Sept. 24, 1957 K. M. HALEY ET AL 2,807,534

METALLIFEROUS AGGLOMERATES HAVING IMPROVED GREEN STRENGTH AND METHOD OF FORMING THE SAME

Filed April 11, 1952 2 Sheets-Sheet 1

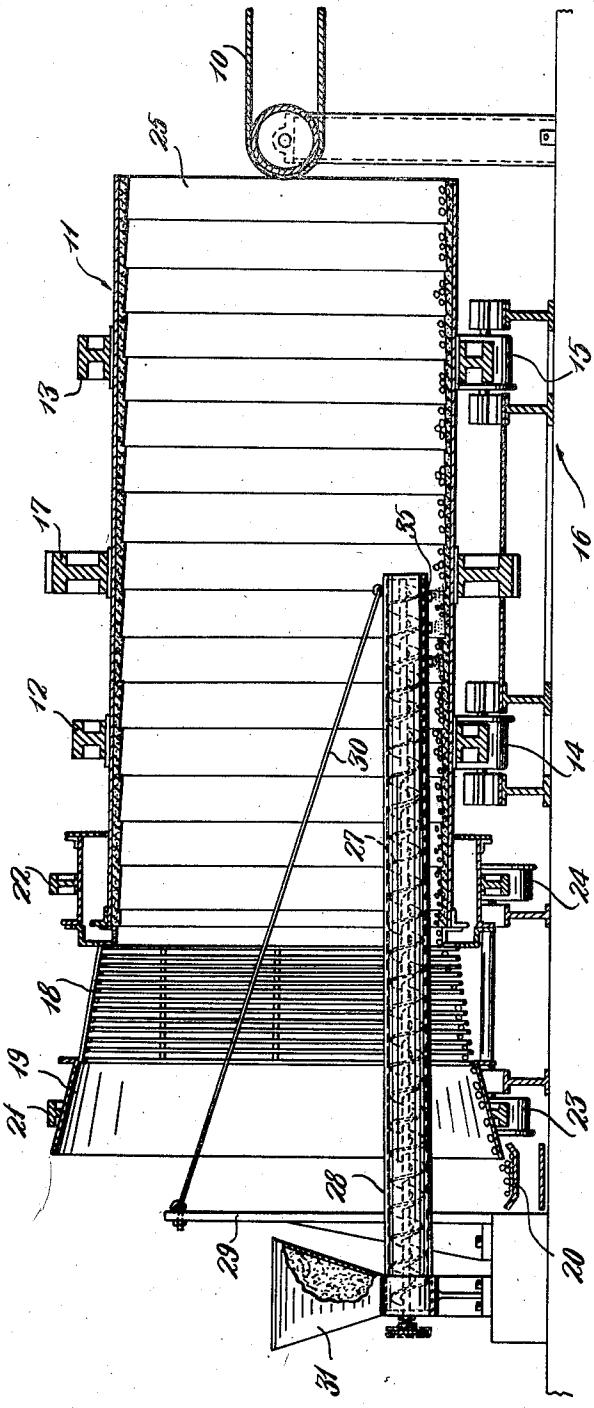


FIG. 1

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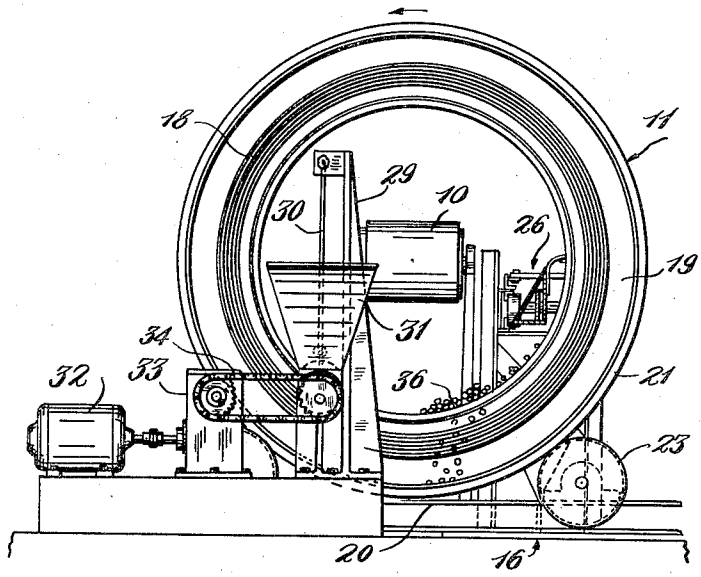


