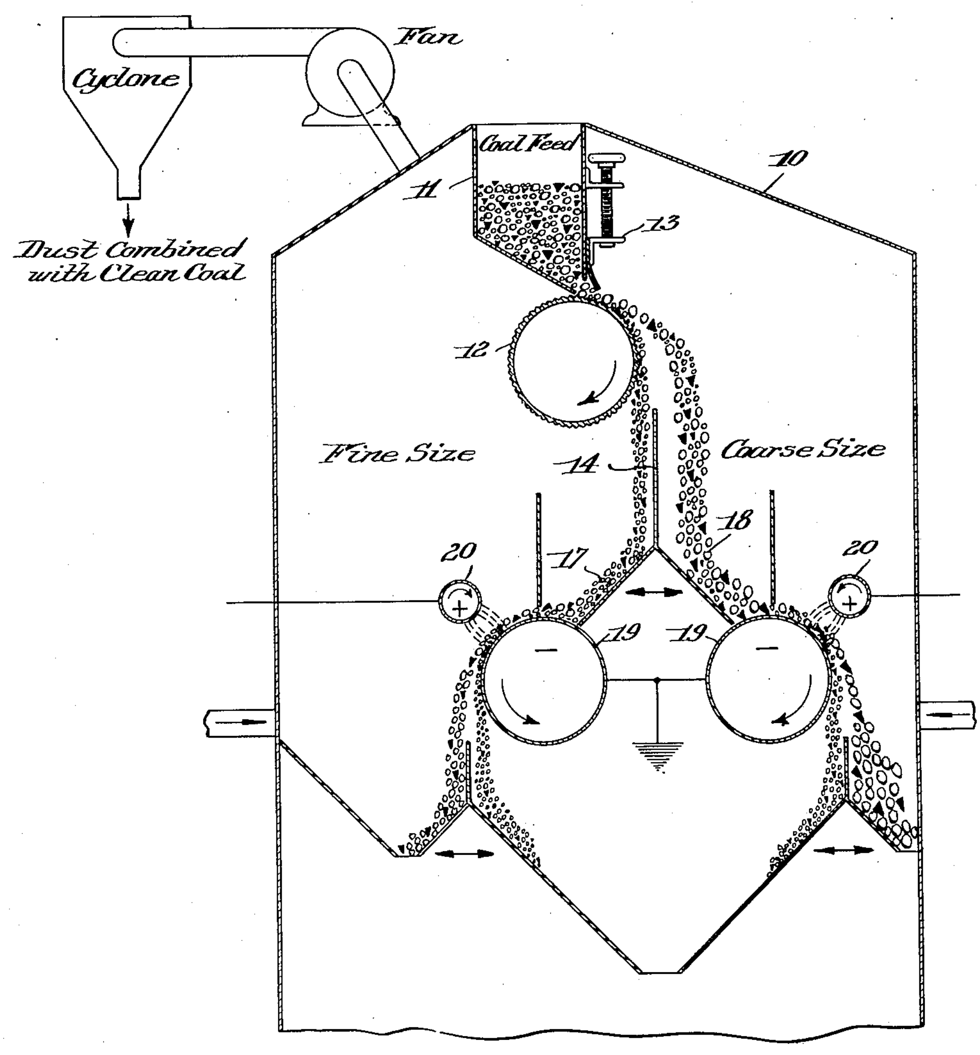
July 3, 1951 H. B. JOHNSON 2,559,076

METHOD OF CLEANING COAL

Filed Oct. 11, 1945 4 Sheets-Sheet 1

Fig.1



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METHOD OF CLEANING COAL

Filed Oct. 11, 1945 4 Sheets-Sheet 2

Fig. 2

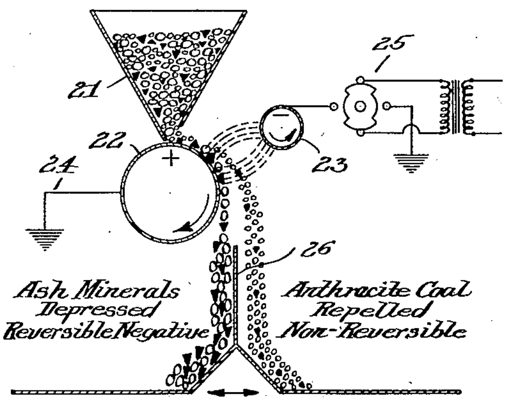


Fig. 3

