PROCESS FOR PURIFYING COAL OR THE LIKE

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The invention relates to novel and useful improvements in dry or air-operating processes for purifying coal and like materials, and more particularly to such improvements whereby an exceedingly complete purification or separation is effected in kinds of coal and the like materials which are very difficult to purify.

Objects and advantages of the invention will be set forth in part hereinafter and in part will be obvious herefrom, or may be learned by practice with the invention, the same being realized and attained by means of the instrumentalities and combinations pointed out in the appended claims.

The accompanying drawings, referred to herein and constituting a part hereof, illustrate apparatus and diagrammatic layouts of apparatus for practicing the invention, and together with the description, serve to explain the principles of the invention.

Of the drawings:

Fig. 1 is a top plan of one form of mechanism for practicing the invention, showing many of the parts diagrammatically;

Fig. 2 is a side elevation looking at Fig. 1 from the bottom of the sheet, and likewise showing certain parts diagrammatically;

Fig. 3 is a transverse vertical section, on a greatly enlarged scale, taken on the lines 3—3 of Fig. 1;

Fig. 4 is a detached side elevation of the upper part of Fig. 1, looking from the top of the sheet;

Fig. 5 is a diagram in plan, showing one system of zoning;

Fig. 6 is a diagram in plan, showing the sub-areal air chambers and regulation; and

Figs. 7, 8 and 9 are diagrammatic layouts of apparatus for carrying out the process and showing different examples of selective sub-processing.

The invention is directed to improvements in the cleaning or purification of coal by the air operating or dry process. My invention effects practically complete purification of substantially all kinds of coal (including those of very great difficulty or refractoriness), substantially to the indications of their respective washability curves, irrespective of the characteristics or conditions of the coal and the intermixed impurities, and the number of such impurities, and effects this without previous size classification or other special preparation.

The difficulties inherent in such generally or universally applicable separation and purification reside largely in the kinds, quantities and characteristics of the intermixed impurities in the coal, such as the percentage quantity of ash, closeness in the specific gravity of the same to that of the coal, the range of sizes of coal and impurities, relative proportions of size ranges of particles or pieces, and especially relatively large quantities of fine material, variations in the state of dryness, and the like. That is, these very difficult kinds of coal may be quite completely cleaned on a single table by the Peale-Davis processes, but the present invention aims to eliminate any losses of coal in the refuse and to eliminate all refuse from the coal in such difficult and refractory cases. Even these coals may be cleaned on a single table and by a single operation to a very high degree of purity, but the present invention, by its selective sequential sub-processing, practically eliminates coal losses which might occur in the refuse of a single table with especially difficult or refractory varieties of coal.

The process of my present invention, broadly considered, includes carrying the purification of the coal through a succession of interrelated and sequential separating or cleaning processes or operations, and predetermining the splitting point between the "floats" (i.e. clean coal) and the "sinks" (i.e. impurities) in each operation in a definite relation to the various kinds and natures of intermixed impurities, especially in relation to their specific gravities, and subjecting certain or most of the products of said various interrelated sub-processes or operations to further selective purifying process action. In connection with such predetermination of "splitting points" in relation to the particular coal and cleaning problem, the products (coal and refuse) from any such process or sub-process and splitting point is selectively subjected to any further purification processing that may conduct to the desired final complete separation of the particular coal and impurities. One further important feature of my invention, optionally applicable to some difficult purification problems, which is directed to securing approximately complete purification and separation thereof, includes the delivery from the entire purifying process of only one practically completely purified coal product and of one refuse product; the latter very closely approximating the total amount of free impurities in the raw coal. In other cases, where a fractional pure product is obtained from any sub-process, it can likewise be delivered for shipment without further purification.

The invention further includes selective sub-
processing dependent upon the relative proportion of refuse in a given size range or ranges of the particles or pieces. That is, most, or even practically all of the refuse in any particular split product may be practically entirely in the relatively very fine particles. By effecting a corresponding size separation for this particular split product, the part passing over the screen may be delivered as purified and only the part passing through the screen need be subjected to further purification.

