May 7, 1929. F. G. BREYER ET AL 1,712,132

REDUCING ZINCIFEROUS MATERIALS

Filed Jan. 27, 1927 2 Sheets-Sheet 1

Fig. 1

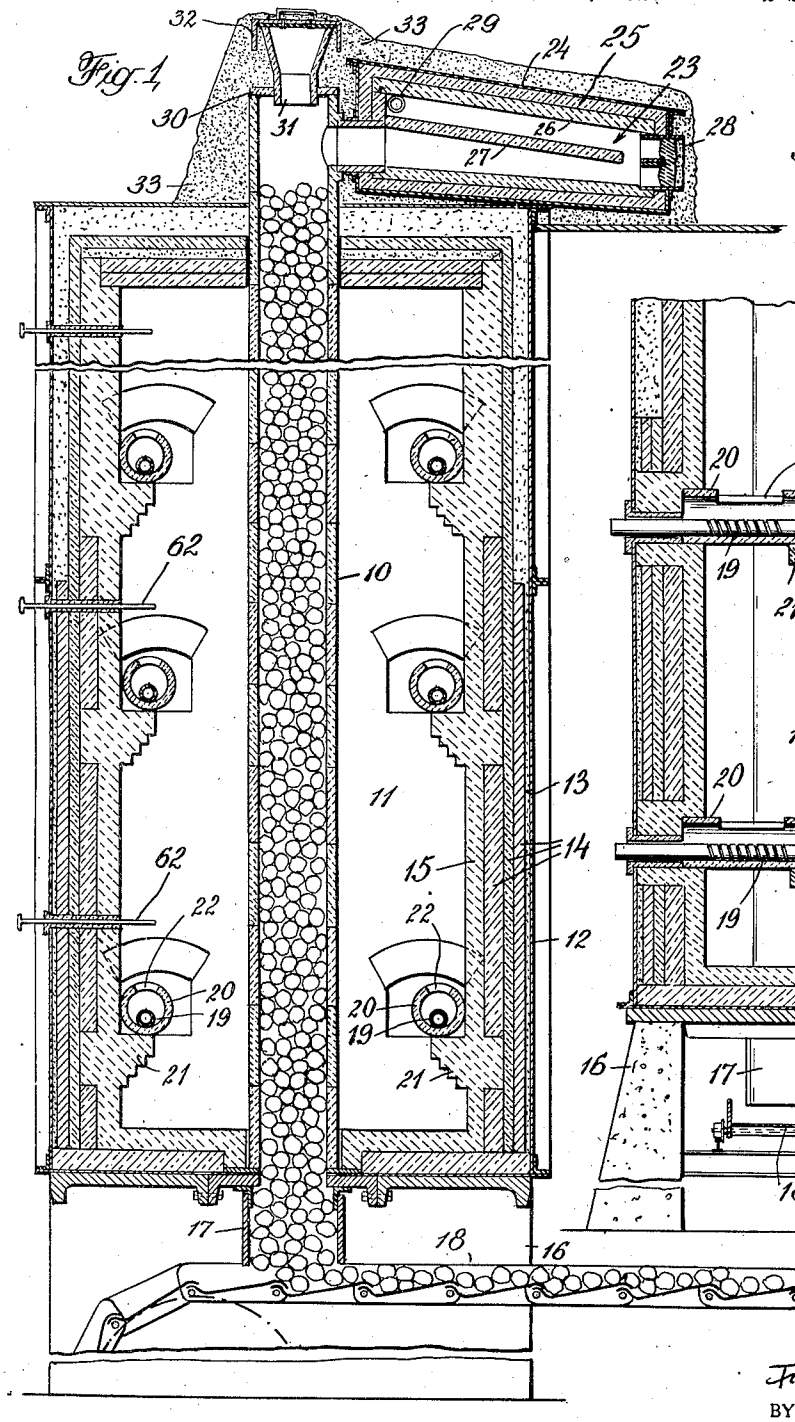


Fig. 2

INVENTORS
Frank G. Breyer
BY Earl H. Bunce
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

