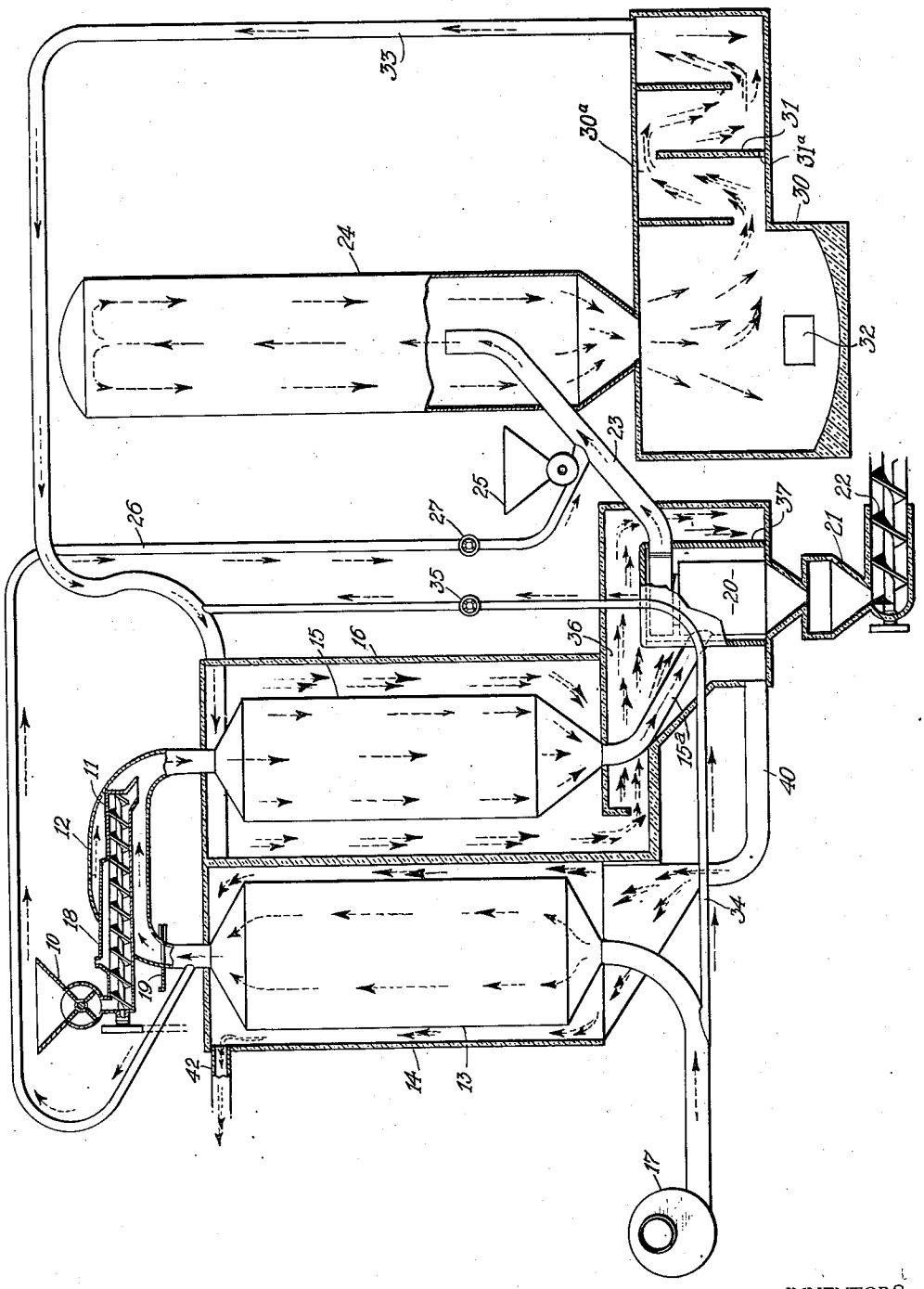
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METHOD OF REDUCING ORES

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INVENTORS
FRANK HODSON
CHUNG YU WANG
PETER HODSON

BY Frank S. Braham

ATTORNEY.