FIG. 2

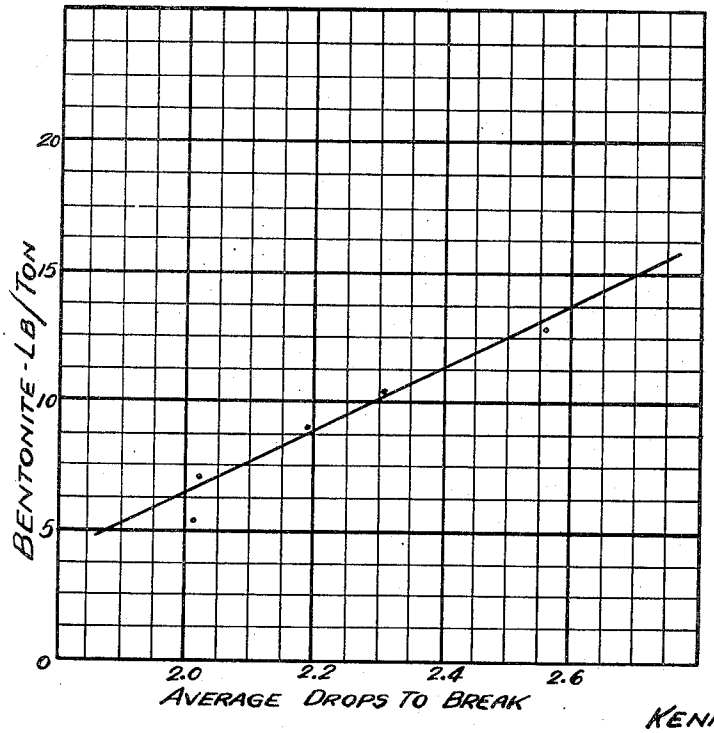


FIG. 3

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United States Patent Office 2,807,534
Patented Sept. 24, 1957

2,807,534

METALLIFEROUS AGGLOMERATES HAVING IMPROVED GREEN STRENGTH AND METHOD OF FORMING THE SAME

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Application April 11, 1952, Serial No. 281,754

2 Claims. (Cl. 75—3)

This invention relates to ball-like agglomerates and to the method of forming such agglomerates from finely divided metalliferous material. More particularly, the invention relates to agglomerates of this nature which have greater strength in their green or unindurated condition than prior agglomerates and to the method by which such improvement is effected.

A number of metalliferous materials either occur or are produced in a finely divided state which is unsuitable for use in conventional metallurgical apparatus such as blast furnaces or the like. Blast furnace flue dust, fines of natural ores or ore concentrates may be mentioned as examples of such materials. It is now known, however, that such finely divided materials may be agglomerated into bodies of suitable size for use in blast furnaces or the like by rolling or tumbling the material while in moist condition in a drum or cylinder thereby producing ball-like bodies. The bodies as thus produced, and which may be termed "green," are relatively fragile and will not withstand rough handling. It has been found, however, that such green agglomerates, especially those produced from metalliferous material containing iron oxide, may be indurated or hardened by heating thereby increasing their strength to the point where they may be handled by conventional equipment used for transporting and handling ore. Consequently, it has become common practice to heat the ball-like agglomerates to temperatures in the order of from 1700° F. to 2400° F. to effect such hardening or induration.

The aforementioned heating or indurating of the green agglomerates has heretofore resulted in the production of an undesirably large proportion of fines and dust. This is not only due to breakage of the green agglomerates in moving the latter from the apparatus in which they are formed into and through the furnace or other indurating device, but also because the green agglomerates are generally moist and, hence, frequently fragment, crack or otherwise deteriorate as the result of conversion of this moisture to vapor or steam at a rapidity which exceeds the ability of the agglomerates to permit escape of such vapor or steam. Moreover, where the agglomerates have been dried prior to introduction into the indurating furnace or the like, in an effort to prevent such fragmentation due to vapor formation, the dried agglomerates have been found to have greatly reduced "green" strength, and, therefore, produce an undesirable quantity of fines and/or dust through abrasion and breakage in moving to and through the upper portion of the furnace or other indurating equipment before induration is effected.

