June 10, 1952 D. F. WELLS ET AL 2,600,351

VOLATILIZATION OF TIN VALUES OF TIN ORES

Filed July 19, 1948 2 SHEETS—SHEET 1

FIG. 1.

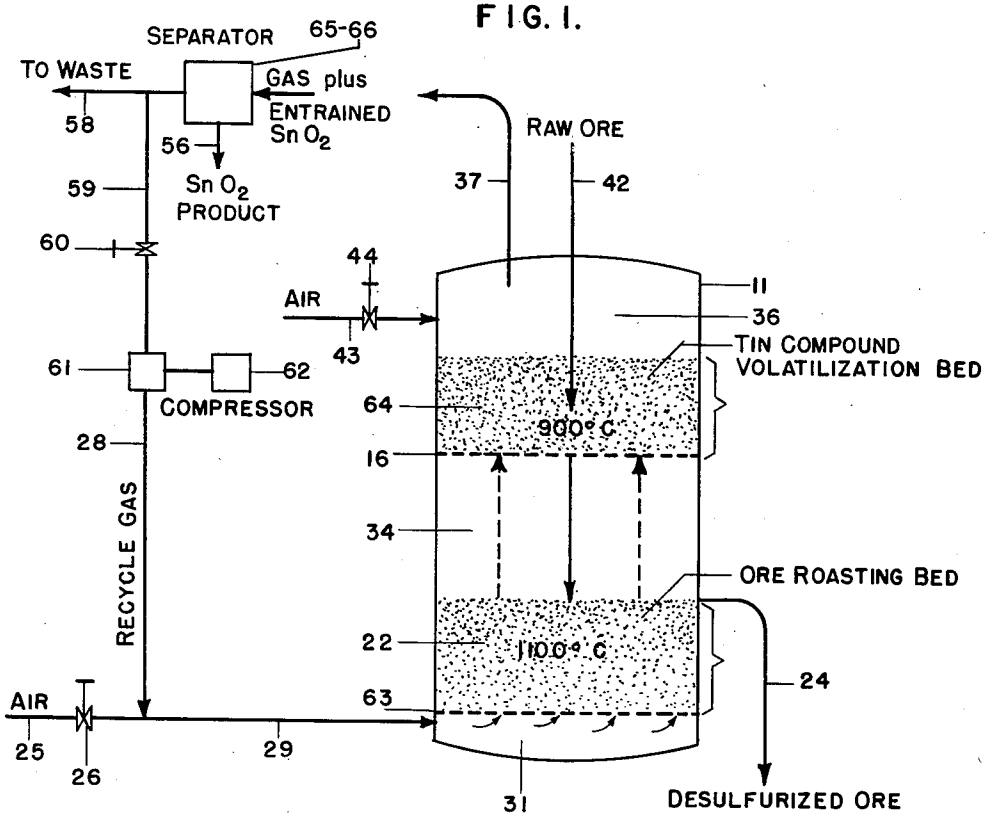
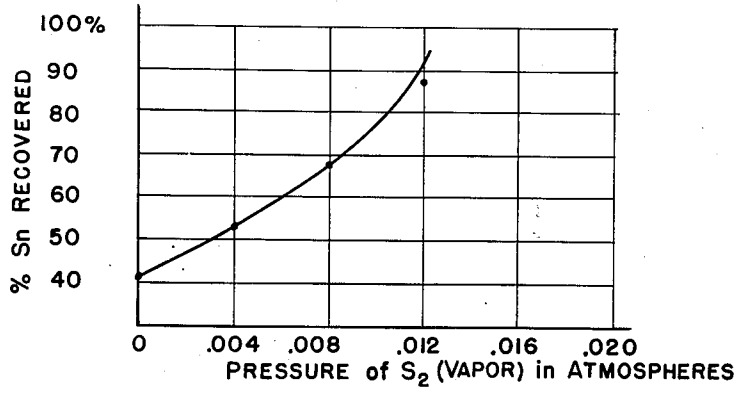


FIG. 2.