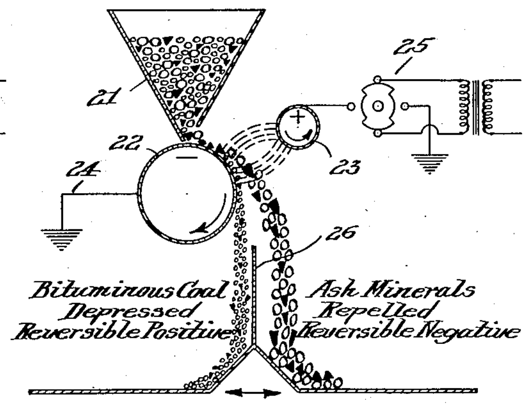


Fig. 4

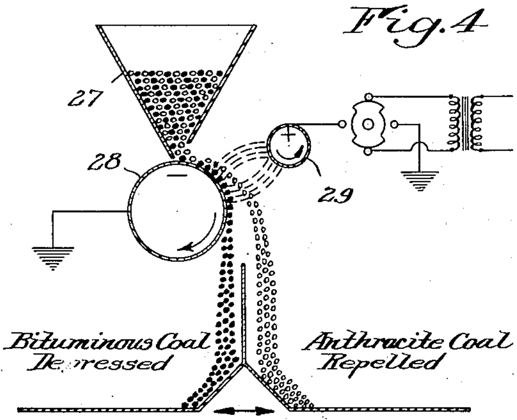
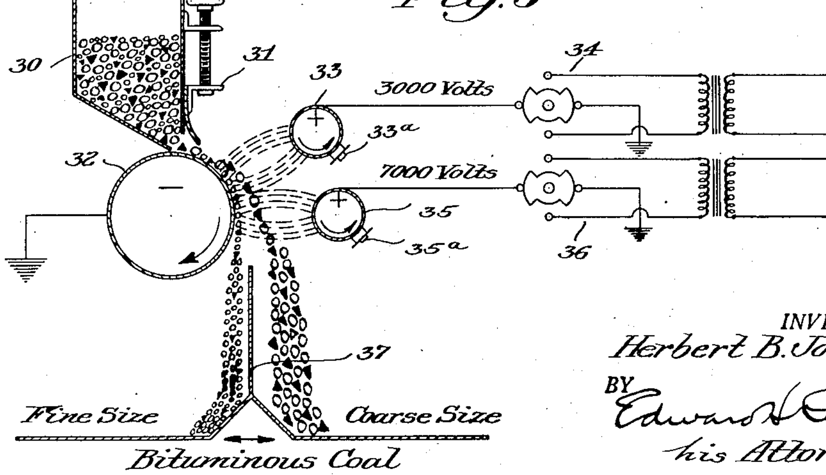


Fig. 5



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METHOD OF CLEANING COAL

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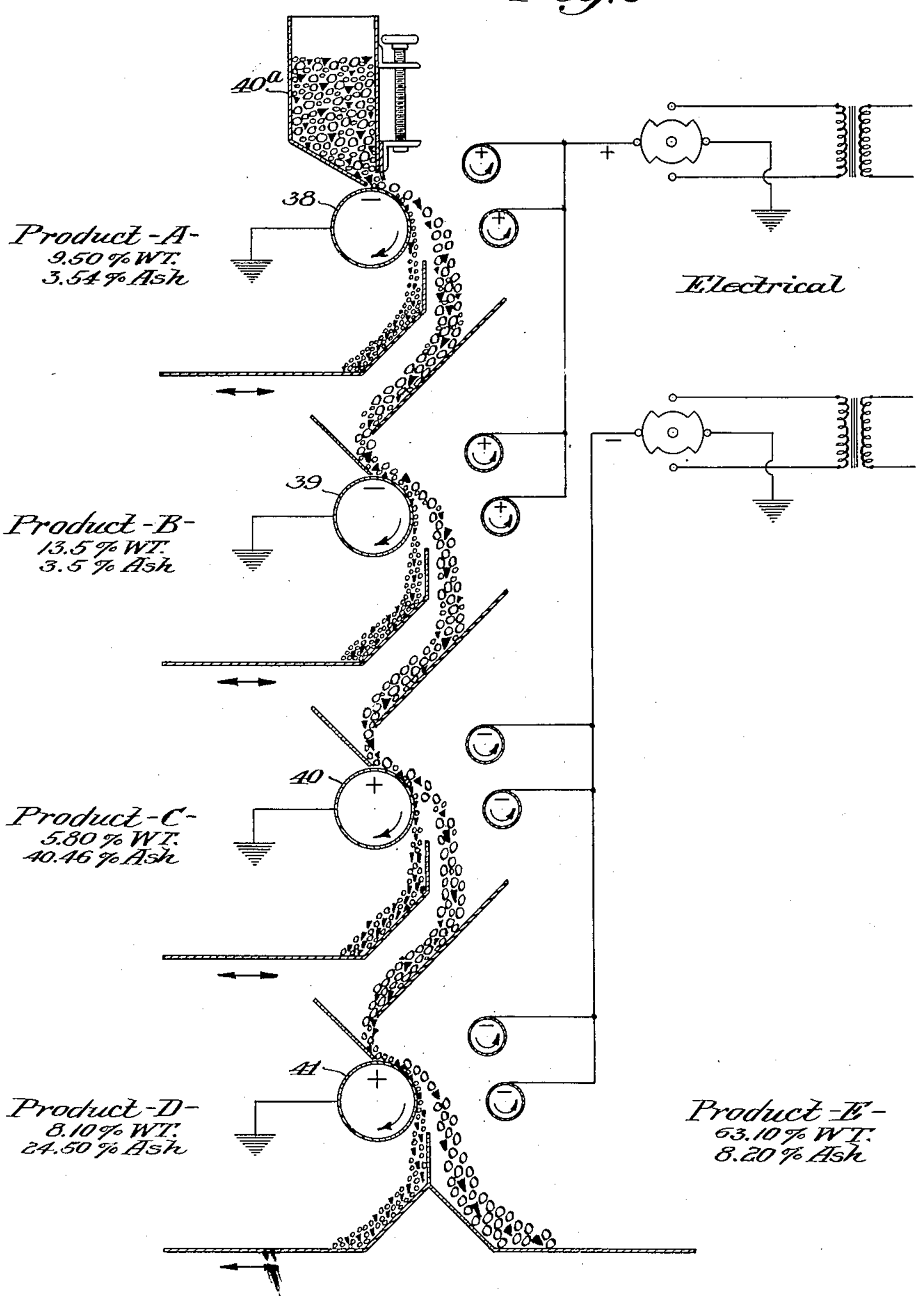
Fig. 6



