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F. W. JUNG

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METHOD OF HEAT TREATMENT, SEPARATION AND COKING COAL

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COAL

Fig. 1.

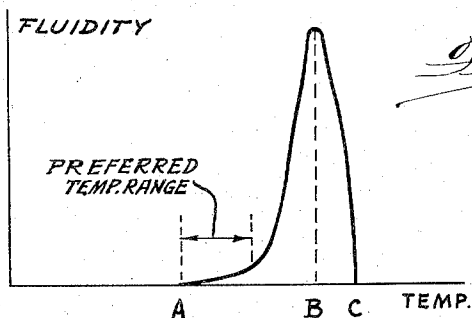
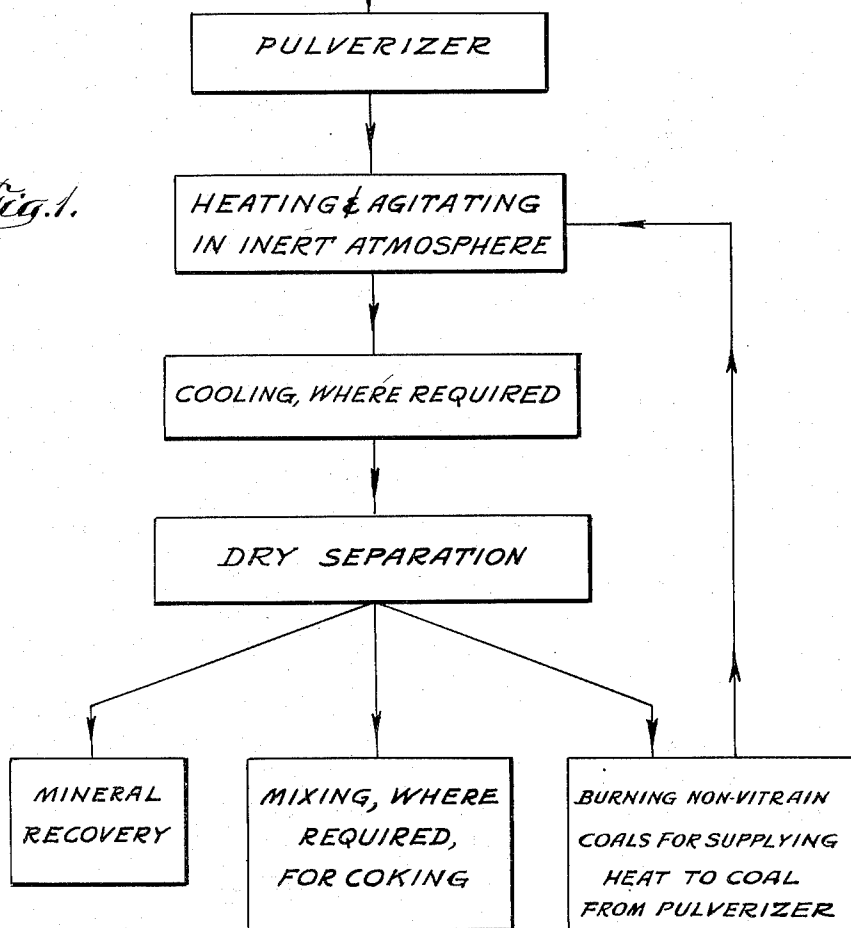


Fig. 2.

INVENTOR.
Frederic W. Jung
BY
Fidler, Crouse & Beardsley
Attorneys.

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METHOD OF HEAT TREATMENT, SEPARATION, AND COKING COAL

Frederic William Jung, Kansas City, Mo.

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7 Claims. (Cl. 202—25)

This invention relates to an improved method of treating coal, and more particularly to a method of separating high or low vitrain coals from non-vitrain types. It is an object of the invention to provide an improved method of this character.

Various applications of coal make it desirable that vitrain in coal be separated from other forms or constituents of coal which are contained in a mixture as commonly found in nature. One such application is in obtaining coal for coking purposes from a coal supply which has poor coking characteristics. Another application concerns the separation of certain valuable mineral content which may be incorporated exclusively or primarily in the vitrain. The present invention relates to the basic separation of vitrain from other forms of coal and to the further manipulation of the separated coal forms in various applications.

The method which constitutes the present invention may be employed not only to separate the high vitrain coals from other forms but may further be employed to separate low vitrain coals from non-vitrain coals. Basically the separation method includes crushing the coal to an advantageous particle size, heating the coal in an inert atmosphere to a temperature at which the vitrain begins to soften, but below that temperature at which the vitrain reaches maximum fluidity, to cause swelling of the vitrain particles and thereby to reduce their effective density, agitating the crushed mixture to prevent agglomeration, and utilizing the resulting difference in density of the mixed particles to effect separation thereof. The latter step may be accomplished by any of various conventional devices for separating dry materials of different densities.