May 7, 1929. F. G. BREYER ET AL 1,712,132

REDUCING ZINCIFEROUS MATERIALS

Filed Jan. 27, 1927 2 Sheets-Sheet 2

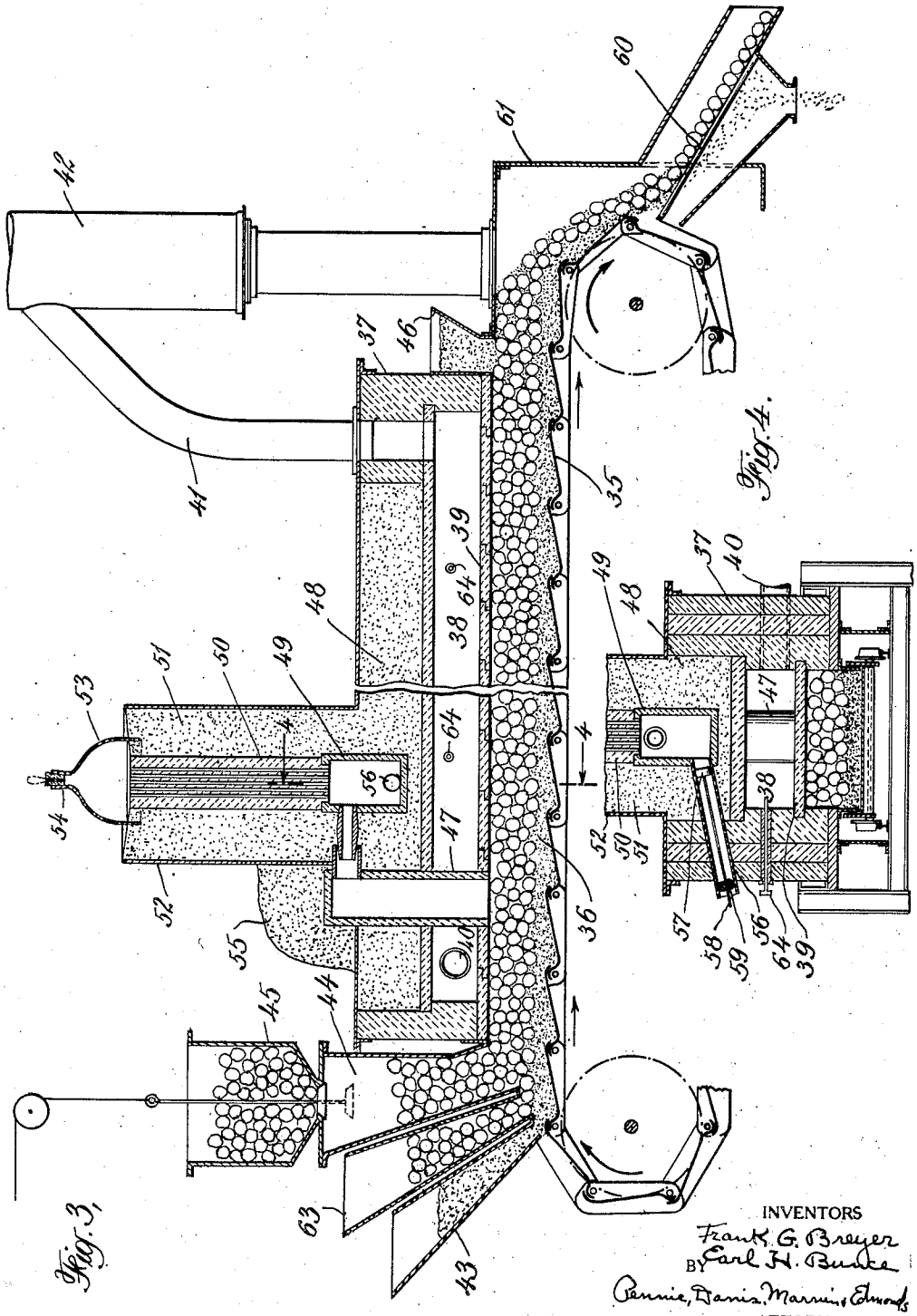


Fig. 4.

Fig. 3.

INVENTORS
Frank G. Breyer
BY Carl H. Burke
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

Patented May 7, 1929. 1,712,132

UNITED STATES PATENT OFFICE.

FRANK G. BREYER AND EARL H. BUNCE, OF PALMERTON, PENNSYLVANIA, ASSIGNORS TO THE NEW JERSEY ZINC COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW JERSEY.

REDUCING ZINCIFEROUS MATERIALS.

Application filed January 27, 1927. Serial No. 163,902.

This invention relates to the reduction or smelting of zinciferous materials and has for its object the provision of certain improvements in the reduction or smelting of such materials. The invention aims particularly to provide a new method of reducing or smelting zinciferous materials in which very substantially larger charges may be more economically worked with substantially increased extraction of zinc and with increased recoveries of commercially marketable forms of zinc, than in the heretofore customary practices of commercial zinc smelting. A further object of the invention is to provide a commercially economical and practical method of reducing or smelting zinciferous material in a substantially continuous manner and on a relatively large scale and in which there is produced metallic zinc vapor capable of being directly and economically condensed to zinc metal. These objects are attained, in the present invention, by a new combination of operative features and manipulative steps never before so combined and producing results not heretofore achieved in commercial zinc smelting.

Metallic zinc or spelter, when produced by the reduction of oxidized zinc ores at high temperatures, is almost universally made at the present time in zinc distillation or spelter furnaces having a number of relatively small retorts to the outer ends of which small condensers are attached. The retorts are usually mounted at a slight inclination, usually inclined downward from the butt or closed end towards the open or outer end. The condenser is in effect an extension or elongation of the retort, although usually mounted in a substantially horizontal position, and hence not in exact alignment with the elongated axis of the retort. The zinc vapor and other gases pass in a substantially horizontal line from the retort through the condenser, and the exhaust gases escape through the open end of the condenser. The efficiency of this present customary condensing apparatus is far from satisfactory, only about 60 to 65% of the metallic zinc vapor passing out of the retort being condensed as metallic zinc or spelter, the remainder being condensed as "blue powder" or burning at the mouth of the condenser to zinc oxide and lost.

The complete operation, in this heretofore customary practice of producing metallic zinc, usually takes a full day of twenty-four hours. The spent residues are removed from the retorts with considerable difficulty, and have to be manually pulled or scraped from the retort with a specially constructed tool. These spent residues are frequently slagged and form very undesirable adhesions to the walls of the retorts. In addition to the labor difficulty of charging and discharging the retorts and the long time element,—24 hours for the complete working-off of a retort charge,—this heretofore customary practice effects far from complete elimination of the available zinc from the zinciferous material of the charge. A comparatively large amount of this uneliminated zinc remains behind with the spent residues and is lost.

Various suggestions and proposals have heretofore been advanced from time to time for overcoming the recognized defects of the present spelter furnaces with their numerous retorts of individual small capacity. Thus, vertical disposition of the small retorts has been proposed with the view of decreasing the charging and discharging labor by charging the retorts by gravity from an overhead crane and discharging by gravity by withdrawing a removable plug or other seal normally closing the lower end of the retorts. It has also been proposed to conduct the exiting gases from a number of such small retorts to a common condenser, with the view of reducing the labor and other difficulties incident to the drawing of zinc metal from so many small condensers and the connection to and removal from the retorts each day of so many small condensers. Continuous or progressive operations of various forms have also been proposed, such, for example, as the progressive passage by gravity of a loose charge through a vertical tube. Sintering and slagging have invariably interfered with the economical maintenance of the charge progression in this latter type of furnace, so much so that only tubes of relatively small dimensions (i. e. relatively short distance of heat penetration through the charge and/or relatively short length of charge progression) have been considered practicable.

These prior suggestions and proposals have

resulted in little, if any, commercial success. In the light of the results of our investigations and experiments, we believe that the failure of these prior investigations has been due, in large measure at least, to the common view among zinc metallurgists that as soon as the zinc smelting chamber attains any substantial cross-sectional dimension, it becomes impossible to work-off the zinc in the center of the charge without overheating and slagging the work-off charge, more especially in the outer portions thereof approximate the heated walls of the chamber. Thus, the general trend of the prior proposals has been towards relatively small masses of charge, and such attempts as have been made to work relatively large charges have failed, or at least achieved no commercial success, because, as we believe, no provisions were present for economically conducting heat into the center or core of the charge.

