Feb. 5, 1952 R. C. NEWHOUSE 2,584,808

METHOD OF AND APPARATUS FOR NODULIZATION OF IRON ORE

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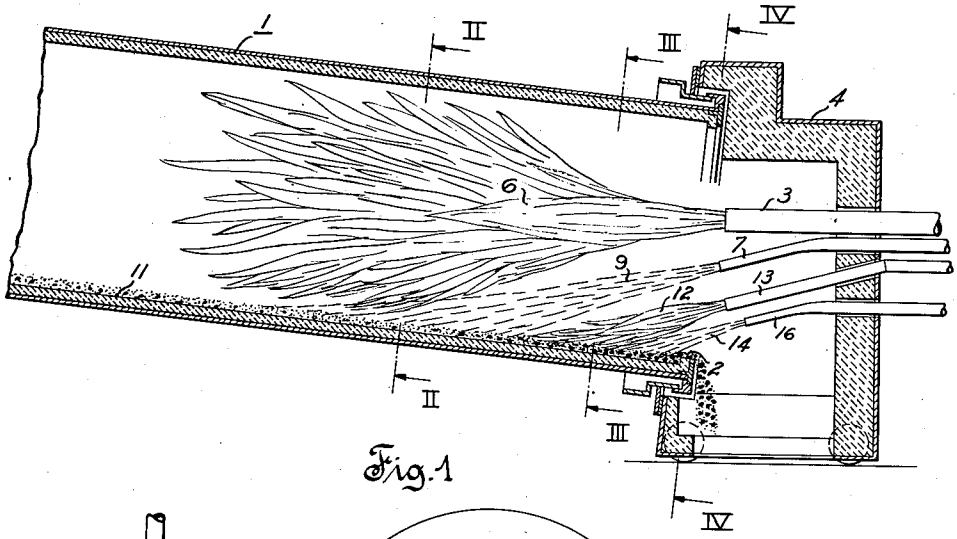


Fig. 1

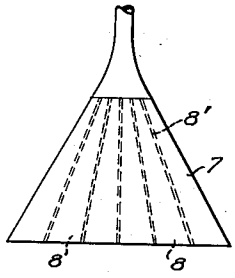


Fig. 6

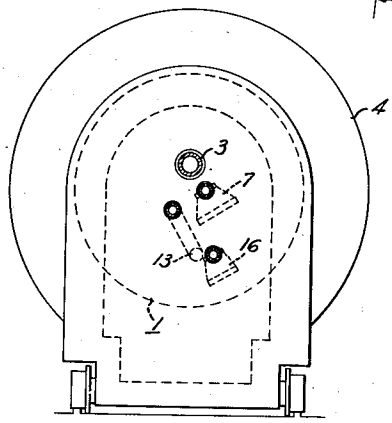


Fig. 5

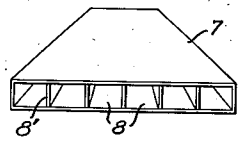


Fig. 7

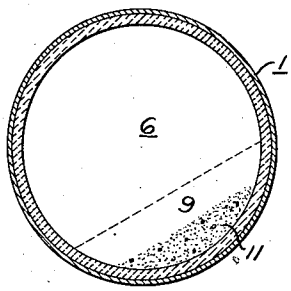


Fig. 2

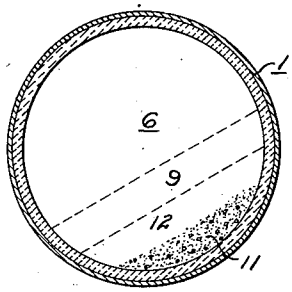


Fig. 3

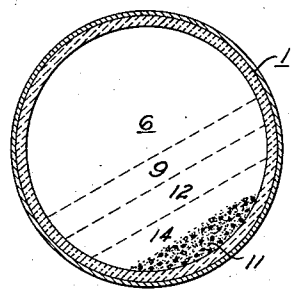


Fig. 4

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METHOD OF AND APPARATUS FOR NODULIZATION OF IRON ORE

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5 Claims. (Cl. 75—5)

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The present invention concerns improvements in the art of nodulizing iron bearing minerals, and apparatus for practicing the art.

It is known to the prior art that finely divided iron ore particles can best be utilized in steel production if bonded together in the form of hard, tough, porous nodules which can withstand the attrition of handling and still be effectively acted upon by the gases and chemicals involved in the steel making process, and nodulization has been practiced for many years. In cases where the ore is to be used in the open hearth steel production, such nodules or ore should be as rich as possible in oxygen so that the oxidation of carbon may occur to the greatest possible degree in the furnace.