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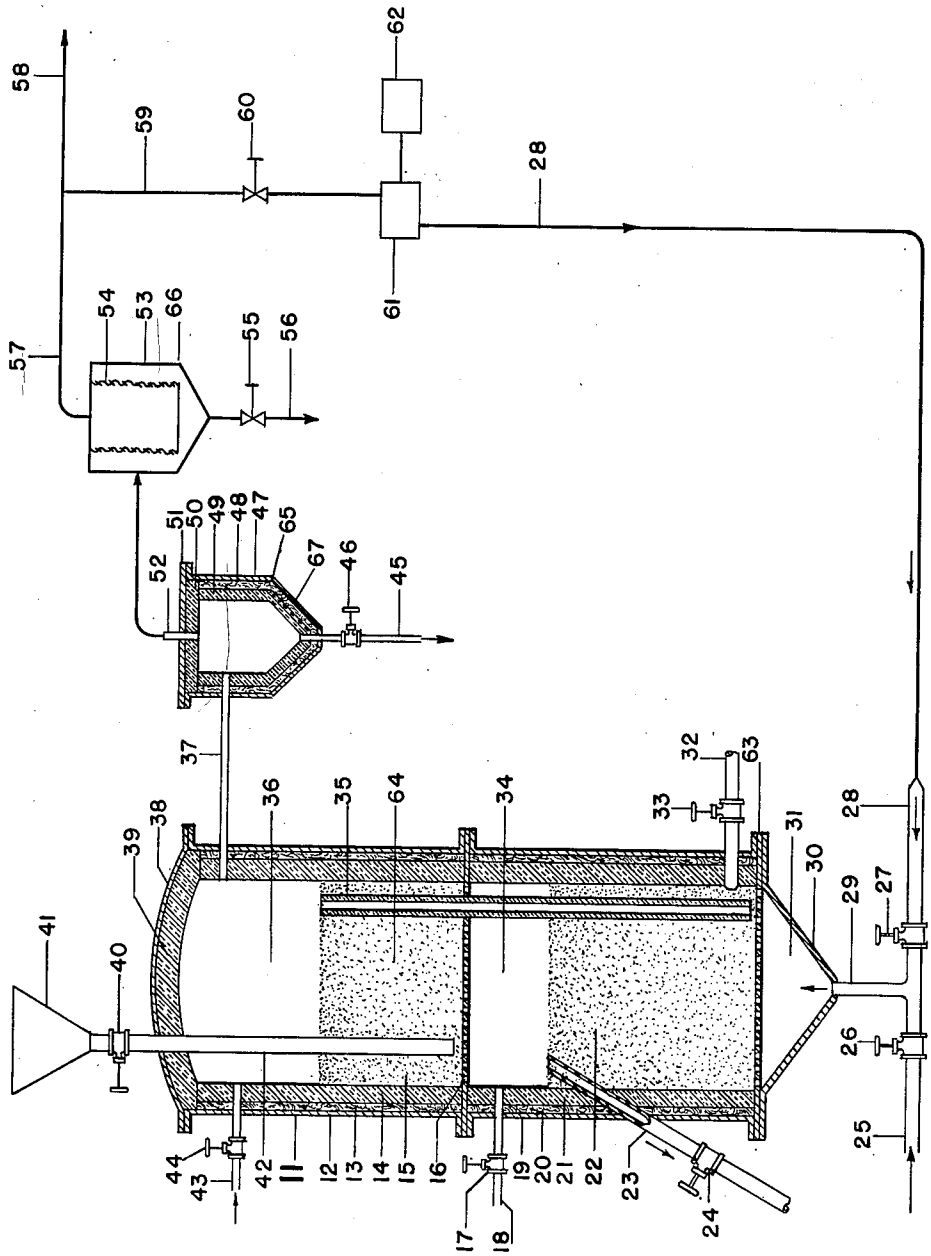


FIG. 3.

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VOLATILIZATION OF TIN VALUES OF TIN ORES

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4 Claims. (Cl. 23—136)

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This invention relates to a fluidized-solids system for selectively recovering tin from ores as a volatilized tin-compound as well as recovering other volatile metallic compounds from their parent ores. It is particularly adaptable for processing low-grade tin ores containing, or admixed with, free or combined sulfur in oxidizable form.