An object of this invention is to provide ball-like agglomerates of finely divided metalliferous material which have greater strength in their green or unindurated condition than those produced heretofore so that there is less breakage and decrescence in handling such agglomerates prior to induration thereof.

Another object of the invention is to increase the green strength of ball-like agglomerates formed from finely divided moist metalliferous material so that the agglomerates do not fragment or fracture when heated.

A further object of the invention is to provide an improved method of forming ball-like agglomerates from finely divided metalliferous material whereby the resulting bodies have greater green strength than heretofore and better resist fragmentation, fracture and abrasion during handling and heating.

An additional object of the invention is to provide a method of improving the ball forming characteristics of the surface of a layer of moist finely divided metalliferous material on which the ball-like agglomerates are formed.

Another object of the invention is to provide an improved ball-like body of finely divided metalliferous material by the inclusion therein of a small quantity of bentonite with the concentration of the bentonite being greater adjacent the surface of the body than at the center thereof whereby greater green strength of the body is secured with a minimum of the bentonite.

A further object of the invention is to provide an improved method of incorporating bentonite into ball-like agglomerates of finely divided metalliferous material so that the concentration of the bentonite is greater adjacent the surface of the body than at the center thereof.

A more specific object of the invention is to improve the formation and green strength of ball-like agglomerates, produced by rolling moist finely divided metalliferous material in a balling drum, by adding finely divided bentonite to the surface of the layer of such material adhering to the interior of said drum at a location circumferentially in advance of the said rolling material so that the latter rolls over the said bentonite thereby incorporating a portion of the bentonite in the resulting agglomerates.

The invention further resides in certain novel steps of procedure and features of the agglomerates produced thereby, and further objects and advantages of the invention will be apparent to those skilled in the art to which it pertains from the following description of the present preferred embodiment described with reference to the accompanying drawings in which;

Fig. 1 is a somewhat schematic longitudinal sectional view through a balling drum illustrating the method of introducing bentonite therein to improve the balling surface and the green strength of agglomerates produced therefrom;

Fig. 2 is an end elevational view of the balling drum and the means for introducing bentonite therein as seen from the discharge end of the drum; and

Fig. 3 is a graph showing the increase in breaking strength of green agglomerates resulting from inclusion of various quantities of bentonite in the agglomerates when added during formation thereof in accordance with this invention.

The formation of ball-like bodies or agglomerates from finely divided metalliferous material, such as ore concentrates or the like, is most advantageously effected by subjecting such material to a rolling and/or tumbling action while in moist condition so that the particles gather together into the ball-like bodies. This action is facilitated by causing the said rolling or tumbling to occur upon a layer of the moist material so that the bodies are compacted as they form and grow by accretions from that layer.

One apparatus by which this balling action may be accomplished is schematically represented in Figs. 1 and 2 of the drawings. As shown therein, a belt conveyor **10** transports the finely divided material, from a suitable source of supply to, and deposits the material within, the interior of a hollow, open ended, cylindrical member or drum **11**. This cylinder or drum is preferably

formed of metal and is rotatably supported with its longitudinal axis extending approximately horizontally. This is accomplished by means of a pair of spaced circular tracks or rails **12** and **13** which are secured to the drum and are rotatably supported upon spaced pairs of flanged wheels, such as **14** and **15**, journaled in suitable bearings mounted upon a frame or base **16**. The frame or base **16** may be adjusted in height by means, not shown, to slightly tilt the axis of the drum from the horizontal, the drum preferably being so positioned that its axis is inclined slightly downwardly to the left, as viewed in Fig. 1. The drum is rotated by power means, not shown, connected by a gear train to the bull gear **17** secured to the drum intermediate the ends of the latter.

