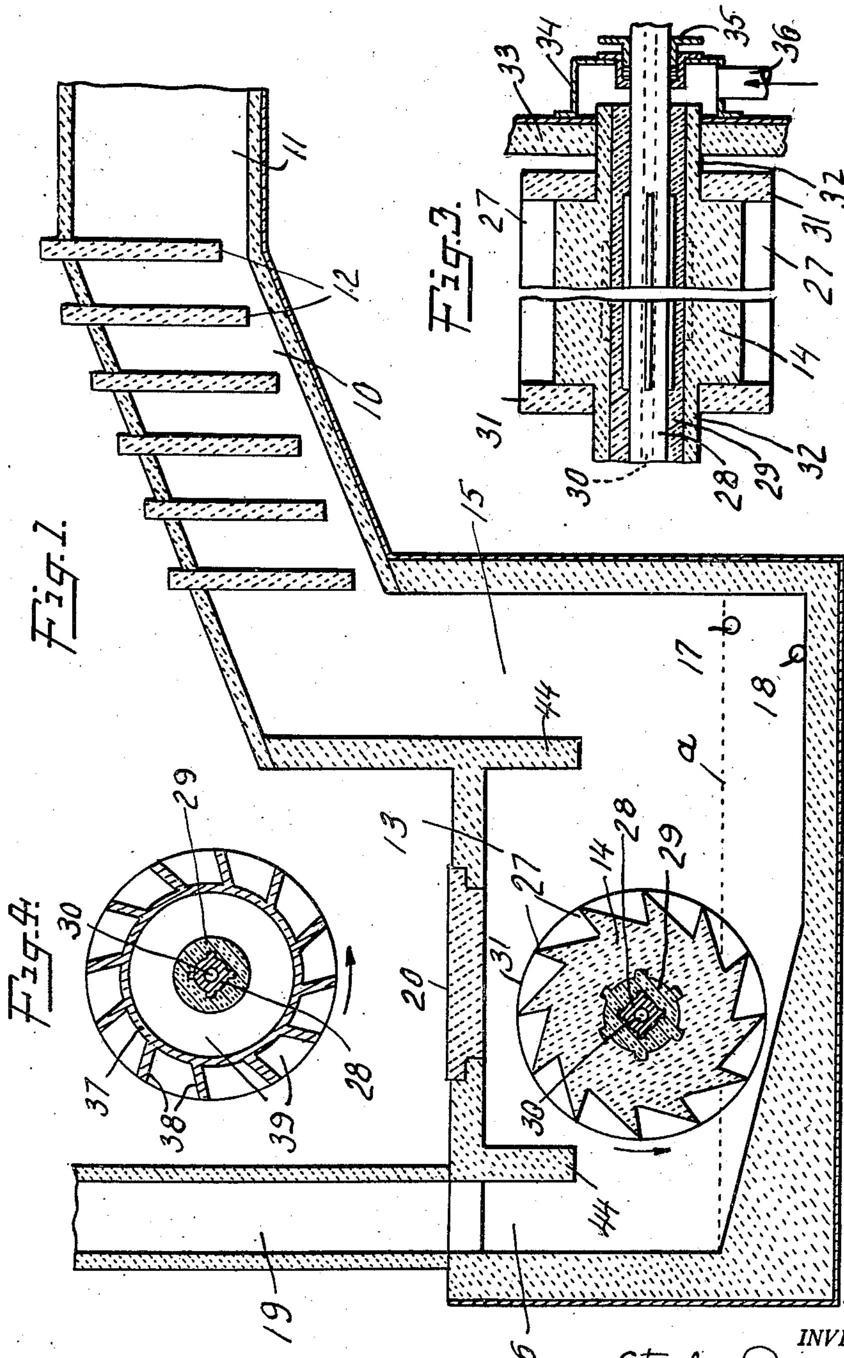
Dec. 28, 1948. S. ROBSON 2,457,551

CONDENSING ZINC VAPOR

Filed Jan. 14, 1947 2 Sheets-Sheet 1



INVENTOR.
Stanley Robson
BY
Pennie, Edmonds, Morton and Barrows
Attorneys

Dec. 28, 1948. S. ROBSON 2,457,551

CONDENSING ZINC VAPOR

Filed Jan. 14, 1947 2 Sheets-Sheet 2

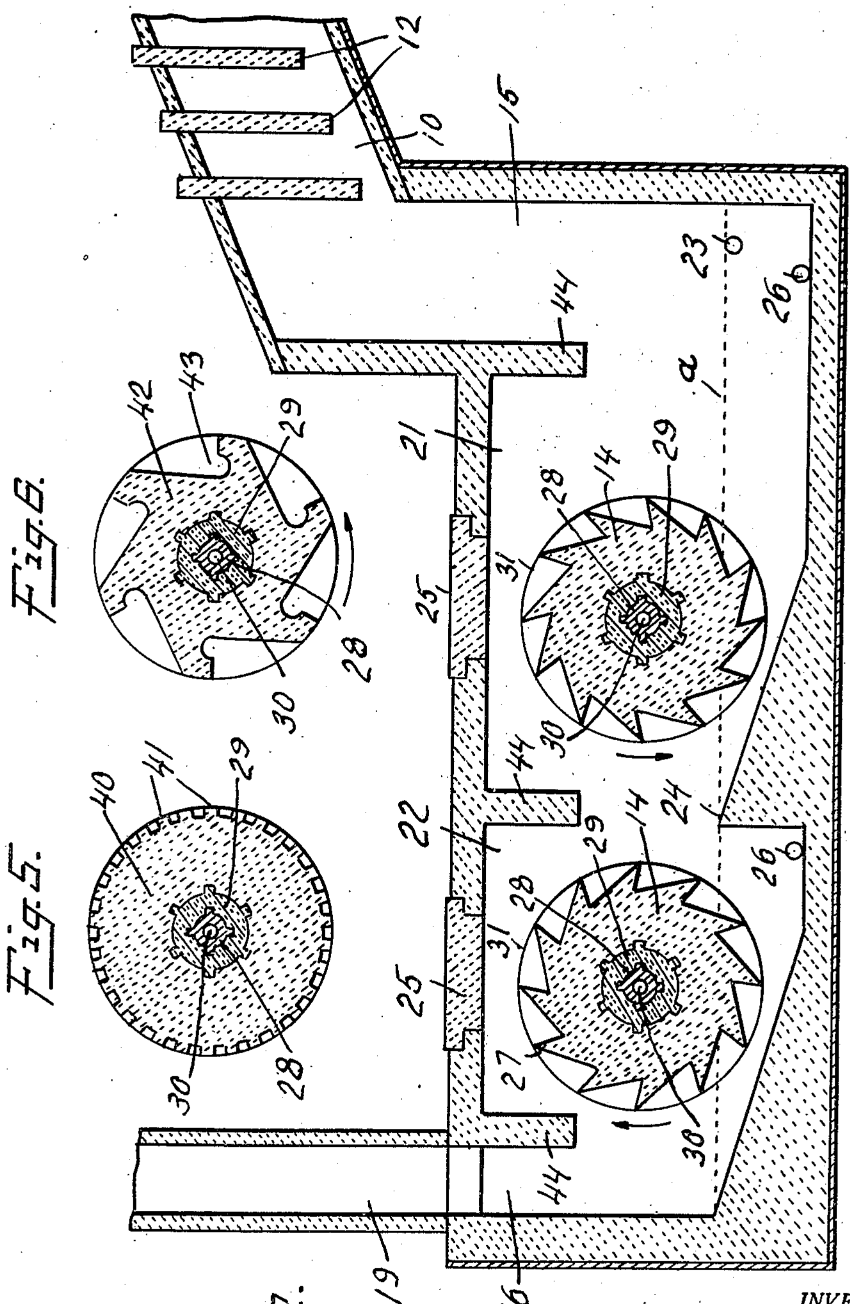


Fig. 6.

Fig. 5.

Fig. 2.

INVENTOR.
Stanley Robson
BY
Pennie, Edmonds, Morton & Barrows
Attorneys.

Patented Dec. 28, 1948

2,457,551

UNITED STATES PATENT OFFICE

2,457,551

CONDENSING ZINC VAPOR

Stanley Robson, Bristol, England, assignor to The New Jersey Zinc Company, New York, N. Y., a corporation of New Jersey

Application January 14, 1947, Serial No. 722,083
In Great Britain March 12, 1946

2 Claims. (Cl. 75—88)

1

This invention relates to an improved method of condensing liquid zinc from a mixture of zinc vapor with permanent gases. It is adapted to deal with, for instance, the gaseous products evolved when oxidized zinciferous materials are reduced by carbonaceous reducing agents in externally heated retorts, electro-thermic furnaces or shaft furnaces. It is an object of this invention to provide an improved method of condensing zinc vapor in which most of the zinc contained in the incoming gases can be condensed to liquid metal. In particular, besides ensuring that no large amount of zinc vapor escapes condensation, the invention prevents the formation of any large quantity of zinc dust and dross, consisting of metallic zinc with more or less zinc oxide, commonly known as blue powder.