Prior attempts have been made to beneficiate tin ores. Generally these methods were directed towards improving the leaching characteristics of the ore so that the tin-content thereof could be recovered from the ore by solvent extraction. However, several processes were developed to separate the tin from the ore as a volatilized compound. These prior tin-volatilization processes were characterized by intrinsic difficulties. Some were suited principally for intermittent operations; some required external heating of the ore in order to reach volatilization temperatures and the presence of weak reducing gases. Others, though directly heating the ore by combustion of sulfide constituents or admixed fuels and air, required fluxes for slagging purposes or quenching agents such as water to control the temperatures in the tin-volatilization zone. In all of these prior art processes, temperature control in the tin-volatilization zone was poor and the recovery of tin from the ore did not attain the ranges indicated by their proponents. Furthermore, those processes which required the use of added fuel were particularly uneconomical in some of the regions where the tin ores are found.

This invention overcomes the difficulties of prior tin-volatilization processes and achieves continuous operation with close temperature control; the invention may be practiced in relatively simple apparatus and over 95% of the tin in the ore may be recovered. Since many low-grade tin ores of the sulfide-type contain sufficient oxidizable sulfur to furnish the heat required by our process, it will ordinarily be unnecessary to supply extraneous fuel. The value of this invention in areas where fuel is at a premium is thus apparent. However, should fuel need to be added when treating certain tin or other ores, our process allows injection of the fuel directly in contact with the ore. It is significant that close temperature control is not sacrificed by this procedure and the added fuel is utilized efficiently.

In its preferred form, this invention uses a heat-treatment reactor, or roasting furnace, which is adapted to contain both a superjacent bed or layer, and a subjacent bed of fluidized, thermally-homogeneous, finely-divided ore particles. Hereafter, in view of their principal functions, the superjacent bed of fluidized solids will be referred to as the upper or tin-volatilization bed, and the heat-supplying subjacent bed as the lower or ore-roasting bed.

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The raw ore in powdered form is supplied to the upper bed; the bulk of the de-tinned ore is removed as residue from the lower bed and volatilized tin-compound product is removed from above the upper bed with the entraining gases. These gases are principally nitrogen and sulfur dioxide. The nature of a bed of densely-suspended or fluidized-solids and its importance in this invention will be more clearly brought out below in the detailed description of this invention.

The concept of our invention in connection with tin ore is that large volumes of carefully proportioned scrubbing gases containing certain minimum quantities of vaporous sulfur pass upwardly through a hot bed of finely-divided tin ore and at such a rate that the tin ore particles form a dense-suspension of fluidized-solids. The temperature of the ore particles is maintained within a narrow range which lies both above and below the melting point (882° C.) of tin (stannous) sulfide but well below the boiling point (1,230° C.) of this compound. Within this temperature range, two distinct phenomena may occur. If tin in the ore is present in the form of cassiterite (SnO_2), it will react even with a small quantity of sulfur-vapor (S_2), such as about 1%, to yield stannous sulfide (SnS). Any tin initially present in the ore as stannous sulfide, plus newly-formed stannous sulfide, exert a slight vapor-pressure at the temperature prevailing in the hot bed of fluidized ore particles; this vapor pressure or tendency of stannous sulfide to become a gas is great enough in our process so that the large volume of scrubbing gas sweeping up through the bed removes practically all the tin-value of the ore as volatilized stannous sulfide. It is an important feature of our invention that the ore particles do not stick or defluidize even when their temperature is above the melting point of stannous sulfide. Other features will appear as this specification proceeds but the ambit of the invention is to be found in the appended claims.

Reverting now to a preferred embodiment of this invention. When treating tin ores containing substantial quantities of pyrites, no extraneous fuel is necessary. The finely-divided ore, which may be as coarse as —4 mesh (Tyler standard screen) is supplied to the upper or tin-volatilization bed in the reactor wherein the tin-content of the ore is removed from the upper bed as

the vaporous stannous sulfide. In addition to the tin-volatilization function referred to heretofore, some burning of sulfur does occur in this bed by combination with oxygen rising with the gases from the lower or ore-roasting bed. This sulfur-burning is, of course, exothermic and supplies a considerable portion of the heat needed for the other heat-consuming or endothermic functions of the upper bed. The remainder of the heat needs are supplied by the sensible heat content of the gases rising from the lower bed.

The heat liberated in the upper bed causes pyritic constituents in the ore to evolve sulfur-vapor. In turn, some of the evolved sulfur-vapor burns; some reacts with the ore to form stannous sulfide, and the remainder accompanies the gases rising from the upper bed. From this, it is apparent that a feature of this invention lies in proportioning the gases rising from the lower bed both as to their quality or composition and their quantity so that all the functions of the tin-volatilization bed may proceed.

