Oct. 9, 1956

H. K. NAJARIAN

2,766,034

CONDENSATION OF METALLIC VAPORS

Filed March 13, 1952

4 Sheets-Sheet 1

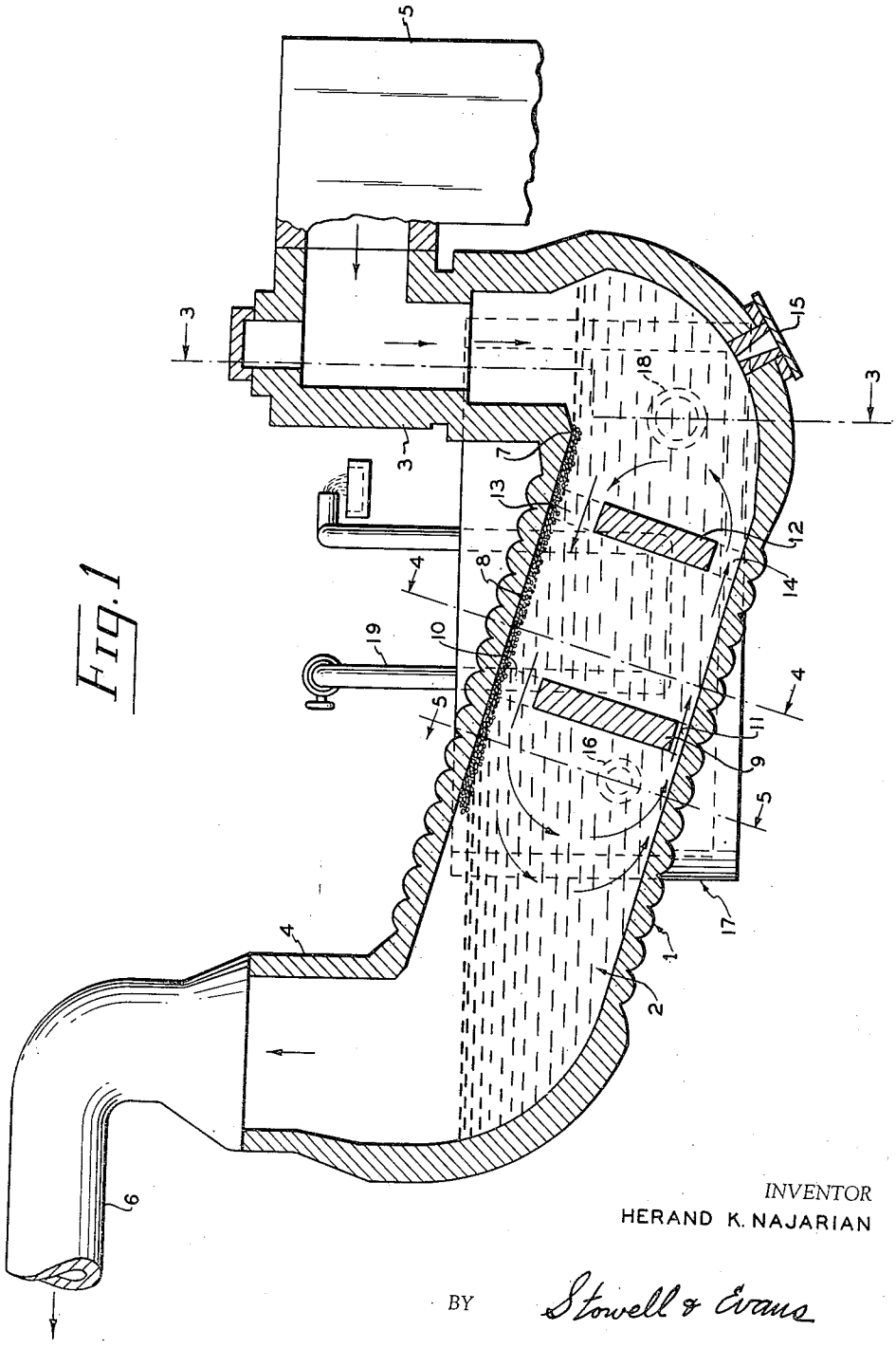


FIG. 1

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4 Sheets-Sheet 2

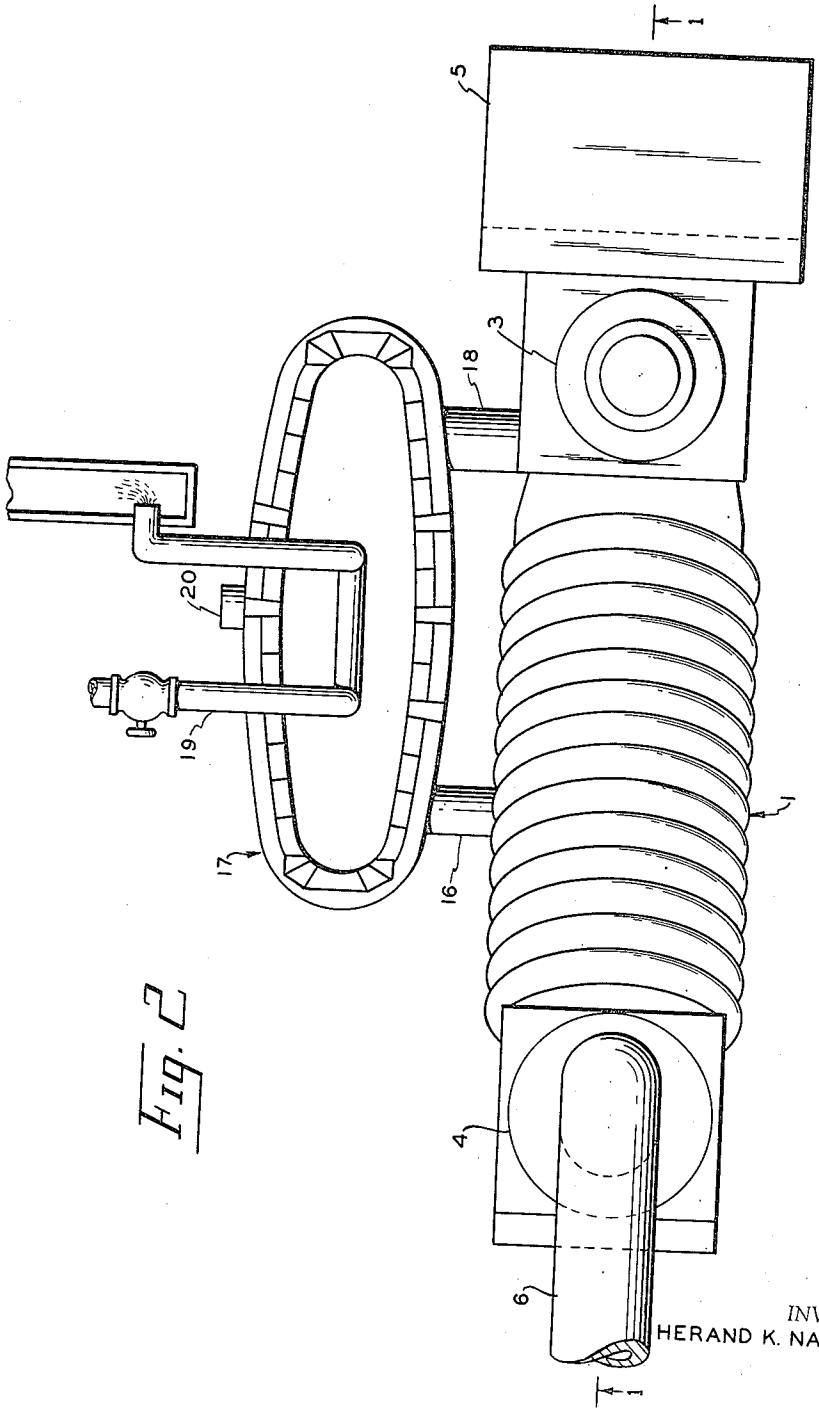


Fig. 2

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4 Sheets-Sheet 3

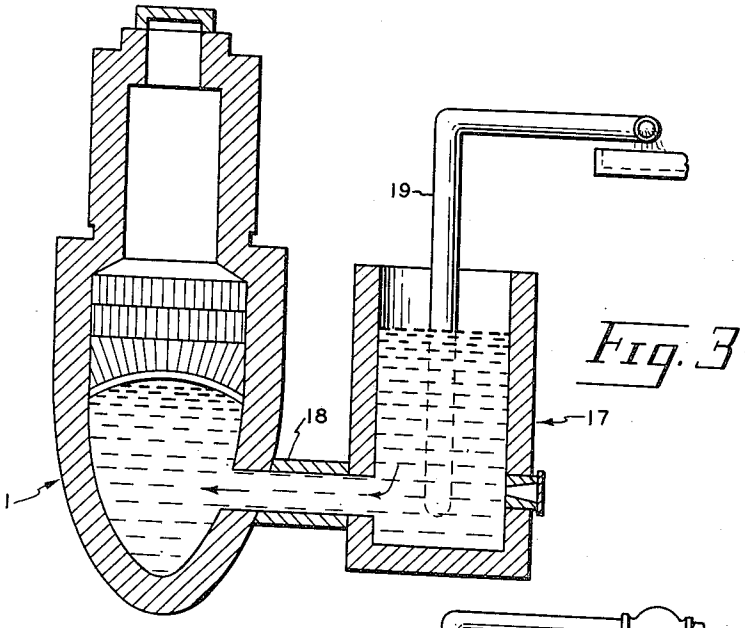


FIG. 3

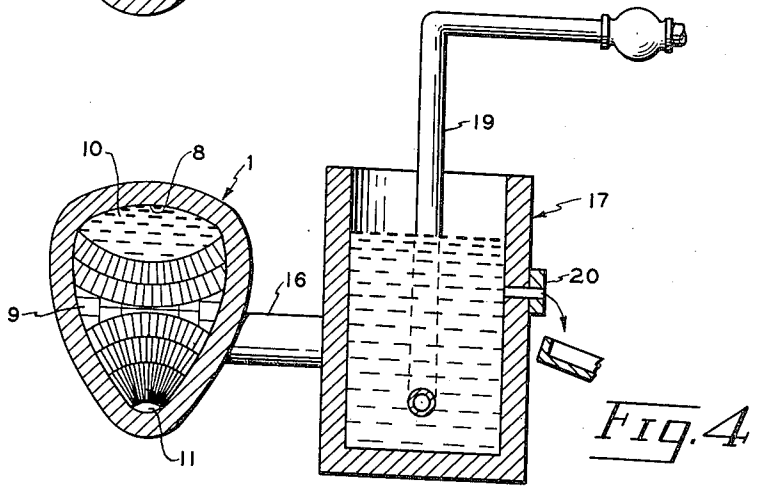


FIG. 4