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METHOD OF CLEANING COAL

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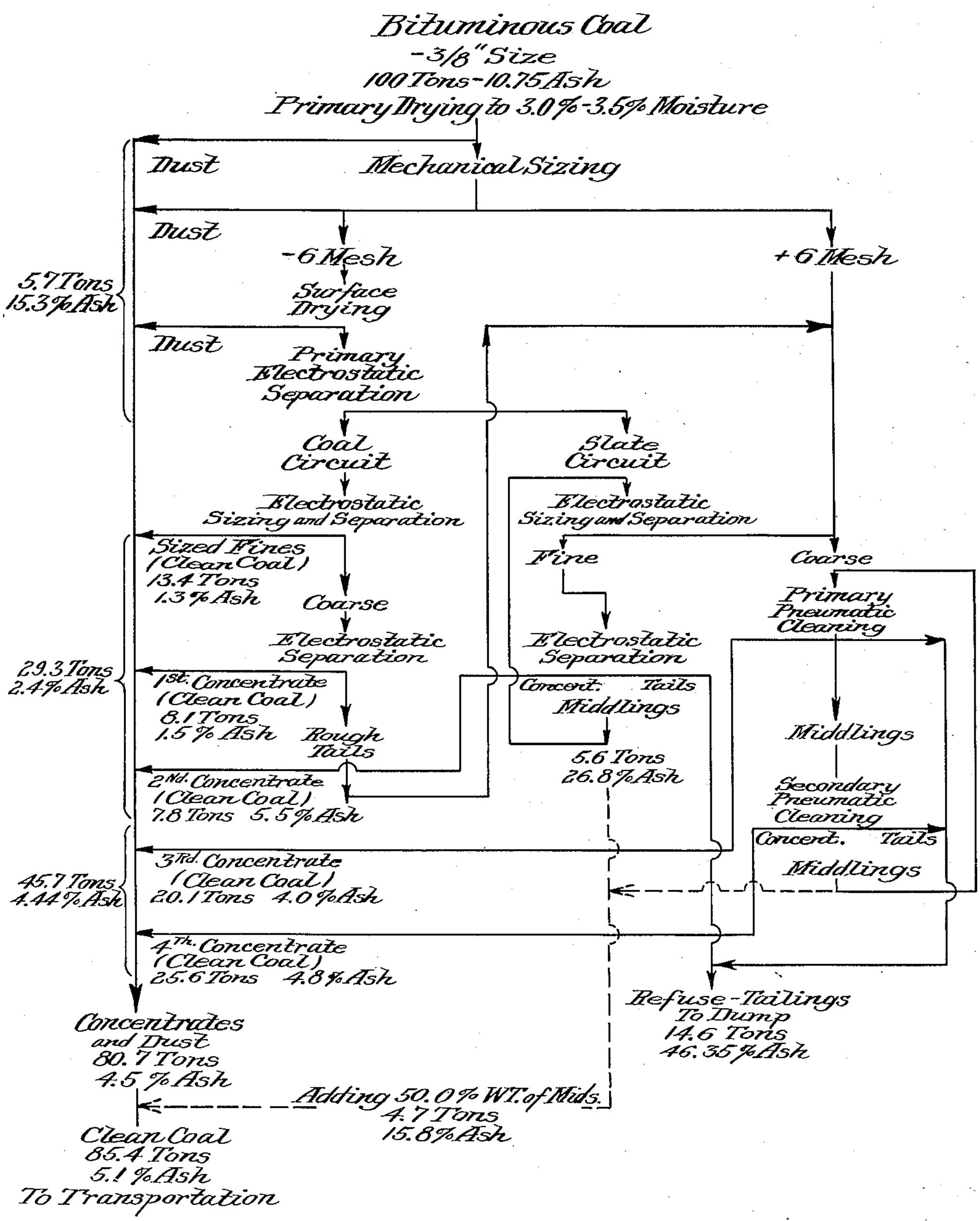
Fig. 7



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Patented July 3, 1951

2,559,076

UNITED STATES PATENT OFFICE

2,559,076

METHOD OF CLEANING COAL

Herbert B. Johnson, Rochester, N. Y., assignor, by mesne assignments, to The Quaker Oats Company, Chicago, Ill., a corporation of New Jersey

Application October 11, 1945, Serial No. 621,725

2 Claims. (Cl. 209—127)

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This invention relates to methods of cleaning coal, and, more particularly, to the cleaning of coal in the finer particle sizes of one fourth of an inch or less in diameter, such as anthracite culms, bituminous slack, and the like, one object of the invention being to provide an efficient and economical dry method of cleaning such coal materials, for metallurgical uses, and various other purposes, such as for heating or power generating plants.

Another object is the provision of an effective method of sizing and cleaning such coal without the use of expensive screens and screen cloth replacements.

Another object is to provide a practical method of cleaning such coal materials by selective electrostatic separation.

Another object is to provide a method for sizing and cleaning such coal by selective electrostatic separation particularly adapted for effectively removing ash minerals such as slate, bone, sand, pyrite, quartz, calcite, fusain, and the like.

A further object is to provide a dry method for cleaning coal in particle sizes ranging down to 200 mesh, in such a way as to initially remove and subsequently recombine the relatively fine but explosive dust portions of the coal which constitutes the most hazardous feature in such operations.

Still a further object is to produce simple and practical apparatus capable of being economically supplied and maintained in operation for carrying out the above method.

To these and other ends the invention resides in certain improvements and combinations of method steps and apparatus parts, all as will be hereinafter more fully described, the novel features being pointed out in the claims at the end of the specification.