A further feature of this invention is the maintenance of the upper or tin-volatilization bed within a narrow temperature range. We found that above substantially 940° C. the particles in the fluidized bed of ore particles tended to stick and become defluidized. Likewise, below substantially 825° C. very little volatilized tin-compound was yielded by the reactor. Either of these conditions render the process inoperable.

The entraining scrubbing gases rising from the upper bed contain the volatilized stannous sulfide plus some unreacted ore particles and some unreacted sulfur vapor. The stannous sulfide can be separated from the entrained solids and entraining gases only with difficulty. So, this invention proposes to inject a free-oxygen-bearing gas, such as air, into these tin-bearing gases, while still hot, to form an entrainable fume of solid stannic oxide (SnO_2). This fume passes through gas-solid separating means, such as cyclones used to remove unreacted ore particles but it will collect on filter means such as a bag-filter; this permits collection of the tin-values as a relatively pure solid product which is amenable to further refining.

The hot, partially de-sulfurized ore from the upper bed is conducted, out of contact with the main body of uprising gases, to within the body of the lower or ore-roasting bed. Here, the pyrrhotite (FeS) present in the particle-form solids reacts with oxygen to form gaseous sulfur dioxide and solid oxide of iron, as well as small amounts of gaseous sulfur trioxide. The oxygen for these exothermic reactions is contained in a gas supplied to the ore-roasting bed; this gas should be proportioned in its composition and quantity so that no great excess of oxygen enters the upper bed. Air, admixed with quantities of dust-free gas leaving the dust-separating means has been satisfactory. This admixing or recycle gas serves as a diluent whereby the oxygen-content of the gas supplied to the ore-roasting bed is of a diminished concentration and thus the proportioned gas required for the functions of the upper bed is thereafter formed.

The function of the ore-roasting bed is chiefly that of a heat-supplying bed and gas-proportioning means. The burning of the sulfide constituents of the ore particles in this bed liberates large quantities of heat; some of this heat is present in the hot gases rising from this bed as so-called sensible heat content. This serves to

impart a portion of the heat required for the functioning of the tin-volatilization bed.

Another feature of this invention in connection with tin ore is that we found that at about 1140° C. the particles of the lower or ore-roasting bed become sticky. This results in agglomeration of the particles and their eventual defluidization. This condition likewise renders the process inoperable.

De-sulfurized ore, which is principally in the form of magnetic iron oxide (Fe_3O_4), is removed from the ore-roasting bed to either discard, further heat recovery and/or recovery of the iron content, as by magnetic separation.

It is within the scope of this invention to supply fuel and/or material containing or capable of forming unoxidized gaseous sulfur to a fluidized bed under the conditions above described for volatilizing the tin-values of ores.

The best apparatus for practicing the invention now known to us has been chosen for the purpose of illustrating how the process steps of this invention may be carried out. This will be described in connection with the processing of a particular type of ore in order to disclose fully how to attain the advantages of this invention. But before describing this illustrative example of our invention, it may be helpful to describe first the nature of fluidization of solid-particles and fluidized-solids type reactors in general.

A fluidized bed is a very dense suspension of fine solids in a supporting, up flowing gas. The density or solids-concentration per unit volume of such a fluidized bed is very high, being commonly of the order of 10 to 100 pounds of solids per cubic foot of bed volume, which is the equivalent of from 160.2 to 1602 kilograms per cubic meter. This bed density is to be contrasted with typical dilute dispersions or suspensions such as dusty air wherein the density or solids-concentration is of the order of only 1/50th of a pound per cubic foot of the dispersion, which is the equivalent of 0.32 kilogram per cubic meter. In addition, the solid particles of a fluidized bed are in a high state of turbulence or erratic, zig-zag motion in the bed even when the velocity of the suspending gas is quite low; this high turbulence results in intimate and rapid mixing of the solid particles so that in a typical bed complete mixing of the particles appears to take place instantaneously. A fluidized bed, by virtue of its high density and great turbulence, is also noted for the rapid transfer of heat between its solid and gaseous components; this heat transfer is so rapid that a remarkable uniformity or homogeneity in the temperature of the bed results.