One object of the present invention is to make the nodulization art more reliable and effective. Another object of the invention concerns improvement of the mechanical properties of the nodules produced. Still another object concerns production of nodules having a maximum combined oxygen content. A still further object concerns improvement of fuel economy in the nodulization process.

One of the distinguishing features of the present invention concerns the oxidation or reoxidation of nodules upon or immediately subsequent to formation by a blast of oxidizing gases (air).

Another distinguishing feature of this invention concerns the control of reduction of oxides in the raw material by gases during the heating process in a manner to produce within the mixture of sufficient quantity of a eutectic mixture of oxides ($3FeO.1Fe_2O_3$) so that nodulization can occur at as low a temperature as possible, thus reducing the fuel requirements.

It is known that a eutectic mixture of iron oxides of approximately the composition

$$3FeO.1Fe_2O_3$$

will melt at a temperature of in the neighborhood of 2200° F., that is, lower than any one of the iron oxides or any other mixture of such oxides. This fact has been taken advantage of in the nodulization process by adding a quantity of a mixture of finely divided materials capable upon heating of forming an agglomerating agent of approximately those proportions. When this is done, the eutectic agglomerating agent melts, at a lower temperature than the raw ore particles, and bonds together particles of iron ore with which it comes in contact which do not melt at such a low temperature. The result of this action is the production of nodules having desirable mechanical properties, but which are somewhat low in combined oxygen content as compared with the desirable maximum.

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In the present invention it is proposed to heat a mass of granular and finely divided ore particles without the addition of any special agglomerating agent and to so heat the materials in a gaseous atmosphere as to produce by reduction of the ferric compounds in the mass of ore particles per se, a substantial quantity of the desirable eutectic mixture of $3FeO.1Fe_2O_3$ which will melt at a temperature lower than any of the other oxides or mixtures of same present. When this eutectic mixture has been formed and the materials are heated to its melting temperature, nodulization will take place; and according to the present invention, the nodules so formed, which are, when formed, somewhat low in combined oxygen content, are subjected to a blast of air, or other oxidizing mixtures of gases, with resultant oxidation of some of the lower iron oxides and the production of a hard, tough, porous nodule with a maximum of combined oxygen.

The present invention can best be carried into effect as described hereinbelow with reference to the drawing in which like reference characters indicate the same or similar parts.

Fig. 1 is a vertical, longitudinal sectional view of a rotary kiln embodying the present invention;

Fig. 2 is a cross-sectional view taken on the line II—II of Fig. 1;

Fig. 3 is a cross-sectional view of the kiln taken on line III—III of Fig. 1;

Fig. 4 is a cross-sectional view taken on line IV—IV;

Fig. 5 is an end view taken from the right of Fig. 1;

Fig. 6 is a detail plan view of a secondary air nozzle; and

Fig. 7 is a detail end view of a secondary nozzle.

A quantity of material consisting of more or less finely divided ore, granular ore or concentrates, containing various quantities of the higher and lower oxides and possibly other iron compounds and gangue materials is heated in an atmosphere so controlled during heating that reduction of the iron oxides present is kept as low as possible until a temperature is reached at which a formation of a eutectic mixtures of oxides ($3FeO.1Fe_2O_3$) will quickly occur when the heated materials are acted upon by a reducing agent. When the temperature of the mixture approaches approximately 2200° F. the stream of materials is subjected to direct action of a reducing flame. The reduction which occurs will re-

sult in the rapid formation and melting of substantial quantities of the above mentioned eutectic mixture. The melting of the eutectic mixture of oxides at about 2200°–2300° F. will cause agglomeration of the particles of unmelted material with which the melted material comes into contact, and simultaneous tumbling of the materials will cause a formation of hard, porous nodules. These nodules will, however, be somewhat deficient in oxygen at the time of formation, owing to the presence of the lower iron oxides, such as Fe_3O_4 and FeO. In order to remedy this deficiency, a blast of air is directed against the newly formed nodules, with the result that the lower oxides are converted into higher oxides, simultaneously raising the melting point of the nodules and increasing the amount of combined oxygen.

The process of the present invehtion lends itself well to the rotary kiln type of nodulizing furnace because, during the heating of the materials to a nodulizing temperature, no melting of the charge will occur. When the materials reach the reducing or nodulizing flame, substantial quantities of the above mentioned eutectic mixture of oxides are formed and melted to produce nodules in a manner and at a temperature such that the materials other than the eutectic mixtures present are not melted and will not stick to the walls of the kiln. With proper control of the temperatures within the kiln, the walls of the kiln need never reach the temperature at which the ore particles will stick to it, thus rings or salamanders are avoided. Immediately after nodulization, such oxidation takes place as a result of the blast of air on the hot, newly formed nodules as to make them more desirable for many uses and also raise their melting temperature so as to inhibit any sticking to the kiln walls.