Accordingly it is another object of the invention to provide an improved method of separating high vitrain coal from a mixture of various coal forms.

It is another object of the invention to provide an improved method of separating a mixture of coal forms into three groups, one containing high vitrain coal, one containing low vitrain coal, and the other containing non-vitrain coal.

It is another object of the invention to provide an improved method for obtaining coal of good coking properties from coal having poor coking properties.

It is another object of the invention to provide an improved method of separating valuable mineral-bearing coal components from a mixture of various forms of coal.

This invention, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, in which like parts are designated by like numerals, Figure 1 is a generalized flow diagram of the method basically constituting the present invention; and

Fig. 2 is a diagram showing a typical relationship between fluidity and temperature for vitrain-containing coal which is subjected to progressive heating out of air.

Coal deposits very commonly occur in banded or striped formation in which there are layers of different petrographic forms of coal resulting from the depositing of different forms of organic material or from the existence of different conditions in prehistoric times. The various types of coal are frequently referred to as and are herein termed, fusain, vitrain, clarain and durain. Vitrain is sometimes referred to as bright coal or anthraxylon. Clarain is sometimes referred to as semi-splint coal or translucent attritus, and durain is sometimes referred to a splint coal or opaque attritus.

Of these four forms of coal it is the vitrain which serves as the adhesive or cement which softens and holds the other forms of coal together when pulverized coal is subjected to a coking process. If there is an insufficient percentage of vitrain the coal will not coke together properly, the result being a large percentage of loose coal particles accompanied by small pebbles of coke. Accordingly, coal deposits in which the vitrain content is too low for good coking are considered as marginal or non-coking coals. When coal, for example, contains 50% vitrain, it is considered high grade coking coal, whereas 20% vitrain is too low for good coking. One end purpose of the method which constitutes the present invention is to increase the percentage of vitrain coal in a mixture, such that good coking coal can be obtained from marginal or non-coking coal. This may be accomplished by removing the vitrain coal, and, if desired, coal forms having small amounts of vitrain incorporated therein, after which these may be mixed with a smaller percentage of other forms of coal than was contained in the original mixture. The method is adapted not only to good quality coals but to sub-bituminous and lignitic coals, and where the term "coal" is employed herein in its general sense it is intended to include there lower ranks of coal.

The first step in the method which constitutes the present invention is the pulverizing of the coal to a desired particle size. In general it has been found that pulverizing the coal to a particle size of approximately $\frac{1}{16}$ of an inch, as obtained with a 10-mesh (per inch) screen, is satisfactory and permits successful application of the method. More basically, however, the particle size may be equal to but not greater than the thickness of the layers of vitrain in the banded coal deposit. For example, if the majority of the vitrain layers in a given deposit measures at least $\frac{1}{8}$ of an inch in thickness, the particle size obtained by pulverization should not exceed $\frac{1}{8}$ inch. By following this basic rule, advantage is taken of the tendency of the coal to separate at the planes of jointure between coal forms. It will readily be seen that if the layers of vitrain are primarily $\frac{1}{8}$ of an inch thick and the coal is pulverized to a particle size of $\frac{1}{16}$ of an inch, very few particles of coal will include both a substantial quantity of vitrain and a substantial quantity of another form of coal such as fusain, clarain or durain. Rather, the layered coal will tend to break, during pulverization, at the planes of jointure such that the vitrain will exist primarily in particles of pure vitrain.

Accordingly, banded coal should be pulverized to a particle size which is substantially equal to or less than the minimum thickness of the vitrain bands. As indicated above, generally satisfactory results are obtained if the coal is pulverized to a particle size of $\frac{1}{16}$ of an inch. Pulverization of the coal can be accomplished by any of the conventional forms of coal crushers or pulverizers. It is desirable that excessive "fines" be avoided for reasons which will subsequently become apparent.

After the coal mixture has been pulverized to the desired particle size, it is heated in an inert atmosphere to a temperature slightly above the point of initial softening of the vitrain and well below the point of maximum fluidity of the vitrain. Because of the fact that no two

coals are exactly the same, even though they may be of the same recognized form, no specific, universal temperature limits can be given which can be employed blindly with full assurance of success. For example, the initial softening point may generally vary from 350° C. to 450° C. and even outside these temperatures for vitrain from different sources. It is recommended that coal from a given source be subjected to tests to determine the initial softening point and the point of maximum fluidity. The well known Gieseler apparatus and the Davis plastometer are suitable for this purpose. Fig. 2 shows a typical curve obtainable from the use of the first-named test apparatus. In the illustrated diagram, point A is the point of initial softening, point B is the point of maximum fluidity, and point C is the setting point. It will be noted that there is a reasonable temperature range between points A and B in the illustrated curve. In some instances this range may be less than in others, such that the temperature must be more closely controlled in the process.

