March 12, 1935. P. McL. GINDER ET AL 1,994,349

PURIFYING ZINC METAL

Filed July 2, 1932 2 Sheets-Sheet 1

Fig. 1,

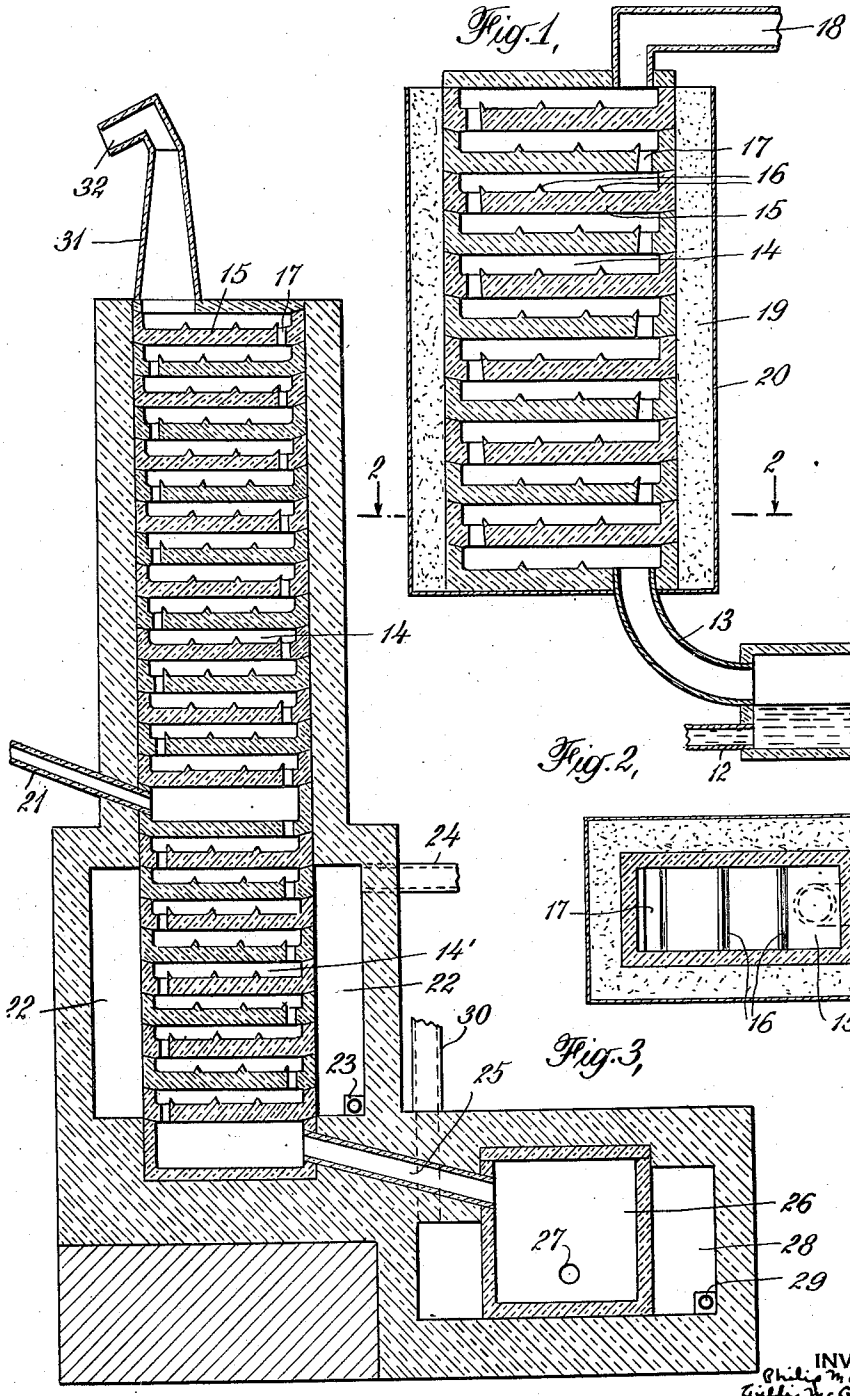


Fig. 2,

Fig. 3,

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Filed July 2, 1932 2 Sheets-Sheet 2

Fig. 4.

