To all whom it may concern:

Be it known that I, FREDERIC W. C. SCHNIEWIND, a citizen of the United States, residing at Englewood, in the county of Bergen and State of New Jersey, have invented certain new and useful Improvements in the Purification of Coal, of which the following is a specification.

This invention relates to the separation or purification of coal; and it comprises a process of purifying coal from gangue and particularly from pyritic gangue, or of separating different kinds of coals having different electrostatic susceptibilities from each other, wherein the coal after having been crushed, or otherwise suitably granulated or disintegrated is subjected to electrostatic separation by being brought into an electrostatic field or into contact with an electrostatically charged surface.

It further comprises a process of electrostatic separation of coal wherein the coal under treatment is protected from explosion by the presence of an explosion-preventing atmosphere, or by the elimination from the coal of the coal particles of such fineness as would be liable to form an explosive dust before the coal is brought into the electrostatic field, or by a combination of these processes, or by quickly removing the explosive particles or the entire mass from the dangerous zone in which explosions could occur, thus limiting any explosion to a small area; and it also comprises a process of electrostatic separation wherein a heated current of dry or inert or explosion-preventing gas is utilized for preventing explosion, or removing the finer particles of coal dust, or both, and also for drying or partially drying the coal and thereby removing surface moisture, the presence of which or an excess of which might prevent effective separation; all as more fully hereinafter set forth and as claimed.

Coal as it occurs in nature, and as mined, contains varying amounts of inorganic material such as slate or gangue and pyrites more or less intimately distributed throughout its mass. This slate or gangue is in part removed during the mining operation, but only the coarser lumps are thus removed, the finer particles remaining with the coal together with what inorganic material is unseparated from the coal or distributed throughout the coal mass. These inorganic materials upon combustion of the coal remain as ash, and are commonly known by this name. The sulfur present in the coal is in part present as “organic” sulfur combined with the coal but for the most part it is present as “inorganic” sulfur and principally as pyrites or iron sulfid which in most instances is distributed throughout the slate or gangue more or less uniformly.

Coals which are used for coking purposes must be relatively low in sulfur and phosphorus as well as in ash owing to the prospective use of the resulting coke for metallurgical purposes. Many coals, owing to their high content of such impurities, cannot be used for this purpose, even though otherwise they would produce satisfactory coke. Other coals, unsuitable for coke, are similarly too high in these inorganic impurities to be used economically for fuel or power generating purposes. It has heretofore been proposed to reduce the amount of ash and sulfur in coal to be used for coking, and for other purposes, by washing processes, but such processes have the disadvantage of all wet processes that they require a subsequent drying of the coal if the added moisture is to be removed. Many coking coals after washing contain from 10 to 20% of added water, and this water unless previously removed must be evaporated in the coke ovens and subsequently condensed and removed from the resulting gas, with resulting loss of heat energy. Moreover with the washing processes there is a considerable loss of coal owing to the washing away of the finer particles; and the wash water containing such fine coal is a waste material the disposal of which presents many difficulties owing to its polluting action. The washing of coal, furthermore, cannot be carried on in many localities owing to the lack of the necessary abundant supply of water.