By selectively subjecting some or all of the intermediate or intervening products of the successive purifying processes or sub-processes to further purification processing, and especially effecting the deliveries thereof on the basis of substantially complete purification, wherever achieved, all of the raw coal mixture or the like is finally separated into two parts, one being practically pure coal, as indicated, and the other practically including all the refuse.

The process, one of its main features, is directed to the purification of a continuous bed of the intermixed materials, progressing forwardly as the separation and purification proceed, the bed being subjected to upwardly-directed lifting and loosening air currents and reciprocation, the bed being regularly inclined transversely and longitudinally, and the intensity of the air current being nicely regulated, throughout relatively small or sub-areas of the bed. The concurrent and coordinated regulation of these factors may be widely varied and may be tuned to meet all the differences in characteristics and conditions of the materials as already outlined, as well as effecting a "splitting" or separation and delivery at a specific gravity point or value in desired predetermined relation to those of the intermixed materials.

In practicing the process, a primary separating or purifying operation is effected, and this process is so regulated or tuned that a relatively large cut of refuse and a relatively small skim of coal are taken therefrom, i.e., the specific gravity of the refuse as determined by the regulation and tuning of the various agencies of the process are such that all the refuse is taken from the coal in this primary process, even at the cost of temporarily taking some coal with it, and the coal discharged from the primary operation is of practically complete purity.

The refuse from this primary purifying process is then subjected to further purifying process action by what may be termed a sequential sub-process, and the specific gravity splitting point may again be predetermined and with reference to the specific gravities of the coal and the various impurities by regulation and tuning of the air currents, including sub-areal regulation, the relative inclinations of the bed, etc., to secure the desired differentiation in the coal and intermixed refuse. In connection with this immediately succeeding sub-process, or any which may be later employed, the coal and refuse, or either, from any particular operation, are optionally and selectively subjected to further process purification, as may be applicable to or efficient with the particular material.

One important feature of the present invention, which is useful especially with coals which are very difficult to purify, provides that the coal from a purifying sub-process may be delivered back to be again processed by the primary purifying process; that is, the coal from this secondary purifying table may again be fed to the primary table, together with the raw coal.

The number of successive purifying sub-processes utilized will correspond to the needs or difficulties of the particular raw coal. Let it be assumed that there is a third purifying process or operation, as the final one. The refuse from the second process would be subjected to purifying processing action during this third process, but in this process as the present final one, the splitting point would be fixed by regulation and tuning so that only impurities will be discharged with the refuse from this table. The coal delivered from this third purifying operation could likewise be again subjected to further purification, preferably to the primary purifying process, as already described in connection with the second purifying sub-process.

It will be understood that the variations in the fixing of the splitting point are very small or close as between the specific gravity of the coal and the lighter of the intermixed impurities, but is nevertheless sufficient to effect a practically perfectly perfect separation described. It will be seen, therefore, that the delivered coal is only that delivered from the primary process, or any subsequent sub-process delivered having an equal purity as to the coal from the last purifying sub-process, or any sub-process delivering practically an entirely refuse discharge. As a result of the selective splitting points established, and subsequent selective sub-process purification, practically only clean coal is delivered as such, and only refuse, and practically all of the refuse or sinks, are delivered as such.

It will be understood that various steps in the process may be omitted or modified, such as the sequence or place of delivery of various discharged products from any sub-process, dependent upon the difficulty of purifying any particular coal.

The "middlings" product (i.e., a product of intermediate specific gravity) from any of these purifying processes or sub-processes is usually returned to, or fed to, the particular bed from which it is discharged in order that it will ultimately be discharged as separated clean coal and refuse. A crusher may be employed on the middlings where advantageous. Sometimes, as where there is coal and refuse together on the same bed or from the same portion of the material, the refuse also is crushed for the purpose of liberating the coal and thereby effecting a more complete separation. The coal liberated by the crusher would thus be separated on the sub-process or "re-treatment" table.