In the kiln installation shown in the drawing, raw material containing finely divided iron oxides and other materials is fed continuously into the upper end of a rotary kiln 1 in quantities sufficient to form a tumbling stream of ore through the lower part of the kiln towards the lower end 2 which forms the discharge point. The raw materials charged into the kiln will ordinarily consist chiefly of the principle ores, such as hematites and magnetites in which the iron is in the form of its oxides Fe_2O_3 and Fe_3O_4. The main burner or flame projector 3, mounted in a firing hood 4, projects a main flame 6 longitudinally into the discharge end 2 of the kiln. This main flame 6 will pass over and countercurrent to the ore stream, through the upper part of the kiln.

Flame projector 3 will project a mixture of gas, or pulverized solid fuel, or atomized liquid fuel and primary air, generally insufficient for complete combustion, and will accordingly have a normally reducing effect. However, secondary air will be separately supplied in sufficient quantities to complete combustion. In order to effect control of the heating atmosphere, or of that portion of the atmosphere in most immediate contact with the ore stream, and control any reduction of iron oxides that might occur, particularly as the material approaches the nodulizing temperature, the secondary air is preferably injected according to the present invention, through nozzle 7 which will localize the air stream.

This nozzle 7 preferably has a flattened orifice 8, or other known orifice, so formed as to project a fan-like stream of air 9 below and more or less

divergent from the flame axis of main flame 6. The stream of air 9 so produced will have the effect of blanketing the stream of materials 11 in process and protecting it from the more reducing parts of the main flame gases, particularly as the materials approach the hottest portion of the kiln. Preheating will thus occur without appreciable reduction of the higher oxides present in the ore. As the ore passes a predetermined intermediate point, approximately on the line II—II of Fig. 1, it will have reached a temperature in the neighborhood of 2200° F. at which temperature its higher iron oxides can readily be reduced by a reducing flame. Beyond this point II—II, the stream, having passed the blanket of secondary air 9, is subjected to the action of a reducing or nodulizing flame 12, projected from burner 13. The hot gases of this flame 12 will cause a reduction of at least a portion of the higher oxides, with a resulting production and melting of substantial quantities of the eutectic mixture of iron oxides ($3FeO.1Fe_2O_3$). The tumbling progress of the stream of materials brings all ore particles into contact with the nodulizing flame, and causes the material particles to roll against each other. The presence of the melted eutectic mixture among the solid particles of other materials will result in a binding together or agglomeration therewith of particles having a higher melting point. The constant rolling and folding over action in the tumbling stream of materials causes the building up of nodules of a size and quality dependent upon the temperatures and speed of kiln rotation and the composition of the materials involved. The temperature and speed of rotation are so controlled that effective nodulization will occur with a sufficient absorption of heat in the melting and agglomeration of materials to prevent the kiln walls from reaching temperatures sufficient to cause adherence between the materials and the lining of the kiln, such as would cause a building up of objectionable rings or salamanders.

Immediately after the newly formed nodules have passed the zone of impingement of the nodulizing flame, they will be subjected to impingement of a second stream 14 of secondary air. This air, contacting the newly formed nodules, and containing oxygen, will oxidize at least a portion of the iron and lower oxides of the hot nodules and take up heat resulting in a fuel economy. This oxidation will result in a raising of the melting point of the material of the nodules above the temperature existing in the kiln; adherence between the nodules and the kiln lining will, as a result, be inhibited, and the combined oxygen content of the nodules will be increased.

The firing hood may be of any known suitable type, with a suitable seal around the firing end of the kiln and a suitable opening for discharge of nodulized material. As to firing equipment, however, the firing hood is equipped according to the present invention with a main burner or flame projector 3, first secondary air projector nozzle 7, a secondary or nodulizing flame projector 13, and a second secondary air projector nozzle 16 which may be similar in construction to nozzle 7. Figs. 6 and 7 show plan and end views of a suitable flattened fan nozzle 7 for secondary air, with anti-turbulene vanes 8'.