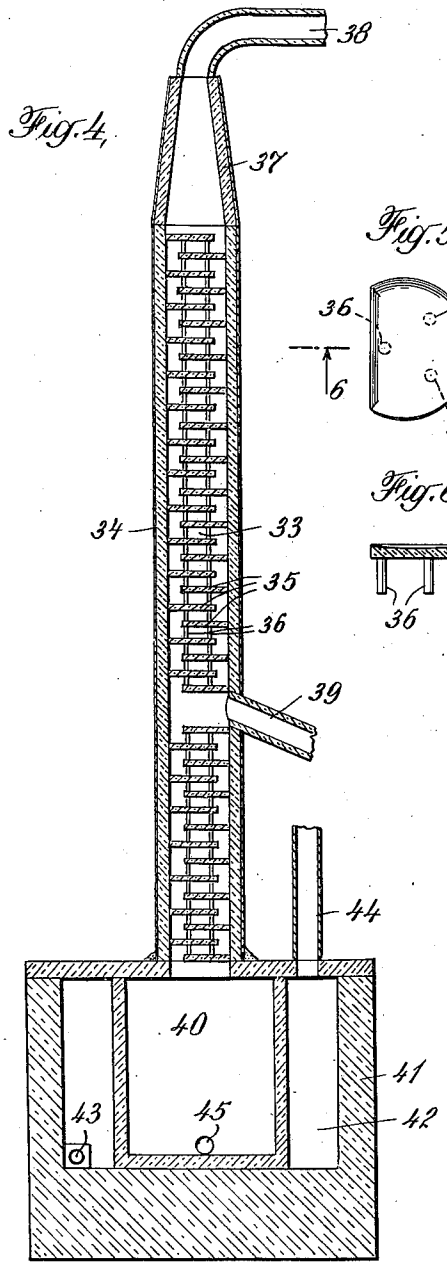


Fig. 5.

Fig. 6.

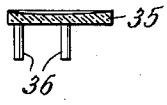


Fig. 7.

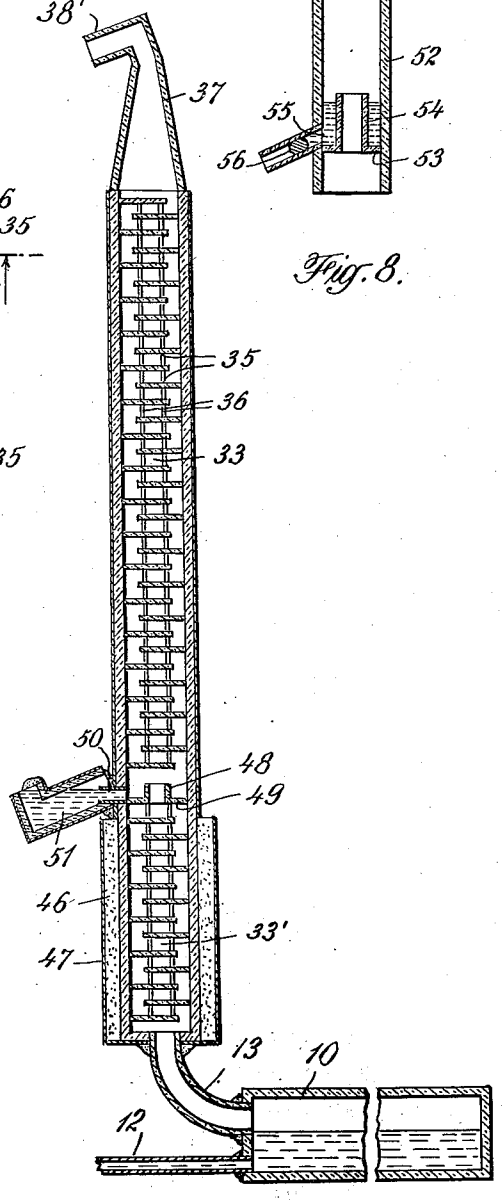


Fig. 8.

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UNITED STATES PATENT OFFICE

1,994,349

PURIFYING ZINC METAL

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Application July 2, 1932, Serial No. 620,634

16 Claims. (Cl. 75—28)

This invention relates to purifying zinc metal or zinc vapor contaminated with a metal whose boiling temperature is lower than that of zinc, and has for its object the provision of an improved method of purifying such zinc metal or zinc vapor. The invention aims particularly to provide an improved method of producing relatively pure zinc from zinc contaminated with a metal whose boiling point is below that of zinc, such, for example, as cadmium. More specifically, the invention aims to provide an improved method of distilling cadmium-bearing zinc metal for the purpose of decreasing or substantially eliminating the cadmium content thereof.

Ordinary commercial zinc metal is commonly contaminated with small and variable amounts of cadmium, for instance, 0.25% cadmium. The presence of cadmium in even such small amounts is highly disadvantageous when the zinc is to be used for certain purposes, as, for example, in compounding zinc base die-casting alloys. Zinc appropriate for use in compounding such alloys should in many cases not contain over 0.005% cadmium. The purification of zinc containing 0.25% cadmium involves the removal of 98% of the cadmium to produce zinc metal containing only 0.005% cadmium. Even where the zinc metal contains as little as 0.05% cadmium, 90% of the cadmium must be removed to bring the cadmium content down to 0.005%.