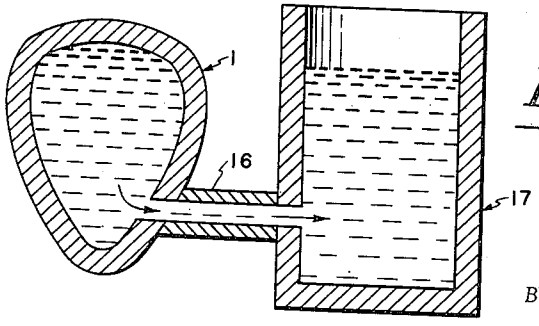


FIG. 5

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CONDENSATION OF METALLIC VAPORS

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4 Sheets-Sheet 4

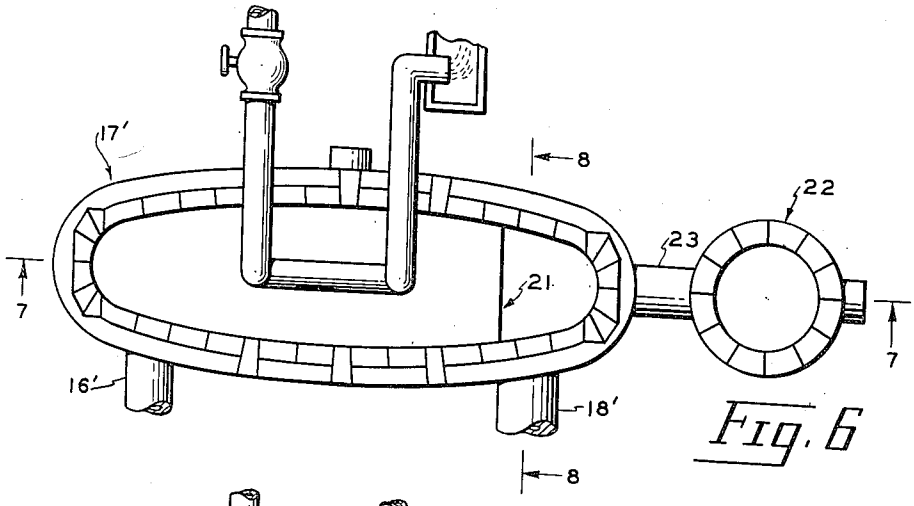


FIG. 6

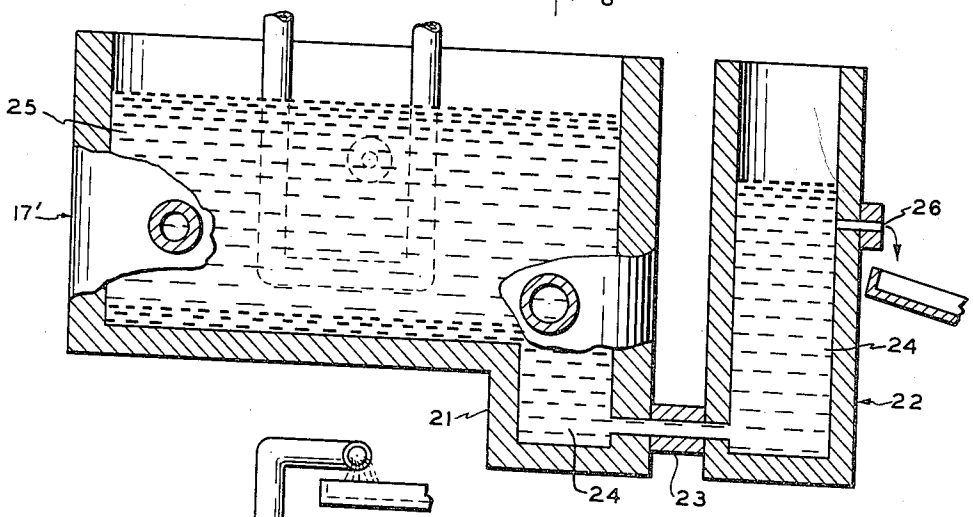


FIG. 7

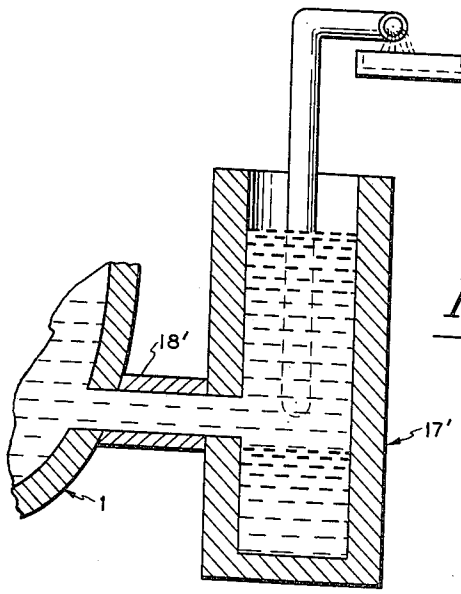


FIG. 8

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United States Patent Office 2,766,034 Patented Oct. 9, 1956

2,766,034

CONDENSATION OF METALLIC VAPORS

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Application March 13, 1952, Serial No. 276,330
7 Claims. (Cl. 266—37)

This invention relates to a method and apparatus for condensation of metallic vapors, particularly zinc, and represents an improvement in the method and apparatus disclosed in U. S. Patent 2,070,101, dated February 9, 1937, George F. Weaton and Herand K. Najarian, "Condensation of Metallic Vapors."