In retort processes of zinc smelting, the main overall reaction occurring is reduction of zinc oxide by carbon to give equal volumes of zinc vapor and carbon monoxide, according to the equation:

$$ZnO+C=Zn+CO$$

The concentration of zinc vapor in the gases evolved may therefore be about 50%. As a typical instance of retort smelting may be mentioned the process in which a briquetted charge of oxidized zinc ores and carbonaceous material is heated in vertical retorts. In this vertical retort process it is customary to admit a certain volume of air or other gas or vapor, e. g. steam, at the bottom of the retort, so that the gases finally evolved contain only 30% to 40% zinc vapor, the balance being chiefly carbon monoxide but including some nitrogen, hydrogen, and a small amount of carbon dioxide. From such gases, in the types of condenser usually employed, it is possible to condense the greater part of the zinc as liquid metal, but quite a considerable fraction, of the order of 10–15%, is obtained as blue powder.

When zinc oxide compounds are reduced by smelting in electric arc furnaces, the main reaction taking place is the same as in retort smelting, namely, reduction of zinc oxide by carbon, according to the aforementioned equation, but condensation of the zinc vapor to liquid zinc is more difficult. The difference may be due to the fact that more dust and fume, and somewhat more carbon dioxide. are present in the gases from an arc furnace than from a vertical retort. In arc furnace smelting with the conventional condensers (refractory chambers fitted with baffles), upwards of 30% of the zinc is generally obtained in the form of blue powder.

2

The difficulties involved in avoiding blue powder formation and the manner in which this invention overcomes these difficulties may be most clearly explained if some account is first given of the theory of blue powder formation. One characteristic of blue powder is that it consists of small particles. Factors which cause the zinc vapor to be condensed as small droplets or particles rather than as coherent liquid metal may be classified as physical causes of blue powder formation. The blue powder generally contains, besides metallic zinc, some zinc oxide. Factors which cause oxidation of zinc in the condenser may be classified as chemical causes of blue powder formation.

Physical causes of blue powder formation operate independently of the chemical composition of the permanent gases with which the zinc vapor is mixed. Sudden chilling, for instance, tends to promote blue powder formation. Indeed, when it is desired to make zinc dust rather than liquid zinc, a method frequently adopted is to conduct the gases to a condenser made of metal and of large surface area to promote rapid heat loss. To minimize formation of "physical" blue powder, the condenser temperature may be kept as high as possible, consistent with the condition that it must be low enough to permit condensation of zinc. The lower the concentration of zinc in the gas, the greater is the tendency for "physical" blue powder to be formed. A possible explanation of the factors effecting "physical" blue powder formation may be given as follows.

In the conventional types of condenser, all the latent heat of condensation is removed through the walls, the inner surfaces of which are at a lower temperature than the dew-point of the gas. Adjacent to the wall surface is a film of gas across which there is a steep temperature gradient, so that the surface, remote from the wall, of this "boundary layer," and the bulk of the gas, is hotter than the wall. Condensation of zinc can then take place by zinc vapor diffusing through the boundary layer to the wall, where it condenses and runs down to the pool of molten metal in the bottom of the condenser. If the bulk of the gas is above the dew-point this is the only way in which the zinc can condense. If the wall is made colder and the bulk of the gas has a temperature at or below the dew point, condensation can then take place in the body of the condenser to yield droplets of metallic zinc. Any particles of dust or fume in the gas can act as nuclei for the formation of such droplets. If these droplets are cooled below their melting point before coalescing, zinc dust or blue powder is formed.

Apart from "physical" blue powder formation in the condenser itself, there is also the question of the zinc vapor which escapes from the condenser as such and is usually caught elsewhere as blue powder. To minimize this loss, the gases must be made as cold as possible during their passage through the condenser.