The discharge end of the drum **11** is preferably provided with a screening means which is here illustrated as a trommel **18** formed of spaced circumferentially extending bars disposed in a substantially frusto-conical configuration. The outer portion of the trommel **18** is connected with a frusto-conical impervious portion **19** over which the ball-like bodies discharge to a conveyor **20** which transports the ball-like bodies to the indurating furnace, not shown. The trommel **18** and impervious portion **19** may be integrally connected with the drum **11** but are here shown as rotatably supported independently of the drum by means of rails **21** and **22** riding upon flanged wheels **23** and **24**. The trommel is rotated by means, not shown connected with one of the supporting wheels.

The metalliferous material deposited within the drum **11** is distributed therein, due to the rotation and slight downward inclination of the drum, and since the material is moist it tends to cling or stick to the inner surface of the drum thereby forming a layer **25** therein. Portions of the material forming this layer, as well as additional portions of the material supplied by the conveyor **10**, tumble and roll upon the layer as the drum is rotated thereby producing ball-like bodies. The bodies thus formed move towards the discharge end of the drum with the larger bodies moving over the bars of the trommel **18** and the impervious portion **19** to the conveyor **20**. The smaller bodies and fragments thereof fall through the openings between the bars of the trommel **18** and are conveyed, by means not shown, back to the conveyor **10** so that they are re-introduced into the drum for re-rolling operations.

The aforementioned operation is the manner in which ball-like bodies have been formed heretofore and, while such bodies may be formed in relatively large quantities in this manner, green strength of such bodies was quite low so that they were easily broken both in transporting on the conveyor such as **20** and when disposed in the upper portion of the indurating furnace. Improvement in the green strength of the bodies was achieved by a careful control of the particle sizes of the metalliferous material and the moisture content thereof and also by maintaining the layer **25** substantially uniform in thickness and by roughening its surface. This latter control, namely, the maintenance of the thickness of the layer and of a roughened surface thereon may be achieved by a suitable cutter bar or scraper, generally designated **26**, see Fig. 2, which is of the type disclosed and claimed in the copending application of Kenneth M. Haley et al., Serial No. 261,048, filed December 11, 1951, and entitled "Apparatus For Making Pellets," to which reference may be had for details of this scraping means and the other structural features of the balling apparatus.

A reliable test of the green strength of the agglomerates is afforded by dropping twenty of the bodies, one at a time, a distance of three feet six inches onto a steel plate. The number of drops to effect breakage of the bodies is then averaged and expressed as the "average drops to break," a body being considered broken if a piece, regardless of size, is broken upon impact with the plate. Correlation of results of this test with operational data

for an agglomerating plant revealed that the green agglomerates should have an "average drop to break" strength of at least 2.0 in order to prevent excessive breakage and production of fines in the indurating furnace and in charging the bodies therein. Although known balling apparatus at times produce agglomerates having green strength of this value, such results cannot be achieved consistently in the routine operation thereof.

In an effort to further increase the green strength of the ball-like agglomerates, the addition of various binders to the metalliferous material before its entrance into the balling drum has heretofore been suggested. The use of such binders has, however, generally proved impractical either because of expense or because the additives produced undesirable results in the indurating furnace or other apparatus or in the subsequent metallurgical apparatus such as a blast furnace or the like in which the agglomerates are to be used. Nevertheless, some further improvement in the green strength of the agglomerates is necessary especially where a small percentage of coke or coal is mixed with the metalliferous material prior to the balling operation to provide fuel in the subsequent indurating operation since such carbon particles tend to reduce the green strength of the agglomerates.

The desired improvement in the green strength of the agglomerates is achieved, in accordance with this invention, by the addition of a small quantity of bentonite during the balling operation. This material, which is principally montmorillonite, is added in dry powdered form to the surface of the layer **25** of moist material within the drum in advance of the bodies or particles of material rolling thereon so that a portion of the bentonite is picked up by the said bodies and incorporated therein. As a result, the bodies have a greater concentration of the bentonite adjacent their surfaces than at the centers thereof and this materially improves the green strength of the agglomerates.