The present invention is based upon our discovery that it is possible to effectively and economically conduct heat from a heated furnace wall into the center or core of a relatively large zinc smelting charge without excessively overheating the charge adjacent that wall. Moreover, we have discovered that it is possible to depart in a substantial degree from the heretofore customary progressive ring method in working-off a zinc smelting charge. In the heretofore customary method of operating spelter retorts, the part of the charge to be first worked-off is that ring of charge immediately adjacent the heated inner wall of the retort. While this ring of charge is working-off its temperature will not rise materially above the temperature at which the particular charge actively reduces, due to the fact that the heat energy is consumed in bringing about the reduction. When, however, the ring of charge is largely worked-off, the temperature of the worked-off charge will rise because there is little, if any, other heat absorption taking place. As the temperature of this ring rises, heat begins to flow more rapidly into the next inner ring of charge where it in turn is absorbed at the active temperature of reaction level. By thus progressively working-off the inner concentric rings of charge and further heating the outer rings of spent charge or residue, the working-off of the charge ultimately progresses to the center or core thereof. Now, we have discovered that it is possible to work-off the center or core of the charge substantially at the same time that the outer ring or portion of the charge nearest the source of heat is worked-off, thereby dispensing with the necessity of overheating those portions of the charge nearest the source of heat in order to drive heat into the center of the charge and also enabling the working-off of a much larger quantity of charge per unit area of heated surface wall. Our present invention, taking advantage of these discoveries, permits us to work a relatively large zinc smelting charge, fifty and more times as large as the customary charge in the heretofore common spelter retorts, and moreover permits us to work such a relatively large charge in a substantially continuous manner.

In its broad aspect, the present invention involves progressively passing a porous charge of agglomerates of mixed zinciferous material and carbonaceous reducing agent through a relatively long reducing chamber of relatively large reducing capacity without substantially breaking-down of the agglomerates during their passage through the chamber, and in the course of such passage heating the agglomerates to a sufficiently high temperature to reduce the compounds of zinc and volatilize the resulting metallic zinc without slagging or fusing the agglomerated charge, and thereby producing metallic zinc vapor which, when withdrawn from the reducing chamber, is capable of being directly and economically condensed to zinc metal. The reducing chamber may be an upright or vertical chamber through which the charge progresses largely, and preferably solely, by the action of gravity, or it may be horizontal and provided with appropriate agencies for progressively advancing the charge. In any case the reducing chamber is relatively long in the direction of the charge progression and of relatively large reducing capacity. While the invention is particularly adapted for the production of metallic zinc or spelter, by condensation to zinc metal of the metallic zinc vapors, these vapors may, if desired, be utilized for the production of commercial pigment zinc oxide or of zinc dust or blue powder.

A statement of the problem of effectively and economically transferring heat from a heated chamber wall to the center or core of a zinc smelting charge and our solution of it will be helpful to a clear understanding and appreciation of the present invention.

In the heretofore customary spelter-retort practice with a loose or unagglomerated charge of mixed zinc ore and coal, the heat conducted through the wall of the retort very quickly reduces the zinc or consumes the coal in that part of the mixed charge adjacent or in immediate proximity to the heated wall of the retort. The exhausted coal ash, which is very loose and cellular as a consequence of the carbon being burned out of it, and the exhausted zinc ore, which is also very loose and cellular as a consequence of the zinc being volatilized out of it, then constitute a most efficient heat insulator and the temperature of the retort wall must consequently be raised very high in order to drive the heat necessary to reduce the ore in the core of the retort into this core in a given time. In the case of the ordinary zinc

or spelter retort (6—9 inches in diameter) operating with a loose or unagglomerated charge, this is a day's (approximately 24 hours) operation. But even with this length of time allowed for the penetration of the heat, the temperature of the retort wall necessary to drive the heat into the core of the charge is so high that the exhausted ore and coal ash in the outer ring next to the retort wall fuse and slag to the wall of the retort, thus causing bridging and hanging up of the charge, lowering the heat conductivity of the retort wall and making the removal of the exhausted charge difficult.

In the method of our present invention, a relatively rapid flow of heat from the heated chamber walls to the center or core of the charge is effected by heat-carrying gases. The rate of which heat will be carried from the heated chamber walls to the center or core of the charge by gases is dependent upon (1) the volume of these gases, (2) the velocity with which they sweep by the hot chamber walls, thereby taking up heat, and the velocity with which they sweep by the center or core of the charge, and (3) the number of times that a given volume of gas travels from the heated chamber walls into the center or core of the charge. We have found that the optimum effect of these three factors in bringing about a rapid transfer of heat from the heated chamber wall to the center or core of the charge may be realized by agglomerating the charge and progressively passing or advancing the agglomerated charge through a reducing chamber relatively long in the direction in which the charge progresses, as compared to the chamber's cross-sectional dimensions. Under such conditions, the gases generated in the charge, in passing therethrough, are constantly flowing and thereby bringing heat from the heated chamber walls into the center or core of the charge. The longer the furnace, in the direction of charge progression, the greater will be the velocity of these heat-carrying gases and the greater the number of contacts of a given volume of gas with heated wall and center of charge. By the progressive movement of the charge, each part thereof passes through the areas or zones of high gas velocity and consequently high heat transfer, and uniformity of charge treatment is assured.

Agglomeration of the charge, in addition to facilitating the transfer of heat by heat-carrying gases, promotes the transfer of heat through the charge by radiation. This results from the voids in the charge, across which the heat will jump with rapidity. The larger these voids the greater the amount of heat transferred in this manner from the heated walls to the center of the charge.