It has heretofore been proposed to purify zinc metal from cadmium by taking advantage of the fact that the vapor pressure of cadmium (the boiling point of which is about 767° C.) is greater than that of zinc (the boiling point of which is about 905° C.). These proposals have been generally directed to simple distillation of the zinc metal or to partial condensation of zinc vapor contaminated with cadmium. When cadmium-bearing zinc is distilled, the vapor evolved contains a higher percentage of cadmium than the molten metal so that as distillation progresses the percentage of cadmium in the molten metal becomes less. However, this method has the serious disadvantage that a large fraction of the zinc must be distilled off and collected as metal with a higher cadmium content than the original zinc metal if the latter is to be purified to any great extent from the cadmium. In the heretofore proposed practices of partial condensation, a fraction relatively free from cadmium is obtained from zinc vapor contaminated with cadmium by condensing only part of the vapor in a condenser. The fraction that condenses first from zinc vapor contaminated with cadmium contains less cadmium than the vapor, so that such condensed fraction is relatively purer than the original zinc metal. This practice has the same disadvantage as that of simple distillation, since the purified fraction recovered is much less than the zinc originally treated, and the further disadvantage that purification is limited to the cadmium content of the molten metal that initially condenses from the vapor.

The present invention utilizes the principle of fractional distillation in a rectifying column for removing cadmium from zinc. We have discovered that zinc-cadmium alloys, at least in the concentration range of ordinary commercial zinc metal, have no maximum boiling point and no minimum boiling point. In other words, in this range of concentration, the vapor evolved from the molten zinc-cadmium alloy contains a higher percentage of cadmium than the molten metal, and the molten metal condensed from the vapor contains a higher percentage of zinc than the vapor. This fact makes it possible to carry out a substantially complete separation of zinc and cadmium by using the principle of a rectifying column, even when the amount of cadmium originally present in the zinc metal as little as 0.25% or even a fraction of this figure.

The characteristic feature of the method of the present invention is a countercurrent flow of vapor and liquid molten metal, so conducted that the vapor moves through a descending temperature gradient (that is, an environment of decreasing temperature) in contact with molten metal moving in the opposite direction and therefore through an ascending temperature gradient (that is, an environment of increasing temperature). Thus, the invention is characterized by a countercurrent flow of molten metal and vapor under spontaneously established thermal conditions such that the vapor moves towards the cooler portion of the system and the molten metal moves towards the hotter portion of the system. The consequence of this countercurrent movement of contacting vapor and molten metal, the vapor moving through a descending temperature gradient and the molten metal moving through the corresponding ascending temperature gradient, is the separation of a large proportion of the cadmium (and/or other contaminating metal or metals with lower boiling points than zinc) mixed with a greatly decreased proportion of zinc and the production of molten zinc with a greatly decreased cadmium content, in an amount equaling a large proportion of the original zinc metal treated.

The molten zinc metal is preferably caused to flow gradually downward by gravity through an environment of gradually increasing temperature, its flow being impeded and delayed by baffles or the like, preferably of such form as to retain small pools or films of molten metal at various temperature levels. The metallic vapor ascends in reverse direction to the molten metal, its flow being impeded by the metal-covered baffles and the descending molten metal whereby the vapor

comes into intimate contact with the molten metal. Multi-stage or repeated condensation of the ascending vapor and revolatilization of molten metal take place at various temperature levels throughout the environment, such temperature levels being established by the transverse baffles, plates, or the like.

The temperature gradient contemplated by the invention may advantageously be embodied in a fractionating or rectifying column where the required temperature gradient is spontaneously established and maintained by the contacting molten metal and vapor of progressively varying compositions with respect to zinc and the contaminating metal. Theoretically, the loss of heat from the outer surface of the column should be nil. In practice, the optimum operating condition is realized by minimizing as far as practical the dissipation or loss of heat from the outer surface of the column, as, for example, by thoroughly heat insulating the column throughout its length. Since the boiling points of the molten metal and the dew points of the contacting vapor automatically become progressively lower towards the top of the column, the proper temperature gradient is thereby secured throughout the entire column. Where the purification of the zinc metal is to be carried further than secured by the first fractional condensation of the metallic vapor entering the column, heat must be appropriately supplied to the bottom of the column.