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METHOD OF REDUCING ORES

Frank Hodson, Elmhurst, Chung Yu Wang, New York, and Peter Hodson, Elmhurst, N. Y., assignors, by direct and mesne assignments, to American Ore Reduction Corporation, New York, N. Y., a corporation of Delaware

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This invention relates to methods of and means for reducing ores, especially those such as antimony sulfide and the like wherein the metal content is capable of being converted into a fume.

At present many different methods are employed to reduce such ores but all are unsatisfactory in that they are incapable of producing substantially pure metal at a cost which permits it to be used commercially to any great extent.

In accordance with the present invention, however, an ore of this sort and particularly antimony sulfide ore may be reduced to a desired state at a cost far below the cost at which it could be reduced to a like state by methods heretofore practiced. Briefly this is accomplished by passing the ore to be heated through an oxidizing zone maintained at temperatures sufficient to convert the metal content thereof to a fume, and then passing the fume thus formed without allowing any substantial condensation or coagulation thereof through a reducing zone maintained at temperatures sufficient to reduce the fume to the desired state.

The ore is preferably ground to a very fine particle size prior to the oxidizing or roasting operation since this leads to economy in fuel and rapidity of roasting by virtue of the added surface area and ease of gas penetration thus provided by the finely divided particles. In addition, the powdered ore and air required during the roasting operation are preferably pre-heated, this being desirable since it speeds up the roasting reaction and makes possible a considerable saving in fuel.

Also, the reduction of the fume is preferably effected in an atmosphere which is maintained violently turbulent at least during the major portion of the period of reaction since under such conditions the speed of the reaction is greatly augmented by the rapid removal of the film of oxidizing gas which tends to form about a particle being reduced.

For a detailed description of the invention, reference may be made to the accompanying drawing. In the drawing, however, the apparatus employed in practicing the present invention is shown merely in preferred form and by way of example, but obviously many changes and variations may be made therein and in its mode of operation, which will still be confined within the spirit of the invention, and it is to be understood, therefore, that the invention is not limited to any specific form of embodiment, except insofar as such limitations are specified in the claims.

In describing the invention, the reduction of antimony sulfide ore has been chosen for purposes of illustration, this being done since this ore is typical of the type of ore which may be reduced with advantage in accordance with the teachings of the present invention.

In practicing the invention with the apparatus shown, the ore is first pulverized and then loaded into a hopper 10, from whence it is fed into a horizontally disposed feed screw conveyor 11 capable of being driven at any desired rate of speed by means of a motor or the like (not shown). The conveyor 11 for the major part of its length is housed in the enlarged horizontal portion of an inverted U-shaped pipe 12, which opens at one end into the upper part of a vertically disposed air chamber 13 housed in a preheating furnace 14 and at its other end into the upper end of a vertically disposed roasting chamber 15 housed in a recuperator furnace 16.

An air or other oxidizing gas stream created by a blower 17, as indicated by the arrows in the drawing, travels upwardly through the vertically disposed air chamber 13, through the inverted U-shaped pipe 12 in which the conveyor 11 is housed, and thence downwardly through the roasting chamber 15. As the oxidizing gas stream passes upwardly through the chamber 13, it is preheated by hot waste gases in the manner hereinafter explained, and as this preheated gas stream travels through the inverted U-shaped pipe 12, the pulverized ore in the conveyor 11 is preheated by indirect heat transfer as its passes therethrough. Any vaporized moisture which may form in the conveyor 11 during the preheating of the ore will be carried away by means of a manifold 18 incorporated in the upper part of the conveyor 11 and so positioned that while water vapor is being discharged the heated air in the inverted U-shaped pipe 12 cannot blow back.