In the drawings:

Fig. 1 is a diagrammatic elevation of the upper parts of an apparatus for carrying out a method embodying the present invention;

Fig. 2 is a diagrammatic view of an electrostatic separation apparatus for carrying out the method as applied to the cleaning of one type of coal;

Fig. 3 is a similar view but showing the electrodes with reversed polarities as applied to the cleaning of another type of coal;

Fig. 4 is a similar view of the apparatus as applied to the separation of different kinds of coal to show their different electrostatic characteristics;

Fig. 5 is a view similar to Fig. 3, but showing a further modification;

Fig. 6 is a similar view, but showing the method and apparatus as more fully applied to the cleaning of the same type of coal as in Fig. 3, and

Fig. 7 is a flow sheet showing the system of treatment of a sample coal mixture.

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My invention is applicable to the dry cleaning of coal material in the finer particle sizes referred to above, for the cleaning of which no efficient dry method is now available. Such coal materials may be either the run-of-the-mine coal, after removal of the larger sizes, or obtained by crushing larger sizes for treatment directly by the present invention. My invention may also be employed to supplement the wet, pneumatic, and other known cleaning methods, in the handling of sizes for which they are not well adapted.

It has been proposed to clean coal in such finer sizes by electrostatic separation methods, by preliminarily mechanically screening the coal to separate the particles passing a 4 mesh screen into a number of portions in which the particles are grouped or classified according to size, to obtain particles in each group as nearly uniform in size as possible. Particles of uniform size have been fed onto a rotary conveying electrode from which the particles are discharged so as to fall by gravity through an electrostatic field created between the conveying electrode and a spaced electrode of opposite polarity produced by either direct or alternating current, in the belief that the coal materials were unaffected by the electrostatic field, while the ash minerals were repelled from the conveying electrode so as to be separately collected beyond the coal.

It has also been proposed to improve on the above method by subjecting the coal mixture to an electrostatic field in a moist condition for the purpose of developing hygroscopic differences in the constituents of the mixture and employing such differences and resulting conductivities for separating the constituents. These prior methods have not been satisfactory, however, and have not been employed to any substantial extent in industry.

I have found, on the contrary, that the manufacturers of mechanical screening equipment will not undertake to dry-screen coal in such fine sizes in commercial quantities, as distinguished from laboratory tests, and that the separation of such coal mixtures into the desired size portions can be more satisfactorily accomplished without screening, as hereafter more fully described.

I have further discovered that the defects of the first of the above prior methods cannot be overcome by treating the coal mixture in a moist condition, as proposed in the second of the above methods, since the impurities or ash minerals to be removed are of various kinds, varying widely and unpredictably in their hygroscopicities, so as to be difficult if not impossible to control in moist condition. The control of the hygroscopic condition of coal materials is also so complicated and expensive as to overbalance the economies to be obtained by cleaning such materials.

I have further discovered, contrary to the above assumption of the prior art, that coal is not unaffected by an electrostatic field, but may be beneficially affected, depending upon the relative polarities and impressed voltage of the opposing electrodes; further, that the impurities or ash minerals may be selectively and beneficially depressed, as well as repelled, from the conveying electrode, depending likewise upon the relative polarities and impressed voltage of the electrodes and that, by selective control of such polarities and voltage, the coal and its impurities may be separated with a marked increase of efficiency. While the above prior methods have been found erroneous in conception and prohibitive in cost of construction and operation, for the cleaning in quantities of such a low priced commodity as coal, the present invention, on the other hand, has been proven highly practicable and successful for economic commercial production.

In carrying out my invention, I find it desirable to have the surface of the coal material reasonably dry for about fifteen minutes while under treatment, with the object of eliminating any effects of hygroscopic surface moisture on the coal and ash minerals, for the reason that such moisture varies the electrostatic behavior of both the coal and ash minerals in ways which are difficult to predict or control, so that such moisture has a detrimental effect on dry cleaning by electrostatic separation. Therefore, in order to assure close control of selective electrostatic separation under all atmosphere and temperature conditions, I have found it desirable to surface-dry the coal within reasonable limitations. This is preferably accomplished by passing heated air or inert gas, or mixtures thereof, through the stream of coal for temporarily drying the particle surfaces. This step is advantageously employed for the further function of removing the finest or dust particles such as would pass a 100 mesh screen, conveniently referred to as —100 mesh size, to thereby eliminate the explosive hazards during the further electrostatic cleaning treatment of the portions of coarser particle size. Such dust portion, however, is not necessarily wasted as I have found that by the use of my invention I can obtain clean coal concentrates so low in ash content that I can recombine the removed —100 mesh dust with the clean coal concentrates and have a final ash content below 5%, which is better than has been accomplished by any other dry method of cleaning coal having a particle size of, say, ¼ inch to zero.

After such dedusting and surface drying of the particles, the coal material to be cleaned is preferably separated according to particle size into two or more portions or classes, to facilitate the electrostatic separation, and I have found that such separation can be accomplished in a simple and practical way so as to eliminate the difficulties and expense of installing and maintaining apparatus employing separating screens. The invention is best described at this point by reference to the drawings of the apparatus devised for carrying out the method.