Other features of the invention will be primarily disclosed in connection with the following detailed description of the invention, and it will be understood that the preceding general description and the following detailed description are explanatory and exemplary of the invention but are not restrictive thereof.

Referring now in detail to the apparatus for practicing the invention illustrated by way of example in the accompanying drawings, Fig. 1 shows, partly diagrammatically, a double table for purifying or "re-treatment" table, embodying the previously known inventions of Kenneth Davis, Richard Peale and myself, practically to the washability curve of such coals. However, in the especially difficult kinds of coals to which the present in-
vention is particularly directed, there is effected one or more subsequent and sequential purification processes, and a table 2 is co-functioning in the manner later described. The broad features of the process are not limited to particular number or arrangement of tables, as one feature of the invention consists in employing the requisite number of tables in the most efficient relation in order to automatically effect complete purification of even the most difficult kinds of coals.

The general type of table which I employ is that commercially known as the Peale-Davis table, and, referring first to the primary table, and describing only one of the two tables which are mounted and used together for mechanical and operative convenience, the table comprises an air-pervious deck 12, and bed-retaining walls projecting upwardly therefrom, comprising the rear bed-retaining wall 14 and 15. For most coals the table is relatively long and narrow, and is provided with a forward spillage or discharge edge 16 for the coal, which is transversely disposed at a relatively long angle to provide ample spillage space.

Mounted upon the surface of the table deck 12 are separating partitions 23, which abut at their rear ends against either the rear end bed-retaining wall 13 or the similar side wall 14. The separating partitions are disposed transversely and forwardly, and terminate at or closely adjacent to the side bed-retaining wall 15, along which edge of the bed the separated refuse is removed, preferably at a plurality of points without accumulation thereof within the bed.

The embodied form of refuse-removing means comprises a plurality of discharge boxes 24. These boxes communicate with the interior of the table by orifices or openings 25, through which the separated refuse passes from the bed into the boxes preparatory to discharge. These openings are provided with one or more air-regulating slides 26, which may be adjusted to regulate the amount of discharge of refuse through the particular opening, and also function to hold back the separated coal from passing out with the refuse. The discharge boxes at their outer ends with hinged rates 27, having variable weighting devices 28 to regulate the pressure at which the refuse is discharged. The discharged refuse empties into a chute 29, and is conveyed away in a suitable manner, or as in the case of the present process, is conveyed to the secondary process or so-called "retreatment" table. The number and spacing of the refuse boxes along the edge of the bed of materials undergoing separation may be regulated as desired. The refuse chutes 29 and the coal middlings chutes 30 and 31 discharge onto conveyors, which are shown conventionally only for the sake of clearness. Movable separating blades 32, shown pivotedally mounted, are variably positionable to secure exactness in effecting a desired splitting point between the coal and middlings.

Reverting now to the means for creating and closely regulating or tuning the lifting and loosening air currents passing upwardly through the bed of materials, a suitable source for the air currents is provided, such as a rotary fan 33, which communicates by means of a duct 40 with the air chamber 41 beneath the table. Suitable means for regulating the volume of air or air currents created by the fan may be provided, of any known or suitable form, and slides or values 42 are conventionally shown mounted upon the fan housing for this purpose. If desired, a pulsating air current may be provided, and for this purpose there is shown in the present embodiment a rotating air valve 43 mounted in the part 44 of the air duct. This valve may be driven by any suitable means, and a driving pulley 45 is shown mounted on the shaft 46 of the fan, and driven by a belt 47 from the table-reciprocating driving mechanism. Valve 43 when employed will be driven in timed relation with the reciprocation of the table.