In the above-mentioned U. S. patent, disclosure is made of a method and apparatus whereby condensation of metallic vapors occurs when metallic vapors are passed into a mass of molten metal held in an enclosed receptacle called the "condenser." The metallic vapors and accompanying gases from a reduction furnace bubbling through the mass of molten metal upwardly and forwardly in the upper region of a mass of molten metal contiguous to the roof portion of the condenser induce flow of molten metal concurrently with the bubbling vapor and gases towards the gas outlet end of the condenser. An equivalent amount of molten metal circulates countercurrently at the lower region of the mass of molten metal contiguous to the bottom portion of the condenser. One or more baffles placed crosswise of the condenser serve to reduce the magnitude of surges of metal, and help define the extent of circulation of metal within the condenser. Cooling of the molten metal in the condenser, made necessary by heat given off by condensation of metallic vapors to liquid metal and contact of the hot gases with the molten metal, is accomplished mainly by applying cooling water to the outside steel shell of the condenser. Due to the limited path of circulation of the molten metal within the condenser and a low rate of heat transmission through the refractory lined shell of the condenser, cooling of the molten metal in the condenser by applying cooling water to the outer steel shell of the condenser is not completely satisfactory and the maintenance of optimum operation conditions has been difficult.

The present invention relates particularly to an improved method and apparatus whereby the flow of molten metal concurrent to the metallic vapors and gases at the upper region of the molten metal contiguous to the roof of the condenser is maintained at a maximum, the countercurrent flow at the bottom region of the mass of molten metal is restricted and reduced to a minimum, while a portion of the hotter metal from the condenser near the gas outlet end is diverted to a point outside of the condenser into a separate receptacle where it is cooled rapidly and efficiently and in large volume and is returned to the condenser near the gas inlet end thereof, whereby better cooling and closer control of the temperature of the molten metal within the condenser is obtained and a more complete condensation of volatile metals with less blue powder formation results together with a substantial increase in the amount of metal condensed per unit volume of condenser over the apparatus of the prior art.

An object of the invention is to provide a method and apparatus for condensing metallic vapors wherein the temperature of the mass of molten metal in the condenser is continuously maintained at a minimum or preselected level consistent with practical, safe and continuous operation.

Another object of the invention is to provide a method and apparatus for condensing metallic vapors wherein there is eliminated the destructive effects of thermal shock to the condenser shell which result when cooling water is

applied over the hot shell after shutdowns for clean-outs, repairs, power failures, etc. In accordance with the present invention, no cooling water need be applied to the condenser shell.

Another object of the invention is to provide a method and apparatus for condensing metallic vapors in which maximum concurrent flow of liquid metal, metallic vapors and gases is maintained in the condenser and a high degree of agitation of the liquid metal is achieved, whereby blue powder suspended in the liquid metal is converted into coherent liquid metal.

Another object of the invention is to provide a method and apparatus for condensing metallic vapors to obtain a larger tonnage of condensed metal per unit volume of condenser and molten metal held in the condenser than hitherto has been realized.

Another object of the invention is to provide a condenser for condensing metallic vapors in which progressive thermal expansion of the condenser is minimized.

Another object of the invention is to provide a method and apparatus for condensing zinc vapors permitting separation of metallic lead from zinc, if such is found in appreciable quantities admixed with the zinc.

The foregoing and other aims, objects and advantages of the invention as may be expressed in or be apparent from the following description, are achieved in apparatus for condensing vapors of metals from a stream of gas carrying the same including a heat insulated entrance chamber connected to a source of gases and metallic vapors, an exit chamber, a receptacle having its respective ends connected to the chambers and normally filled with molten metal for a substantial portion of its length, a suction producing device to draw off gases from the exit chamber and to lift the exposed upper surface of the molten metal substantially above its exposed lower surface, an enclosing roof portion to the receptacle in contact with and confining the molten metal intermediate the chambers, baffle means submerged in the liquid metal in the receptacle to impede and retard the flow of metal from the exit chamber side of the baffle means to the entrance chamber side thereof, means providing a cooling chamber external to and adjacent the receptacle, first conduit means connecting the receptacle at a point submerged in the metal on the exit chamber side of the baffle means to the cooling chamber, and second conduit means connecting the cooling chamber to the receptacle at a point submerged in the metal on the entrance chamber side of the baffle means.

The receptacle may take the form of an inclined tubular member and a cooling coil may be provided in the cooling chamber.

