COAL BENEFICIATING PROCESS

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ABSTRACT

A coal beneficiating process for the efficient production of high quality coal at higher yields through a concept of stage separation which requires a minimum of crushing.

2 Claims, 2 Drawing Figures
COAL BENEFICIANING PROCESS

BACKGROUND OF THE INVENTION

This invention relates to classifying, separating and assorting solids, and more particularly to coal beneficiating.

Current interests in coal beneficiating processes are directed to the problem of upgrading low grade ore. With the depletion of sources of top grade ore, and the increasing need to combat pollution problems associated with the use of low grade (and consequently high sulfur) coal, much interest is now centered in methods of liberating coal from a feed which has a high content of sulfur and other refuse.

Conventional practice today includes processes which initially completely crush all the feed to be processed to very fine sizes in order to liberate the coal from both the sulfur constituents and non-sulfur refuse (clays) and thereafter perform multiple operations to separate the fine coal from the refuse. U.S. Pat. Nos. 2,319,394 and 2,330,479 to Erickson are examples where coal is initially completely crushed to a fine size and thereafter undergoes several and various separation processes such as gravity separations and screening. It has been found that gravity separations, specifically hydro-cycloning, are normal means of separating coal from refuse of dissimilar densities. Unfortunately, the finer the coal and refuse, the more difficult the separation of the coal from the refuse. U.S. Pat. Nos. 3,638,791 to Harrison 3,023,893 to Zabrowski and 3,446,349 to Benzon are illustrative of the methods currently employed in fine coal beneficiating processes.

It is, therefore, an object of this invention to provide a process which will beneficiate coal but minimize the amount of fines, both coal and refuse, which must be processed in the various sizing and classifying apparatus employed for this purpose.

SUMMARY OF THE INVENTION

We have discovered a process for beneficiating coal, particularly coal middlings, which is simpler and more efficient than the prior art. By middlings, we refer to low grade coal which is characterized by high ash about 15% by weight and above and high sulfur about 1.75% by weight and above. If the middlings are crushed, finer coal and refuse are released from the middlings. In the process of this invention beneficiating steps such as separating, classifying and sizing are arranged to minimize the production of a fines fraction during the course of crushing operations performed to liberate the coal from adherent refuse and middlings. Our method, unlike prior art processes, crushes ore in successive steps to obtain increasingly smaller size with concurrent removal of coal values such that crushing and separating steps are limited substantially to the middlings fraction each time. The system increases efficiency in that larger sizes of coal and refuse are separated and removed and only middlings are continually crushed, minimizing thereby the percentage of original ore which must be classified and separated as fines. In addition to the concept of stage separation, we have discovered a combination of beneficiating steps which utilized together result in an overall improved circuit unknown heretofore. The present invention may be better understood from a consideration of the following drawings and exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of our process showing beneficiation of a coal middlings fraction. FIG. 2 is a diagrammatic illustration of an embodiment of our process.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The instant invention is directed to improvements in processing fine coal to remove sulfur and ash constituents while increasing yield by crushing middlings. Presently in the industry, there are many different systems used for reducing sulfur and ash in fine coal, but all feature common unit operations noted hereinbefore that are combined in various ways. Unit operations such as hydrocycloning, tabling, screening, crushing and those that use classifying cyclones and flotation are the most common. The instant invention presents a unique combination of these components which, when working in a system, results in improved coal quality and increased yield.

In the instant invention raw coal with a top size of several inches is initially separated in a high density separator to remove a refuse that contains no value. The product stream from this first separation, which contains all sizes of coal, middling and some refuse, is then sized to separate out a coarse fraction (from about 5 inches to about 1/2 inch) from the intermediate sized material (about 1/2 inch to about 28 mesh) and the fines (about 28 mesh to 0). The coarse material is then separated in a low density separator to recover a quality product (low sulfur) and a middling fraction. Middling is crushed to liberate ash and sulfur constituents from coal, and this crushed material is combined with the undersize material from the first sizing operation. Complete crushing, where needed, is obtained by recirculating oversize to the crusher feed. The combined material is then screened to separate an intermediate size material from the fines. The intermediate size material is next separated in a low density separator to recover a quality, low sulfur product and a middling. This middling is crushed and combined with the fines.

The total raw coal would normally be treated as described only if the low density fractions are low in sulfur. When the low density material is high in sulfur, all the material in the product stream from the first separator is crushed to a finer size.