Furthermore, each individual agglomerate, due to its increased density as a consequence of having been agglomerated, has very much greater heat conductivity than the same weight of loose charge. The operation of agglomerating not only facilitates the transfer of heat from the hot walls of the reducing chamber to an agglomerate in the center or core of the charge in consequence of the free gas passages between the agglomerates, but each agglomerate in the charge is much more capable of conveying heat from its surface into its center than an equivalent weight of loose charge in consequence of the densifying operation involved in agglomerating. The long carry of heat, say six to twelve inches, or more, is hastened by providing free play for heat-carrying currents of gas and by radiation across the voids in the charge. The short carry of heat, say one-half to three inches, in an individual unit of the charge (an agglomerate) near the core of the reducing chamber is hastened by increasing the conductivity of this unit volume of charge by densifying it.

Thus, the improved method of our present invention involves a combination of these three efficient modes of securing heat transfer; namely, rapid transfer of heat by heat-carrying gases flowing with considerable velocity through the voids of the agglomerated charge, rapid radiation of heat across the voids themselves, and good conduction of heat through individual densified agglomerates.

While it is true that the larger the agglomerates, within a certain range of size and considering a particular reducing chamber through which the agglomerates progressively advance, the greater is the porosity of the charge as a whole and consequently larger volumes of gases at high velocity can be driven through the charge at a given pressure differential. However, there comes a time when the agglomerates become so large that the gases at high velocity bring heat to the surface of the agglomerates faster than this heat can be carried from the surface of the agglomerate to its core. The optimum size of the agglomerates should therefore be determined by balancing these two factors, and will depend, on the one hand, upon the relationship between the size of the agglomerates and the cross-sectional dimensions of the reducing chamber and, on the other hand, upon the conductivity for heat of an individual agglomerate; that is to say, the specific heat-conducting nature of the material of which the agglomerate is made and the density of the agglomerate.

The advantages of progressively passing the agglomerates through the reducing chamber, rather than intermittently charging the chamber as a whole, working off the charge and then discharging the spent residue from the chamber, are many, but two are of outstanding importance in a reducing chamber of relatively large capacity. The first of

these advantages is the fact that as the progression of the charge through the chamber becomes more and more nearly continuous, the nature of the charge within the chamber becomes more and more nearly uniform, and hence the volume and composition of the laden gases exiting from the chamber become more and more uniform, thereby proportionately diminishing the size of the condensation apparatus and the difficulty of gas condensation. The second outstanding advantage is that the working-off of the charge and its retention in the reducing chamber is not unduly prolonged as a consequence of one portion of the charge working-off at a faster rate than other portions. The velocity of the heat-carrying gases at the gas discharge end of the reducing chamber is relatively high and the working-off of the charge at this end of the chamber proceeds more rapidly than at the other end of the chamber. In the absence of a progressive movement of the charge through the reducing chamber, the charge would be more rapidly worked-off at the gas discharge end than at the other end and thereby the working-off of the charge as a whole and its retention in the reducing chamber would be prolonged, because the entire charge must be held in the reducing chamber until that portion at the slow working end of the chamber has worked-off while that portion of the charge at the gas discharge end of the chamber has already worked-off and lies idle pending the completion of the working-off of the charge at the slow working end of the chamber.

The effective and economical transfer of heat from the walls of the reducing chamber to the center or core of the charge by heat-carrying gas depends furthermore upon the shape and dimensions of the reducing chamber. We have found that the best results are obtained in a reducing chamber relatively long in the direction of charge progression as compared with its cross-sectional dimensions, while at the same time having relatively large reducing capacity. The longer the reducing chamber, for given cross-sectional dimensions, the higher will be the velocity of the heat-carrying gases at the gas exit end, and in fact throughout the entire chamber, and the greater will be the number of times that a given volume of gas will flow between and make contact with the heated chamber walls and the center or core of the charge in its flow from its most removed point of generation to the point or points of gas exit.

In order to provide within the reducing chamber optimum conditions for the effective and economical transfer of heat throughout the charge by heat-carrying gases, the agglomerates should be of substantially uniform size and of such shape that the porosity of the charge as a whole is substantially uniform. Moreover, since it is important to maintain these conditions favorable to heat transfer throughout the entire working-off of the charge, the agglomerates should remain substantially unbroken in their passage through the reducing chamber.

The mixed charge of zinciferous material and carbonaceous reducing agent may be agglomerated in any appropriate manner to give agglomerates of the desired size, shape and strength. In general, we have found it of advantage to agglomerate by briquetting or by extrusion, since we can thereby conveniently produce agglomerates of substantially uniform size and shape and of relatively high heat conductivity. In the case of certain zinciferous materials and carbonaceous reducing agents, pressure alone, such as obtained in briquetting or in extrusion, may produce agglomerates of the required strength and heat conductivity. In other cases, it may be desirable to include in the mixed charge a binding agent, such for example, as caking coal, sulfite waste liquor, tar, pitch, and the like. The agglomerates may be subjected to appropriate treatment, such as drying, heating and the like, to develop requisite strength and other advantageous properties, or to effect or promote the desired cementing action of the binding agent.

The strength which it is necessary to impart to the agglomerates depends to some extent upon the type of reducing chamber employed and the method of charge progression therethrough. Where the agglomerates are subjected to attrition, as in rubbing against each other, greater strength is necessary than where the relative movement between individual agglomerates in the progressively advancing charge is slight. Thus, stronger agglomerates are necessary in the case of an upright or vertical reducing chamber through which the agglomerates progressively pass by the action of gravity, than in the case of a horizontal reducing chamber through which the charge is progressively advanced while supported on a movable hearth or the like. In any event the agglomerates should be sufficiently strong to insure their passage through tne reducing chamber without substantial breaking down either by "sanding" or slagging, and by substantial breaking down we mean the breaking down of the agglomerates into pieces and fines, by rupture, or attrition, or slagging or in any other way, to a degree sufficient to substantially interfere with the flow of heat and/or gases through the charge, in consequence of the filling in by the fine material of the voids or gas spaces between the agglomerates.

The agglomerates should be of such shape that the agglomerated charge as a whole will possess and will maintain throughout its progression through the reducing chamber substantially uniform and adequate porosity for the desired flow through the charge at

relatively high velocity of the heat-carrying gases. We have found agglomerates of substantially spherical and cylindrical shapes with and without holes through them, as well as the over-stuffed pillow block forms, entirely satisfactory, but it is to be understood that other and less regular shapes like broken coke may be employed. Thus, the agglomerates may be longer in one dimension than in the other two to facilitate heat-conductivity from the heated chamber walls into the most remote portions of the charge. And again, the agglomerates may have hollow centers or may be otherwise provided with hollow interior portions. Where the agglomerates are of other than spherical shape, it is important in charging and in advancing the charge through the reducing chamber that the agglomerates assume and maintain such positions with respect to one another in their passage through the reducing chamber as will impart the necessary porosity to the flow of gases between the heated chamber walls and the center or core of the charge.