Where zinc containing appreciable amounts of lead is condensed, a stand pipe is provided adjacent the cooling chamber and the latter has a well connected to the stand pipe for separation of liquid lead from liquid zinc.

The baffle means may have a small opening adjacent the floor of the condensing receptacle to provide for limited recirculation of liquid metal in the receptacle, or it may have no opening at this point.

In its method aspect, the invention comprises condensing vapors of metals from a stream of gas carrying the same by passing the gas upwardly through a body of liquid metal confined in a restricted path between a lower free surface of the liquid metal and an upper free surface of the liquid metal whereby to effect condensation of the metal vapors solely in contact with the liquid metal and with surfaces actively wiped thereby and to effect a generally upward transportation of metal in the restricted path, withdrawing a portion of the metal from the upper portion of the restricted path and returning at least a portion of it through a cooling zone external to the restricted

path to the lower portion of the restricted path by utilizing the head created by the upward transportation of metal.

The apparatus of the invention preferably includes an inclined, refractory lined metal tube with upwardly projecting, vertically disposed, insulated connecting conduits at each end, whereby a mass of molten metal is maintained in the inclined tube portion thereof. Suction is applied to the above assembly through the vertical conduit contiguous to the higher end of the inclined tubular condenser portion. Hot gases, for example from a reduction furnace, comprising metallic vapors and accompanying gases from which air is excluded, are admitted to the condenser through the insulated vertically disposed conduit contiguous to the lower end of the inclined tubular condenser portion.

The suction, applied above the level of molten metal at the gas discharge end, is of such magnitude as to raise and maintain the level of the upper exposed surface of the molten metal in the inclined tube at a substantial height above the lower exposed surface of molten metal and to depress and maintain the lower surface at a level that permits the vapor and gases to enter the mass of molten metal at a lower exposed surface.

The metallic vapor and gases are maintained submerged in said mass of molten metal by the roof portion of the inclined tubular condenser and travel upwardly and forwardly in an inclined path through a circumferentially confined mass of molten metal, inducing a flow of molten metal concurrent to the vapors and gases bubbling through the mass of molten metal. The metallic vapors are condensed to coherent liquid metal by contact with the molten metal and internal surfaces of the condenser wiper by the metal, while the uncondensed vapor and gases escape, after passing through the mass of molten metal, into the connecting outlet conduit, and thence through suitable conduits to a suction-producing device such as a vacuum pump.

The heat energy released by the condensation of the vapors of volatile metals into liquid raises the temperature of the mass of relatively cool molten metal held in the condenser. To secure continuous efficient condensation of metallic vapors, it is necessary to extract the heat energy from the mass of molten metal in the condenser and maintain the temperature thereof as low as and as near the melting point of the metal as practical operational procedures permit, for reasons more fully explained hereinafter. Heretofore cooling of the mass of molten metal in the condenser has usually been accomplished by applying cooling medium such as water to the outside surface of the refractory lined steel shell of the condenser. However, the low rate of heat transfer through the inside refractory lining of the condenser and the relatively limited path of circulation induced within the condenser by bubbling vapors and gases impose definite limitations on the rate of cooling of the mass of molten metal in the condenser, making it difficult to maintain a uniform optimum temperature level necessary for efficient condensation of vapors and resulting in excessive blue powder formation and low condensation efficiency.

In accordance with the preferred method of this invention, continuous and efficient cooling of the mass of molten metal is obtained by continuously diverting a portion of the molten metal from the condenser to an outside cooling receptacle through a conduit connected to the condenser near the gas outlet end, cooling the portion of molten metal while it flows through the outside receptacle, and returning at least a portion of the diverted and cooled molten metal back to the condenser through a second conduit connecting the outside receptacle to the condenser near gas inlet end thereof. The outside receptacle, hereinafter called the tapping well, is, in the simplest form, a refractory lined and insulated vessel preferably open on top.

The diverted increment of molten metal flows out from the condenser to the outside tapping well, through

the tapping well, and back to the condenser entirely by gravity-circulation and preferably without the aid of power driven impellers, pumps, and the like. The gravity flow of molten metal is induced by hydraulic head created within the mass of molten metal in the condenser by air-lift action of metallic vapors and gases bubbling in an inclined path upwardly through the molten metal near the roof portion of the condenser, forcing some of the molten metal upwardly towards the gas discharge end of the mass of molten metal, while the return of an equivalent amount of metal through the bottom portion of the condenser back towards the lower end of condenser is prevented or substantially prevented by baffles positioned crosswise of the condenser and acting as dams. Thus, the level of molten metal at the gas outlet end of the condenser is raised higher than the level otherwise attained solely by suction applied thereon. This added height of metal forces a portion of the molten metal out through the upper conduit into the tapping well and, in turn through the second conduit near the lower end of the condenser, back into the condenser. This flow continues as long as sufficient suction is applied at the upper end of the inclined condenser tube to draw vapors and gases through the molten metal.