According to the novel process of the present invention, not only are these disadvantages of the known washing and other wet purification processes avoided, but the coal is purified in a dry way by a process
having many material advantages over known purification processes. This novel process relates particularly to the separation of coal from its admixed gangue, or of different kinds of coal having different electrostatic susceptibilities from each other, by electrostatic means. The process is applicable to various kinds of coal as anthracite, the various grades of bituminous and semi-bituminous coal and shale, lignite and peat, all of which are included in the generic term coal in the present specification. This novel process relates particularly to the separation of coal from its admixed gangue, or of different kinds of coal having different electrostatic susceptibilities from each other, by electrostatic means. The process is applicable to various kinds of coal as anthracite, the various grades of bituminous and semi-bituminous coal and shale, lignite and peat, all of which are included in the generic term coal in the present specification. The term gangue is similarly used in the present specification and claims to indicate the inorganic or ash constituents of coal, including slate and the inorganic sulfur compounds, particularly iron sulfid or pyrites, and the other inorganic impurities whether in an isolated state or admixed with and adhering to particles of the coal. The phosphorus contained in the coal is, as well as the sulfur, principally present in the gangue or slate, and hence it will be at the same time removed, so that the coal will be freed from this impurity, at the same time as from the gangue and pyrites, and to a corresponding degree. The coal to be purified may be obtained from widely varying sources and in different forms and conditions. In some cases run-of-mine coal can be used and all treated according to the present process after having been first crushed if necessary. Again the coal can be partly crushed and screened and only the finer particles further crushed and purified; or only certain fractions can be so treated, other fractions being treated otherwise or used without treatment. Waste coal or "slack," particularly bituminous slack, and anthracite culms, or other granular coal such as that intended for coking, briquetting and fuel purposes, can be used. With some coals, breaking up the lumps to give the usual sizes of lump, egg, etc., will upon screening give the larger sizes of coal in a sufficient state of purity, the more brittle impurities and the impurer coal being found among the finer sizes. With such coals only the finer sizes may be treated by the present process. In such cases the other sizes can be used without treatment or can be subjected to other processes, e.g., washing processes, pneumatic processes, etc., and only such fractions treated by the present process as are less advantageously treated otherwise. Coal which is to be separated effectively by electrostatic means must be free or comparatively free from moisture, particularly surface moisture, since the presence of too much moisture on the surface of the coal makes the coal a conductor, and prevents the necessary selective action of the electrostatic apparatus. Such coal, containing too much moisture, must be dried and part of this water removed before or during or after the crushing of the coal and before the actual separation. Many of the common coals do not require any such drying since their normal content of moisture is too small; but on the other hand, coals from wet mines, and lignite or peat which contain relatively large amounts of water require drying previous to separation. The presence of moisture is harmful only when it interferes with the effective separation. With some coals it may even be advantageous to add slight amounts, particularly where the mineral impurities and in general the poorer grades of coal are more hygroscopic or condense or retain more moisture on their surface than the purer and better grades or vice versa. When an excess of moisture is already present or has been added, a partial removal only can be effected by drying, the harder or greasy coal drying more readily than that which is softer and more porous or more hygroscopic. The coal before electrostatic separation must be crushed sufficiently to separate, as much as possible, the gangue from the coal or the coals having different electrostatic susceptibilities from each other. In general, the more finely the coal is crushed the more complete the separation of the particles of the coal and the gangue and of the different kinds of coal. But in the case of the removal of pyritic gangue the comminution need not be carried to such an extent as to separate the slate or gangue from the contained pyrites, since this union of the pyrites and gangue aids in the effective separation as will be hereinafter explained. Usually the coal and slate or the different kinds of coal are found in well defined layers so that upon crushing the separation of the slate and coal or of the different kinds of coal from each other takes place at the same time that the lumps of the materials themselves are crushed. Where there are seams or cracks running through the coal lumps the crushing tends to separate the coal along such seams and thus expose any impurities found in them. Such impurities will either be broken off or will still adhere to coal particles and in the latter case the coal will tend to be removed along with the gangue. It is usually necessary to crush the coal so that it will pass a four-mesh screen (four meshes to the inch), and in most cases it has been found that crushing to pass an eight or twelve mesh screen gives better results. The particles should be as uniform in size as possible and to this end can be screened and separated into fractions and the various fractions separately treated. But if the crushing has been carried to the extent indicated it has been found that the coal can nevertheless be satisfactorily treated in most cases. Large lumps of coal can be crushed.
directly in one or more stages to give the coal of the requisite size. Or coal can be partly crushed and the larger lumps used as such, the smaller sizes only being crushed if necessary and subjected to electrostatic separation. Of course coal which has been previously reduced to the necessary size need not be further crushed, and hence the so-called waste coal dust, or anthracite culms or bituminous slack in many cases furnish material which upon screening to remove the larger particles can be used directly, or with a previous drying if necessary; while the larger particles can be further crushed and also subjected to electrostatic separation, or otherwise used or treated without further crushing.

The present process offers the advantage that the size of the coal purified is such that it can be used directly for coking or briquetting purposes, or for pulverized fuel or other purposes where a pulverized coal is desired, and that for those purposes the coal is available not only in a pulverized, but also in a purified condition. Coal that already contains, or yields upon crushing, a large amount of fine dust, or of so-called float dust, can in many cases be more advantageously treated electrostatically after this fine dust has been removed from the crushed coal by pneumatic or other means.