The main burner 3 is arranged to project its flame longitudinally through the upper portion of the kiln space, the first secondary air projector

nozzle 7, is arranged to project its stream of air 9 below, and preferably slightly downwardly divergent with relation to the main flame 6, and with the major transverse axis of the stream 9 roughly parallel to the general surface of the tumbling stream of material 11 as shown in Fig. 2. The secondary burner 13 projects its flame definitely downwardly toward the material stream, to impinge thereon at a point near the discharge end of the kiln, but spaced therefrom. A section through the nodulizing zone is shown in Fig. 3. The second secondary air supply nozzle 16 directs its stream 14 downwardly, substantially parallel to, and below, or even divergently downwardly with relation to the secondary nodulizing flame 12, to impinge upon the materials at a point between the nodulizing zone and the discharge end of the kiln. Fig. 4 shows a cross-section through the kiln at the zone where the second secondary air stream 14 impinges on the nodules to cause cooling and oxidation.

Basically speaking, the invention is in the nature of a process of nodulization. It may however be equally well defined as a method of operating a nodulizing kiln, and it includes certain features of mechanical construction of an apparatus for carrying out the process when operated by the method of the invention.

It will be understood that the invention is not limited to the precise details of the apparatus as illustrated in the drawing, but is intended to include the process and method of operation involved, and such modifications and equivalents of the process, method and apparatus shown as would readily occur to persons skilled in the art, within the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. In a process for nodulizing a mixture of granular iron oxide bearing minerals, the steps of raising the said minerals to nodulizing temperature in a atmosphere controlled as to reducing effects so as to produce in said materials substantial quantities of a eutectic mixture of iron oxides ($3FeO.1Fe_2O_3$) nodulizable at a minimum temperature, nodulizing said minerals at said temperature by directing a reducing flame of burning gases against them, and subsequently impinging a blast of gases having oxidizing characteristics upon said nodulizing mixture immediately following its formation and while still at substantially nodulizing temperature.

2. In a process for nodulizing a mixture of granular iron oxide bearing materials, the steps of heating said minerals to a temperature at which a reduction of Fe_2O_3 to Fe_3O_4 and FeO can occur, controlling the reducing effect of the heating atmosphere in such a manner that substantial quantity of a eutectic mixture of oxides having the proportions $3FeO.1Fe_2O_3$ is formed, further heating said mixture to a nodulizing temperature in a reducing flame of burning gases while tumbling same progressively through said flame to produce nodules, and suddenly oxidizing the materials of said nodules by impinging a blast of oxidizing gases on said nodules after they have passed through said flame and while still at their nodulizing temperature.

3. A method of nodulizing iron bearing minerals in a moving stream of said minerals, comprising establishing a tumbling stream of iron bearing minerals moving progressively from a starting point to a nodulized material discharge point, preheating said minerals by a counter-current of heated gases as they proceed from said starting point towards an intermediate point, quickly raising said minerals to a nodulizing temperature under reducing conditions by directing a nodulizing flame of burning gases against them as they pass said intermediate point, and impinging an oxidizing mixture of gases upon the hot nodulized minerals as they pass from said nodulizing flame to said discharge point.

4. A process for nodulizing iron bearing materials to produce hard, dense, high oxygen bearing nodules, comprising establishing a moving bed of such materials passing through a preheating zone, agitating said materials in said bed and supplying additional raw material at one end of said zone while removing material at a substantially equal rate beyond the other end of said zone into a nodulizing zone, passing a preheating flame in counter-current to said moving bed of materials through said preheating zone, supplying secondary air cocurrent to said flame in a curtain-like stream directed to blanket said bed and control the character of that portion of the gases most immediately in the vicinity of the bed of materials to inhibit excessive reduction of said materials during preheating, directing a high temperature nodulizing flame having reducing characteristics to impinge upon the heated materials of said bed in said nodulizing zone to cause a partial reduction of the higher oxides and creation of substantial quantities of eutectic mixture of higher and lower oxides ($3FeO.1Fe_2O_3$) nodulizable at a minimum nodulizing temperature and nodulize said mixture, and directing a stream of oxidizing gas to impinge upon the said nodulized mixture as it emerges from said nodulizing flame to increase the combined oxygen content of said nodules.

5. In a kiln for heating and agglomerating materials, means for receiving and continuously advancing a stream of materials along a path from a material receiving point of said kiln to a discharge point thereof, means projecting a main material heating flame into said kiln above the path of said stream of materials in direction counter to the direction of flow of said materials, means projecting a reducing flame into said kiln below said main flame and directing same to impinge on the path of said stream of materials at an intermediate point near said discharge point, means projecting a first stream of oxidizing gases into said kiln above said reducing flame and below said main flame to prevent any substantial reducing action on said materials by said main flame, and means introducing a second stream of oxidizing gases into said kiln and directing same to impinge on the path of said stream of materials at a point between the point of impingement of said reducing flame on the path of said stream of materials and said discharge point.

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