The above described physical mode of formation of blue powder is unaffected by the chemical composition of the permanent gases with which the zinc vapor is mixed. If these gases contain any considerable content of carbon dioxide (CO_2) or other oxidizing gas, the formation of blue powder is initiated and promoted by oxidation direct from the vapor phase, and this chemical cause of blue powder formation becomes serious when the zinc concentration in the gases is low. The present invention is concerned with the condensation of zinc metal from zinc-rich gases of a reducing character, such as those given off by retort processes or electric arc furnaces, in which the content of carbon dioxide (or other oxidizing gas) is low in comparison with the content of carbon monoxide; and therefore for the purposes of this invention the chemical cause of blue powder formation is of very minor importance.

It will be clear from the foregoing discussion that the later stages of the conventional condensation processes are the critical ones for the formation of "physical" blue powder, and the main aim of the invention is to overcome the defects of the conventional processes in this particular respect.

In accordance with the present invention, the zinc vapor-bearing gases are first led from the producing unit directly into an initial condensing unit, in which condensation is effected on walls, baffles or the like condensing surfaces, and the residual zinc vapor bearing gases then pass into a second condsening unit, in which they are brought into intimate contact with a spray or shower of molten zinc maintained by mechanical means. The process thus comprises essentially two stages or zones—firstly a stage of conventional surface condensation and secondly a stage of condensation on or in a shower of molten zinc. For reasons already stated, the temperatures of the condensing surfaces in the first stage should be relatively high, and, indeed, the higher the better, provided they are not too high for condensation to take place; and the temperature of the shower of molten zinc in the second stage should be relatively low, and preferably as low as possible having regard to the need to keep the metal fluid and to enable it to be tapped. Thus, the method of condensing zinc vapor in accordance with the invention comprises condensing the vapors in a first zone comprising a baffle-type condenser wherein the condensing surfaces are maintained at a temperature sufficiently high to prevent substantial formation of physical blue powder, and effecting condensation of previously uncondensed zinc vapor in a second zone comprising a splash-type condenser wherein a substantially continuous shower of molten zinc is hurled by centrifugal action in an upward direction with such violence as to provide by itself and its splashing against the confining upper portion of the condenser turbulent sheetlike showers of molten zinc through which the residual zinc vapor-containing gases pass.

In an apparatus for performing the process of this invention, the condensing unit for the first stage of the process may be of the conventional surface-condenser type, but is preferably arranged so that the condensate drains into a bath or pool of molten zinc maintained in the second-stage of condensation. The latter may be carried out in a condensing unit of the rotary type, but the preferred form of the second-stage condensing unit comprises a stationary chamber in which a bath or pool of molten zinc is maintained and which contains one or more mechanical devices for agitating the molten zinc in the pool to produce the spray or shower of molten zinc. The gas inlet of the second stage condensing unit and the gas outlet stack are arranged to ensure that the zinc vapor bearing gases are brought into intimate contact with the molten zinc shower in their passage through the condensing chamber of the second stage unit.

The spray or shower of molten zinc through which the gases are caused to pass may be produced by a number of devices. One method is to cause a rotary paddle-wheel to dip into and agitate a pool of molten zinc so as to produce a spray or shower. All portions of the paddle-wheel and its shaft coming within the condenser are constructed of, or encased in, a material, such as graphite or silicon carbide, that is not attacked by zinc liquid or vapor at the temperature at which the condenser works. The paddle-wheel is enclosed in a chamber having at one end an opening for the admission of the zinc vapor and gases and at the other end an outlet for the gases out of which the zinc has been condensed. The chamber is made of a steel casing, the lid of which is removable, and is lined throughout with bricks or a cement that is not attacked by liquid zinc.

The invention will be better understood from the following description taken in conjunction with the accompanying drawings in which

Fig. 1 is a longitudinal sectional elevation of an apparatus for practicing the invention,

Fig. 2 is a longitudinal sectional elevation of the apparatus with the second stage condensing unit divided into two chambers,

Fig. 3 is transverse sectional elevation of the paddle wheel, and

Figs. 4, 5 and 6 are sectional elevations of modified forms of the paddle wheel.

