining means at 3^a, which, while permitting the free escape of the gases of combustion, or chemical reaction, is nevertheless of such nature as to prevent displacement, agitation or disturbance of the ore particles under the action of the rising and escaping air or gases. Consequently, here also, when the desulfurizing is completed it is found that the entire mass has been thoroughly sintered, the result generally being that from the top to the bottom a single coherent cake is formed with practically no perceptible fines or pulverulent material, whatever, present. The entire mass that was initially placed in the ore holder has passed into such sintered condition that without further treatment it is ready for introduction into the smelting furnace.

As above remarked agitating or disturbing, by rabbles or otherwise, intentionally or incidentally, any of the particles of the ore mass is detrimental to the peculiar results we seek. This quiescence of the particles which compose the charge as an entirety is to be understood as a state of rest of each particle in relation to the adjacent ones and in relation to the adjacent parts of the mass. We do not, by such descriptive terms, mean that the charge or mass, as an entirety, must be held stationary. What we have discovered is that one of the important factors in producing the result we achieve is preventing the agitation, or restraining the movement of the several particles of the charge among themselves, irrespective of whether or not the charge or mass as a whole is undergoing bodily movement at the time of treatment.

From what has been set forth it will be seen that the heat availed of in our method is after the initial igniting generated exclusively by internal combustion, it resulting from the chemical reactions which take place in the raw materials themselves. This is in contradistinction from the methods heretofore proposed which contemplated the disposing of the ore on the bottom of an exposed chamber (of one form or another) in the upper part of which chamber heat was generated by the combustion of gaseous fuel in a region entirely outside of the ore mass, the heat last referred to being entirely

other than that herein contemplated as the heat of internal combustion. In some of the said earlier instances the gases for generating the heat and the gases resulting from the action of the heat were carried through or across the upper part of the inclosed chamber, above the ore mass, in violent currents from the points of entry to the exit flues. In other instances, the external combustion in the inclosed chamber above the ore was produced in such way that the gases supporting it (including atmospheric oxygen) were intentionally rendered inert and powerless for the support of internal combustion in the ore mass below. In such cases distillation or sublimation of the sulfur bodies was the objective point, and the internal combustion which we essentially rely upon was purposely avoided. Patent No. 39,684, dated August 25, 1863, to M. W. Sinding, presents an illustration and a description of an apparatus and a method such as last referred to; and of course we present no claim for subjects matter such as therein disclosed.

We are aware that there were earlier processes, some practiced and some proposed, which included the passing of air upward from the bottom of and through an ore mass, and in some cases the ore masses have been supplied at the top and sides with layers or strata of covering materials. In carrying out these earlier processes, it was necessary, at the outset, to divide, by classification, the original ore mass into several sub-masses, varying, each from the others, in respect to the sizes of their component particles. In forming the "heap" (as in treating the ore in the open air), or in forming the "charge" (as when the ore is more or less confined), the larger lumps or particles were arranged in one region or regions, along lines extending from the bottom to the top of the heap or charge, while the "fines" or sub-masses of pulverulent material were arranged in different regions and in masses extending continuously from the bottom to the top of the heap or charge. In such cases there were, according to intention, masses of one density or closeness of packing at places, and other masses at other places, of different densities or closeness of packing, these different sections of the heap or charge presenting correspondingly different air passages along vertical lines through the mass. And in some cases an attempt was made to secure a crude sort of control or regulation of the air or gas by placing at the sides or on the top, or both, of the heap or charge a layer or stratum of material with the expectation of thereby causing the air or gas to follow one vertical path or another. The layer or stratum at the top or sides was sometimes a mass of dry "fines" and sometimes a moist or mud-like jacket which was tightly packed or tamped by suitable tools to confine the air at one place or another. In contra-distinction from this, we form a mass in such way that it shall be approximately uniform throughout and readily and uniformly permeable to air currents. That is to say, the ore mass is uniform throughout the structure, or formed in such way that the characteristics along any vertical line shall be substantially similar to those along any other vertical line. At all points the densities are substantially equal along the lines followed by the currents of air or gas, and consequently the mass at all points has substantially similar air passages or gas passages.