In their natural state, the differences in specific gravities of the previously-listed petrographic constituents of coal are too small for practical large-scale gravity separations. The purpose of heating the coal in accordance with the present invention is to cause substantial preferential or differential expansion of the vitrain, these particles becoming substantially hollow spheres, with the result that the apparent or effective density thereof is substantially reduced. Such expansion and consequent reduction in effective density occurs when the vitrain is heated above its initial softening point because of the increased evolution of volatilized matter at such temperatures. Heating of the coal to a substantially higher temperature, at which the vitrain reaches or closely approaches its point of maximum fluidity, is to be avoided since this may cause agglomeration of the melted vitrain particles with each other, and with other non-softened particles of other forms of coal. The true limitations of this method are as defined immediately above, namely, that the vitrain be heated to the temperature immediately above its initial softening point but below its point of maximum fluidity.

It is also desirable that the mixture be mechanically agitated while the coal particles are at the prescribed elevated temperature to reduce or eliminate agglomeration. Apparatus for accomplishing such agitation of the pulverized coal is commonly known in the art, typical examples being the Disco (Leshner) oxidizing stoves and the Wisner and Hayes rotary retorts. Mechanical agitation of the particles should, of course, continue throughout the time that the particles are maintained at elevated temperatures.

As indicated above, the pulverized coal should be maintained in an inert atmosphere while it is at these elevated temperatures for reasons well recognized in the art. Primarily the inert atmosphere should be non-oxidizing, in order to prevent combustion and/or oxidation and general deterioration of the various forms of coal. Secondly the atmosphere employed should contain no other elements or components which will tend to combine with the coal and produce characteristics which are undesirable in a given application. It has been found that properly controlled combustion gases form a suitable inert atmosphere for protecting the coal while it is maintained at elevated temperatures. Such combustion gases may be obtained from the heating process itself and may actually carry the desired heat to the pulverized coal. However, other forms of inert atmosphere may well be employed where economic conditions and other factors so dictate. It will of course be understood that the coal should be maintained in an inert atmosphere as long as it is maintained at elevated temperatures.

It has been found that where the particle size is on the

order of $\frac{1}{16}$ of an inch, the desired swelling and consequent reduction in apparent density of the vitrain particles takes place almost immediately upon subjection of the coal particles to the hot inert gases. This of course assumes that the drum, tray or other device or medium which may support the pulverized coal is already hot. In other words, with coal particles of this size the required period of heating to obtain the desired swelling of the vitrain particles is governed almost exclusively by the initial temperature and thermal capacity of the supporting medium. Where a larger particle size is employed, a longer heating period is theoretically required, but as a practical matter the required time may still be determined primarily by the apparatus rather than by the particle size.

Another factor affecting the required heating time is the moisture content of the coal. As will readily be understood by those skilled in the art, if a substantial amount of moisture is incorporated in the coal (lignitic coals frequently containing 30% moisture) this moisture must be evaporated before the coal particles can be heated to a temperature substantially above the boiling point of water. This of course increases the necessary heating period and amount of heat required.

In some applications of coal it is desired that volatile matter in the coal be reduced to some predetermined level. The driving off of such volatiles can readily be accomplished as a part of this method. In such case it may be desired that the coal be maintained within the critical temperature range, defined above, for a longer period of time, or it may be desired that the coal be maintained at a somewhat lower temperature for an appreciable period of time to drive off the volatiles before or after the coal is raised to a temperature within the above defined range. Since the removal of volatiles of coal is well known in the art, particularly in connection with coking and charring processes, this supplementary function of the method which constitutes the present invention is not described in further detail herein.

In order to obtain maximum use of a coal heating unit and to minimize oxidation it is desirable to heat the coal rapidly. This produces a transient condition wherein fines will be heated to an objectionably high temperature while the particles of basic size are reaching the desired temperature. For this and other reasons excessive fines should be avoided, as suggested above.

In some applications of this method it may be desired that the coal after being treated to this point be cooled such that it may be stored or transported. It will of course be apparent that the coal should be cooled while remaining in an inert atmosphere, to permit protective absorption of inert gases by reactive new pore surface, and while being further mechanically agitated, if needed, to prevent agglomeration. Cooling of the coal may be accomplished in any suitable manner, but is preferably effected outside the heating apparatus as a part of a continuous process in order to obtain maximum use of equipment.