As illustrated in Fig. 1, the first stage condensing unit may be of the same general construction as the downwardly sloping chamber 10 of the conventional condensers (U. S. Patent 1,873,861) used with continuously operated vertical retorts. It is conveniently of square cross-section and built of flat tiles made of silicon carbide. A cylindrical orifice 11 connects the higher end of this chamber with the source of zinc vapor. Baffles 12 are hung from the roof tiles. The roof tiles and baffles can be removed by hand, thus access can be obtained to any part so that any deposits or accretions can be dislodged and removed by means of suitable rakes or scraping tools.

The downwardly sloping first stage condensing unit leads directly into the second stage condensing unit, which in a preferred forom of construction comprises a stationary chamber 13 containing a rotating paddle-wheel 14 dipping into a pool of molten zinc. The inlet 15 and outlet 16 of this chamber are so located that the gases pass through a spray or shower of molten zinc that is produced by the vanes of the wheel as the latter is rotated at an appropriate speed. The wheel extends across the chamber to within a short distance of each side so as to ensure that the shower extends completely across the chamber. The top holes 17, through which molten zinc is removed, is situated at such a level *a* that the paddle-wheel at all times dips into the molten zinc bath sufficiently to produce the necessary shower of molten zinc. The refractory lining on the bottom of the chamber is made to slope upwards from the floor underneath the paddle-wheel to form a ramp leading to the tap-hole. A rake or scraper can be inserted through the tap-hole to remove any blue powder or dross that has accumulated on the bottom of the chamber. At the lowest level of the bottom of the chamber a drain hole 18 is provided, which is normally kept closed, but enables all the metal to be drained off if necessary. The exhaust stack 19 leaves the chamber at the end opposite to that at which the gases entered. Insulating bricks may be placed round the chamber for controlling the heat loss, and the chamber has a removable lid 20 permitting access thereto for cleaning, etc.

In the first stage of condensation, in the refractory chamber fitted with baffles, no large amount of zinc oxide is formed. Most of the zinc condensed during this stage runs down as a stream of molten metal into the second stage condensing unit. Some globules of liquid or molten zinc will, however, form during the first condensation stage and there is always sufficient carbon dioxide present to react with these droplets and coat them with a film of zinc oxide, by the reaction

$$Zn+CO_2=ZnO+CO$$

This superficial oxide film tends to prevent the droplets coalescing. When these droplets enter the second stage condensing unit, the vigorous scrubbing action to which the gases are subjected by the motion of the paddle-wheel and the resultant spray of molten zinc serves to disrupt the oxide film and allow the droplets to coalesce to form molten zinc.

The gases entering the second stage condensing unit still contain some zinc vapor. They are very rapidly brought into contact with a large superficial area of molten zinc in the form of spray. Consequently the temperature of the gas is brought down very nearly to that of the molten zinc. By varying the amount of insulation, the temperature of the zinc in the condenser can be controlled so that it is only so far above its melting-point as to possess sufficient sensible heat to permit tapping and casting into ingots without premature freezing. By bringing the gas temperature almost down to that of the molten metal, practically complete condensation of zinc vapor is assured. Furthermore, being condensed by cooling by and in contact with molten zinc, most of the zinc vapor probably condenses directly to augment pre-existing drops of molten zinc, and any blue powder formed is converted to coherent molten zinc by the violent mechanical action to which it is subjected.

It should be pointed out that while the use of the present invention prevents the formation of any large amount of blue powder, a small amount of dross or accretions may under certain conditions form in time within the condenser. For instance, although there is never much carbon dioxide, it may be present in small amounts in the gas, and some zinc oxide may be formed in the first, downwardly sloping, portion of the condenser. Some of this zinc oxide is carried forward to the mechanical condenser (second stage condensing unit), where any liquid zinc droplets with which it is associated are largely stripped from it. The zinc oxide, however, is still left as such, and must form some dross or accretions. Accordingly, provision should be made for periodical cleaning. For this reason, the lid of the mechanical condenser may be made removable, so that rakes or scraping tools can be inserted to remove any deposits.

An advantage of this invention when used in combination with continuously operated vertical retorts is that the mechanical condenser can replace the condenser sump now usually fitted to vertical retorts. The downwardly sloping member of the condenser now generally fitted can then be left almost unchanged. Thus the condenser of the present invention can be fitted onto existing vertical retorts within the floor space now allocated to the conventional type condenser without modification of the foundations or buildings.