Raw and crushed fines are treated in primary hydrocyclones which make an initial product separation. Because of the inefficiencies of hydrocyclone separations (coal lost to refuse and refuse misplaced to coal), auxiliary back-up systems are required. To cope with this inefficiency, we have found that good results can be achieved by (1) using secondary hydrocyclones to re-clean the product (overflow), and (2) using tables to reject fine sulfur, to recover coal lost to refuse (underflow) and to recover a middling which can be crushed and retreated to increase yield. The secondary hydrocyclone product (overflow), however, may still contain some misplaced fine, high-density sulfur components and to reject these fines, we use cyclones which classify by particle mass. Heavy density fines and light density coarser sizes are collected to underflow, and this stream is sized to separate product from fine sulfur components. Cyclone overflow is then sent to flotation to eliminate high ash impurities from the product.
Referring now to the FIGURES, and particularly to FIG. 1, a raw coal feed in all size ranges is subjected to a high density separator to remove a high density refuse of, for example, mine rock. The feed is then sized to separate a coarse fraction from the feed. The coarse fraction is subjected to a low density separation to generate a coarse coal product which is recovered and a middlings fraction which is crushed and returned to the circuit. At this juncture in the process the coarse sizes of both coal and refuse have been fully processed and the feed is now of intermediate size. The feed now comprises a combination of the crushed middlings and the undersized fraction from the initial screenings and is now subjected to a second sizing step to separate the intermediate sizes from the fines. The intermediates are separated in a low density separator to generate a coal product of intermediate size and an intermediate fraction comprising middlings and any refuse. The middlings and any refuse that was liberated in the first crushing are crushed and returned to the circuit where they are combined with the undersized fraction from the second size, to form a feed which is generally fines. The fines now proceed to a first hydrocyclone which performs first a combined density and size separation. The overflow from the first hydrocyclone, containing generally finer average size than the underflow, may be further classified in a second cyclone and the products of the second cyclone classification refined by flotation (for the overflow) and sizing (for the underflow).

The hydrocyclone step also generates an underflow which is subjected to concentrating tables to refine a coal product, refuse and middlings. The first two, that is the coal product and refuse, exit the circuit and the middlings are crushed and recycled.

In a more detailed description of our process, and referring now to FIG. 2, a raw coal feed of a top size of about 5 inches and an ore content comprising, generally coal, middling and refuse is subjected to treatment in a jig 10 to separate refuse having a specific gravity above about 1.80 comprising mostly mine rock. Feed material having a specific gravity less than about 1.80 is sent to a screen 14 as shown in line 12. Screen 14 sizes the feed at about ½ inch (more or less) and the oversize travels by line 16 to heavy media vessel 18. Heavy media vessel 18 separate the feed at a specific gravity of about 1.30 to produce a coarse coal product of about 5 inch to about ½ inch size and a similarly sized middlings fraction that has a specific gravity heavier than about 1.30 but lighter than about 1.80. The middlings fraction is sent by line 20 to a crusher 22 and from there the crushed fraction is combined with the minus ½ inch size feed from screen 14. The combined feed, now line 26 is screened on screen 28 at about 28 mesh. The plus 28 mesh size fraction, from screen 28 travels by line 30 to heavy medium cyclone 32. Heavy medium cyclone 32 separates the feed to yield an intermediate size coal product of about ⅛ inch to 28 mesh and an intermediate size middlings that has a specific gravity heavier than about 1.33. The middlings fraction leaves cyclone 32 in line 34 and enters crusher 36.

The crushed middlings exit crusher 36 by line 35 and are combined in line 38 with the minus 28 mesh fines from line 29 which come from screen 28 comprising fine coal, fine middlings and fine refuse. Oversize material can be recycled as needed to the crusher 36 by line 37.

Hydrocyclone 39 processes the fines fraction slurry 38 to separate an overflow fraction 40 comprising mainly 28 mesh to 0 fine coal and some misplaced 150 mesh to 0 fine refuse from the underflow fraction 46 comprising mainly 28 mesh to 0 fine refuse and some misplaced 28 to 100 mesh fine coal. Although the system is effective using only one hydrocyclone 39, additional stages of hydrocyclones will improve the efficiency of the process as will be understood by those skilled in the art. The fine coal slurry 40 is retreated in a classifying cyclone 41 to separate an overflow fraction 42 comprising mainly 60 mesh to 0 coal and 200 mesh to 0 refuse from the underflow fraction 44 comprising mainly plus 60 mesh coal and 150 mesh to 0 refuse. Slurry 42 is retreated to remove the contaminating refuse fines by a flotation stage 50 and separate a final fine coal product 52 from a fine refuse 51. Classifying cyclone underflow 44 is processed on screen 60 which separates at about 150 mesh, and recovers a plus 150 mesh coal product 62 and rejects a 150 mesh to 0 refuse 61.