The agglomerates are preferably of substantially uniform size, in order to give the charge as a whole maximum uniform porosity. The actual size of the agglomerates will be determined to some extent by the cross-sectional dimensions and length of the reducing chamber. As a result of our investigations and experiments, we have found that the average size of the agglomerates should be proportional to the ratio that the distance heat has to travel to penetrate portions of the charge most remote from the heated chamber walls bears to the length of the charge path through the reducing chamber. In other words, for any given length of furnace the greater the distance heat has to penetrate into the charge the larger should be the average size of agglomerates. The longer the furnace for any given heat penetration the smaller may be the average size of the agglomerates. Moreover, the average size of the agglomerates should not be substantially greater than that size which will impart to the agglomerate sufficient surface (which is the heat-absorbing medium) for the conduction of heat therefrom into the core of the agglomerate as fast as heat flows from the heated chamber wall to the surface of the agglomerate.

As a result of our experiments and investigations, we have determined that where the heat penetration through the charge as a whole is more than six inches (i. e., a 6 inch deep bed of charge on a horizontal hearth or a 12 inch diameter vertical shaft), the average diameter or cross-sectional dimensions of the agglomerates should not be less than about one inch. Where the heat penetration of the charge as a whole is more than six inches but not over twenty-four inches, the maximum distance of heat conduction in an individual agglomerate (i. e. distance from surface to remotest part of core) should not be more than about 3 to 4 inches. For greater distances of heat penetration of the charge as a whole, the greater will be the average minimum and average maximum size of agglomerates.

Accordingly, we have determined that, in practicing the invention, the average size and shape of the agglomerates should be such that the voids through the charge shall impart to the charge as a whole a porosity not less than the equivalent of the porosity of a similar charge of one inch spheres, and no portion of an individual agglomerate shall be more than about 3 to 4 inches from the surface thereof. By porosity of the charge as a whole we mean the reciprocal of the resistance to the passage of a gas through a unit depth of the charge, and we measure this porosity in terms of the reciprocal of the resistance to the passage of a gas through a similar bed of one-inch spheres. As hereinbefore mentioned the porosity should be as favorable as possible to the flow of gases back and forth between the heated chamber walls and the core or center of the charge and should be preferably uniformly distributed as it is in the case of a similar charge of one-inch spheres.

The reducing chamber, as previously stated, should be relatively long in the direction of charge progression, and the charge should preferably pass through the chamber in the direction opposite to the general direction of the flow through the chamber of the gases generated therein. Where structural or thermal difficulties do not interfere, we prefer to provide the reducing chamber with a maximum of heated surface in contact with or on the wall or walls facing the charge. In furnaces of the traveling hearth type, we prefer to have relatively wide hearths and relatively shallow beds of charge. The ratio of the inner heated surface of the reducing chamber to the charge volume may be increased by serrating, ruffling, fluting or scalloping that surface.

The reducing chamber may be constructed of any material possessing sufficient strength to retain the requisite loads of charge at temperatures of from 1050 to 1300° C. Where the reducing operation is carried on at the higher temperatures, the reducing chamber should be made of heat refractory materials such as fire-brick, carborundum, aluminum oxide, and the like. With operating temperatures below about 1150° C., the reducing chamber may be made of metal, such as wrought iron, nickel-chromium-iron alloys and the like.

The reducing chamber may be heated in any appropriate manner. We prefer to externally heat the chamber walls by heat derived from electric-energy or by the hot products of combustion from burning fuel, such as coal,

oil or gas. If desired, heat may be generated in the wall of the reducing chamber itself, as in an electric induction furnace, the wall of the reducing chamber acting as the absorber and converter to heat of the electromagnetic energy radiated from a surrounding primary electric circuit. So far as heating the charge is concerned this is the equivalent of external heating of the chamber.

In the progressive passage of the charge through the reducing chamber, the charge is introduced at one place in the chamber, for example one end, and is withdrawn or discharged at another place in the chamber, for example the other end. The charge may be advanced through the reducing chamber by the action of gravity alone as in upright or vertical retorts, or by mechanical means, such as pan conveyors, traveling hearth or movable cars, or by both gravity and mechanical means as in an inclined rotary furnace. The charging and discharging may be continuous, but in actual practice on a vertical reducing chamber we have found it generally preferable to charge and discharge at periodic intervals; such an amount of the spent residues being discharged from the chamber from time to time as is required for the charging of fresh agglomerates, while maintaining continuity of operation of the charge as a whole confined in the reducing chamber.

The charging and discharging ends of the chamber are appropriately sealed to prevent loss of zinc as well as to inhibit the ingress of excess air or other gases. This sealing may be mechanically effected by spent residues, dust coal, bulkheads, dampers, charging bells and the like. The sealing of the chamber may also be effected by gas pressure differentials, that is by maintaining within the chamber at the discharge end a less gas pressure than prevails outside the chamber at this location, and maintaining within the chamber at the charging end a greater pressure than prevails outside the chamber at this location. Bulkheads, dampers, charging bells and similar mechanical sealing means are not entirely gas-tight, but they serve to facilitate the flow of gases in the desired direction through the reducing chamber while preventing objectionable flow of gases in the wrong direction. When supplemented by gas-pressure differentials, mechanical sealing means can be made most effective and satisfactory.

The agglomerates may be charged into the reducing chamber just as delivered by the agglomerating agencies, and may thus be cold and/or wet. Or the agglomerates may be naturally or artificially dried, and then charged into the reducing chamber. If desired, the agglomerates may be preheated to any appropriate temperature preparatory to their introduction into the reducing chamber. Where the agglomerating procedure involving heating the agglomerates, as in coking, it is generally advantageous to introduce the resulting hot agglomerates into the reducing chamber without substantial loss of heat after the agglomerating operation.