The extent of this improved green strength of the agglomerates due to the addition of bentonite thereto can be readily demonstrated by the aforementioned drop test upon samples of the bodies so produced. Thus, representative results of such tests for different quantities of bentonite added, in the manner aforementioned, are as follows:

Bentonite added into balling drum

Lbs./ton of metalliferous material	Av. drops to break
5.13	2.01
7.13	2.02
8.99	2.19
10.73	2.22
12.80	2.56

These values are graphically represented in Fig. 3.

It will be evident from these tests that when quantities of bentonite in the order of from 5 to 13 pounds per ton of metalliferous material are added, as aforementioned, the green strength of the pellets is increased to a point above the minimum requirements which has been determined by experience to be equal to a break index of 2.0. Moreover, bodies having green strengths of the desired values can be consistently produced in operations of commercial scale with a minimum of attention from the operator. Additions of larger quantities of bentonite further increase the break strength or green strength of the agglomerates but such further increases in strength are not deemed necessary and, hence, the larger quantities of bentonite need not be employed.

The improvement in the green strength of the agglomerates is not restricted to their ability to better withstand abrasion and impact in handling but improvement is also found in their ability to withstand the creation of steam or vapor therein while in the upper portion of the indurating furnace. This latter improvement is evidently

connected with the greater concentration of the bentonite adjacent the surfaces of the agglomerates which apparently facilitates the escape of the vapor or steam without rupture of the agglomerates. This characteristic of the agglomerates has been particularly noted when the bentonite utilized is of the high swelling western type such as Wyoming bentonite.

In addition to improving the green strength of the agglomerates, the introduction of bentonite into the balling drum has been found to improve ball forming characteristics of the surface of the layer **25** of moist material. That is to say, the material which is being rolled or tumbled to produce the ball-like bodies is found to move over the layer **25** with less sticking or sliding than when the bentonite is not employed. Consequently, the balling operation can be more easily controlled so that the ball-like agglomerates produced are of more uniform size and of uniformly better strength than when the bentonite is not employed.

A practical evaluation of the actual improvement secured by the introduction of bentonite is to be found in the percentage of the material which must be re-circulated through the balling drum as a result of dust formation and screenings from the output of both the balling drum and the indurating furnace. Without the use of bentonite, the lowest re-circulation for a month's operation of an agglomerating plant was 20% of the entire materials handled. With the use of bentonite in accordance with this invention the re-circulating load was reduced to 6%. This improvement reduced the cost of operations an amount which more than offset the cost of adding the bentonite. Moreover, introduction of the bentonite into the balling drum produces the desired increased green strength with a minimum of bentonite since the latter is concentrated adjacent the surface of the agglomerates where it does the most good. This not only results in less cost than would be the case if the bentonite were uniformly mixed with the metalliferous material but also reduces the non-metal bearing material in the agglomerates which must be eventually removed in subsequent metallurgical processes.

The bentonite may be added to the interior of the balling drum by any suitable mechanism. As illustrated in the drawings, one mode of so adding the material is by a screw type conveyor **27** extending into the interior of the drum from the discharge end and to a point adjacent the longitudinal center of the drum. The screw conveyor **27** is preferably enclosed in a hollow tube **28** which is supported by a suitable structural member **29** exteriorly of the drum and by a cable or rod **30** extending from a point adjacent the top of the member **29** to the tube **28** adjacent its inner end, see Figs. 1 and 2. The tube **28** communicates adjacent its outer end with a hopper **31** into which the powdered bentonite is introduced and from which the bentonite is moved by rotation of the conveyor screw **27**, screw **27** being driven through a suitable means comprising a motor **32**, speed reduction unit **33** and a chain and sprocket drive **34**. The tube **28** is provided with a plurality of spaced openings **35** on its lower side through which the bentonite fed by the conveyor **27** is deposited onto the layer **25** within the drum **11**.