As already indicated the coal from which the conductive gangue is to be separated before electrostatic treatment should be crushed to such an extent only that the gangue is separated as completely as possible from the coal particles while the gangue in turn is not separated to any considerable extent from its contained pyrites. After having been crushed to the extent indicated the coal is subjected to electrostatic separation. I have found that many coals, particularly bituminous coals, which have been suitably crushed and which are free from any excess of moisture are from an electrostatic standpoint, non-conductors; but that the gangue in such coals, which often is itself also considered as a non-conductor, is nevertheless in the present case, owing to its content of pyrites or of other active conductor, itself a conductor; and that by taking advantage of these properties of the coal and gangue respectively they can be effectively separated from each other. It will of course be understood that these terms "conductive" and "non-conductive" are used with their relative and not with their absolute signification. Thus the particles of pyritic gangue in such bituminous coals are much more readily charged either inductively or by actual contact and after being so charged are more quickly and more energetically repelled, while the coal particles are not appreciably affected, or are affected so slowly that for practical purposes they may be considered as non-conductors. I have also found that certain bituminous coals which contain intermixed "bone" and lustrous coal (glanzkohle) can be similarly treated, and separation thereof effected in a similar manner to that of the coal itself from its pyritic impurities. These bony and lustrous coal particles are found to have in many cases such different electrostatic susceptibilities, similar to those referred to above of the coal and pyritical gangue. It is by taking advantage of these different electrostatic susceptibilities which I have found the different coal constituents to possess that the present novel purification or separation is effected. While the present process is described more particularly with respect to the separation of the conductive gangue from the coal it is intended that this description be illustrative also of the process of separating different coal constituents having different electrostatic susceptibilities from each other, e.g., bony from lustrous coal, the pyritical gangue and the admixed coal being taken as an example of the coal constituents having such different electrostatic susceptibilities. In many coals the bony coal may be itself higher in ash and pyritic content and the selective electrostatic action of the pyritical gangue may in such cases be supplemental to the greater electrostatic susceptibility of the bony coal.

If the crushed coal containing its gangue is first charged electrostatically either by induction or by direct contact and then brought into an electrostatic field the more strongly charged particles of gangue will be more strongly repelled by an electrode similarly charged and attracted by one oppositely charged. If the coal thus previously charged is brought in contact with an electrode of opposite charge the conductive particles will have their charges neutralized and become charged with the same kind of charges as that of the electrode and will be then repelled while the non-conductive and less strongly charged particles will remain relatively unaffected. Similarly if coal without any previous charge is brought in contact with a suitably charged surface or electrode the conductive particles of gangue will first receive an inductive charge before contact but will upon contact have this charge neutralized and become charged the same as the surface and then repelled, while the non-conductive coal remains unacted upon. Thus by the repulsion of the gangue particles their separation from the coal particles can be to a greater or less extent effected, and the repelled and the unacted upon particles can thus be collected separately. This separation is not in most cases a sharply defined and complete separation, but only a partial one. More or less gangue will be found remaining with the coal and similarly
more or less coal always accompanies the repelled and rejected conductive gangue; but it is nevertheless thus possible to purify the coal to a very material extent from its inorganic impurities.

Various types of apparatus can be used in practising the process of the present invention; and various forms and arrangements of electrostatic surfaces or electrodes. Also the surfaces may be charged either by a unidirectional current or by an alternating current; and the amount of the charge will also vary somewhat with the form, size, material, and arrangement of the electrode or electrodes. A voltage of 15,000 to 28,000 volts has been found to give satisfactory results.

The accompanying drawings illustrate different types of apparatus in which the present novel process of separation can be carried out, it being understood that these types are merely illustrative of the invention and do not in any way limit its scope. In carrying out this process it is necessary only that suitable means be provided for enabling the conductive particles (in this case the gangue) to become electrostatically charged and thereafter repelled by an electrode similarly charged, or attracted by one of opposite charge, or simultaneously repelled and attracted, while the coal particles, as already indicated, remain relatively unaffected during the treatment.

In the accompanying drawings,—Figure 1 shows, diagrammatically, one type of apparatus. Fig. 2 is a section on a somewhat larger scale of the top of the apparatus taken on line a—a, Fig. 1. Fig. 3 is a diagrammatic view showing a modified form of apparatus. Fig. 4, shows a modified form of apparatus similar to Fig. 1 and, Figs. 5 and 6 show still further modifications and Fig. 7 shows diagrammatically certain elements of a coal treating plant.