In a rectifying column operated in the aforesaid manner, the descending molten mixture of zinc and cadmium (or the like), of progressively varying composition, is evaporated as it descends, and is replaced by an equivalent amount of molten metal condensed from the ascending vapor. The heat of condensation liberated by the condensing metal serves to re-evaporate metal at the levels at which the condensation occurs and this re-evaporated metal contains more cadmium than the molten metal from which it originates. The net effect of this is to utilize the heat of condensation of the zinc vapor to evaporate cadmium from the condensed mixture of zinc and cadmium. In this way the ascending metal vapor becomes progressively enriched in cadmium while the descending molten metal is progressively freed from cadmium.

The invention may be carried out in various forms and types of apparatus. We have illustrated in the accompanying drawings certain apparatus adapted for the practice of the invention. The apparatus shown in the drawings are merely illustrative of certain practical applications of the invention and are not to be regarded as restricting the invention. In the drawings

Fig. 1 is a sectional elevation of an apparatus for refining molten zinc contaminated with cadmium, or the like, in accordance with the invention,

Fig. 2 is a section on the line 2—2 of Fig. 1,

Fig. 3 is a sectional elevation of an apparatus for refining zinc metal in a continuous process,

Fig. 4 is a sectional elevation of an apparatus for refining zinc vapor,

Figs. 5 and 6 are detailed views of the transverse plates or baffles in the apparatus of Fig. 4,

Fig. 7 is a sectional elevation of an apparatus for practicing the present invention in conjunction with the method of lead elimination described in the copending application of Messrs. Holstein and Ginder, Serial No. 540,566, filed May 28, 1931, and

Fig. 8 illustrates a dephlegmator adapted for use with the apparatus of Figs. 1, 3, 4 and 7.

Referring to Fig. 1 of the drawings, there is shown a retort 10 for volatilizing metallic zinc, mounted in an appropriate heating furnace of conventional construction (not shown). Molten zinc metal contaminated with cadmium (or other metal of lower boiling temperature than zinc) is charged into the retort through a connection 12 leading to a charging well (not shown) as well as to a tap hole (not shown) through which the purified molten zinc can be tapped out of the retort after its cadmium content has been reduced to the desired extent. A vapor conduit or pipe 13 connects the retort 10 with the bottom of the rectifying column 14. The rectifying column 14 consists of a tube of silicon carbide, or other appropriate refractory material, of rectangular cross section provided with spaced and superposed horizontal baffle plates 15. The baffle plates have transverse ribs 16 on their upper surface and are provided with openings 17 in staggered relation.

The volatilized zinc metal (to be purified) enters the bottom of the rectifying column and passes through the staggered openings 17 at the ends of the baffle plates and thus ascends the column in zig-zag fashion. The molten metal condensing from the vapor is in part retained in shallow pools on the upper surface of the baffles 15 by the ribs 16, the overflow descending in zig-zag fashion through the column. The residual vapor, containing the cadmium-rich distillate, escapes through an outlet 18 to a suitable collecting device therefor, such as a condenser for collecting metallic cadmium or a cadmium-rich zinc alloy, or a prolong for collecting cadmium-rich zinc dust, or a device for burning the vapor to cadmium oxide or a mixture of cadmium oxide and zinc oxide.

The rectifying column 14 is surrounded by appropriate heat insulation 19 confined in place by a steel casing 20. Refuse zinc oxide is a suitable insulating material. In the operation of the apparatus, the cadmium vapor expelled from the cadmium-contaminated zinc metal in the retort 10 is progressively enriched by fractional distillation as it ascends through the rectifying column 14. It is preferable in such an operation to prevent the escape of heat from the column as effectively as possible, except at the very top. In such a case the top of the column acts as a dephlegmator, condensing the metallic vapor ascending through the column and returning it to the baffle plates of the column to be refined from cadmium by the principle of fractional distillation. The cadmium-rich product may be removed from such a column in vapor form by a vapor outlet at the top; in which case the dephlegmator is operated so as not to condense all of the metallic vapor. The cadmium-rich product may be removed as molten cadmium-rich zinc alloy by completely condensing the vapor at the top of the column, and tapping out an appropriate fraction of the condensate.

After the cadmium has been eliminated, the refined zinc metal is tapped out of the retort through the connection 12 leading to the tap hole, and the retort is then recharged with zinc contaminated with cadmium.