As already mentioned, this invention is intended only for use when the zinc content of the gases is high and the carbon dioxide content low. With but little carbon dioxide present, there is no pressing need to take steps to avoid oxidation during the first stage of condensation; the loss as actual zinc oxide is small and the mechanical condenser through which the gases subsequently pass ensures that any droplets of zinc which may form round the zinc oxide particles are converted to coherent liquid zinc and are not collected as blue powder.

In order to effect as complete condensation as possible, it is desirable to cool the gases to a temperature below that at which liquid zinc can be conveniently tapped for casting into ingots. According to a feature of the invention, this is achieved by conducting the second stage of condensation in two phases in the first of which a higher temperature is maintained than in the second and through which the zinc vapor bearing gases and the condensed molten zinc flow countercurrently. This feature of the invention may be conveniently carried out by constructing the second stage condensing unit with two chambers or compartments 21 and 22 (Fig. 2), each containing a rotary paddle-wheel 14 or other mechanism for producing a shower or spray of molten zinc, the gases passing from one to the other. The tap hole 23 is situated in the compartment 21 into which the gas enters first, and the heat insulation round this compartment is so controlled that the metal leaves the tap hole at a suitable temperature. It is impracticable to have to tap metal at a temperature only just above its melting point, and it is generally considered convenient to have molten zinc leave the condenser at least above 500° C. In the other condensing compartment 22, where the stack 19 for the exhaust gases is situated, the heat insulation is so adjusted that the temperature is only slightly above the melting point of zinc, and as zinc is condensed in this compartment, it forms a pool there, and then flows over a weir 24 into the other condensing compartment. Each compartment 21 and 22 has a removable lid 25 and a drain hole 26.

With the mechanical condenser the temperature of the gases can be reduced very nearly to that of the liquid metal. The vapor pressure of zinc is such that if the gas entering the condensing chamber contains only about 5% zinc, and the gases leaving the chamber are saturated with zinc at somewhat over 500° C., an appreciable fraction of the zinc is lost. By using two condensing compartments, with molten zinc and zinc vapor bearing gases flowing in countercurrent, the zinc vapor can be condensed till the gas leaving is saturated with zinc vapor at a temperature not greatly in excess of 420° C., while the molten metal can still be tapped off at above 500° C.

The paddle-wheel or mechanized rotor referred to can have a variety of forms in all of which it is designed to dip beneath the surface *a* of the pool of molten zinc and by mechanical agitation produce a shower or spray of molten zinc in the condensing chamber of the second stage condensing unit. It may consist of a drum with projecting paddles, which may be shrouded by end flanges. Alternatively, it may have a saw-tooth profile. Furthermore, the depth of the projections, and the number of them disposed around the circumference, may be varied. In one case, which may be of importance, a notched, fluted, or grooved roller is used; in this case there will be numerous indentations or, alternatively regarded, very numerous teeth, all of small size. Whatever type of rotating apparatus is employed, it is advisable to cool the glands through which the shaft is introduced into the condenser by means of water. There is serious risk of zinc vapor diffusing to the glands and solidifying there. Arrangements should be made to force a slow stream of gas from the outside through the glands to ensure that no zinc vapor can reach them. A suitable gas for this purpose is one consisting chiefly of carbon monoxide, such as the exhaust condenser gas after it has been scrubbed and cooled.

The mechanized rotor **14** in Figs. 1, 2 and 3 of the drawings has the aforementioned saw-tooth profile **27**. The rotor may conveniently be made of graphite, and is separated from direct contact with the rotatably mounted metal shaft **28** by a sleeve **29** of insulating cement (Fig. 3). The shaft **28** has an axial bore **30** through which flows a cooling medium, such as water. Each end of the rotor has an annular end flange **31** whose outside diameter is the same as the outside diameter of the saw-tooth profile **27**. The rotor has a laterally extending sleeve **32** at each end thereof surrounding the cement sleeve **29** where the later extends through the side walls **33** of the condenser. The outer ends of the concentric sleeves **29** and **32** are enclosed in a gas seal comprising a stationary cap **34** held tightly against the condenser wall by a gland bushing **35** through which the shaft **28** extends. A suitable gas, such as the exhaust condenser gas after it has been scrubbed and cooled, is forced into the cap **34** through a pipe **36** to ensure that no zinc vapor diffuses into and freezes between the openings in the condenser walls through which the rotor sleeves **32** extend.

The rotor shown in Fig. 4 is a metal drum **37** with projecting paddles **38** and circular ends **39**. The drum is carried on the cement sleeve **29** by the ends **39** which are of sufficient diameter to shroud the paddles **38**.