Referring to Fig. 1, for a further description of the surface drying and sizing steps, the invention preferably comprises a casing **10** having at its top a receiving hopper **11** for receiving the material to be cleaned, which is discharged through an opening in the hopper bottom and distributed in a thin layer over a rotary drum or electrode **12**, the discharge being regulated by an adjustable feed gate **13**, of any known or suitable construction, as well understood in the art. Drum **12** is preferably three inches or more in diameter with a knurled, fluted, corrugated, or otherwise suitably roughened, cylindrical surface, and is rotated at a peripheral speed between, say, 100 to 450 feet per minute, depending upon the character of the materials handled, so as to discharge the particles in a gravity stream under some centrifugal force proportional to the particle masses and tending to repel them somewhat forwardly from the point of discharge from the drum. As the particles are rotated and discharged by the conveyor drum, the coarser particles of greater mass tend to become segregated on the outside of the stream, while the finer particles have a tendency to stratify and follow the downward direction of rotation of the drum so as to be, in effect, depressed and thus separated from the repelled coarser particles. The degree of stratification is controlled by the centrifugal force imparted by the drum and the falling stream is separated along a desired line of stratification by a divider plate **14**, which is mounted for horizontal and vertical adjustment by any suitable means (not shown), as well understood in the art.

By means of such apparatus, it has been found possible to size or classify coal material from 1'' to 100 mesh with practically the same efficiency as obtained by the use of screens. In the course of such sizing there is practically no more concentration of the ash content than would occur in separation by the use of screens and the sizing operation is accomplished economically at a low cost of between six and ten cents per ton. This method of sizing, therefore, is substantially as efficient in operation as sizing by means of screen cloth and eliminates the problems of obtaining suitable screens as well as the high maintenance and replacement costs involved in the use of such screens.

The following data show representative operations in sizing anthracite and bituminous coals at approximately 40 mesh particle size, using the above mechanical method of sizing without resort to any electrostatic field. A small difference in ash content between coarse and fine sizes of anthracite coal is observable, due to the fact that a larger percentage of river sand is contained in the coarser sizes. With the bituminous coal, the ash content of the coarse and fine sizes is approximately the same, due to a more even, natural distribution of the ash minerals in the coal. There is practically no concentration of ash, however, in this sizing treatment of either coal.

Mechanical sizing—Anthracite river coal head feed, 100.0% weight at 35.20% ash

Size	Coarse Size, Per Cent, Weight		Fine Size, Per Cent, Weight	
−10+16 mesh	12.10	+40 mesh 91.8% wt.	.10	+40 mesh 12% wt.
−16+20 mesh	6.70		.20	
−20+40 mesh	33.50		4.80	
−40+80 mesh	4.10	−40 mesh 8.2% wt.	30.30	−40 mesh 88% wt.
−80 mesh	.60		7.60	
Total	57.00 at 37.01% ash.		43.00 at 32.79% ash.	

Mechanical sizing—Bituminous coal head feed, 100.0% weight at 11.21% ash

Size	Coarse Size, Per Cent, Weight		Fine Size, Per Cent, Weight	
−10+16 mesh	34.30	+40 mesh 95.5% wt.	.00	+40 mesh 11.7% wt.
−16+20 mesh	7.10		.00	
−20+40 mesh	35.60		2.30	
−40+80 mesh	3.30	−40 mesh 4.5% wt.	12.20	−40 mesh 88.3% wt.
−80 mesh	.30		4.90	
Total	80.60 at 11.17% ash.		19.40 at 11.37% ash.	

The fine portion 17 and the coarse portion 18, separated as described above, are each conducted and passed between a pair of spaced electrodes 19 and 20, being delivered to the rotary conveying electrode 19 for discharge through the electrostatic field created between it and its spaced electrode 20 of opposite polarity, to effect electrostatic separation of the coal and the ash minerals in accordance with principles which will now be described.

My invention comprises the important discovery referred to above, that the ash mineral contents of such coal materials are generally capable of being either depressed or repelled, when passed between spaced electrodes and in close proximity to one of them, where the electrodes are maintained at a relatively high difference in uni-directional voltage, say 4,000 to 10,000 volts, depending upon the spacing of the electrodes, the character of materials cleaned and the like. That is, I have found that when the near electrode, such as a rotary conveying electrode, is maintained with a positive polarity, the ash minerals have a substantial tendency to be depressed, whereas with an opposite polarity they tend to be repelled, being "reversible negative" in accordance with the principles described and claimed in my Letters Patent No. 2,197,864, dated April 23, 1940.

I have likewise discovered, as new characteristics of coals, that anthracite coals tend to be repelled under such conditions regardless of the polarity of the conveying electrode, whereas bituminous coals tend to be depressed from a conveying electrode of negative polarity but repelled from one of positive polarity, so as to be "reversible positive" in accordance with the principles described in my said patent. The present invention invokes these newly discovered characteristics of the ingredients of coal materials to produce efficient separation and cleaning of the coal, as will now be further described.

In Fig. 2 are shown a method and apparatus for cleaning anthracite coal in which the mixture to be cleaned is fed from a hopper 21 onto a rotary conveying electrode 22 and discharged by the latter through an electrostatic field maintained between it and a spaced rotary electrode 23. Electrode 22 is connected to ground, as at 24, and a substantial difference of uni-directional voltage is maintained between the electrodes, as by means of a known or suitable rectifying system indicated generally at 25. Electrode 22 may have a diameter of three or more inches and electrode 23 a diameter of ¼ inch to 3 inches or more, with a spacing between the electrode surfaces of from about ½ inch to 2½ inches, depending upon the related factors of the particular application. It has been found that when the electrode 22 is maintained with a positive polarity relative to the electrode 23 and at a substantial difference therefrom of uni-directional voltage of, say, 7000 volts or more, the ash minerals in the stream discharged from the conveying electrode are, to a substantial degree, depressed behind the usual divider 26, whereas the particles of anthracite coal tend to be repelled to the other or front side of the divider, so as to effect, through such repelling of the coal, and depressing of the ash minerals, a substantial cleaning of the coal.