A fluidized-solids bed is also characterized by its flow qualities. Such a bed behaves substantially like a boiling liquid, in that it will flow under fluistatic head and is capable of presenting a level. Thus, a conduit may be inserted in a fluidized-solids bed and the solid particles will flow down the conduit at their level just like water overflows into a drain pipe. These flow qualities of fluidized-solids make it feasible to employ successive, vertically-positioned beds.

For maintaining and utilizing a fluidized bed, a vertical vessel, usually referred to as a fluidized-solids reactor, or furnace, is used. In rudimentary form, this vessel is adapted to contain only one fluidized bed by having a single perforated horizontal partition in its lower portion. Finely-divided solids particles are supplied to

the vessel above the partition by a conduit and gas is passed upwardly from the bottom of the vessel through the partition and the solid particles. The gas passes through the solid particles at such a rate that the particles are kept densely-suspended as a bed or layer in the vessel. Conduits are provided for separately removing the gas from above the fluidized bed and for removing portions of the solids from some point in the bed.

In more complex forms, such as is envisaged in the preferred form of this invention, the vessel may be adapted to contain a plurality of vertically-positioned beds, each of which lies above a gas-permeable partition. Generally, the solid particles are supplied to the uppermost of these beds and overflow by gravity from the fluid-level in this bed down through a conduit to a point below the fluid-level in the next subjacent or lower bed. The solids particles thus gravitate successively downward from upper to lower beds and are removed from the vessel at the level of the lowermost bed. The treatment gas is supplied below this lowermost bed and rises successively through each bed to fluidize and react with the solids of each bed, being emitted at the top of the vessel. By this system of progressively descending solids contacting upflowing gas a general counter-current treatment of the gas and solids is achieved.

In the drawings, Figure 1 represents a flowsheet of how the solids and gases proceed when using the preferred two-bed form of our invention.

Figure 2 is a graph which emphasizes the relationship between the amount of tin recoverable from a particular tin-ore, and the small minimum pressure of sulfur-vapor (S_2) needed in the tin-volatilization zone. The sulfur-vapor pressure is expressed in atmospheres.

Figure 3 represents apparatus suitable for practicing the invention in its preferred two-bed form.

Illustrative example

The following description is given in some detail to illustrate the practice of our invention as well as some factors which are environmental but will aid in practicing the invention.

An ore analyzed as containing 2.38% tin (of which 0.67% is stannous sulfide i. e., roughly one-third of the total tin present is in the form of stannous sulfide), 30% total sulfur, 27.2% iron and 0.81% arsenic may be effectively detinned in a two-bed reactor, as outlined above, without the use of extraneous fuel. It may be remarked that the interior surfaces in the upper section of the reactor, especially those surfaces above the gas-inlet points of the upper bed, should be lined with a refractory material which will resist the high temperatures prevailing in the reactor as well as the corrosive action of the gases. In our work, we found silicon carbide satisfactory as a lining material.

In starting up the reactor, air and fuel are burned in the lower portion to pre-heat the reactor. When the reactor is up to the desired temperature, raw ore in finely-divided form is continuously introduced into the upper portion of the reactor. This may be done by means of a conduit or a device such as a feed screw. It may be remarked that the ore may be as coarse as −4 mesh (Tyler screen), and is preferably dry and free-flowing. The raw ore may be supplied at a rate of approximately 1200 pounds per day per square foot of horizontal reactor area; variations will occur when using different ores.

The raw ore is continuously supplied as described, and when the fluid-level in the thus-formed upper bed exceeds the overflow point (usually between about 3 and 5 feet), ore particles flow down into the lower portion of the reactor (while out of contact with the main body of up-flowing gases) and form a lower bed of solid-particles of about the same depth as the upper bed. From the lower bed, hot treated solids are conducted either outside the reactor where they may be discarded or utilized for their iron content, or they may be passed through one or more successive fluidized beds for recovery of their heat content prior to being removed from the reactor. The remaining steps of this example will be described as though the solids are directly removed from the reactor's lower bed to outside the reactor.