The air currents from the fan are discharged into the non-vibrating part 53 of the air chamber 41, and the cross section of the air chamber is decreased for the purpose of effecting a uniform upward air current pressure except as this may be further modified by other agencies. This lower or non-vibrating section 53 of the air chamber is mounted in connection with the devices for varying the longitudinal inclination of the table, and accordingly this part of the chamber is mounted upon side channel-frame members 54 and 55, which are pivotally mounted at 59, and at their rear end, upon the foundation walls 60 and 61. The side frame members rest upon a plurality of screw-threaded supporting members 62 and 63, whereby the longitudinal inclination of the table may be effected or regulated. This inclination may be forwardly upwardly or forwardly downwardly, as may be desired or required.

Means are provided for effecting longitudinal reciprocation of the table and of the bed of materials thereon through a very short path by suitable means. As embodied, the table proper is carried upon side frame members 71 and 72, which are mounted by means of pivoted arms 73 and 74 upon the frame members 84 and 85. The arms 73 and 74 are preferably inclined so as to give the table a very slight rising and falling movement together with the longitudinal movement thereof. The driving means for this mechanism comprises a link 77 connected to the vibratable table frame at one end and at the other end to an eccentric 78, mounted on a shaft 79, which is journaled upon a support 80, which is driven by any suitable means, such as a drive pulley 81 over which runs a belt 82, which is driven by a motor 83. Suitable spring balancing or compensating devices (not shown) will preferably be employed. The air chamber system is provided with suitable flexible parts 84 and 85 to permit of the relative movement between the fan duct and also the upper and lower parts of the air chamber due to the longitudinal reciprocation or vibration of the table.

The means for variably transversely inclining the table and bed may be of any known or other suitable form. As embodied, however, one side of each table rests upon a support, 91, and the other side thereof, the outer side in this case, has fixed thereto a longitudinally extending angle iron 92, which rests either directly upon the reciprocable side frame 11 or upon interposed supports 93, which may be varied in number or thickness so as to give the desired transverse inclination to the table and bed.

The embodied form of means for controlling the relative intensity of the lifting and loosening air currents passing upwardly through the bed, comprise a system of so-called "zoning," that is, a difference in air-perviousness of different zones of the deck, and as embodied, a difference in the size and number of the air apertures in the table.
or deck 1; and also means for effecting an additional sub-area regulation within the zones thus established. As to the embossed zoning, in Fig. 5, the deck is provided with an area or zone a of greatest air-perviosity, and areas or zones b, c, and d of correspondingly decreasing air-perviosity. It will be understood, however, that these may be varied in size, location and sequence in so far as the present invention is concerned.

In the embodied form of sub-area zoning, a series of chambers 103 is provided directly beneath the deck 1, these chambers having side walls 104-107, the deck 1 itself constituting the top thereof. The chambers are provided with a bottom 108, which has many relatively large perforations 109 therein. These perforations 109 may be left open or may be closed by stoppers 110 or other suitable means. There is thus provided a very minute and finely graded regulation of the air current action throughout the entire table. This will take care of local conditions in the sub-areas, as they are established or may change from time to time, to prevent local dead-spots or "boiling"; and they may be used to adapt a general type of tablet or separator kind of coal presenting different problems.

The air current system also provides means for exerting a backward air pressure through the refuse boxes 24 (Figs. 2 and 3). Accordingly an air-conveying manifold or header 111 carries air current from the air chamber and discharges it by flexible pipes 112 into the air boxes 24. Bands 113 may be employed to regulate the amount of air current discharged into the respective boxes.

The means for supplying the coal or like inter-mixed materials to be purified may be of any suitable form, and is shown herein conventionally as comprising a bin 114, having a variable-speed feeding device 115. Certain other features of the feeding mechanism will be described later herein in connection with the movement of the various components or products of the different processes and sub-processes.

The foregoing constitutes means for supplying the materials, the coal or the like, at the desired rate to maintain the forwardly-moving bed, undergoing progressive separation, of the desired thickness most efficient for the particular kind of coal; also means for reciprocating the table; and means for nicely varying the longitudinal and transverse inclination of the bed, and for varying these with respect to each other; regulatory discharge devices; and for creating either a steady or pulsating lifting and loosening air current force passing through the bed, and for nicely adjusting or regulating the force thereof in different parts of the bed, together with wide and accurate regulation of the sub-area air-pressure action. The specific means for effecting these, in so far as the present invention is concerned, may be widely varied; and the form of such means already described is disclosed and claimed in previous applications of Kenneth Davis, Richard Peale, and myself.