The rotor **40** shown in Fig. 5 is a cylinder of graphite or the like with its cylindrical surface notched with numerous teeth **41**. The rotor **42** shown in Fig. 6 has a plurality of circumferentially spaced pockets or cups **43** which, rotating in the direction indicated by the arrow, pick up and throw into the condensing chamber small amounts of molten zinc in rapid succession, thereby producing an effective shower of molten zinc within the chamber. The rotors **40** and **42** have shrouding end flanges similar to the end flanges of rotors **14** and **37**.

The condensing chambers or compartments **13**, **21** and **22** are provided at each end with depending baffles **44** for forcing the zinc vapor bearing gases to pass through the cloud of metal spray set up by the rotor. The rotor **14** in the chamber **13** rotates counterclockwise, as viewed in Fig. 1 and as indicated by the arrow, so that the small amounts of molten zinc picked-up by the saw-tooth profile are thrown upwardly against the roof of the chamber and the baffle **44** adjacent the gas inlet **15**. The rotor **14** in the chamber **21** similarly rotates counterclockwise as viewed in Fig. 2 and as indicated by the arrow. The rotor **14** in chamber **22**, however, rotates clockwise, as indicated by the arrow, so that the small amounts of molten zinc picked-up by the saw tooth profile are thrown upwardly toward the baffle **44** adjacent the gas outlet **16**, to provide an effective cloud of metal spray for condensing the last traces of zinc vapor in the gases as they leave the chamber **22**.

The process of this invention may also include the step of condensing residual zinc from the gases exhausted through the stack in the form of blue powder and allowing this blue powder to fall into the mechanical condenser for recovery as liquid metal, and the apparatus according to this invention may be constructed to enable this step to be performed, as described in the specification of the copending British patent application No. 7621/46, Stack condensation of blue powder.

I claim:

1. In the method of condensing zinc vapor in which zinc vapor bearing gases are condensed in a first zone comprising a baffle-type condenser, and the residual zinc vapor bearing gases and molten zinc are passed into a second zone within a chamber wherein the molten zinc collects in a pool, the improvement which comprises condensing zinc vapor in said first zone while maintaining the condensing surfaces in said zone at a temperature sufficiently high to prevent substantial formation of physical blue powder, and effecting in said second zone condensation of previously uncondensed zinc vapor in said gases by hurling by centrifugal action a substantially continuous and upwardly-directed shower of said molten zinc of such violence as to provide by itself and by its splashing against the confining upper portion of the chamber turbulent sheet-like showers of molten zinc through which said zinc vapor-containing gases pass, the condensation in said second condensing zone being conducted in two phases having separate pools of molten zinc which communicate with one another, the molten zinc in the pool of the first phase being maintained at a temperature of at least about 500° C. to permit tapping of the molten metal therefrom and the temperature of the molten zinc in the pool of the second phase being maintained approximate the melting point thereof, causing the zinc vapor bearing gases and the condensed molten zinc to flow countercurrently through the two phases, tapping molten zinc from the pool thereof in the first phase, and withdrawing uncondensed gases from the second phase.

2. In the condensation of zinc vapor in which zinc vapor bearing gases are passed through a shower of molten zinc thrown upwardly from a body thereof within a condensing chamber, the

improvement which comprises conducting the condensation in two phases having separate bodies of molten zinc which communicate with one another, the temperature of the molten zinc in the body thereof in the first phase being maintained sufficiently high to permit tapping of the molten metal therefrom and the temperature of the molten zinc in the body thereof in the second phase being maintained approximate the melting point thereof, hurling by centrifugal action a substantially continuous and upwardly-directed shower of molten zinc from each body thereof of such violence as to provide by itself and by its splashing against the confining upper portion of the chamber turbulent sheet-like showers of molten zinc through which said gases pass, causing the zinc vapor bearing gases and the condensed molten zinc to flow counter-currently through the two phases, tapping molten

zinc from the body thereof in the first phase, and withdrawing uncondensed gases from the second phase.

STANLEY ROBSON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,873,861	Bunce	Aug. 23, 1932
2,348,194	Crane et al.	May 9, 1944
2,381,405	Griswold	Aug. 7, 1945

FOREIGN PATENTS

Number	Country	Date
55,473	Sweden	May 24, 1922