We do not here claim any of the specific matters of novelty incident to the mechanism shown in Fig. 5, or to the matters of novelty incident to the process described in connection therewith, as these are made the subjects matter of the claims in other applications filed by us jointly and by A. S. Dwight solely.

We have above directed attention particularly to the "fines" of the raw ore in order that the characteristic features of the invention should be clearly presented; but it is to be understood that finely divided materials other than the raw ore, such as concentrates, can be treated in the way above described without departing from the invention. And in each of numerous respects there can be modification, as the skilled metallurgist will readily understand.

What we claim is:—

1. The process of treating metal bearing ores in a mass of fine particles containing combustible elements and adapted to be sintered by internal combustion in the mass, which consists in igniting the combustible ingredients of the said ore, causing oxygen or a combustion supporting gas to pass to the interior of the mass of ore thereby causing the combustion to extend from the place of initial igniting gradually into the interior of and through the mass, said mass having at all points substantially similar gas passages therethrough raising the temperature of the interior of the mass by such internal combustion to the point of sinter forming, and restraining from agitation or movement (in relation to the adjacent parts of the mass) those particles which are on the side where the gases or products of combustion escape until they have been sintered.

2. The process of treating metal bearing ores in a mass of fine particles containing combustible elements and adapted to be sintered by internal combustion in the mass, which consists in igniting the combustible ingredients of the said ore, causing oxygen or a combustion supporting gas to pass to the interior of the ore mass, thereby causing the combustion to extend from the place of initial igniting gradually into the interior of and

through the mass, said mass having at all points substantially similar gas passages therethrough preventing the agitation of movement (in relation to the adjacent parts of the mass) of those particles which are on the side where the gases and products of combustion escape, and forming a solid sinter extending from the surface of ignition to the surface of gas exit, substantially as described.

3. The process of treating metal bearing ore in a relatively fine condition containing combustible elements and adapted to be sintered by internal combustion in the mass which consists in forming a mass thereof of substantially uniform thickness, and having at all points substantially similar gas passages therethrough igniting the combustible elements of the said ore at points near one of the surfaces of said mass, supplying combustion supporting gas to the interior of the mass, causing the ignition to gradually permeate the mass, producing a sintering heat by internal combustion, preventing the agitation of any of the particles of the mass while the combustion is taking place and gradually sintering the entire mass from the surface of ignition to the surface of gas exit, substantially as set forth.

4. The herein described process of treating a metal bearing ore in an initially relatively fine condition containing combustible elements for the production of a sintered mass containing substantially all the metallic particles of the said ore which consists in forming of the fine ore a mass having at all points substantially similar gas passages therethrough, igniting the combustible ingredients of the said ore, causing currents of combustion supporting gas to positively enter and permeate the interior of the mass, thereby causing the internal combustion of the mass, holding all the particles of the mass against agitation or movement in relation to each other while the combustion is taking place, and forming a sinter extending from the surface of ignition to the surface of gas escape, substantially as set forth.

5. The process of treating metal bearing ores in a relatively fine condition containing combustible elements and adapted to be sintered by internal combustion in the mass, which consists in forming a mass of said ore having at all points substantially similar gas passages therethrough and two surfaces adapted to permit gases to pass through them to and from the interior of the said mass, holding or restraining the ore near said surfaces from agitation or movement in relation to the neighboring body of the mass, positively causing oxygen or combustion supporting gas to pass through one of the said surfaces into the interior of the said mass, igniting the combustible ingredients of the said ore at or near one of the said surfaces, causing the ignition to gradually pass to the interior of and through said mass while the parts thereof are held stationary and quiescent as aforesaid, agglomerating the particles of the said mass into relatively large sinter blocks or cakes and withdrawing the gases or products of combustion through one of the said restrained surfaces, substantially as set forth.

6. The process of treating relatively fine metal bearing ores containing combustible elements and adapted to be sintered by internal combustion in the mass, which consists in forming a mass thereof adapted to have gas pass therethrough on approximately vertical lines holding the said mass in its initially taken form and preventing the movement or the agitation of the particles thereof in relation to each other, igniting the upper portion of the said mass, causing air or combustion supporting gas to positively move downward into and through the mass for carrying the combustion from the region of igniting into and through the mass and while held in the said quiescent condition, and drawing the gases or products of combustion from the bottom of the mass, substantially as set forth.