As the portion of molten metal flows through the tapping well, it is cooled by suitable means, as for instance by natural direct radiation from the mass of metal in the tapping well, by cool air circulation around the tapping well, or, in addition, by having the molten metal come in contact with cooling surfaces such as a pipe coil carrying water and immersed in the flowing metal. The rate of cooling is regulated as for example by varying the extent of immersion of the cooling coils in the flowing molten metal, and in turn dictated by the desired temperature level in the mass of molten metal in the condenser for continuous practical and efficient operation. For example, in zinc condensers of the type of the present invention, attached to large electrothermic furnaces and employing the cooling method described herein, it is possible to maintain the temperature of the molten metal in the condenser at from 475° C. to 525° C. continuously, in which temperature range a very small amount of blue powder is formed and condenser efficiency is very high. The importance of efficient cooling of molten metal in the condenser and maintenance of temperature at the lowest level possible in practical operation will be seen from the following table from which it is apparent that blue powder formation, which is a direct function of "theoretical uncondensable zinc," increases sharply as the temperature of the condenser increases, being very low at temperatures near the melting point of zinc, for example, only one-half of one percent at 500° C.

TABLE I

Uncondensed zinc vapor, at equilibrium conditions

Condenser Temperature, Deg. C.	Vapor Pressure of Zinc, Mm. Hg	Theoretical Minimum Uncondensable Zinc as Percentage of Slab Zinc Produced [a]
450	0.43	0.2
500	1.30	0.5
550	3.87	1.5
560	4.80	1.8
570	6.00	2.3
580	7.40	2.8
590	9.00	3.5
600	11.00	4.4
610	13.20	5.4
620	16.00	6.5
630	19.00	8.0
640	22.50	9.7
650	26.70	11.9
700	60.00	36.3

[a] At 16 in. Hg vacuum (29.2 in. Hg barometer) and 45 percent Zn vapor, 55 percent noncondensable gas mixture entering condenser.

The outside tapping well communicating with the condenser and permitting improved cooling of the liquid metal in the condenser furthermore provides a simple means whereby excess liquid metal, as it is produced in the condenser by condensation of metallic vapors therein, may be drawn off continuously or intermittently without interfering with the normal operation of the condenser assembly. The molten metal may be drawn off from the tapping well continuously through an opening in the wall of the tapping well at the elevation of the liquid metal flowing through the tapping well; or, preferably, the metal may be tapped out intermittently by opening a tap hole in the wall of the tapping well placed some distance below the level of the liquid metal in the tapping well. The present method of controlling the temperature of the molten metal in the condenser, wherein cooling is obtained principally in the cooperating tapping well attached to the condenser, permits more advantageous construction of the condensing receptacle by obviating the necessity of limiting the thickness of refractory lining and the resilient interlining between the refractory and the steel outside shell of the condenser in order to secure reasonably adequate heat transfer coefficient through the condenser wall. The improved method of cooling of the invention permits the construction of the condenser wall without regard to its heat transfer characteristic as an important and controlling factor of design, making it possible to use a thicker refractory lining inside the condenser and to provide more space between the inner refractory lining and the outer steel shell. The enclosing, vacuum tight, steel shell may be filled with resilient material such as sheets of mica and asbestos cloth and the like which permits the refractory lining to expand, under continued exposure to heat inside the condenser, without imposing undue strain on the outside steel shell or the refractory lining and resulting in a long operating life for the entire condenser assembly.

Improvement in condensing efficiency, realized by the present invention increases the over-all capacity of the condenser assembly in terms of tone of zinc produced per day per unit condenser volume upwards of 25 percent. For example, on one electrothermic zinc furnace with nominal daily production capacity of 40 tons of zinc metal, the condenser of the type shown in the aforementioned Weaton et al. patent of 250 cubic feet was replaced with a new condenser assembly built according to the principles of the present invention and having only 170 cubic feet of active condenser volume. The new and smaller condenser handles the same daily furnace capacity with less blue powder formation, less maintenance on refractory and steel shell of the condenser, and longer periods between shutdowns for rehabilitation.

The invention will be described with greater particularity with reference to the drawings in which

Fig. 1 is a vertical longitudinal sectional view of one form of zinc condenser embodying the invention;

Fig. 2 is a plan view thereof;

Figs. 3, 4 and 5 are transverse sectional views taken along the lines 3—3, 4—4 and 5—5, respectively of Fig. 1;

Fig. 6 is a plan view of another form of cooling chamber or tapping well;

Fig. 7 is a sectional view taken along the line 7—7 of Fig. 6; and

Fig. 8 is a sectional view taken along the line 8—8 of Fig. 6.

Referring to the drawings, particularly to Figs. 1 to 5 thereof, the condensing apparatus shown is especially adapted for condensing zinc vapors, either pure or impure, from zinc reduction furnace gases. The condensing apparatus has a tubular condensing receptacle 1, inclined from 10° to 45° to the horizontal, preferably inclined 12 to 18 degrees from the horizontal, holding a mass of molten metal 2 and having a vertically disposed gas inlet conduit 3 communicating with the lower end of the condensing receptacle and a vertically disposed gas outlet connection 4 at the opposite upper end of the condensing receptacle. Gases from a reduction furnace 5 comprising metallic vapors, such as zinc vapors, and accompanying noncondensable gases such as CO enter the condensing receptacle or "condenser" through conduit 3. When sufficient suction is applied to the mass of molten metal held in the condenser through outlet conduit 4 and suction pipe 6 connected to a suction-producing device such as a vacuum pump, not shown, the level of molten metal at the upper end of the inclined condenser rises and the surface thereof is maintained at a substantial height above the lower exposed surface of molten metal at the lower end of the inclined condenser, the lower surface being maintained sufficiently depressed to permit the vapor and gases to enter the mass of molten metal at the lower exposed surface at the lip 7 and bubble upwardly in an inclined path through the circumferentially enclosed portion of molten metal contiguous to the roof portion 8 of the condenser. The vapors and gases bubble upwardly through the mass of molten metal while the noncondensable gases pass through the mass of molten metal to the outlet conduit and thence through pipe 6 to the vacuum pump, not shown. The air-lift action produced by the gases bubbling through the portion of the body of molten metal adjacent the roof 8 carries forward and upward part of the molten metal concurrently with the vapors and gases towards the upper exposed surface of the mass of molten metal.