In the accompanying drawings, we have illustrated two different types of furnaces adapted for the practice of the invention. It is to be understood that the drawings are illustratory, and that the invention may be practiced in other types of furnace. In the drawings

Fig. 1 is a front sectional elevation and Fig. 2 is a side sectional elevation of a vertical retort furnace, and

Fig. 3 is a longitudinal sectional elevation and Fig. 4 a transverse sectional elevation of a horizontal traveling hearth furnace.

The vertical retort furnace illustrated in Figs. 1 and 2 of the drawings comprises a vertically disposed cylindrical retort 10 preferably built up of a plurality of superposed carbofrax tubes. The retort 10 is surrounded, for the greater part of its length, by a heating chamber 11. The heating chamber 11 is built within a furnace structure comprising an outer steel shell or casing 12, a layer of sil-o-cel powder 13, an intermediate lining 14 of fire brick or other appropriate material and an inner lining 15 of heat refractory material such, for example, as carbofrax brick. Appropriate openings are preferably provided through the wall of the furnace structure permitting the insertion of pyrometers within the heating chamber 11, for ascertaining and appropriately controlling the temperature throughout the length of this chamber. The furnace structure is mounted on an appropriate foundation 16. A cylindrical extension 17 is bolted, or otherwise appropriately secured, to the underside of the bottom steel plate of the furnace structure and serves as an extension of the retort 10 below the bottom of the furnace structure. A pan conveyor 18 is operatively mounted directly beneath the extension 17 and is adapted to withdraw the worked-off charge or spent residue from the bottom of the retort 10 and convey the same from underneath the furnace structure to appropriate means of discharge.

Any appropriate means may be employed for heating the retort 10, Thus, for example, the products of combustion from burning fuel, such as coal, oil, or gas, may be conducted through the heating chamber 11 around the retort 10 and to an appropriate stack. In the apparatus illustrated in the accompanying drawings, the heating of the retort 10 is effected by electric energy. The electric heating units comprise three pairs of graphite resistors 19 positioned at different levels within the heating chamber 11. The resistors 19 are hollow for an appropriate length thereof and have a spiral slot so as to provide a helical resistance path for the flow of the

electric current. The resistors 19 of each pair are connected together on one side of the furnace structure and at the opposite side of the furnace structure the two resistors are connected respectively to opposite terminals of the source of electric energy.

The resistors 19 are supported within carbofrax tubes 20. The ends of these tubes rest on shelves in the opposite walls of the furnace structure and the centers of the tubes are supported on shelves 21. The tubes 20 have openings 22 in the top thereof. This arrangement of the resistors within the carbofrax tubes produces very uniform heating throughout the length of the retort 10.

The top unit of the retort 10, above the furnace structure, has a lateral opening communicating with a condenser 23 resting on the top of the furnace structure. This condenser comprises an exterior steel casing 24, an intermediate layer 25 of carbon paste and an inner lining 26 of graphite. A longitudinally extending graphite partition 27 divides the interior of the condenser into a lower and upper chamber through which the gaseous products from the retort pass and in which the metallic zinc vapor condenses and collects in a pool at the lower end of the condenser. The molten zinc is withdrawn from the condenser, from time to time, through a tap hole 28, normally closed with a fire clay or other appropriate plug. An opening 29 is provided near the top of the upper condensing chamber for the escape from the condenser of the exhaust gases.

The top unit of the retort 10 is closed by a plate 30, of refractory material, having an appropriate center opening into which is fitted a charging hopper 31. The top of the hopper 31 is closed, except when charging fresh agglomerates into the retort, by a cover 32. The top of the retort, the charging hopper with its cover and the condenser are covered with a mass 33 of fine coal, coke dust, or the like, of appropriate thickness to insulate these parts.

The following specific example illustrates the principles of the present invention as practiced in an apparatus of the form shown in Figs. 1 and 2, although it is to be understood that this example is merely illustrative and in no sense restrictive of the invention.

The charge was made up of approximately 60 parts by weight of finely divided zinc silicate ore (containing from 45–50% of zinc) and 40 parts by weight of a bituminous caking coal (containing about 18% volatile) matter and 3% of 50% solids, waste sulfite liquor. Approximately 80% of the zinc ore passed through a 20 mesh screen. The caking coal (Consolidation Georges Creek Big Vein) was pulverized so that approximately 80% passed through 20 mesh screen. The zinc ore and coal were placed in a revolving mixer of the kind employed for the mixing of concrete and thoroughly mixed. From the revolving mixer, the material was dumped directly into a dry pan Chilean mill and subjected to the mixing and comminuting action of the mill for some minutes. From the Chilean mill, the material was taken to a briquetting press and formed into briquettes by a compressive force of approximately 2000 pounds to the square inch. The briquettes were approximately spherical and about 2¾ inches in diameter.

The briquettes, without drying, were charged into an externally heated vertical coking retort. In this retort, the briquettes were subjected to a coking temperature of about 700° C. In the coking operation, it is desirable to leave behind in the coked product as high a percentage as possible of the non-condensible volatile substances, and at the same time eliminate as completely as possible the tars. As a result of the coking action, the intimately mixed particles of ore and coal are firmly held together by the binding action of the coke formed in the coking operation.

The coked agglomerates were transferred without substantial loss of heat from the coking retort to the vertical smelting retort, and introduced therein at the rate of approximately 350 pounds at intervals of 1½ hours. The heating of the retort was controlled so as not to overheat the charge, and no slag was formed and no fusion of the agglomerates took place. The temperature within the heating chamber 11 was about 1250–1300° C. In the particular example being discussed, the retort 10 was about 25 feet long (high) and was built up of carbofrax tube sections 15 inches internal diameter, 18 inches long and 2 inches wall thickness.