7. The process of treating and sintering a metal bearing ore containing combustible elements and adapted to be sintered by internal combustion in the mass, which consists in spreading the ore in a thin mass with relatively extended surfaces adapted to have gases pass therethrough and substantially uniform throughout along all the lines of travel of the gas, igniting the ore, maintaining internal combustion of the ingredients of the ore within the body of the ore mass, producing by said internal combustion a high heat and therewith forming relatively large blocks or cakes of sinter and preventing the agitation, movement or disturbance of the particles of the ore mass while the combustion is taking place, substantially as set forth.

8. The process of treating metallic sulfid ores and similar materials of relatively fine nature adapted to be sintered by internal combustion in the ore mass, which consists in forming a mass of the said materials having at all points substantially similar gas passages therethrough, igniting one surface of said mass, causing the flame of said ignition to penetrate gradually deeper into said mass by passing forced currents of air through said mass, preventing the agitation, disturbance or movement of the material at or near the opposite surface of the said mass by a pervious screen or stratum, in order to cause the said internal combustion to form relatively large blocks or cakes of agglomerated sinter and removing through the said screen or stratum the products of the reactions within the mass, substantially as set forth.

9. The process of treating metallic sulfid ores and similar materials in a relatively fine condition, to eliminate volatile constituents thereof and to sinter the remainder, which consists in forming a relatively shallow uniformly thick mass of the ore having at all points substantially similar gas passages therethrough and subjecting said mass to a current of gas adapted to produce the desired chemical re-actions in the interior thereof, generating a sintering heat in the interior of the mass, and confining the surface of the mass from which the gas escapes by a pervious stratum of material differing chemically from the ore being treated, whereby the fine particles of the treated ore are held in place at rest and are not agitated by the current of gas, substantially as set forth.

10. The process of treating metallic sulfid ores and similar materials of relatively fine nature, to eliminate the sulfur or analogous constituents and to sinter the remainder, which consists in forming a mass of the said material which is exposed substantially to the open air upon at least one side thereof and has at all points substantially similar air passages therethrough, igniting the combustible elements of the mass, forcing currents of air into and through the mass to gradually extend the combustion therethrough, sintering the entire mass solely by the internal combustion therein and maintaining those particles of the mass at the gas exit in a state of rest relative to each other, substantially as set forth.

11. The process of treating metallic sulfid ores and similar materials in a relatively fine condition, to eliminate volatile constituents thereof and to sinter the remainder, which consists in forming a substantially horizontally extended mass thereof, placing said mass on a pervious stratum or support, subjecting said mass to downward moving currents of gas adapted to produce the desired chemical re-actions in the interior thereof, generating a sintering heat in the interior of the mass, and causing the gases of re-action to escape from the mass through the said pervious stratum below the ore, maintaining the said mass and all the particles thereof in quiescence and preventing the disturbance or agitation thereof during the said treatment, whereby the sintering from the top to the bottom of the mass can be permitted, substantially as set forth.

12. The process for roasting finely divided ores or metallurgical products containing sulfur or other combustible elements and sintering or agglomerating the particles of the roasted material into a coherent mass through the action of the heat generated by internal combustion, which consists in disposing said fine material in a layer upon a support, substantially as set forth, whereby there are gas exit passages provided below the said layer, igniting the material at its upper surface, causing a current or currents of suitable oxidizing gas to pass downward through the said surface and under uniform distribution over the same and to pass thence in a downward direction through the layer and through the gas exits below it, whereby the combustion is carried from said upper ignited surface downward through the mass to the lower surface thereof, maintaining all particles of the mass under treatment in a relatively quiescent state, whereby is effected the complete sintering together of the roasted particles into a coherent cake, and finally removing the cake or sintered mass independently of its supporting or holding devices, substantially as set forth.

13. The process for roasting finely divided ores or metallurgical products containing sulfur or other combustible elements and for sintering or agglomerating the particles of the roasted material into a coherent mass by the action of the heat generated by internal combustion, which consists in disposing the fine material in a mass having at all points substantially similar gas passages therethrough, confining the material at the vertical sides of the mass by walls or vertical supports, exposing the upper and the lower surfaces of the mass, igniting the combustible components of the mass at or near one of the said surfaces, causing a current or currents of suitable oxidizing gas to pass from the said ignited surface through the mass to the opposite surface, maintaining all the particles of the mass under treatment in a relatively quiescent state, causing the combustion to advance from the ignited surface to the opposite surface and sintering together the roasted particles and forming therewith an agglomerated mass or masses extending completely from the ignited surface to the opposite surface, substantially as set forth.