After the treated coal has been cooled, such that it may be exposed to normal atmosphere, the expanded vitrain particles, being of lesser effective density than the particles of other forms of coal included in the mixture, may readily be separated therefrom by any of various well known separating devices. Preferably a dry separation process is employed, and among the devices which may be used satisfactorily in this step of the method are cyclone separators, air separation tables such as those of Roberts and Schaefer or Sutton, Steele & Steele, and belt separators. Since these devices and their principles of operation are well known in the art, they are not described in detail herein. For the purpose of disclosing the present invention it is sufficient to indicate that such devices are capable of separating low density dry materials from higher density materials. Accordingly they can successfully separate the

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expanded vitrain particles, having low effective density, from the remaining coal particles.

In some applications of the present invention it may be desired that the heated coal particles be fed directly to utilization stations without being cooled. In such applications the loss of heat and the time delay attending the cooling of the pulverized coal can be avoided by subjecting the treated coal particles to a dry separation process while still hot and while still being maintained in an inert atmosphere. It is required simply that the separation apparatus be incorporated in the same enclosure or a continuation thereof and that it be continuously maintained in an inert atmosphere. After separation, the vitrain particles or the remaining coal particles, or both, may be fed directly to their ultimate utilization stations without cooling.

Apparatus incorporating a fluidized column may be utilized for both heating and separating. Such apparatus is recommended for use in this method as being rapid and efficient, but it should be recognized that it requires delicate control for satisfactory results.

The method as described above has been presented primarily as a method of separating vitrain from other forms of coal. It frequently occurs that these other forms of coal may have incorporated therein a small but significant percentage of vitrain. Clarain, for example, generally contains some substantial amount of the essential component, vitrinite, of vitrain. Those particles which thus contain a significant amount of vitrain will be caused to swell by the heating process in much the same manner as the pure or high vitrain particles but to a much lesser extent. Accordingly, the apparent density of these heated particles will be significantly less than the non-vitain coal particles but their density will not be reduced as much as the pure vitrain particles. The lessening in apparent density of these coal particles in accordance with the percentage of vitrain contained therein may be employed, however, to separate these particles of intermediate density from the pure vitrain particles and from the non-vitain particles by the same dry separation apparatus suggested above. By this means three groups of coal result, namely, substantially pure vitrain, other forms of coal containing a significant percentage of vitrain, and a third group consisting of non-vitain coals.

The same separation step may be employed, if desired, to clean the coal of unaltered or but slightly altered pyritic matter and ash-forming minerals freed in the pulverization, these foreign materials being substantially heavier than the coal forms and therefore being readily separable from coal by the same apparatus that separates the treated coal.

As indicated above, coal which is to be used in a coking process should contain a certain minimum percentage of vitrain since the latter is the particular form of coal which provides the adhesive or bonding power to effect coking. The method described above may be used to substantial advantage in obtaining good coking coals from poor coking coal since it separates the vitrain particles from the non-vitain particles. After such separation the vitrain particles may be tested for purity and may be mixed, if desired, with a given percentage of non-vitain coal particles or low vitrain coal particles, or both, to produce the desired ratio of vitrain to non-vitain coals. If preferred, a good coking mixture of reasonably accurate proportions can be obtained directly by controlling the separation of the treated coals such that the vitrain and desired percentage of low vitrain and/or non-vitain coals are separated as a group from the residue of low vitrain and/or non-vitain coals. It is of course necessary in any case that the original coal supply contain a significant percentage of vitrain in order for the method to be practical.

Another application of the described method relates to the separation of valuable minerals which are most commonly present in vitrain and not in other coal forms. Frequently, germanium or uranium oxide is extracted from

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coal simply by controlled burning of the coal and then treating the ashes to recover these valuable minerals. The above described method can be employed to great advantage as a preliminary to such a process, since these minerals are concentrated primarily in vitrain when present in coal or lignite. If the vitrain is first separated from the other coal forms according to the method described above, the vitrain coal can be burned separately, with the result that a much smaller quantity of ash need be treated to recover all or practically all of these valuable minerals than would be required if the entire supply of coal were burned together.

In accordance with one practical method of employing the method which constitutes the present invention, the non-vitain coals, or a portion thereof, which are obtained from the process may be burned to supply the heat necessary to effect the separation of the coals. Heat transfer apparatus may be employed, or the combustion gases, properly controlled, may be used directly to supply the necessary heat.