The conveyor 11 preferably discharges the dry powdered ore into the inverted U-shaped pipe 12 beyond the beginning of the bend which leads downwardly into the roasting chamber 15, this being desirable so that the ore will be delivered into the chamber 15 by gravity, as well as under the influence of the air or gas stream set up by the blower 17. The amount of oxidizing gas thus directed through the chamber 15 is such as to ensure the complete oxidization of the ore, it being controlled by a damper 19, and the chamber 15 is maintained at temperatures (350° to 450° C.) sufficient to roast the ore and bring about the conversion of the antimony content to antimony trioxide fume and the sulphur content to sulphurous gases; and here it is to be noted that the roasting chamber 15 is of greater cross-section than that of the lower end of the inverted V-shaped pipe 12 which opens into it so that the stream will be slowed down to ensure substantially complete roasting and volatilization of the ore as it travels therethrough. In this phase of the cycle of operations, however,

care must be exercised to insure that the temperature of the chamber 15 is not raised sufficiently high (800° C.) to convert the antimony content of the ore into the stable antimony tetroxide.

From the roasting chamber 15, the stream of antimony trioxide fume, the sulphurous as well as any other gases which might be created during the roasting process, and the solid gangue particles, are directed downwardly through a pipe 15a, as indicated by the arrows in the drawing, to a collector 20, which is maintained at temperatures sufficiently high, to prevent the antimony trioxide fume content of the stream from coagulating and condensing therein. As the stream of antimony trioxide fume, solid gangue particles and gases pass through the collector 20, the solid gangue particles settle to the bottom and into a heat insulated hopper 21, from whence they may be removed by means of a screw conveyor 22.

From the gangue collector 20 the stream which now comprises antimony trioxide fume and the gases created during the roasting operation is directed into the lower end of a vertical shaft furnace 24 by means of a pipe 23 having a discharge end adapted to direct the incoming stream upwardly through the central portion of the furnace 24 towards its dome shaped top. As the stream enters the furnace 24, a mixture of preheated air or other oxidizing gas and powdered coal or other carbonaceous fuel is injected therein and in such a manner that the combined stream of antimony trioxide fume, the gases created during the roasting operation and the injected oxidizing gas and fuel is forced upwardly through the furnace 24 at high velocity. As the upwardly flowing center stream nears the top of the furnace 24 its direction of travel is reversed and it then flows downwardly about the upwardly flowing center stream in the form of a tubular envelope. The powdered fuel thus injected into the pipe 23 is stored in a hopper 25 and the preheated oxidizing gas is conveyed through a pipe 26 to the pipe 23 from the narrow lower end of the inverted U-shaped pipe 12 opening from the air chamber 13 through which the preheated air stream flows with high velocity, and the arrangement of parts is such that the air carries the fuel from the hopper 25 into the pipe 23 in syphon fashion. Instead of powdered fuel a reducing gas, such as water gas, may be used. The pipe 26 carrying the preheated air is provided with a valve 27 for regulating the amount of air injected into the pipe 23, and enough fuel must be used with this air to heat the furnace 24 to approximately 800° C., and to supply carbon or other reducing medium to reduce this antimony trioxide fume, as well as to keep the atmosphere within the furnace 24 strongly reducing in nature.

In the furnace 24 the antimony trioxide fume is reduced to metal droplets, the speed of the reaction being promoted by the violent turbulence therein which, in keeping the materials in a constant co-mingled and agitated state, prevents envelopes of non-reducing gases from forming about partially reduced molecules of this trioxide fume.

In the hotter portions of the furnace 24 it is possible that some antimony tetroxide may be formed by oxidation of the antimony trioxide, but if it is formed it will also be reduced by the reducing medium present. In addition, any carbon dioxide that may be formed will be reduced to carbon monoxide by the action of the free carbon present, and so assist instantaneous reduction of the antimony trioxide fume.

From the furnace 24 the stream of antimony metal droplets and the resultant gases is directed into and through a heat insulated collecting chamber 30. The chamber 30 is of larger cross section than that of the furnace 24 so that the stream will be slowed down to the point where the metal droplets will fall to the bottom. To further promote the separation of the metal from the gases, the chamber 30 is provided with an extension 30a having baffles 31 secured to the top and bottom walls thereof over which the stream must pass, and to permit the metal to drain from the extension 30a back into the chamber 30, the baffles 31 secured to the bottom wall are provided with apertures 31a.