The apparatus of Fig. 3 of the drawings is adapted for the continuous refining of molten zinc metal by the process of the invention. The molten zinc metal to be freed from cadmium (or the like) is charged into the base of the rectifying column 14 through a tube 21 communicating with an

appropriate charging well or equivalent feeding means (not shown). The molten metal may be charged continuously or in small batches at frequent intervals. The rectifying column has a downward extension 14' of similar construction, but surrounded by a combustion chamber or heating laboratory 22, provided with a fuel gas burner 23 and a flue 24 for the escape of exhaust combustion gases. The lower extension 14' communicates at its base, through a conduit 25, with a molten metal sump 26, provided with a tap hole 27 and externally heated by a combustion chamber 28 having a burner 29 and a stack 30 for the escape of exhaust combustion gases.

The rectifying column 14 is surmounted by a dephlegmator in the form of a cone 31 of silicon carbide or other material of good heat conductivity and inert to zinc and cadmium vapors. The upper portion of the cone 31 is connected through a pipe 32 to an appropriate cadmium-collecting device (not shown).

The molten zinc metal to be refined enters the apparatus through the tube 21 at a point between the upper heat insulated rectifying column 14 and the lower externally heated extension 14'. The firing of the combustion chambers 22 and 28 is so adjusted and regulated as to rectify continuously the mixture of zinc and cadmium entering the apparatus through the feed pipe 21. A cadmium-rich zinc vapor escapes from the outlet 32, while refined zinc metal (that is, zinc metal with greatly decreased cadmium content) is tapped from the sump 26 through the tap hole 27.

In Fig. 4 of the drawings the rectifying column comprises a cylindrical tube 33, of clay or other refractory of moderate heat conductivity, surrounded by heat insulation 34 and provided with spaced and superimposed baffles 35 in the form of saucer plates. The saucer plates (Figs. 5 and 6) are circular with a segment cut-away and have a recessed or dished upper surface so as to retain shallow pools of molten metal thereon. Three pins 36 depend from the lower side of each saucer plate and serve to support and properly space the superimposed plates. The saucer plates are arranged with their cut-away segments staggered to provide a tortuous or zig-zag path for the countercurrently flowing vapor and molten metal.

The rectifying column 33 is surmounted by a cone 37 of silicon carbide or equivalent material. The cone 37 has an outlet 38 communicating with an appropriate device (not shown) for collecting cadmium-rich vapor escaping from the top of the rectifying column.

Zinc metal vapor to be purified enters the rectifying column 34 at a point some distance above the bottom thereof through a connection 39 communicating with a retort (not shown) in which zinc metal contaminated with cadmium (or the like) is being volatilized. The zinc metal vapor begins to condense at the point of its introduction into the rectifying column and establishes at that point a temperature corresponding to its own dew point and to the boiling point of the metal that condenses from it. This condensed metal contains less cadmium than the vapor from which it originates. The metal condensed at this point tends to flow down over the plates 35 located in that part of the rectifying column below the connection 39. Heat is supplied to this lower part of the rectifying column by an externally heated molten metal sump 40 appropriately constructed and positioned to collect molten metal flowing from the rectifying column. The sump 40 is surrounded by a furnace structure 41 embodying a combustion chamber 42 heated by a fuel burner 43 and having a stack 44 for discharging the exhaust combustion gases. The sump 40 has a tap hole 45 through which purified zinc metal is withdrawn.

The apparatus of Fig. 4 is so operated that the cone 37 (of silicon carbide or other suitable refractory material of good heat conductivity) acts as a dephlegmator, that is to say it condenses all but a cadmium-rich fraction of the vapor and returns the condensate to the rectifying column for the further removal of cadmium therefrom.

The method of the invention may, if desired, be advantageously carried out in conjunction with the method of removing contaminating metals of higher boiling temperatures than zinc (such as lead) as described in the copending application of Messrs. Holstein and Ginder Serial No. 540,566 filed May 28, 1931. An apparatus for the conjoint practice of these two methods is shown in Fig. 7 of the accompanying drawings. The apparatus of Fig. 7 comprises a retort 10 equipped with a connection 12 leading to a charging well and a tap hole as in the apparatus of Fig. 1. The retort 10, of Fig. 7, is charged with the zinc metal to be refined containing both cadmium and lead, or equivalent metals. The molten metal withdrawn from the retort 10 through the tap hole is not purified zinc metal in the apparatus of Fig. 7, but is a residue consisting of some residual zinc and the other metals with boiling points higher than zinc with which the original zinc metal was contaminated, as will be better understood from the following description.

The retort 10, of Fig. 7, is connected by a pipe 13 to the bottom of the refluxing or rectifying column 33', operating to remove lead and other metals with boiling points higher than that of zinc in accordance with the method of the aforementioned patent application. The refluxing column 33' is surmounted by a rectifying column 33, the two columns being advantageously of similar construction containing spaced superposed staggered saucer plates 35 of the same general type and construction as illustrated in Figs. 4, 5 and 6 of the drawings. The refluxing column 33' is surrounded by appropriate heat insulation 46 held in place by a steel casing 47.