With reference to the cleaning of bituminous coals, I have discovered that such coals are generally "reversible positive" in character, that is, they tend to be repelled from a conveying electrode of positive polarity and depressed from a conveying electrode of negative polarity. Fig. 3 shows an arrangement of apparatus similar to that of Fig. 2, except that the polarities of the electrodes are reversed from those of Fig. 2, with the result that the finer portions of the bituminous coal tend to be depressed behind the divider 26, while the coarser coal particles of greater mass and the ash minerals are largely repelled in front of the divider. The depressed bituminous "fines" thus separated represent a product relatively high in pure coal of fine particle size so as to provide a valuable partial product, as hereafter further described.

My discovery of these differing characteristics of anthracite and bituminous coal has been confirmed by employing such characteristics as a means of separating them from each other. While the specific gravities of anthracite and bituminous coals are practically the same, being about 1.5 and 1.3, respectively, so that they cannot be separated by gravity means, I have formed a mixture of such coals having a particle size passing a 10 mesh screen and made a practically complete separation of the two coals by passing the same through three successive pairs of electrodes. This procedure is illustrated in Fig. 4 where such mixture is fed from a hopper 27 onto a rotary conveying electrode 28 of negative polarity so as to fall through a field created by a spaced electrode 29 of opposite polarity. With a substantial uni-directional voltage difference between the electrodes and a negative polarity at the conveying electrode 28, the bituminous coal is depressed and the anthracite coal repelled in accordance with the principles described above.

In the cleaning of some coals, where it is advisable to separately clean both the fine and coarse sizes electrostatically, I have found it desirable to first accomplish the separation of the coal into sized portions by the mechanical method described above. On many other coals, however, I have found it desirable to not only size the coal but also to simultaneously clean the finer sizes of approximately −40 mesh which can thus be advantageously removed from the cleaning system because of the explosive hazard which they present in a dry cleaning operation.

Such simultaneous sizing and cleaning of coal may be accomplished by taking advantage of the above described reversibility characteristics of the coal and ash minerals and an apparatus for this purpose is shown in Fig. 5 where 30 is a feed hopper delivering coal through a feed gate control 31, of any known or suitable variety, for delivering a thin layer of the coal mixture onto the periphery of a rotary conveying electrode 32, from which it is discharged by centrifugal force and gravity through an electrostatic field between electrode 32 and a spaced charged electrode 33 of opposite polarity. Electrode 32 has a negative polarity and positive electrode 33 is maintained at a voltage difference therefrom of about 3000 volts by any known or suitable rectifying device 34 for producing uni-directional voltage. At 35 is a second electrode with its center in the same horizontal plane as the center of electrode 32, and electrode 35 has a positive polarity and a potential difference from electrode 32 of about 7000 volts maintained by a separate rectifying source 36 of uni-directional voltage of any known or suitable variety. Electrode 33 is preferably so located that the line of centers of electrodes 32 and 33 makes an angle of about 30° with the said horizontal plane. Electrode 32 may have a diameter of three inches or more and a peripheral speed of from 100 to 450 feet per minute, depending upon the character of the materials. Electrodes **33** and **35** may have diameters of about ¾ of an inch with their surfaces located, say 1½ inches from the surfaces of the conveying electrodes, depending upon the impressed voltages and the character and size of materials being handled. Electrode **33** is employed to precharge the materials, while electrode **35** operates to selectively size and separate them so that, in the cleaning of bituminous coals, the finer sizes of ash minerals are repelled, along with the coarser sized and heavier particles of coal, beyond the usual adjustable divider **37**, while the finer sizes of coal, low in ash minerals, are depressed behind the divider as shown, thus separating out from 20 to 40% of the coal as a clean product low in ash mineral content and at the same time eliminating the explosive hazard in the further cleaning of the repelled ingredients.

Representative tests made on samples of bituminous coal by the above method and apparatus shown in Fig. 5 yield the following data, showing that from 22.4% to 37% by weight of the coal to be cleaned is removed as "fines" with an ash content from 1.9% to 5%, depending upon the particular type of coal. It will also be noted that from 82.9% to as high as 90.6% of the ash minerals are in the coarser sizes requiring further electrostatic separation. These coarser sizes are practically free from the smaller particles of coal which involve explosive hazards. These samples of different coals were sized and separated at a particle size of approximately 30 mesh, with a negative charge on the conveying electrode. The weight of head feed, dedusted coal in each sample, is taken at 100.0%, with initial ash content as noted.

Product	Per Cent Weight	Per Cent Ash	Units Ash	Per Cent of Total Ash
SAMPLE NO. 1—9.3% ASH				
Sized Fines	37.0	4.30	1.591	17.1
Sized Coarse	63.0	12.20	7.686	82.9
Total	100.0	9.27	9.277	100.0
SAMPLE NO. 2—4.9% ASH				
Sized Fines	24.2	1.90	.459	9.4
Sized Coarse	75.8	5.86	4.441	90.6
Total	100.0	4.90	4.900	100.0
SAMPLE NO. 3—11.0% ASH				
Sized Fines	34.3	5.00	1.715	15.7
Sized Coarse	65.7	14.03	9.217	84.3
Total	100.0	11.03	10.932	100.0
SAMPLE NO. 4—9% ASH				
Sized Fines	31.2	4.04	1.260	14.1
Sized Coarse	68.8	11.17	7.684	85.9
Total	100.0	8.94	8.944	100.0

Fig. 6 shows schematically one of the possible combinations of steps and arrangements of apparatus for employing the present invention in the commercial quantity treatment of a sample of bituminous coal the weight of which is taken to be 100% at 10.3% ash.