In the diagrammatic representation of Figs. 1, 2 and 3 the rotary electrode 1 and the stationary electrode 2 are shown as provided with wires 3 and 4 leading to a suitable source of electrostatic energy. Above the roll 1 is shown a hopper 5 by means of which the granulated coal is introduced and which in practice can be provided with suitable means (not shown) for agitating the coal or otherwise insuring a continuous or regulated feed in the form of a thin layer to the separating apparatus. The hopper 5 is shown extending to an appreciable extent within the inclosing casing 12 and as having transverse tubes or passages 6' for the purpose hereinafter indicated. In front of the roll 1 is a partition 7 for dividing the material and deflecting the same as will be apparent. A brush 8 is also provided for removing any particles adhering to the roll and receptacles 10 and 11 are provided for receiving the gangue and coal respectively.

Surrounding the apparatus and suitably insulated is a casing 12 which in Fig. 3 is provided with inlet and outlet openings 13 and 14 for the introduction and removal of a current of gas, and in Fig. 1 is provided with three such openings 13, 14 and 15, to one of which, 14, is shown attached an induction or reduction fan 16.

In carrying out the present process the granulated coal is introduced by means of the hopper 5 and is fed onto the revolving electrostatically charged electrode 1. The particles of gangue become thus charged by contact and then repelled while the coal particles are relatively unacted upon. The gangue upon repulsion, tends to fall outside the partition 7 and to collect in the receptacle 10 while the coal tends to fall by gravity inside the partition 7.

The coal should be fed in thin streams in order that the action of the roll in repelling the conductive particles may not be retarded by interference with the non-conductive particles as would be the case with a thicker layer.

In Fig. 1, the coal is shown as being separated on the upper roll only. It will, of course, be understood that a similar action takes place on the other rolls; it will also be understood that the distribution of the coal particles in Figs. 1 and 3 is shown merely for purposes of illustration, and will vary with the kind of coal as well as with the electrostatic condition and the arrangement of the electrostatic apparatus.

In some cases it is desirable to carry the purification to a greater extent than is possible with only one treatment. In such cases the partly purified coal or the separated impure coal or gangue can be subjected to one or more subsequent treatments and a further separation effected, the treatment in each case resulting in a product relatively richer in coal and less rich in gangue and one poorer in coal and richer in gangue. In Fig. 1 is shown means for effecting a further separation or purification of the partly purified coal. In this figure the deflecting plate 9, together with the partition 7, guide the material falling inside the plate 7, and made up of the partly purified coal, on to the second roller 1', similar to that already described, on which a further purification takes place, the repelled and rejected gangue falling outside the deflector 7 with that previously rejected. A third roll 1'' is also shown on which a third separation can be effected, the resulting purified material collecting in the receptacle 11. The rejected portion rich in gangue can also be subjected to one or more additional treatments in a similar manner to further separate the coal and the impurities contained in it. The rolls 1, 1' and 1'' are shown as all three con-
nected to the same wire 3 and the groups of electrodes 2, 2' and 2'' of which four are shown in each group are connected to the wire 4. These various elements are shown only diagrammatically and their number, size and relative arrangements can be varied to obtain varying results. Thus the brush 6 can be provided with spring means (not shown) for holding it in place; and the rolls 1, 1' and 1'' can be made larger or smaller in diameter. The partition 7 is shown as slightly further separated from the roll 1 than the partitions 7' and 7'', although all three may be adjusted to give varying results. As will be obvious the amount of rejected material can be varied by varying the location of these partitions and in some cases it is advantageous to include more material inside the partition 7 in order to subject it to a subsequent separation.