Initially, pure air is supplied to the reactor below the lower bed. When the two beds are fully formed and the reactor is at the proper heat, the fuel supply may be discontinued. Thereafter, air plus a diluent gas, such as mixtures of N_2 and SO_2, is supplied to the lower bed at about 4 pounds per square inch gauge pressure and at a sufficient rate so that the superficial gas velocity through the reactor is about 2 feet per second. By superficial velocity is meant the speed of the gases through the reactor as determined in portions of the reactor wherein there are practically no solid particles and wherein the reactor has its full cross-sectional area.

The free-oxygen in the gas combines with sulfidic constituents of the particles in the lower bed to form gaseous sulfur oxides and liberate a good deal of heat, which maintains the solids and gases in this bed at about 1100° C. These reactions, of course, diminish the free-oxygen content of the gases rising from the lower bed. When treating the particular ore referred to above, the hot gases rising from the lower bed will contain about 83% nitrogen (N_2), 3% oxygen, 14% sulfur-dioxide (SO_2) and 0.1% sulfur-trioxide (SO_3). This should be contrasted with the gases entering the lower bed, which will contain about 83% nitrogen, 10% oxygen and 7% sulfur-dioxide.

The hot gases rising from the lower bed flow through the perforated partition beneath the upper bed and also pass through the upper bed at fluidizing velocity to densely-suspend the particles in this upper bed. Since these gases are quite hot initially, they serve to keep the solid particles in the upper bed (which are supplied to the reactor at a low temperature) at around 900° C. At this temperature, the pyrite (FeS_2) present in the ore decomposes to yield pyrrhotite (FeS) and sulfur-vapor. The sulfur-vapor formed exerts a pressure of about 0.012 atmospheres; this is the equivalent of about 1% by volume of the gases present in the upper bed at normal pressures. The sulfur-vapor is present in sufficient volume and concentration to convert tin oxides in the ore to the stannous sulfide form which is volatilized and swept from the upper bed by the rising gases. At the upper bed temperature, any stannous sulfide originally present in the ore will likewise be swept out of the upper bed by the gases. It may be remarked that it may prove desirable to keep the absolute pressure in the upper portion of the reactor below atmosphere to increase the relative pressure of the stannous sulfide.

Any oxygen entering the upper bed with the fluidizing gases reacts with a portion of the sulfur-vapor to yield sulfur-dioxide and heat. Likewise, any sulfur trioxide entering the upper bed reacts with some of the sulfur-vapor to form sulfur dioxide; thus the gases leaving the upper bed will contain about 1% S_2, 15% SO_2, 84% N_2 and practically no free-oxygen. The tin-compound is present in the gases in practically immeasurable amounts.

Just before the hot gases containing the tin-compound (SnS) leave the reactor or shortly thereafter, air is admixed with them. These gases react with the air to form a fine fume of solid stannic oxide (SnO_2) and gaseous sulfur dioxide. The fume is composed of such fine particles that it will not separate to any great extent from the entraining gases when they are conducted through a conventional gas-solids separating device such as a cyclone but entrained ore particles will be so separated. Thereafter, the gases are passed through a separating medium such as a woven or matted filter or even an electrosatic precipitator in order to separate and collect the rather pure stannic oxide as the principal product of our process. The dust-free gases, which are practically all nitrogen and sulfur dioxide are thereafter conducted so that about 50% of them may be compressed and combined with the air supplied to the lower bed. The remainder is either discarded or utilized in a manner unconnected with our process. The total volume of treatment gas supplied to the lower bed is about 36 standard cubic feet per pound of ore of the particular type described supplied to the reactor.

Referring to the drawings: Figure 1 represents a simplified scheme of the flow of the ore-solids, gases and products when practicing the preferred two-bed form of our invention. The crude ore enters the reactor 11 through conduit 42 and is discharged therein within the upper or tin-compound volatilization bed 64. Partially treated ore is conducted from upper bed 64 down to the lower or ore-roasting bed 22 and is conducted to discharge through conduit 24. Air supplied through conduit 25 and regulated by valve 26 joins recycle gas (mainly nitrogen and sulfur dioxide) at conduit 29 and enters the wind-box 31 of reactor 11 below the constriction plate 63. The gases flow up through bed 22 and the disengaging or freeboard space 34 through constriction plate 16 to upper bed 64. Therefrom, the gases bearing the volatilized tin-compound enter the oxidation zone 36 where they join with air supplied to this zone by conduit 43. The rate thereof is regulated by valve 44.