During the separation of the metal in the chamber 30 some carbon matter or ash may also settle out, but since it is much lighter than antimony, it will float on top of the metal and so form a protective coating thereon.

The chamber 30 is provided with a door 32 through which the antimony metal can be worked or ladled out under cover of a starting mixture and poured into molds or, if desired, run off into another furnace for further working or refining, if the quantity or nature of any impurities present makes this necessary.

From the metal collecting chamber, the stream of gases is conducted through a pipe 33 to the recuperator furnace 16 which heats the roasting chamber 15, and to maintain the temperature thereof at desired values the unburnt gases in the stream are burnt by admitting a portion of the stream of preheated air or other oxidizing gas created by the blower 17 through a pipe 34, the amount of air thus admitted being regulated by a valve 35.

From the recuperator furnace 16 the stream of hot gases is conducted to a housing 36 which surrounds the upper part of the gangue collector 20 but which is separated from it by a gas tight heat transmitting wall 37. By this arrangement the gangue collector 20 is kept hot enough by indirect heat transfer to prevent the coagulation and condensation of the antimony trioxide fume contained in the mixture of gas and gangue particles, which are discharged therein from the lower end of the roasting chamber 15.

From the housing 36 the stream of gases flows through a conductor 40 into the lower end of the preheating chamber 14 from whence it passes upwardly about the chamber 13 to preheat the actuating stream of air created by the blower 17.

From the preheater 14 the stream of gases is led off by a stack 42 for the removal of the sulphur content, as well as for further utilization of any other valuable gases which might be present.

If an ore containing arsenic is used, the process of reduction is the same as outlined above. A mixture of arsenic trioxide and antimony trioxide is formed in the roasting chamber 15 and since both are volatile at the temperature of roasting, they both take the form of fume and after the gangue has been separated out in the collector 20 they pass through the pipe 23 along with the gases resulting from the roasting, the reducing medium and the secondary supply of air into the reduction furnace 24, where they are both reduced to the elemental form. However, as the temperature in both the furnace 24 and condensation chamber 30 is at all times kept

above the melting point of antimony, which is 630° C., the arsenic will not condense, but will remain as a vapor since arsenic sublimes directly into the gaseous state at a temperature of 615° C. In consequence, the antimony will condense out as a liquid while the gaseous arsenic passes off with the other gases through the pipe 33 leading from the condensation chamber 30 and may be either condensed to the metal in a second cooler condenser if the amount present makes this worth while, or it may be burnt with other gases resulting from the reduction in the recuperator furnace 16 and later, if desired, separated out as arsenic trioxide.

The solid gangue particles discharged by the conveyor 22 from the hopper 21 will contain all the non-volatile impurities in the ore and, if any precious metals were originally present in the ore, they will be found in this gangue and may be easily recovered, along with any other metals or substances that may be present in commercially profitable quantities.

In case an oxide ore of antimony is used, the process, as stated heretofore, is essentially the same, save for roasting operation in the volatilizing chamber 15. The finely pulverized ore would be introduced with the air for combustion and the reducing medium directly into the furnace 24 and reduced therein in the manner heretofore described. The collection of the antimony droplets and the disposal of the solid gangue particles would be the same as described in connection with the reduction of antimony sulfide.

While air has been specified as the medium for converting the antimony content of the ore into fume it is to be understood that equally favorable results may be obtained by the use of other mediums, the essential feature in all cases being that the medium employed shall react chemically with the ore as it passes through the chamber 15 to volatilize the antimony content into fume from which the resultant gangue can be separated as it passes through the collector 20.

While the reduction of antimony sulfide ore to substantially pure metal has been described, it is to be understood that this was done merely for purposes of illustration and that the reduction of other ores capable of being roasted to a fume may be accomplished in substantially the same manner.

Having thus described our invention, we claim:

1. In the method of reducing ore, the steps which include roasting the ore to convert a metallic constituent content thereof to fume, and then reducing the fumed constituent to metal before any substantial condensation thereof is permitted to take place.