A baffle 9 is positioned transversely within the condenser 1 at a point approximately mid-way between the ends of the tube. The baffle together with the tube provides a large opening 10 adjacent the roof of the tube and a very much smaller opening 11 adjacent the floor of the tube. A second parallel baffle 12 is positioned in the tube near the gas inlet end thereof. This baffle cooperates with the tube to provide an opening 13 adjacent the roof that is about the same size as the opening 10 and an opening 14 adjacent the floor that is considerably larger than the opening 11. By virtue of the air-lift action of the gases and vapors bubbling up through the liquid metal, the metal tends to circulate in the condenser tube 1 in the direction shown by the arrows in Fig. 1. However, the opening 11 is of such a small size as to restrict materially the normal tendency of the metal to circulate in the tube and, in the extreme case, the opening 11 may be dispensed with entirely, the baffle 9 extending to the floor of the tube. For practical reasons a small opening 11 is desired. It permits limited and restricted recirculation of metal eliminating stagnant zones in the condenser, equalizing temperatures, and assisting the condensing action in the roof zone of the tube. Moreover, the hole 11 permits complete drainage of the condenser through the tap hole 15 when it is desired to shut down the apparatus.

By suitably proportioning the dam or baffle 9 and the opening 11, it is possible to force the accumulated metal above the dam to flow out of the condenser through conduit 16 into an associated cooling vessel 17 and from there back into the condenser through conduit 18. In the prior condenser of the aforementioned Weaton et al. patent, it has been found desirable to use one or more baffles or dams to prevent high amplitude surging of the large mass of molten metal. That is, the dams served as damping devices. In effect, the present invention utilizes the damping energy to cause the above-described flow of metal.

All parts of the apparatus contacted by liquid metal are refractory lined, suitably by pre-fired shapes of silicon carbide. The open outside receptacle 17 serves both as tapping well and as a heat transfer region.

Conduit 16 is located near the bottom of the mass of molten metal to prevent an undue amount of suspended blue powder from passing from the condenser to the tapping well. The small portion of blue powder which

may nevertheless be entrained in the molten metal circulating through the vessel 17 comes to the surface of the metal in the tapping well 17 and is skimmed from time to time. If molten metal in the condenser intermediate the baffle 9 and the upper exposed surface of the metal is prevented from flowing downwardly, as for instance by closing or greatly constricting orifice 11 at the bottom of baffle 9, the molten metal being carried upwardly towards the upper exposed surface of the metal flows at a greater rate through conduit 16 to the outside receptacle 17 and thence back into the condenser through the conduit 18. Preferred practice is to make orifice 11 at the bottom of baffle 9 small enough, usually 1½ to 2" in diameter, to permit complete draining of molten metal from the condenser through an orifice at the lowest place in the condenser, as for instance at tap hole 15, yet offer sufficient constriction to permit substantial flow of molten metal out of the condenser to the outside tapping well.

In the preferred method of cooling the metal in the tapping well, the cooling coil 19, the lower part of which is immersed in molten metal flowing through the tapping well 17, is moved up and down by a hoist, not shown, to vary the extent of cooling surfaces immersed in the molten metal, thus controlling the temperature of the flowing molten metal and, in turn, the temperature of the mass of molten metal held in the condenser.

Liquid metal, as condensed from vapors during operation, preferably is allowed to accumulate in the condenser. Periodically, tap hole 20 on the cooling receptacle 17 is opened and a portion of liquid metal is tapped out and cast into slabs. The condenser may be emptied out completely, as for instance at the end of a campaign, through bottom tap hole 15 which is normally closed during the entire campaign.

Vacuum type condensers of large capacity having the preferred cooling apparatus, including an external tapping well with cooling coils and attached to the condensing unit, substantially as described herein, may be operated for long periods condensing upwards of 40 tons of zinc metal per day from zinc vapor and gases produced in large electrothermic zinc furnaces. Condenser temperatures in the neighborhood of 500° C. are easily maintained, at which temperatures very efficient condensation of zinc vapors from furnace gases is realized.

As an example, a condenser assembly having a tapping well with a cooling coil made of 2-inch pipe carrying cold water at 65° F. receives zinc vapors and CO gas mixture from an electrothermic zinc furnace. The condenser holds a normal "charge" of approximately 40 tons of molten metal and condenses zinc vapors to metallic zinc at an average daily rate of 20 tons. Temperature of the metal in the condenser is maintained at 500° C. to 525° C.