The gases from the oxidation zone 36 bear the tin-compound fume and leave the reactor 11 through conduit 37; they thereupon enter separating-means collectively designated as 65—66. The tin-compound product is removed from the separating-means 65—66 through conduit 56 and the dust-free gases are conducted from the separating-means 65—66 through conduit 57. From conduit 57 the gases are partially discharged through conduit 58 and are partially recycled to reactor 11 through conduit 59 and compressor 61—62. The rate of recycling is controlled by valve 60 in conduit 59.

Figure 2 represents graphically the percentage by weight of tin-value recovered from the particular tin ore described in the illustrative example of this invention as a function of the vapor-pressure of sulfur in the upper bed. The vapor pressure of sulfur is expressed in atmospheres. Thus at 0.012 atmospheres of sulfur vapor some 92% of the tin was recoverable from the ore; at 0.004 atmospheres, only 52% of the tin was recoverable.

Figure 3 is a detailed view of apparatus suitable for practicing the preferred two-bed form of this invention. The gas impermeable reactor collectively designated as 11 has an upper side-wall member 12 surmounted by a detachable casing member 38 and a lower side-wall member 19 to which is detachably secured the bottom casing member 30. Insulation material such a rock-wool 13 is between upper casing member 12 and inner refractory material 14. This refractory material may be silicon carbide. Likewise, insulation material 20 lies between lower casing member 19 and inner refractory material 21. Refractory material 39 is positioned beneath the top casing member 38. Gas-permeable or apertured rigid constriction plate 16 lies horizontally between upper casing member 12 and lower casing member 19. This division the reactor 11 into an upper zone 64 for tin-volatilization and a lower zone 22 for ore-roasting. Gas-permeable or apertured rigid constriction plate 63 lies horizontally between lower casing member 19 and bottom casing member 30.

Ore supply hopper 41 lies above feed-supply conduit 42 which goes through upper casing member 38 and terminates at its lower extremity, at a point adjacent to but above constriction plate 16. The rate of ore fed to reactor 11 may be controllably adjusted by valve 40.

During processing, the ore particles supplied to the reactor 11 form the tin-volatilization zone or fluidized-bed 64 surmounted by oxidation zone 36 and the ore-roasting zone or fluidized-solids bed 22 surmounted by freeboard zone 34 above the bed 22. Solids from bed 64 overflow into conduit 35 which is composed of refractory material such as silicon carbide. The conduit 35 terminates at its upper end at the fluid level of the solids in the bed 64 and at its lower end at a point just above the constriction plate 63. Treated solids overflow from the fluid level of the bed 22 into the upper end of conduit 23 and are conducted to outside the reactor 11. The rate thereof is controlled by valve 24.

Air is supplied to the oxidation zone 36 through conduit 43 and the rate is controlled by valve 44.

Treatment gas is supplied to the reactor 11 through conduit 29 to wind-box 31 and is diffusingly distributed by constriction plate 63 to the bed 22. Air and/or fuel may be supplied to bed 22 through conduit 32; the rate thereof is controlled by valve 33. Likewise air or fuel or treatment gas may be supplied to the freeboard zone 34 through conduit 18 and the rate of supply controlled by valve 17.

The treatment gas flowing upwardly through conduit 29 is composed of air and recycle gas from the reactor 11. The air is supplied to conduit 29 through conduit 25 having valve 26; the recycle gas is supplied to conduit 29 through conduit 28 having valve 27.

The entrained product as well as entraining gases and some entrained, untreated solids leave the oxidation zone 36 through conduit 37. These enter the cyclone collectively designated 65.

The unreacted solids settle in the lower portion of cyclone 65 and are removed therefrom through conduit 45 having valve 46. The entraining gases and tin-compound product leave the top of

cyclone 65 through conduit 52 and enter bag-filter apparatus collectively designated 66.

Cyclone 65 has casing members 47 and 67 lined with insulating material 48 and refractory material 49 plus a top casing member 51 positioned above refractory material 50.

The bag-filter apparatus 66 has a fibrous material 54 positioned within a shell collectively designated 53. The solid tin-compound product separated in bag-filter apparatus 66 is removed therefrom at its lower end through conduit 56 having valve 55. The dust-free gases leave bag-filter apparatus 66 at the top thereof through conduit 57.