Coal dust, as is well known, is when mixed with air or a combustion supporting gas in proper proportions a dangerous explosive. When coal is crushed to the fineness necessary in the present process more or less dust of explosive fineness is produced and it is sometimes necessary or advantageous to prevent any possibility of explosion during the electrostatic treatment by removing such dust or rendering it non-explosive. According to one means for accomplishing this result the coal dust of explosive fineness is separated from the coal as by screening or by pneumatic means before it reaches the electrostatic apparatus, or again it may be separated during the separation, or its explosion prevented during this treatment. This last mentioned result can be accomplished with the apparatus illustrated in Figs. 1 to 4 in the following manner: In order to prevent coal dust explosions it is necessary to reduce the content of oxygen in the atmosphere from 21% to only 17.5% or in some cases and with some coals to only 15.5%. In the apparatus shown in Figs. 1 to 4 inclusive of the accompanying drawings the casing is provided with inlet and outlet connections for the introduction of an inert or a diluent gas or a mixture of such gas with air which will serve to reduce the oxygen inside the casing below the danger line. Ordinary flue gases are suitable for this purpose, containing as they do essentially nitrogen and carbon dioxide, with only small amounts of carbon monoxide and oxygen. A current of such an inert gas or mixture of such inert gas with air serves not only to prevent explosions but it also serves to carry away with it any dust of such fineness that it would remain suspended in the air and otherwise accumulate inside the casing. Such a current of gas or mixture of gas and air may be introduced at the bottom of the apparatus at 13 and escape at 14 (Fig. 3) or at 14 and 15 (Fig. 1) as indicated by the arrows x (Fig. 3) and y (Fig. 1). or it may flow in the reverse direction as indicated by the arrows y (Fig. 3) and x. Or in the arrangement of Fig. 1 both connections 14 and 15 at the top may be used as inlets or as outlets. In Fig. 1 a branch pipe 14 is shown with branches 17 and 18 for introducing either air or flue gas or a mixture in any desired proportions. In Fig. 4 the outlet is through the hopper itself. In this figure the tubes 5 extend through the sides of the hopper and permit the diluted air or gas to escape into the hopper and to pass out through the coal, taking with it not only any dust present in the casing but also any found with the coal in the hopper. Any dust formed by the rubbing or grinding of the coal particles in the apparatus with each other will be thus removed and the main portion of the dust will be removed from the coal in the hopper before it reaches the inside of the casing. When a heated current of air or gas or gaseous mixture is used moisture will also be removed and the coal in the hopper thus dried, as more fully described below. With such a circulation of inert gas or gas and air through the apparatus the oxygen content of the atmosphere surrounding the electrodes can be readily reduced below the danger limit. A very small current is sufficient for this purpose. A stronger current can however be used and the oxygen reduced to an even greater extent. When a casing is used around the apparatus it is advantageous that the current should be sufficient to carry away the suspended or “float” dust which otherwise might accumulate to too great an extent and interfere with the electrostatic separation. If the fine dust has been previously removed from the pulverized coal the inert gas will still protect the coal from accidental combustion or ignition by the electrostatic apparatus; and if in the previous removal all of the finest dust has not been removed it will be removed in the manner above described. Explosions can also be limited in their effect by means of screens or other devices for preventing propagation of a flame, thus localizing the effect of any incipient combustion to the immediate vicinity of the electrodes.

In case the coal contains a small amount of moisture which might interfere with its separation provision is made for its removal, according to the present invention, by the use of a heated current of gas which will blow the same gas already referred to for preventing explosions and for carrying away the “float dust”. By reference to Fig. 2 it will be seen that the hopper 5 has transverse tubes or passages through it at frequent intervals. This allows circulation through the hopper as well as around it, and when
a heated current of gas such as hot flue gas is passed through the apparatus it heats the coal in the hopper by circulation around the outside of the hopper and through the passages 6' and thus evaporates and removes part or all of the water contained with the coal, and particularly that found on the outside of the coal particles where it would be most susceptible both to removal by evaporation and to the influence of the electrostatic process if not removed. In the structure shown in Fig. 1, the hot gas can be introduced at both 14 and 15 and escape at 13 or it may be introduced only at 14 and escape partly or wholly at 15 as indicated by the arrows. By allowing a part only to escape at 13 and the rest at 15 a stronger current can be utilized for drying the coal in the top of the apparatus without interference with the electrostatic separation. A fan is shown diagrammatically at 16 which may be used either for forcing in the hot gas or for sucking it out as may be desired. Obviously other means of inducing circulation might be used either supplemental to, or as a substitute for, that shown. Similarly other means might be provided for heating or drying the coal before or during the separation, and such heating current may be independent of the explosion-preventing gaseous current, as will be obvious. When the current of gas passes upward or downward through the casing as well as across its top it exerts a further drying action as well as the coal in the hopper, and this drying action may be utilized even where, owing to previous removal of explosive dust, an explosion-preventing atmosphere is not necessary.