Volatilized zinc metal from the retort 10 flows upwardly through the refluxing column 33' in contact with downwardly flowing molten metal containing a higher percentage of lead than the metallic vapor. On leaving the top of the refluxing column 33', the metallic vapor has been deprived of all contaminants (such as lead) with boiling points exceeding that of zinc. The chief remaining impurity in the metallic vapor is generally cadmium. The metallic vapor enters the bottom of the rectifying column 33 through a nozzle 48 supported by a transverse annular plate 49 separating the reflux column 33' from the rectifying column 33.

The rectifying column 33, of the apparatus of Fig. 7, is operated to eliminate cadmium (or the like) in the manner hereinbefore described. The molten zinc metal freed from cadmium descending the column 33 is caught in the annular sump formed at the bottom of the column by the plate 49 and the nozzle 48, whence it escapes continuously through an opening 50 into a sump 51, from which it is tapped or ladled out at appropriate intervals.

It will be desirable in many cases to supply external heat to the lower portion of the cadmium

rectifying column 33. This may be done by appropriately lengthening the column and applying external heat at the lower portion thereof, as for example, by a combustion chamber surrounding the lower portion of the column, similar to the combustion chamber 22 surrounding the downward extension 14' of the rectifying column shown in Fig. 3 of the drawings.

In case it is desired to condense all of the metallic vapor in the dephlegmator, and remove the cadmium from the apparatus in the form of molten cadmium-rich alloy instead of cadmium-rich vapor, a closed dephlegmator, such as shown in Fig. 8, may be substituted for the cones and vapor outlets 37—38' of Fig. 7, 37—38 of Fig. 4, 31—32 of Fig. 3, and the vapor outlet 18 of Fig. 1. The closed dephlegmator of Fig. 8 comprises a cylinder 52, of suitable refractory material, closed at its top and having near its bottom a transverse annular plate 53. A nozzle 54 registers with the circular opening in the plate 53 and extends upwardly to provide a molten metal collecting well or sump 55. The metallic vapor ascending into the closed dephlegmator from the rectifying column is condensed, and collects in the well 55. The overflow of molten metal from the well 55 returns to the rectifying column, where it is rectified. Cadmium-rich molten metal is removed from the apparatus by tapping off appropriate amounts thereof collecting in the well 55, by means of a tap hole 56.

The following results have been obtained in the practical operation of the invention in an apparatus of the type shown in Fig. 4, in which the sump and likewise the lower portion (3 feet) of the rectifying column were externally heated. The column 33 was eight inches in internal diameter and contained fifty-seven saucer plates 35. The vapor inlet 39 was about five feet from the bottom of the column.

Operating data on cadmium elimination where external heat was applied to the lower part of the column

1. Heat applied to maintain a combustion chamber temperature of 910° C. around the sump

Cd in metal charged, per cent	0.47
Metal recovered from bottom of column per day, pounds	1602
Metal recovered from top of column per day, pounds	20
Estimated fume loss at top of column per day, pounds	20
Recovery of purified zinc, per cent	97.6

	Per cent
Cd in purified zinc	0.0135
Cd elimination	97.1

2. Heat applied to maintain a combustion chamber temperature of 950° C. around the sump.

Cd in metal charged, per cent	0.46
Metal recovered from bottom of column per day, pounds	1557
Metal recovered from top of column per day, pounds	36
Estimated fume loss at top of column per day, pounds	30
Recovery of purified zinc, per cent	95.9

	Per cent
Cd in purified zinc	0.0041
Cd in drip metal from top of column	7.8
Cd in fume from top of column	12.2
Cd elimination	99.1

3. Heat applied to maintain a combustion chamber temperature of 975° C. around the sump.

Cd in metal charged, per cent	0.47
Metal recovered from bottom of column per day, pounds	1600
Metal recovered from top of column per day, pounds	20
Estimated fume loss at top of column per day, pounds	20
Recovery of purified zinc, per cent	97.6