14. The process of sintering metal bearing material in fine condition containing combustible elements and adapted to be sintered by internal combustion in the ore mass which consists in forming a mass thereof having two surfaces permeable to gases and having at all points substantially similar gas passages through the mass, igniting the combustible constituents of the mass at one of the said surfaces, forming a layer or stratum of sinter at or along the surface where the material is initially ignited, passing air or combustion supporting gas through said surface of ignition into and through the interior of the body of the mass, causing the area of combustion to move through the mass toward the opposite surface in the direction of travel of air and gas, maintaining the particles of the mass in advance of the combustion in a state of rest relatively to each other,

and finally sintering the stratum of the mass at or near the surface of gas exit.

15. The process of sintering metal bearing material in fine condition containing combustible elements and adapted to be sintered by internal combustion in the ore mass which consists in forming a mass thereof, igniting the combustible constituents of the mass at the top thereof, forming a layer or stratum of sinter at the top, passing air or combustion supporting gas downward through the said sinter stratum, causing the area of combustion to move downward through the mass in the direction of travel of the air and gas, and finally sintering the lower stratum of the mass, substantially as set forth.

16. The process for sintering metal bearing material in fine condition containing combustible elements and adapted to be sintered by internal combustion in the ore mass which consists in forming a mass or layer thereof having at all points substantially similar gas passages therethrough, igniting the mass, forming a stratum of sinter in the region of the initial ignition, causing combustion supporting gas to enter, across the region of combustion, the interior of the mass, and maintaining the particles of the body of the mass which are in advance of the region of ignition in substantially fixed relation to each other and to the mass, whereby the particles which are in the region of combustion and sintering are held against agitation or disturbance, substantially as set forth.

17. The process for sintering metal bearing material in fine condition containing combustible elements and adapted to be sintered by internal combustion in the ore mass which consists in forming a mass or layer thereof having at all points substantially similar gas passages therethrough, igniting the mass, forming a stratum of sinter in the region of the initial ignition, causing combustion supporting gas to enter, across the region of combustion, the interior of the mass, and maintaining the particles of the body of the mass which are in advance of the region of ignition in substantially fixed relation to each other and to the mass, whereby the particles which are in the region of combustion and sintering are held against agitation or disturbance, said combustion traveling through the mass in the same direction as the combustion supporting gas, substantially as set forth.

18. The process of treating metal sulfid ores when in a relatively fine condition and adapted to be sintered by internal combustion in the ore mass, which consists in igniting the sulfur element of the said ore at the surface of a mass thereof, causing currents of oxygen to support the combustion at said surface and to enter the interior of the mass of ore said mass having at all points substantially similar gas passages therethrough, the combustion being the result of the oxidizing of the said sulfur elements, said oxidizing currents causing the combustion to extend from the place of initial igniting gradually into and through the interior of the mass, raising the temperature of the interior of the mass by said internal combustion to the point of sintering and restraining from agitation or movement those particles which are on the side of the mass where the gases or products of combustion escape to permit them to uniformly sinter.

19. The process of treating metal sulfid ores while they are in a relatively fine condition, which consists in igniting the sulfur elements of the said ore at the surface of the mass thereof, causing currents of oxygen to support the combustion at said surface and to pass through said surface and enter the interior of the mass of ore, the combustion being the result of the oxidizing of the said sulfur elements, and said oxidizing currents causing the combustion to extend from the place of initial igniting gradually into and through the interior of the mass, preventing the agitation or movements (in relation to the adjacent parts of the mass) of those particles which are on the side of the mass where the products of combustion escape, and forming a solid sinter, commencing at the surface of igniting and extending to the surface of gas exit, substantially as described.

In testimony whereof we affix our signatures, in presence of two witnesses.

ARTHUR S. DWIGHT.
RICHARD L. LLOYD.

Witnesses:
CHAS. L. MONTAGUE,
F. B. HENNEY.