It will be seen that of the series of electrode units, such as described above and shown in Fig. 6, the first two rotary conveying electrodes **38** and **39** are negatively charged, while the two electrodes opposite each conveying electrode are positively charged. The head feed or original coal of −6+100 mesh and containing 10.3% ash is fed through hopper **40a** to conveying electrode **38** while the separated product which is depressed back of the divider contains only 3.54% ash and 93.68% of it will pass a 20 mesh screen. A screen test of this product by size and weight is as follows:

	Per cent weight
+6 mesh	0.00
+10 mesh	0.00
+20 mesh	6.32
+40 mesh	54.03
+80 mesh	36.14
+100 mesh	2.63
−100 mesh	.88

The coarse size which is repelled in front of the divider and contains most of the ash minerals is then subjected to treatment over the second rotary electrode **39** where a further separation and sizing action takes place, depressing a second product which contains only 3.5% ash and of which 65.51% by weight will pass a 20 mesh screen. A screen test of this product by size and weight is as follows:

	Per cent weight
+6 mesh	0.00
+10 mesh	1.36
+20 mesh	33.13
+40 mesh	50.68
+80 mesh	13.10
+100 mesh	1.11
−100 mesh	.62

In these two electrode treatments, 23% by weight of the original head feed is removed as a fine-sized, clean coal product containing only 3.52% ash. The coarser size, repelled from electrode **39**, including most of the ash minerals, is then subjected to treatment over a third electrode **40** having a charge of reversed or positive polarity which tends to depress the ash minerals behind the divider as shown by the fact that the product contains 40.46% ash. The simultaneous sizing action is shown by the fact that 77.74% by weight of this product will pass a 20 mesh screen. A screen test of this product by size and weight is as follows:

	Per cent weight
+6 mesh	0.00
+10 mesh	2.44
+20 mesh	19.82
+40 mesh	52.74
+80 mesh	21.34
+100 mesh	2.44
−100 mesh	1.22

The coarse sizes repelled from electrode **40** are then delivered to a second positively charged conveying electrode **41** at which a fourth product is depressed containing 24.5% ash and of which 43.51% by weight will pass a 20 mesh screen, due to the continued sizing action. A screen test of this product by size and weight is as follows:

	Per cent weight
+6 mesh	0.00
+10 mesh	9.24
+20 mesh	47.25
+40 mesh	37.14
+80 mesh	5.72
+100 mesh	.44
−100 mesh	.21

The coarse product repelled from electrode 41, amounting to 63.1% by weight, contains 8.2% ash and 90.6% by weight of this coarse product is +20 mesh. By combining the first and second products depressed at electrodes 38 and 39, respectively, with the coarse product repelled at electrode 41, an end product is obtained representing 86.1% of the total coal cleaned and containing only 6.94% ash. By combining the third and fourth products depressed at electrodes 40 and 41, respectively, a refuse tailing is obtained amounting to 13.9% by weight of the total and containing 31.7% ash. This four electrode treatment, therefore, has yielded 86.1% of the original coal at 6.94% ash, as against the original ash content of 10.3%. Other similar tests on different coals have yielded from 85 to 94% of the original weight as a clean coal product containing between 4.5 and 5% content.

On some coals, however, I have found it advisable to first clean the raw coal electrostatically, producing the maximum tonnage of clean coal to the desired ash content and then to recrush the rough tailings and further clean in order to obtain the maximum recovering of clean coal at lowest capital investment and operation cost.

Fig. 7 shows a typical flow sheet and equipment arrangement for the cleaning of —3/8" bituminous coal in accordance with the invention, supplemented by pneumatic cleaning treatment. The coal is first preliminarily dried to approximately 3% moisture in order to deliver coal of uniform moisture to the pneumatic cleaning equipment. After such drying, the coal is sized or classified mechanically, as shown in Fig. 1, producing two sizes, one being +6 mesh which is cleaned pneumatically, and the other —6 mesh which is cleaned electrostatically. The —6 mesh sizes are again surface dried and subjected to primary electrostatic separation, as explained in connection with Figs. 3 and 5, where the bulk of the slate and other refuse is repelled to the slate circuit and the coal concentrate delivered to the coal circuit. Both of these products are further electrostatically sized and cleaned, as explained in connection with Figs. 3 and 5, so that the finer sizes are much higher in coal content and much lower in ash content than the coarser sizes. In the coal circuit the fine size is removed as clean coal containing 1.3% ash, while the coarse size is subjected to further electrostatic separation, as described above in connection with Figs. 3 and 5, where a first concentrate is produced containing 1.5% ash, and the rough tailings from this operation are delivered to the pneumatic cleaning process.

In the slate circuit, the feed is first electrostatically sized, as explained above in connection with Figs. 3 and 5, producing a fine product much lower in ash than the coarse product which latter is delivered to the pneumatic cleaning operation. The fine size is then subjected to further electrostatic separating treatment of the character described in connection with Fig. 6 wherein the head feed is first subjected to a grounded conveying electrode having a negative charge and producing a clean coal and a rough tailing, the latter being further subjected to conveying electrodes having a positive charge, wherein the clean coal is repelled and the refuse or tailing depressed, thereby producing clean coal, middlings and refuse, the clean coal containing 5.5% ash. The middlings containing 26.8% ash are returned to the head feed of the slate circuit for recleaning and the tails or refuse are delivered to waste or dump. Assuming, as commonly found in practice that approximately 50% of the middling product is recovered as coal containing 15.8%, this is recombined, along with a similar recovery from the middlings of the pneumatic process, with the clean coal.