The present invention, in solving the problem of practically completely purifying exceedingly difficult kinds of coal, substantially to the limits of the coal washability curve, comprises primarily the regulation and tuning of the various agencies already described so as to effect or establish splitting points, that is, a point of separation between the purified material and the refuse for each separate purification processing, at a gravity point, and to selectively subject the separated material on either side of the splitting point to further similar treatment, as may be required with any particular coal or other material being separated. The remaining principal feature of my invention consists in subjecting the various products thus completely separated, whether "floats" or "sinks", to further processing or to further sub-process purification in certain relations and sequence so that a final "clean" product, i. e., purified coal, and a practically complete "sink" product, i. e., total free refuse, is delivered from the system.

In the exemplary diagrammatical showing of Fig. 7, there is one primary process table A, a sequential secondary process table B and a similar third table C. The raw coal, or run-of-the-mine coal, supply is fed at the desired rate to table A, the tables of the general type indicated being capacitated to handle practically all sizes of run-of-the-mine coal, except very fine sands disclosed in said previous applications. The floats or purified coal A-1 from table A, by regulation and tuning of said table, are "split" at such predetermined specific gravity point as to insure practically entirely pure "float" product, i.e., delivered from said table to the storage or shipping conveyor (Fig. 7). The refuse or sinks A-2 from this table, due to the predetermined splitting point as established, consequently and purposely carry some coal, and are delivered to the feed end of sub-process table B. This table or bed B presents the condition of a relatively high percentage of sinks or refuse, and the table will be regulated or tuned accordingly. The "floats" or purified coal A-1 from table A are conveyed preferably to the feed end of the table A, and are subjected to the primary purification process. The splitting point on table B, by regulation and tuning thereof, will be such that all the "sinks" will be discharged with the refuse, or at least the floats will not contain as high a percentage of refuse as the raw coal supply. The refuse B-2 from table B is conveyed to the feed end of table C, and the bed being processed upon this table will consist of a very high percentage of sinks. The floats or purified material C-1 from this table are likewise conveyed to the feed end of the table A. The splitting point on this table will be established by regulation and tuning so as to insure that the refuse discharge will take out only sinks, and this refuse C-2 is conveyed away as waste. If desired, a middlings product Am, Bm, Cm may be taken from each table and may be re-fed to that particular table.

Where a certain refuse element or a certain part of the refuse contains pieces of attached coal and refuse, these may be crushed in order to separate them and avoid the alternative of delivering the attached refuse into the coal or the attached coal into the refuse. This is shown in Fig. 8 of the drawings as accomplished by a crusher interposed in the feed of the sinks B-2 to the feed end of table C. It is furthermore advantageous at times to have a delayed delivery, especially where it may carry some very fine dirt or refuse, which may thus be separated out without further joint retreatment. Accordingly, a screen is shown receiving the floats from the table B, the coarsest component thereof being directed to the feed end of table A, where-
as the finer component thereof is directed to the feed end of table C.

In Fig. 9 is exemplarily shown a different arrangement or sequence of selective sub-processing. The raw coal supply, which may be unsized run-of-the-mine coal except that very large lumps are crushed, is fed to the primary table A. We will suppose that it is advantageous to take off a coal product which is relatively very pure except that it contains impurities in the very small sizes. In such case, the product may be run over a screen which would pass everything to the maximum size of the contained impurities, say, one quarter or one-half inch, the coarser pure product therefrom being sent to shipment, and the finer and partially impure product being directed to further purification on a table B. In case the middlings or the refuse is laminated, or otherwise carries attached coal and impurities, they may be run through a crushe...