It will be observed that the tube **28** with its conveyor screw **27** is located circumferentially in advance of the loose material or ball-like bodies such as **36** which are rolling upon the surface **25**, the direction of rotation of the drum being counter-clockwise as viewed in Fig. 2. Hence, the bentonite is deposited upon the layer of moist material within the drum rather than directly upon the bodies themselves. Consequently, the bentonite which is incorporated into the bodies is acquired by rolling of the bodies over the bentonite enriched layer of moist material, thereby effecting distribution of the bentonite over the growing surfaces of the bodies and firmly incorporating it therein due to the pressures exerted by the rolling action. Moreover, it will be apparent that, since the bentonite is added to the interior of the drum adjacent the central portion thereof, the concentration of the bentonite will be greater adjacent the surfaces of the completed bodies than at the centers thereof since the said bodies will have at least partially formed before contacting the bentonite enriched surface. Although but three openings **35** have been shown in the tube **28** with these located adjacent the central portion of the balling drum, it will be apparent that other openings may be provided some of which are more closely adjacent the trommel **18**, if this be found desirable, to further increase the concentration of the bentonite in the outer surfaces of the bodies.

The invention may be practiced by other means for supplying the bentonite than the mechanism here illustrated and described. Moreover, the invention is not limited to use with a balling drum of any particular construction or dimensions, to specific speeds of rotation of the balling drum, or to other structural details or operating characteristics. However, it may be mentioned by way of example, that in one installation the drum used was in the order of 7 feet in outside diameter and 16 feet long and was rotated at speeds of from 9 to 18 R. P. M. This drum, provided with a reciprocating scraping member or bar similar to that indicated at **26**, produced agglomerates ¾" in diameter or larger from metalliferous material in the form of magnetite concentrates, 80% of which were of a minus 325 mesh size and had a moisture content in the order of 9.5 to 10.5%. The metalliferous material also contained in the order of 1% of pulverized anthracite coal of minus 100 mesh size. In operating with this material Wyoming bentonite in finely divided condition was supplied to the surface of the layer of material adhering to the interior of the drum at the rate of about 12 pounds to the ton of the material to be agglomerated, the moisture content when such additive was utilized being then increased to 10.5%. The resulting agglomerates were found to have improved breaking strength both with respect to ability to withstand the stresses of handling and transportation from the balling drum to the indurating furnace and in ability to withstand breakage due to heating in the furnace itself.

The invention is, of course, not limited to use of apparatus of these characteristics nor in fact is it limited to use with a balling drum since improved green strength of the agglomerates and improvement of the balling surface may be effected by the addition of bentonite to a layer of the moist material on which the agglomerates roll as being formed whether that layer of material and the rolling be provided within a hollow drum or by other means. Consequently, this description and the accompanying drawings are intended only as illustrative of the presently preferred embodiment of the invention, the ambit of which is determined by the spirit and scope of the subjoined claims.

Having thus described the invention, we claim:

1. The method of forming in a single operation ball-like agglomerates each comprised of bentonite and a material containing finely divided metalliferous particles with the bentonite being concentrated in the portion of the final ball-like agglomerate adjacent the outer periphery thereof, the steps comprising introducing said material in a moist condition into the charging end of a rotating balling drum and producing a first layer of the material adhering to the inner surface of the drum and extending from a point adjacent the charging end of the drum toward the exit end of the drum, continuing the introduction of the moist material after the formation of said layer on the inner surface of the drum and continuing the rotation of said drum and causing loose portions of said material to ball up and form ball-like agglomerates by rolling on said layer from the charging end to the exit end thereof,

and depositing bentonite onto said layer from depositing means disposed above the layer at the place of deposition which place of deposition is disposed intermediate the exit end and the charging end of the drum to provide a second layer comprised of bentonite superimposed on a portion of said first layer and extending circumferentially of the drum and spaced from the charging end of the drum in the direction of advance of the agglomerates being formed a distance such that the portion of the first layer having the bentonite deposited thereon is rolled upon by the ball-like agglomerates after the ball-like agglomerates are partially formed to provide an outer layer on each of the partially formed agglomerates comprised of bentonite and said material and to provide final ball-like agglomerates each having the bentonite therein concentrated on outer layer portion of the ball-like agglomerate.

2. The method of forming ball-like agglomerates as defined in claim 1 wherein the bentonite is continuously supplied into the balling-drum at the rate of from about 5 to about 13 lbs. of bentonite per ton of said material introduced at the charging end of the drum.

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