By this procedure 29.3% by weight is removed electrostatically as clean coal containing 2.4% ash, and 45.7% of clean coal is removed from the coarse sizes by pneumatic cleaning containing 4.44% ash.

The dust removed in each operation is combined with the clean coal producing 80.7% by weight at 4.5% ash content. Assuming a recovery of 50% weight of the middlings as indicated containing 15.8% ash, the total recovery of clean coal is 85.4% containing 5.1% ash.

On some coals we have found it advantageous to clean the middlings produced pneumatically by electrostatic means, and we have found it advantageous on some coals to clean the middlings produced electrostatically by pneumatic means, for the reason that while middlings produced pneumatically may be of the same specific gravity, there is often a considerable difference in electrostatic susceptibility. Likewise, middlings produced electrostatically which are of approximately the same electrostatic susceptibility may show considerable difference in gravity between the coal and slate impurities and therefore can be further cleaned more economically by pneumatic means than by electrostatic.

Similar flow sheets may be devised for the cleaning of coal by combination of the above electrostatic method and apparatus with known methods involving the use of Chance or Mendez cones or the like, jigs, sink-and-float devices, wet tables and flotation apparatus.

It will be noted that my method and apparatus employ the above principles that the ash minerals of coal are generally "reversible negative" or repelled from a negative conveying electrode and vice versa, that bituminous coals are generally "reversible positive" or repelled from a positively charged conveying electrode and vice versa, and that anthracite coals generally are unaffected by relative polarities of the electrodes, for the purpose of separating out substantial proportions of clean coal or substantial proportions of the ash minerals, to derive an end product high in clean coal.

In practicing my invention, I have been able on some coals to use a single charged electrode opposite each conveying electrode, while on other coals I have found it desirable to use two charged electrodes as described above in connection with Figs. 5 and 6, and in such cases, I prefer to employ a separate source of uni-directional voltage for each charged electrode as shown, so that different potentials and polarities may be under rheostat adjustment control. The charged electrodes 33 and 35 are preferably rotated on suitable mountings and provided with suitable cleaning or wiping devices as 33a, 35a, such, for example, as described and claimed in the copending patent application filed by me jointly with Ralph H. Johnson, Serial No. 491,347, now Patent No. 2,428,224, Wipers for Rotary Electrodes.

While I have indicated, by way of example, various operating details which have been successfully employed, such as the speed, size, spacing and voltages of the electrodes, it will be understood that such operating adjustments are subject to variation depending upon the varying operating factors of character, conductivity and size of the material particles and the like. Thus the speed of the conveying electrode, as well as the relative spacing and elevation of the electrodes, may require variation to suit varying particle size of the materials to be treated, while various conductivities in the materials may require various intensities in the electrostatic field obtained either by varying the spacing of the electrodes, or the impressed voltage, or both. But these adjustments may be readily ascertained by observation and analysis of results and varied and coordinated to suit each particular application, as well understood in the art.

It will thus be seen that the invention accomplishes its objects and while it has been herein described by reference to the details of preferred embodiments, it is to be understood that such disclosure is intended in an illustrative, rather than a limiting sense, as it is contemplated that various changes in the construction and arrangement of the parts will readily occur to those skilled in the art, within the spirit of the invention and the scope of the appended claims.

I claim:

1. The method of cleaning bituminous coal material comprising a mixture of particles of bituminous coal and ash minerals, which comprises the steps of delivering said mixture to a rotary conveying electrode forming one of a pair of spaced electrodes, discharging said mixture through the field between said pair of electrodes, maintaining said electrodes at a relatively high difference of unidirectional, electrical potential, to centrifugally repel the coarser particles of coal and ash and separate said mixture into portions respectively richer in coal and ash minerals than the initial mixture, delivering at least one of said separated mixture portions to a rotary conveying electrode forming one of another pair of spaced electrodes, discharging said mixture portion through the field between said other pair of electrodes, maintaining said other pair of electrodes at a relatively high difference of undirectional, electrical potential with their polarities opposite to those of the first mentioned pair of electrodes, to centrifugally repel the coarser particles of coal and ash and separate said mixture portion into further portions respectively richer in coal and ash minerals than the first mentioned separated mixture portion, and combining said separated portions richer in coal to form a coal product of relatively low ash content.

2. The method of cleaning bituminous coal material comprising a mixture of particles of bituminous coal and ash minerals which comprises the steps of delivering said mixture to a rotary conveying electrode forming one of a pair of spaced rotary electrodes, discharging said mixture through the field between said pair of electrodes, maintaining said electrodes at a relatively high difference of unidirectional electrical potential with said conveying electrode at negative polarity, to centrifugally repel the coarser particles of coal and ash in one separated portion while the finer particles of coal are depressed in another separated portion by said field, delivering said separated coal and ash portion to another rotary conveying electrode forming one of another pair of spaced rotary electrodes, discharging said separated coal and ash portion through the field between said other pair of electrodes, maintaining said other pair of electrodes at a relatively high difference of unidirectional, electrical potential with said other conveying electrode at positive polarity, to centrifugally repel the coarser particles of coal and ash in another separated coal and ash portion, while the finer particles of ash are depressed in a separated ash portion by said field, and recombining said fine coal portion and said other coal and ash portion to form a product of relatively low ash content.

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The following references are of record in the file of this patent:

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