Underflow fraction 46 from hydrocyclone 39 is reprocessed in concentrating table 70 to recover the misplaced 28 to 100 mesh coal fines as product 72 from a final refuse fraction 71. Table 70 can also be set up to recover a plus 100 mesh middling fraction 73, which can be crushed in crushe 80 to liberate additional coal values from refuse and by line 81 be reprocessed in the system beginning with hydrocyclone 39 or a similar system.

The new process provides an improved method for reducing the sulfur and ash content in coal, and increasing yield while producing a minimum of fine sizes. The improvement features stage crushing of middlings, that are high in sulfur content, followed by reprocessing to (1) recover the low sulfur and low ash coal liberated during crushing, (2) reject high sulfur components, and (3) separate additional middlings that can be crushed to a finer size to further improve its quality and increase overall yield.

In addition, the system provides improved processing techniques for treating coal fines. We have used known components (tables, hydrocyclones, classifying cyclones, fine screens presently used for processing fine coal) in unique combinations that give improved sulfur removal performance as well as more efficient coal recovery, than is now available in the industry.

The following example lists in tabular form, see Table 1, the results of an experimental sampling of the stage crushing of middlings. A raw coal feed was subjected to a high density separator which produced high density mine rock, which was discarded, and a product stream. The product stream was sized and a coarse middlings (5 inch to ½ inch) fraction produced which was subjected to a first stage crushing operation crushing the middlings to -¼ inch size. Sizing of the middlings fraction from the first stage crushing operation resulted in a ¼ inch to 28 mesh product representing 51% by weight of the original coarse middlings fraction feed, 28 mesh to 0 product in the amount of 16% by weight, 28 mesh to 0 refuse of 4%. The remaining 29% by weight was ¼ inch to 28 mesh middlings fraction having a relatively high 2.51% sulfur by weight and 29.0% ash by weight content.

The 29% by weight ¼ inch to 28 mesh middling fraction remaining was subjected to a second stage crushing to 14 mesh to produce a 14 mesh to 0 coal product
having 1.77% by weight sulfur and 9.5% by weight ash content, an acceptable relatively high quality coal. The remaining 13% by weight was 14 mesh to 0 refuse.

It will be understood that further processing including additional crushing stages may be made as desired.

<table>
<thead>
<tr>
<th>Material</th>
<th>Stage Crushing of Middlings</th>
<th>% Sulfur by Wt.</th>
<th>% Ash by Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 - Separate raw coal feed:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) High density mine rock-discard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Coarse coal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Coarse middlings (5&quot; to 14&quot;)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2 - 1st Stage Crushing of coarse middlings (5&quot; to 14&quot;) from step 1(c) above crushed to - ¼&quot;</td>
<td>100</td>
<td>1.89</td>
<td>13.7</td>
</tr>
<tr>
<td>a) ¼&quot; to 28 mesh coal product</td>
<td>51</td>
<td>1.37</td>
<td>5.7</td>
</tr>
<tr>
<td>b) 28 mesh to 0 coal product</td>
<td>16</td>
<td>1.41</td>
<td>6.6</td>
</tr>
<tr>
<td>c) 28 mesh to 0 refuse</td>
<td>4</td>
<td>6.15</td>
<td>33.2</td>
</tr>
<tr>
<td>d) ¼&quot; to 28 mesh intermediate middlings</td>
<td>29</td>
<td>2.51</td>
<td>29.0</td>
</tr>
<tr>
<td>Step 3 - 2nd Stage Crushing of middlings from step 2(d) above, crushed to 14 mesh</td>
<td>29</td>
<td>2.51</td>
<td>29.0</td>
</tr>
<tr>
<td>a) 14 mesh to 0 coal product</td>
<td>16</td>
<td>1.77</td>
<td>9.5</td>
</tr>
<tr>
<td>b) 14 mesh to 0 refuse</td>
<td>13</td>
<td>3.42</td>
<td>53.0</td>
</tr>
</tbody>
</table>