Zinc metal flows out of the condenser to the tapping well and back into the condenser at the rate of approximately 120 tons per hour. The temperature of the metal flowing through the tapping well and around the cooling coils drops an average 10° C. to 12° C.

Figures 6, 7 and 8 show in plan and sectional views a modification of the outside cooling receptacle whereby, when there is an appreciable amount of metallic lead found in the condensed zinc, the major portion of the metallic lead is separated by settling and separately drawing it off from a stand-pipe attached to and communicating with the outside receptacle. When lead ores smelted in a lead blast furnace contain high percentages of zinc, practically all the zinc content of the ore, together with small amounts of lead, find their way into the slag drawn off the blast furnace. When such slag is smelted further to extract the metallic constituents, as for example in a slag bath electric furnace, the zinc and lead compounds are volatilized from the slag, and both are reduced to the metallic state as they pass through the bed of overlying reduction fuel and pass out of the furnace into the zinc condenser mainly as metallic vapors. Depending on the lead content of the liquid slag bath in the furnace, the zinc condensed may carry, for example 1 to 5% metallic lead.

When impure zinc ores or concentrates having appreciable amount of lead are smelted, the gaseous products from the reduction furnace comprising the metallic vapors and accompanying non-condensible gases may carry substantial amounts of reduced volatile compounds of lead entrained with zinc vapors. Depending on the lead content of such impure zinc ores or concentrates, the liquid zinc condensed from such gaseous products may carry appreciable amount of metallic lead, as for example 1 to 5%.

Referring to Figures 6, 7 and 8, a portion of the bottom of the outside cooling receptacle 17' is depressed to form a well 21. A refractory lined stand-pipe 22 is attached to the outside cooling receptacle 17' by a refractory lined conduit 23, thus connecting the cooling receptacle with the stand pipe at or near the bottom of the depressed well portion of the outside cooling receptacle. During operation, metallic lead 24, separating from the molten zinc 25 by gravity, collects at the bottom of the well and communicating stand pipe 22. As metallic lead accumulates at the bottom of the outside cooling receptacle 17', the level of lead in stand pipe 22 rises somewhat, the level of molten lead in the stand pipe being lower than the level of molten zinc flowing through the cooling receptacle 17' to an extent dependent on the difference in specific gravities of metallic zinc and lead and the height of metallic lead in the cooling receptacle. In order to prevent molten zinc from finding its way into the stand pipe, a sufficient amount of molten lead is poured into the assembly at the start of operations, before the priming charge of molten zinc is filled into the condenser and cooling receptacle. Molten lead is tapped out of the stand pipe at intervals and as molten lead accumulates by opening lead tap hole 26.

I claim:

1. Apparatus for condensing metals from a stream of gas carrying the same comprising an inclined tubular member, gas outlet means communicating with the upper end of said tubular member, wall means providing a liquid receptacle communicating with the lower end of said tubular member, gas inlet means communicating with said liquid receptacle above the level of communication of the tubular member therewith, transverse dam means in said tubular member intermediate the ends thereof, the upper edge of said dam means being spaced from the roof of said tubular member to permit upward flow of gases and liquid metal adjacent the roof of the tubular member while preventing substantial downward flow of liquid metal adjacent the floor of the tubular member, means providing a cooling chamber adjacent said tubular member, first conduit means connecting said cooling chamber with said tubular member at one side of said dam means and second conduit means connecting said cooling chamber with said tubular member at the other side of said dam means.

2. Apparatus as defined in claim 1 including cooling means in said cooling chamber.

3. Apparatus as defined in claim 1 wherein said cooling chamber means has a well, a stand pipe adjacent said cooling chamber means, and conduit means connecting said well to said stand pipe.

4. Apparatus for condensing vapors of metals from a stream of gas carrying the same comprising a heat insulated entrance chamber connected to a source of gases and said vapors, an exit chamber, a receptacle having its respective ends connected to said chambers and normally filled with molten metal for a substantial portion of its length, a suction producing device to draw off gases from said exit chamber and to lift the exposed upper surface of said metal substantially above its exposed lower surface, an enclosing roof portion to said receptacle in contact with and confining said molten metal intermediate said chambers, dam means submerged in the liquid

metal in said receptacle the upper edge of said dam means being spaced from the roof of said receptacle to permit upward flow of gases and liquid metal adjacent the roof of the tubular member and any opening in the lower part of said dam means being much smaller than the space between the upper edge of the dam means and the roof of said receptacle to prevent substantial downward flow of liquid metal adjacent the floor portion of said receptacle from the exit chamber side of said dam means to the entrance chamber side of said dam means, means providing a cooling chamber external to and adjacent said receptacle, first conduit means connecting said receptacle at a point submerged in said metal on the exit chamber side of said dam means to said cooling chamber, and second conduit means connecting said cooling chamber to said receptacle at a point submerged in said metal on the entrance chamber side of said dam means.

5. Apparatus as defined in claim 4 including a cooling coil in said chamber and means for varying the area of cooling coil exposed to liquid metal in said cooling chamber.

6. Apparatus as defined in claim 4 wherein said enclosing roof portion is inclined at an angle of from 10° to 45° from the horizontal.

7. Apparatus as defined in claim 4 wherein said enclosing roof portion is inclined at an angle of from 12° to 18° from the horizontal.

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