A portion of the dust-free gases flowing through conduit 57 enter recycle conduit 59 having valve 60 and enter compressor 61 powered by motor 62. These are delivered through conduit 28 to conduit 29.

The remainder of the gases not entering recycle conduit 59 flow through conduit 58 for further utilization, if desired.

In operation of the reactor 11 and appended equipment, reactor 11 is first pre-heated by burning fuel and air supplied through conduit 32. Then the ore is supplied from hopper 41 to bed 64 through conduit 42. Partially treated ore overflows from bed 64 at its fluid-level into conduit 35 and is discharged into bed 22 at a point above the constriction plate 63. Treated ore from bed 22 is discharged at the level therein through conduit 23.

Treatment gas, comprising air and recycle gas from conduits 25 and 28 respectively enters the wind-box 31 through conduit 29 and flows successively upward through beds 22 and 64, joining with air supplied through conduit 43 in oxidation zone 36; thereafter it leaves the reactor 11 through conduit 37 and enters cyclone 65. Gases plus the tin-fume leave cyclone 65 and enter bag-filter 66 by conduit 52. Solids separated in cyclone 65 are removed through conduit 45.

In bag-filter 66, the tin-fume is separated from the gases and are removed therefrom through conduit 56 for further treatment or utilization. Gases leave bag-filter 66 through conduit 57. A portion thereof is recycled to the reactor 11 by means of conduit 59, compressor 61 and conduit 28. The remaining gases are conducted through line 58 for further recovery or waste.

As used in describing this invention, the words tin ore embrace natural or treated solids containing free or combined tin associated with relatively worthless gangue material. The solids should be capable of being in particle form.

The words metallo-values embrace free or combined metals in their natural or treated state which are associated with relatively valueless solids.

What we claim is:

1. A process for continuously volatilizing tin-values of tin-bearing sulfide ore, which comprises establishing a bed of such ore in a volatilizing zone, passing an uprising stream of gas therethrough at a velocity sufficient to fluidize the ore of the bed and heated to a temperature sufficient to maintain the temperature of the bed between substantially 825° C. and substantially 940° C., establishing and maintaining the sulfur-vapor content of the uprising gas while in the bed at least at a value of 1% by volume to volatilize tin-sulfide, discharging ore solids from the bed to establish a further bed, maintaining the latter at roasting temperature, passing through the further bed a stream of uprising gas at a velocity sufficient to fluidize the ore thereof bearing oxygen in quantity sufficient to roast the oxidizable contents of the bed as well as to yield an oxygen-lean gas heated substantially to roasting temperature, and introducing the oxygen-lean heated gas to the volatilizing zone to control simultaneously the temperature as well as the sulfur-vapor pressure in the volatilizing zone.

2. A process according to claim 1, with the addition of conducting the gas containing the volatilized sulfidic tin compound as well as entrained ore particles from the volatilizing zone through an oxidation zone wherein an entrainable tin oxide fume is formed, entraining the tin oxide fume in the gas, separating the entrained ore particles from the gas and entrained tin oxide fume, separating the entrained tin oxide fume from the gas, and supplying a portion of the resulting clean gas to the roasting zone.

3. A process according to claim 1 wherein the temperature of the lower bed is less than 1,140° C. and fuel is supplied to this bed.

4. A process for selectively volatilizing tin values of tin-bearing sulfide ores which comprises establishing and maintaining a bed of finely-divided ore solids in a volatilization zone at a volatilizing temperature, upflowing therethrough a stream of oxygen-lean gas at a velocity sufficient to fluidize the ore of the bed, volatilizing the volatilizable metallic sulfides from the ore by controlling the quantity of oxygen in the upflowing gas so as to yield a pre-determined sulfur-vapor pressure in the bed, discharging the non-volatilized residual sulfidic ore from the bed to a further zone maintained at a roasting temperature, establishing and maintaining a bed of the ore in the latter zone, roasting the ore in the latter bed while passing therethrough an uprising stream of oxygen-bearing gas at a velocity sufficient to fluidize the ore of that bed as well as to yield an oxygen-lean gas heated to substantially roasting temperature, introducing the resulting heated gas to the volatilizing zone to control simultaneously both the temperature and the sulfur-vapor pressure in the volatilizing zone.

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