It is seen from Table I that a coarse middlings fraction crushed to -¼ inch having 1.89% by weight of sulfur and 13.7% by weight of ash produces four increments. The first increment which amounts to 51% of the coarse middlings fraction is withdrawn from the system and consists of ¼ inch to 28 mesh coal product having a sulfur content of 1.37% by weight and an ash content of 5.7% by weight representing a usable coal product. A 16% increment of 28 mesh to 0 coal product contains 1.41% by weight sulfur and 6.6% by weight of ash, also a usable coal product. A third increment of 4% by weight of the coarse middlings ends up as refuse. The remaining increment, which amounts to 29% of the coarse middlings feed in this first stage crushing step and which has a sulfur content of 2.51% by weight and an ash content of 29.0% by weight, is fed to a second stage crushing operation as intermediate (¼ inch to 28 mesh) middlings. Crushing the intermediate middlings to 14 mesh results in a coal product amounting to 16% of the intermediate middlings and having a sulfur content of 1.77% by weight and an ash content of 9.5% by weight. The remaining 13% is refuse.

Thus it is seen that from a coarse middlings fraction having 1.89% by weight of sulfur and 13.7% by weight of ash, 83% by weight of usable coal product is recovered having 1.45% by weight of sulfur and 6.6% by weight of ash.

We claim:

1. A method for recovering high quality coal from a raw coal ore feed, which feed comprises a high middlings content, comprising:
   a. separating a raw coal ore feed into high density mine rock and a raw feed material consisting substantially of coal and middlings,
   b. discarding the high density mine rock,
   c. sizing the raw feed material from (a) to recover a coarse coal product which is separated from coarse middlings,
   d. crushing the coarse middlings from (c) to provide a feed ranging in average size from intermediate to fine,
   e. sizing the feed from step (d) at a finer mesh than the sizing of step (c) to recover an intermediate sized coal product which is separated from an intermediate sized middlings,
   f. crushing the intermediate sized middlings from (e) to a fines size to provide a fines feed including coal, middlings and high density refuse,
   g. separating the fines feed from step (f) to produce a fines product fraction and a refuse fraction,
   h. treating the product fraction from step (g) by flotation to recover coal,
   i. separating the refuse fraction from step (g) to produce three separate material fractions, including first sized coal values which are recovered, refuse which is discarded and middlings, and
   j. crushing the middlings of step (i) and recycling the crushed material to step (g).

2. A method for recovering high quality coal from a raw coal ore feed, which feed comprises a high middlings content, comprising:
   a. separating a raw coal ore feed into high density mine rock and a raw feed material which includes sizes ranging from coarse to fine and consisting substantially of coal and middlings,
   b. discarding the high density mine rock,
   c. sizing the raw feed material from (a) to separate a coarse fraction from an intermediate size fraction and dividing the coarse fraction at low density to recover a coarse coal product which is separated from coarse middlings,
   d. crushing the coarse middlings from (c) to an intermediate size and combining same with intermediates from the sizing fraction of step (c) to provide a feed ranging in average size from intermediate to fine,
   e. sizing the feed from step (d) at a finer mesh than the sizing of step (c) to separate an intermediate fraction from a fines fraction and dividing the intermediate fraction at low density to recover an intermediate sized coal product which is separated from an intermediate sized middlings,
   f. crushing the intermediate sized middling from (e) to a fines size and combining same with the fines fraction of step (e) to provide a fines feed including coal, middlings and high density refuse,
   g. separating the fines feed from step (f) by hydrocycloning to produce a first overflow and a first underflow fraction, the overflow fraction comprising various fine sizes of coal and finer refuse, the underflow fraction comprising various fine sizes of refuse and some fine coal,
   h. classifying the overflow fraction from step (g) to separate, by mass, the light mass particles from the heavier mass particles, the light mass particles comprising very fine sized coal and ultranine sized refuse, the heavier mass particles comprising fine sized coal and very fine sized refuse, and treating the light mass particles by a flotation step to recover coal and screening the heavier mass particles to recover coal,
   i. separating the first underflow fraction from step (g) to produce three separate material fractions, including fine sized coal values which are recovered, refuse which is discarded and middlings, and
   j. crushing the middlings of step (i) and recycling the crushed material to step (g).
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,908,912 Dated September 30, 1975
Inventor(s) Stanton D. Irons and Francis G. Miller

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 46, "separate" should read -- separates --.
Column 6, subparagraph (i), line 19, "first sized" should read -- fine-sized --.

Signed and Sealed this

third Day of February 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks
UNITED STATES PATENT OFFICE
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