	Per cent
Cd in purified zinc	0.0013
Cd elimination	99.723

In case external heat is not applied to the column, or an equivalent step practiced, such high cadmium elimination cannot be obtained. In this case the minimum cadmium content that can be secured is the concentration of cadmium in the molten metal which is in equilibrium with the vapor entering the apparatus so that with respect to purity of the zinc product obtained this method of operating the process of the invention does not excel the methods heretofore practiced in which zinc with decreased cadmium content has been obtained by one step of partial condensation. However, by the practice of the invention, yields (that is, percentages of purified product on the basis of impure metal treated) are secured greatly exceeding those secured in any previous method of partial condensation, since the zinc vapor is subjected to multi-stage condensation and revolatilization until the cadmium is concentrated in a cadmium-rich vapor at the top of the column, and the bulk of the zinc is returned to the bottom of the column with a cadmium content lower than that of the zinc vapor entering the bottom of the column. In this modification of the invention, economy is secured by eliminating the necessity of supplying heat from an external source to the base of the column. This method is particularly applicable to the further refining of zinc that initially contains a very low cadmium content; and is also of advantage where an economical method of removing part of the cadmium content of zinc metal with high yield of purified zinc and consequent low cost is desired. The column in this case (as in the case where external heat is supplied to the base of the column) may be so operated as to discharge relatively pure cadmium vapor at the top and purified zinc at the bottom, the purified zinc containing substantially all of the zinc in the metal originally treated.

Examples of purifying zinc metal from cadmium by this modification of the method of the invention are given below:

Operating data on cadmium elimination where no external heat was applied to the bottom of the column (continuous operation)

a. Run with 0.22 per cent Cd in zinc charged.

Purified metal recovered from column per day, pounds	1722
Estimated metal and fume loss from top of column per day, pounds	40
Recovery of purified zinc, per cent	97.7

	Per cent
Cd in purified zinc	0.033
Cd elimination	85

b. Run with 0.43 per cent Cd in zinc charged.

Purified metal recovered from column per day—pounds	1770
Estimated metal and fume loss from top of column per day—pounds	40
Recovery of purified zinc—per cent	97.8
	Per cent
Cd in purified zinc	0.09
Cd elimination	79

In continuous operation without application of external heat to the base of the column, the degree of purification secured can be carried beyond the purity of the molten metal in equilibrium with the vapor evolved from the zinc metal originally charged by practicing a step equivalent to the application of external heat, as hereinbefore indicated. For example, part of the metal collecting at the base of the rectifying column may be permitted to flow back into the volatilizing retort, where it is revolatilized. Since the revolatilization of this purified metal dilutes the cadmium content of the metallic vapor entering the base of the rectifying column, the purity of the metal in equilibrium with said vapor is increased. In operating in this manner purified metal may be tapped from the base of the column, or from the retort, and an appropriate amount of impure zinc metal is introduced into the retort. Such a method of operating can be carried out with relatively simple apparatus, but involves a substantial increase in heat-consumption, on account of the re-evaporation of the metal fed back to the retort; more metal must be re-evaporated in this method to secure the desired degree of purity than when the re-evaporation occurs in a separate sump connected with the base of the rectifying column; because the metal re-evaporated in the retort is contaminated with the impure zinc metal charged into the retort.

As will be apparent from the foregoing examples, the invention permits of the elimination of cadmium from zinc to a much greater degree than the methods heretofore practiced and/or secures a higher yield of purified zinc metal. As will be apparent from the discussion above, the degree of purification obtained in the process depends on the number of re-evaporations on the baffles in the rectifying column, and on the amount of reflux. Various modifications can be made in practical operations without sacrificing the advantages and without departing from the spirit of the invention.

We claim:

1. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises passing metallic vapor derived from said zinc metal through a decreasing temperature gradient established by repeated condensation of vapor and revolatilization of molten metal which flows back through the temperature gradient toward the higher temperature end thereof in contact with countercurrently flowing vapor, and recovering purified zinc metal from the high temperature end of the gradient and removing the contaminating metal from the low temperature end of the gradient.

2. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises subjecting countercurrently flowing vapor derived from said zinc metal and molten metal condensed from said vapor to multi-stage condensation of vapor and revolatilization of molten metal at different temperature levels with the vapor moving towards the low temperature level and the molten metal moving towards the high temperature level, and recovering purified zinc metal from the high temperature end of the gradient and removing the contaminating metal from the low temperature end of the gradient.

3. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises subjecting ascending metallic vapor derived from said zinc metal in contact with countercurrently flowing molten metal condensed from said vapor to repeated condensation of vapor and revolatilization of molten metal with accompanying progressive enrichment of the ascending vapor in the contaminating metal and corresponding progressive depletion of the descending molten metal in the contaminating metal, and recovering purified zinc metal from the lower end and removing the contaminating metal from the upper end of the environment of contact between said vapor and molten metal.

4. The method of purifying zinc metal containing cadmium which comprises passing vapor derived from said zinc metal in contact with countercurrently flowing molten metal condensed from said vapor through a temperature gradient established by repeated condensation of vapor and revolatilization of molten metal which flows back through the temperature gradient toward the high temperature end thereof, and recovering purified zinc metal from the high temperature end of the gradient and removing cadmium from the low temperature end of the gradient.

5. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises passing the volatilized zinc metal through a temperature gradient established by progressive condensation and re-evaporation of the vapor whereby purified zinc is collected from the high temperature end of the gradient and the metal with boiling temperature lower than that of zinc is removed from the low temperature end of the gradient.

6. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises passing the volatilized zinc metal through a decreasing temperature gradient wherein repeated condensation of vapor and revolatilization of molten metal takes place at various temperature levels accompanied by a flow of molten metal countercurrently to the flow of vapor, and recovering purified zinc metal from the high temperature end of the gradient and removing the contaminating metal from the low temperature end of the gradient.

7. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises maintaining a countercurrent flow of metallic vapor and molten metal through a temperature gradient spontaneously established by repeated condensation of vapor and revolatilization of molten metal at different temperatures, and recovering purified zinc metal from the high temperature end of the gradient and removing the contaminating metal from the low temperature end of the gradient.

8. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises passing vapor derived from said zinc metal upwardly

through a heat-insulated rectifying column wherein multi-stage condensation of vapor and revolatilization of molten metal takes place with accompanying progressive enrichment of the ascending vapor in the contaminating metal and progressive depletion of the descending molten metal in the contaminating metal, supplying heat to the base of said rectifying column, and recovering purified zinc metal from the base of said column and removing the contaminating metal from the top of said column.

9. The method of purifying zinc metal containing cadmium which comprises passing vapor derived from said zinc metal upwardly through a heat-insulated rectifying column wherein multi-stage condensation of vapor and revolatilization of molten metal takes place with accompanying progressive enrichment of the ascending vapor in cadmium and progressive depletion of the descending molten metal in cadmium, and recovering purified zinc metal from the base of said column and removing cadmium from the top of said column.

10. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises subjecting the volatilized zinc metal to fractional distillation in a rectifying column in the course of which the ascending vapor is progressively enriched in the contaminating metal and the descending molten metal is progressively depleted of the contaminating metal, introducing the zinc metal to be purified into the lower end of said column in the form of vapor, and recovering purified zinc metal from the base of said column and removing the contaminating metal from the top of said column.

11. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises subjecting the volatilized zinc metal to fractional distillation in a rectifying column in the course of which the ascending vapor is progressively enriched in the contaminating metal and the descending molten metal is progressively depleted of the contaminating metal, introducing the zinc metal to be purified into the lower end of said column in the form of molten metal, and recovering purified zinc metal from the base of said column and removing the contaminating metal from the top of said column.

12. The method of purifying zinc metal contaminated with a metal whose boiling temperature is lower than that of zinc which comprises subjecting the volatilized zinc metal to fractional distillation in a rectifying column in the course of which the ascending vapor is progressively enriched in the contaminating metal and the descending molten metal is progressively depleted of the contaminating metal, introducing the zinc metal to be purified into the lower end of said column, supplying heat to the lower end of said column, and recovering purified zinc metal from the base of said column and removing the contaminating metal from the top of said column.

13. The method of purifiying zinc metal containing cadmium which comprises subjecting the volatilized zinc metal to fractional distillation in a rectifying column in the course of which the ascending vapor is progressively enriched in cadmium and the descending molten metal is progressively depleted of cadmium, and recovering purified zinc metal from the base of said column and removing cadmium from the top of said column.

14. The method of purifying zinc metal containing cadmium which comprises subjecting the volatilized zinc metal to fractional distillation in a rectifying column in the course of which the ascending vapor is progresively enriched in cadmium and the descending molten metal is progressively depleted of cadmium, suplying heat to the lower end of said column, and recovering purified zinc metal from the base of said column and removing cadmium from the top of said column.

15. The method of purifying zinc contaminated with substances that are more volatile than zinc and do not form with zinc mixtures that have constant boiling points, for example cadmium, comprising passing zinc vapor upwards through a rectifying column in intimate contact with molten metal that is formed by condensation from the ascending zinc vapor and descends through the column in countercurrent with the ascending zinc vapor, and removing purified zinc from the lower end of the column and the contaminating substances, for example, cadmium, from the upper end of the column.

16. The method of treating zinc contaminated with metals having normal boiling points below the boiling point of zinc to effect a separation between the zinc and said contaminating metals which consists in forming a vapor of such contaminated zinc and passing said vapor in countercurrent contact and exchange to a reflux liquid which is composed of the same elements as the impure vapor and in which the mol fraction of zinc is higher than the mol fraction of zinc in said impure vapor.

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