2. In the method of reducing ore, the steps which include powdering the ore, roasting the ore to convert a metallic constituent thereof to fume, and then reducing the fumed constituent to metal before any substantial condensation thereof is permitted to take place.

3. In the method of reducing ore, the steps which include roasting the ore to convert a metallic constituent thereof to fume, removing the solid gangue particles from said fume, and then reducing said fume to metal before any substantial condensation thereof is permitted to take place.

4. In the method of reducing antimony ore to metal, the steps which include so roasting said ore as to convert the antimony content of the ore into antimony trioxide fume, and then directing said fume before any substantial condensation thereof takes place through a reduction zone to convert said fume into metal.

5. In the method of reducing antimony ore to metal, the steps which include roasting said ore while in gaseous suspension to convert the antimony content of the ore into fume, separating solid gangue particles from the fume, and then directing the fume before condensation thereof through a reducing zone to effect a reduction thereof.

6. In the method of reducing antimony ore to metal, the steps which include directing a stream of oxidizing gas through a roasting chamber, introducing the ore to be treated into said stream, maintaining the temperature and the composition of the gases in said chamber at values sufficient to insure the conversion of the antimony content of the ore to fume, during its travel through said chamber, separating solid gangue particles from the resultant stream of gases and fume, directing the resultant stream of gases and fume before condensation of the fume through a reduction furnace, maintaining in said reduction furnace a reducing atmosphere at temperatures sufficient to convert the fume content of the stream into metal during its travel through said furnace, and then collecting the antimony metal.

7. The method of reducing antimony ore to metal set forth in claim 6 characterized in that waste heat created in the reduction furnace is utilized to maintain the temperature of the stream in the roasting chamber at desired values.

8. The method of reducing antimony ore to metal set forth in claim 6 characterized in that the ore is powdered before it is mixed with the stream of oxidizing gas and in that the waste heat from the reduction furnace is utilized to dry the powdered ore.

9. The method of reducing antimony ore set forth in claim 6 characterized in that the waste heat from the reduction furnace is utilized to prevent condensation of the fume during its travel from the roasting chamber to the reduction furnace.

10. The method of reducing antimony ore set forth in claim 6 characterized in that the stream of gases and fume is directed upwardly and then downwardly through the reduction furnace to insure that the conversion of the fume to metal is brought about under turbulent conditions.

11. The method of reducing antimony ore set forth in claim 6 characterized in that the conversion of the antimony content of the fume to metal in the reduction furnace is brought about under turbulent conditions.

12. The method of reducing antimony ore to metal set forth in claim 6 characterized in that the stream of oxidizing gas and ore is fed downwardly through the roasting chamber into a collecting chamber and in that the resultant stream of gases and fume from the collecting chamber is directed upwardly and then downwardly through the reduction furnace to insure that the conversion of the antimony content of the stream to metal is brought about under turbulent conditions.

13. The method of reducing antimony ore to metal set forth in claim 6 characterized in that an intermixture of oxidizing gas and fuel is injected into the stream of fume and gases to insure the conversion of the fume to metal in the reduction furnace.

14. The method of reducing antimony ore to

metal set forth in claim 6 characterized in that a stream of oxidizing gas is intermixed with the resultant gases from the reducing furnace to burn these gases and thus to maintain the temperature of the roasting chamber at desired values.

15. The method of reducing antimony ore to metal set forth in claim 6 characterized in that the hot gases and metal from the reduction furnace are directed through a metal collecting chamber having means for separating the antimony metal from the gases and maintained at a temperature above the melting point of antimony.

16. In the method of reducing antimony ore, the steps which include roasting said ore to convert the antimony content thereof into fume, and then directing the fume thus created before condensation thereof through a violently turbulent reducing zone to effect a rapid reduction thereof to metal.

17. In the method of reducing ore, the steps which include roasting said ore to convert a metallic constituent thereof to fume, and then subjecting said fume before condensation thereof to the action of reducing gas maintained in a turbulent condition to effect a rapid reduction of the fume to metal.