The gaseous products of the reaction for the most part zinc vapor and carbon monoxide gas with from 0.4% to 0.8% of carbon dioxide pass through the condenser where the zinc vapor is condensed, collected and periodically withdrawn. Although the charging of the furnace was intermittent (every 1½ hours), its operation as a whole was continuous, the retort 10 being at all times filled with an agglomerated charge undergoing reduction. Spent residues were withdrawn from the bottom of the retort preceding each charging operation in such amount as required for the subsequent charging of approximately 350 pounds of fresh agglomerates. For the most part, these residues as discharges retained their original briquetted form and were free and non-adherent (what the zinc metallurgist would call a dry residue). The amount of zinc in these residues averaged about 2%, thus representing an elimination or extraction of about 96% of the total zinc in the original ore. 96% of the zinc eliminated or extracted from the ore was condensed and collected as

slab zinc metal; the remaining 4% being for the most part recoverable as zinc oxide and blue powder.

Coked agglomerates of mixed zinciferous and carbonaceous materials are peculiarly suited for reduction or smelting in an upright or vertical retort through which the agglomerated charge progressively passes substantially by the action of gravity alone. The intimate mixture of zinciferous material and carbonaceous reducing agent is bonded together into a strong, coherent agglomerate (or briquette) by the binding action of the coke formed in the coking action. Such coked agglomerates are sufficiently strong to withstand the attrition forces encountered in their passage through the vertical retort without substantial breaking down, and thereby the advantages of an agglomerated charge, as hereinbefore discussed, are secured throughout the entire passage of the charge through the retort. Moreover, coked agglomerates when properly made are substantially deoxidized, especially when charged hot from the coking apparatus into the reducing chamber. By "deoxidized" we mean that the agglomerates, if placed in a gas-tight chamber provided with exit only and heated to zinc-reducing temperatures, will give off gases with an average content of carbon dioxide (CO_2) not in excess of 2%.

The apparatus illustrated in Figs. 3 and 4 of the drawings comprises a traveling hearth 35, of the pan-conveyor type, constituting the bottom of a relatively long reducing chamber 36 of rectangular section. The reducing chamber is embodied in an appropriate furnace structure 37 having a heating flue 38 overlying the top wall 39 of the reducing chamber. Fuel burners 40 extend through the side wall (or walls) of the furnace structure into the flue 38, and the hot products of combustion from these burners flow through the flue to an exhaust conduit 41 communicating with a stack 42.

The pan conveyors, as they enter the reducing chamber traveling in the direction indicated by the arrows, are covered with an appropriate layer of fine material delivered onto the pans from a hopper 43 at the charging end of the furnace. The agglomerates are charged onto the layer of fines from a feed hopper 44 provided with a charging bell 45. At the discharge end of the furnace, additional fine material is charged from a hopper 46 onto the spent residues as they emerge from the reducing chamber. By these agencies, in conjunction with the gas pressures prevailing throughout the length of the reducing chamber, the reducing chamber is appropriately sealed to induce the desired flow of gases generated in the chamber towards a gas outlet 47 and to prevent objectionable ingress into the chamber of air or other gases.

The gas outlet 47 communicates with the top of the reducing chamber 36 near the charging end and extends upwardly through the flue 38 and the overlying layer or layers 48 of heat refractory material. The upper end of the gas outlet 47 communicates through a horizontal passage with the condenser for the metallic vapor. Such portions of the gas outlet 47 as extend beyond the heat protecting influence of the furnace structure are covered with an appropriate mass 55 of heat-insulating matter, such as dust coal, coke dust or the like.

The condenser comprises a rectangular chamber 49 of graphite and a multi-tubular top or tower 50 of graphite. The chamber 49 and tower 50 are embedded in a mass 51 of dust coal, coke dust, or equivalent heat-insulating material, appropriately confined by a metal shell 52. The top of the tower 50 is covered by a hood 53 having its lower edge or rim embedded in the insulating mass 51 and having an orifice 54 at the top through which the exhaust gases from the condenser escape.

In the practice of our present invention, the apparatus of Figs. 3 and 4 is operated as follows: The pan conveyor 35 moves at a relatively slow rate in the direction of the arrows, and at the charging end of the furnace receives a layer of fine material upon which is superimposed the agglomerated charge. The agglomerated charge substantially fills the reducing chamber 36 above the bed of fine material and is progressively advanced through the chamber by the movement of the pan conveyor. Heat is transferred and conducted into the agglomerated charge from the heated roof or top wall 39 of the reducing chamber in the manner characteristic of our present invention and as hereinbefore particularly described.

The mixture of metallic zinc vapor and carbon monoxide gas (resulting from the reduction of the zinciferous material in the agglomerated charge) passes from the reducing chamber through the gas outlet 47 into the condenser, where substantially all of the metallic zinc vapor is condensed to molten zinc metal. From time to time, molten zinc metal is withdrawn from the condenser through an opening in the bottom of the chamber 49 communicating with a pipe 56 extending through the side wall of the furnace structure. Normally, the tap hole in the bottom of the condenser is closed by an inner plug 57 secured to a rod 58 projecting through and beyond an outer plug 59 in the end of the pipe 56.

The spent residues and fines are discharged from the pan conveyor onto a grizzly 60 through which the fines pass while the agglomerates, substantially unbroken in their passage through the furnace, slide down the grizzly and are appropriately disposed of. The fine material passing through the grizzly

is conveyed back to the fine hoppers 43 and 46 in such relative amounts as required. This fine material may conveniently consist of spent residues from previously worked-off charges. In the normal operation of the furnace a sufficient quantity, and usually a slight excess, of fines will pass through the grizzly 60 for the requirements of the fine hoppers 43 and 46. The discharge end of the furnace is enclosed by a sheet metal casing 61 and any dust resulting from the discharging operation is carried from the casing 61 to the stack 42.

Various charge mixtures may be employed in the practice of the invention. Thus, we have secured satisfactory results with mixtures of from 10 to 50% by weight of carbonaceous reducing agent and 90 to 50% by weight of zinciferous material.

In the working off of the agglomerated charge, the zinc compounds in the ore (or other zinciferous material) are reduced to metallic zinc when the carbon in the carbonaceous reducing agent combines with the oxygen of the zinc compounds. The resulting metallic zinc vapor and carbon monoxide gas constitute the gaseous products of the reduction, and it is the flow of these gases from their points of generation in the charge through the agglomerates towards the gas outlet of the reducing chamber that provides the medium for the effective transfer of heat from the hot chamber wall throughout the charge by currents of highly heated gases moving at relatively high velocity.