It will be understood that after dry separation of the vitrain particles, they may be used in any one of the several further steps above described, or a portion of the vitrain particles may be used in one of such steps and one or more remaining portions may be used in one or more of the other steps separately. In other words, the vitrain particles may be used in the mineral recovery or in the compounding of a coking mixture or for supplying heat to the coal from the pulverizer.

It will also be understood therefore that the flow diagram of Figure 1 indicates that the three steps may be carried out either alternately or any two or three may be carried out simultaneously.

I claim:

1. The method of separating high vitrain coal from a banded mixture of coal forms which comprises crushing said mixture to particle size not greater than the minimum thickness of the included vitrain layers, heating the crushed mixture while in an inert atmosphere to a temperature above the initial softening point of the included vitrain and below the point of maximum fluidity thereof thereby causing swelling of said high vitrain particles and consequent reduction in effective density thereof, mechanically agitating said crushed mixture while at elevated temperature to prevent agglomeration, and utilizing the resulting difference in density of the mixed particles to effect separation thereof.

2. The method of separating high vitrain coal from a banded mixture of coal forms which comprises crushing said mixture to particle size not greater than the minimum thickness of the included vitrain layers, heating the crushed mixture while in an inert atmosphere to a temperature above the initial softening point of the included vitrain and below the point of maximum fluidity thereof thereby causing swelling of said high vitrain particles and consequent reduction in effective density thereof, agitating said crushed mixture while at elevated temperature to prevent agglomeration, and separating the high vitrain particles from the remaining particles, utilizing the differences in densities of the mixed particles to effect such separation.

3. The method of separating high vitrain coal from a banded mixture of coal forms which comprises crushing said mixture to particle size not greater than the minimum thickness of the included vitrain layers, heating the crushed mixture while in an inert atmosphere to a temperature above the initial softening point of the included vitrain and below the point of maximum fluidity thereof thereby causing swelling of said high vitrain particles and consequent reduction in effective density thereof, mechanically agitating said crushed mixture while at elevated temperature to prevent agglomeration, cooling the mixture in an inert atmosphere, and separating the high vitrain particles from the remaining particles, and utiliz-

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ing the differences in densities of the mixed particles to effect such separation.

4. The method of separating high vitrain coal from a banded mixture of coal forms which comprises crushing said mixture to particle size not greater than the minimum thickness of the included vitrain layers, heating the crushed mixture while in an inert atmosphere to a temperature above the initial softening point of the included vitrain and below the point of maximum fluidity thereof thereby causing swelling of said high vitrain particles and consequent reduction in effective density thereof, agitating said crushed mixture while at elevated temperature to prevent agglomeration, separating the high vitrain particles from the remaining particles, utilizing the differences in densities of the mixed particles to effect such separation and recovering included minerals from the separated high vitrain particles.

5. The method of separating high vitrain coal from a banded mixture of coal forms which comprises crushing said mixture to particle size not greater than the minimum thickness of the included vitrain layers, heating the crushed mixture while in an inert atmosphere to a temperature above the initial softening point of the included vitrain and below the point of maximum fluidity thereof thereby causing swelling of said high vitrain particles and consequent reduction in effective density thereof, agitating said crushed mixture while at elevated temperature to prevent agglomeration, separating the high vitrain particles from the remaining particles, utilizing the differences in densities of the mixed particles to effect such separation and mixing said separated high vitrain particles with particles of lower vitrain coals to form

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a coking mixture; and heating the mixture to form a coke.

6. The method of separating high vitrain coal from a banded mixture of coal forms which comprises crushing said mixture to particle size not greater than the minimum thickness of the included vitrain layers, heating the crushed mixture while in an inert atmosphere to a temperature above the initial softening point of the included vitrain and below the point of maximum fluidity thereof, agitating said crushed mixture while at elevated temperature to prevent agglomeration, separating the high vitrain particles from the remaining particles, utilizing the differences in densities of the mixed particles to effect such separation, and utilizing at least a portion of the separated non-vitain coal to supply heat for heating the crushed particles.

7. The method of separating high vitrain coal from a banded mixture of coal forms which comprises crushing said mixture to particle size not greater than the minimum thickness of the included vitrain layers, subjecting the crushed mixture while in an inert atmosphere to a temperature above the initial softening point of the included vitrain and below the point of maximum fluidity to the action of a heated fluidized column to thereby effect swelling of said high vitrain particles and consequent reduction in effective density thereof, agitation of said crushed mixture and separation of the high vitrain particles from the remaining particles, utilizing the differences in densities of the mixed particles to effect such separation.

No references cited.