18. In the method of reducing ore, the steps which include directing a stream of the ore to be treated through a roasting chamber, subjecting said ore during its travel through said chamber to the action of an oxidizing gas at temperatures sufficient to convert a metallic constituent thereof to fume, directing the resultant stream of fume and gases before condensation of the fume through a reduction furnace, subjecting said fume during its travel through said reduction furnace to the action of a reducing agent at temperatures sufficient to effect a reduction of the fume to metal, and then separating said reduced metal from the resultant gases.

19. In the method of reducing ore, the steps which include powdering the ore to be treated, directing a stream of said powdered ore through a roasting chamber, subjecting said ore during its travel through said chamber to the action of an oxidizing gas at temperatures sufficient to convert a metallic constituent thereof into fume, directing the resultant stream of fume and gases before condensation of the fume together with a reducing agent and air through a reduction furnace in a violently turbulent manner to effect a rapid reduction of the fume to metal, and separating the reduced metal from the resultant stream of gases.

20. In the method of reducing ore, the steps which includes powdering the ore to be treated, directing a stream of said powdered ore through a roasting chamber, subjecting said ore during its travel through said chamber to the action of an oxidizing gas at temperatures sufficient to convert a metallic constituent thereof into fume, directing the resultant stream of fume and gases before condensation of the fume together with a reducing agent and air through a reduction furnace in a violently turbulent manner to effect a rapid reduction of said fume to metal, removing said reduced metal from the resultant gases, and utilizing the resultant gases to preheat the ore prior to its introduction into the roasting chamber.

21. In the method of reducing ore, the steps which includes passing a stream of oxidizing gas through a roasting chamber, introducing the ore to be treated into said stream, maintaining the temperature and the composition of the gases in the chamber at values sufficient to effect the conversion of a metallic constituent of the ore into fume, directing the resultant stream of gases and fume from the roasting chamber together with a reducing agent and air through a reduction furnace in a violently turbulent manner to effect a rapid reduction of the fume to metal, and then separating the reduced metal from the resultant stream of gases.

22. The method of reducing ore set forth in claim 21 characterized in that the gases after the reduced metal has been separated therefrom are used to preheat the air stream prior to its introduction into the roasting chamber.

23. In the method of reducing ore, the steps which include passing a stream of air through a roasting chamber, introducing the ore to be treated into said stream, maintaining the temperature and composition of the gases in the chamber at values sufficient to effect the conversion of a metallic constituent of the ore into fume, directing the resultant stream of gases, fume and solid gangue particles from the roasting chamber through a gangue collecting chamber maintained at temperatures sufficiently high to prevent condensation of the fume, directing the resultant stream of fume and gases from the collecting chamber together with a reducing agent and air through a reduction furnace in a violently turbulent manner to effect the rapid reduction of the fume, and removing the reduced metal from the resultant stream.

24. The method set forth in claim 23 characterized in that the gases after the reduced metal has been removed therefrom are utilized to maintain the temperature of the collecting chamber at desired values.

25. In the method of reducing ore, the steps which include passing a stream of air and ore to be treated through a roasting chamber, maintaining the temperature and composition of the gases in the chamber at values sufficient to effect the conversion of a metallic constituent of the ore into fume, directing the resultant stream of gases, fume and solid gangue particles through a collecting chamber to effect the separation of the gangue particles from the stream, maintaining the temperature of said collecting chamber above the condensation point of the fume, directing the remaining stream of fume and gases together with a reducing agent and air through a reduction furnace in a violently turbulent manner to effect a rapid reduction of the fume, and removing said reduced metal from the resultant gases.

26. The method of reducing ore set forth in claim 21 characterized in that the gases after the reduced metal has been removed therefrom are used to maintain the temperature of the roasting chamber at desired values.

27. In the method of reducing ore, the steps which include roasting the ore in an atmosphere free of combustion gases to convert a metallic constituent thereof to fume, and then reducing said fume to metal before any substantial condensation thereof is permitted to take place.

FRANK HODSON.
CHUNG YU WANG.
PETER HODSON.