It is desirable that the gaseous products of the reduction issuing from the reducing chamber be relatively pure carbon monoxide gas and zinc vapor, and for this reason it is desirable to maintain within the reducing chamber a strictly reducing atmosphere. It is characteristic of our invention that the gaseous product issuing from the reducing chamber contains metallic zinc vapor capable of being directly and economically condensed to zinc metal. By directly condensible to zinc metal we mean that if the gaseous product is conducted directly (and without intermediate treatment) from the reducing chamber into one or more condensers of the present spelter retort furnace type, at least 60% of the metallic zinc vapor in the gaseous product will be condensed as zinc metal. By economically condensible to zinc metal we mean the condensation to zinc metal of at least 60% of the metallic zinc vapor in the gaseous product with a reasonable number of condensers of the present spelter retort type per ton of metal condensed in a given time. It is to be understood, of course, that this language is used merely to describe the qualities of the gaseous product, and is not intended to necessarily mean that the metallic zinc vapor is, in practicing the invention, actually condensed to zinc metal. For, as previously stated, the metallic zinc vapor contained in the gaseous product issuing from the reducing chamber may, if desired, be condensed as zinc dust or blue powder, or burned or oxidized to pigment zinc oxide, where it is desired to manufacture these zinc products rather than zinc metal or spelter.

We claim:

1. The method of reducing zinciferous materials, which comprises progressively passing a porous charge of agglomerates of mixed zinciferous material and carbonaceous reducing agent through a reducing chamber without substantial breaking down of the agglomerates during their entire passage through the chamber, heating the agglomerates in the course of such passage to a sufficiently high temperature to reduce the compounds of zinc and volatilize the resulting metallic zinc without slagging or fusing the agglomerated charge, and withdrawing from the reducing chamber a gaseous product containing metallic zinc vapor capable of being directly and economically condensed to zinc metal.

2. The method of reducing zinciferous materials, which comprises progressively passing a porous charge of agglomerates of mixed zinciferous material and carbonaceous reducing agent through an externally heated reducing chamber without substantial breaking-down of the agglomerates during their entire passage through the chamber, heating the agglomerates in the course of such passage to a sufficiently high temperature to reduce the compounds of zinc and volatilize the resulting metallic zinc without slagging or fusing the agglomerated charge, the transfer of heat from the heated wall of the reducing chamber through the agglomerated charge being effected in large part by currents of hot gases generated within the charge and flowing through the voids thereof towards the gas outlet of the reducing chamber, and withdrawing from the reducing chamber a gaseous product containing metallic zinc vapor capable of being directly and economically condensed to zinc metal.

3. The method of reducing zinciferous materials, which comprises progressively passing a porous charge of agglomerates of mixed zinciferous material and carbonaceous reducing agent through an externally heated and continuously operating reducing chamber relatively long in the direction of charge progression and of relatively large reducing capacity, heating the agglomerates in the course of their passage through said chamber to a sufficiently high temperature to reduce the compounds of zinc and volatilize the resulting metallic zinc without slagging or fusing the agglomerated charge, the transfer of heat from the heated wall of the reducing chamber through the agglomerated charge being effected in large part by cur-

rents of hot gases generated within the charge and flowing through the voids thereof towards the gas outlet of the reducing chamber, discharging spent residues for the most part in the form of agglomerates from said chamber as required for the charging thereto of fresh agglomerates, and withdrawing from the reducing chamber a gaseous product containing metallic zinc vapor capable of being directly and economically condensed to zinc metal.

4. The method of reducing zinciferous materials, which comprises progressively passing a porous charge of agglomerates of mixed zinciferous material and carbonaceous reducing agent through a reducing chamber without substantial breaking down of the agglomerates during their entire passage through the chamber, the agglomerates being of such shape and size that no part of an agglomerate is more than four inches from the surface thereof and the porosity of the agglomerated charge as a whole is not less than the equivalent of the porosity of a similar charge of one inch spheres, heating the agglomerates in the course of such passage to a sufficiently high temperature to reduce the compounds of zinc and volatilize the resulting metallic zinc without slagging or fusing the agglomerated charge, and withdrawing from the reducing chamber a gaseous product containing metallic zinc vapor capable of being directly and economically condensed to zinc metal.

5. The method of reducing zinciferous materials, which comprises progressively passing a porous charge of agglomerates of mixed zinciferous materials and carbonaceous reducing agent through an externally heated reducing chamber without substantial breaking down of the agglomerates during their entire passage through the chamber, the agglomerates being of such shape and size that no part of an agglomerate is more than four inches from the surface thereof and the porosity of the agglomerated charge as a whole is substantially uniform and favorable to the flow of gases back and forth between the heated chamber walls and the center or core of the charge and not less than the equivalent of the porosity of a similar charge of one inch spheres, heating the agglomerates in the course of their passage through the reducing chamber to a sufficiently high temperature to reduce the compounds of zinc and volatilize the resulting metallic zinc without slagging or fusing the agglomerated charge, the transfer of heat from the heated wall of the reducing chamber through the agglomerated charge being effected in large part by currents of hot gases generated within the charge and flowing through the voids thereof towards the gas outlet of the reducing chamber, and withdrawing from the reducing chamber a gaseous product containing metallic zinc vapor capable of being directly and economically condensed to zinc metal.

6. The method of reducing zinciferous materials which comprises progressively passing a porous charge of agglomerates of mixed zinciferous material and carbonaceous reducing agent without substantial breaking down through an externally heated vertical retort, heating the agglomerates in the course of their passage through said retort to a sufficiently high temperature to reduce the compounds of zinc and volatilize the resulting metallic zinc without slagging or fusing the charge, the transfer of heat from the heated wall of the retort through the agglomerated charge being effected in large part by currents of hot gases generated within the retort and flowing through the voids of the charge towards the gas and vapor outlet of the retort, discharging spent residues from the bottom of the retort, and withdrawing from the retort a gaseous product containing metallic zinc vapor capable of being directly and economically condensed to zinc metal.

In testimony whereof we affix our signatures.

FRANK G. BREYER.
EARL H. BUNCE.