In some cases where the coal does not require drying, or where owing to the absence of explosive dust or for other reasons the provision of a heating or other current of gas is not necessary, it may of course be dispensed with, and in such a case the apparatus can be used without a surrounding casing and without heating means as is evident. In Figs. 5 and 6 are shown diagrammatically types of apparatus without such casings although it is obvious that they are capable of use with them. In Fig. 5 the arrangement of electrodes and hopper is similar to that of Fig. 5, but means is shown in this figure for separating the treated coal into various fractions as desired. As already pointed out, the separation of the impurities from the coal is not a sharply defined separation. More or less coal is always found in the repelled and rejected portion, and particularly the coal which still contains or is attached to small particles of the conductive impurities. Moreover some coals occur with harder coal and softer coal in alternate layers or otherwise intermixed, and frequently larger amounts of conductive impurities are present in the softer coal, and in such cases the separation tends to free the harder purer coal from the softer impurer, or more conductive, portions. In such cases several fractions may be obtained, and in Fig. 5 four receptacles are shown for receiving the treated coal, the partitions being adjustable as indicated at 24 to throw more or less of the product in one or the other of these receptacles. The impurer and more conductive coal will be repelled most strongly and will be principally received in 23. Coal less impure and slightly less conductive will be less strongly repelled and will be received in the receptacle 22. The main portion of coal, purer than those just referred to, will fall by gravity into the receptacle 21. By adjusting the central partitions 24 as illustrated this fraction can be increased, and particles which are given a slight throw centrifugally also included. Any adhering particles removed by the scraper 8 will fall into the receptacle 20. Any or all of these fractions can be further treated to effect a further purification.

With such coal as contains admixed lustrous particles and dull particles of impurer coal, such as certain grades of bituminous, the separation of the present invention gives a purified coal essentially granular in nature, containing most of the lustrous and purer particles, and having a clean appearance; while the rejected portion is noticeably duller and more porous in appearance and irregular in shape, and contains a larger amount of fine dull-appearing particles.

In Fig. 6 the electrode 30 is shown as a screen instead of a surface roller. With this arrangement there is obtained both a screening and a separating action. The conductive particles will be repelled much the same as with the other forms of electrodes already described, and can be collected in the receptacle 53. The larger coal particles 110 will tend to fall off the lower edge of the screen into the receptacle 32 while the other finer particles will tend to fall through the screen and collect in 31. The amount of material which passes through the screen will of course vary with the mesh of the screen and the amount of fine material in the coal. With such an arrangement some of the finer particles of impurities will also pass through the screen with the coal dust. With such a screen suitable means (not shown) may be provided for shaking or brushing the screen to remove any adhering particles.

In Fig. 7 is shown somewhat diagrammatically an arrangement of apparatus in which the complete process of the present invention can be carried out. The coal in a relatively coarse condition such as run-of-mine coal is crushed in the crusher 35 so that the impurer coal will for the most part pass...
through a 4-mesh screen. The fineness will vary somewhat with the different coals. With some coals, as already indicated, the larger lumps may contain the purer coal and in such cases such coal can be removed as such. Again all the coal can be crushed to pass a 4-mesh screen, as where the coal is to be used after purification for coking purposes. The crushed coal falls on to a 4-mesh screen 30 which separates the coarser lump and all allows all undersize to pass through into the bin 37, the oversize being collected in the bin 38. From the bin 37 the coal is conveyed to the foot of an elevator 39 which discharges into a screen chute 40 containing a 16-mesh screen 41 and an 8-mesh screen 42. The coal is by these screens divided into a fraction over 8-mesh which passes into the bin 43, a fraction through 8-mesh and on

16-mesh which passes into the bin 44 and a fraction through 16-mesh which passes into the bin 45. The bins 43 and 44 discharge into the electrostatic separators 46, 47 and 48 by means of controlling valves (not shown) being provided if regulation is necessary. The fine coal through 16-mesh passes from the bin 45 through the extension 46 to the electrostatic machine 47 which may be of a smaller size than those for coarser coal, or may be specially designed for fine coal. Bins 48, 49, 50 and 51 are arranged below the electrostatic separators into which, by communications not shown, the purified and refuse or rejected coal from the separators are separately discharged. The fine dust accompanying the coal is found almost entirely in the finer fraction (through 16-mesh) and provision is made for its removal before the finer coal reaches the electrostatic machine. The bin 45 containing the fine coal discharges into a hopper 52 provided with a gas inlet 54 and gas outlet leading to the fan 53 which discharges into a tangential or cyclone dust separator the central top outlet 56 of which is connected to the gas inlet 54 of the hopper 52. From the dust separator the dust is discharged into the dust bin 58 through the pipe 57. To the top of the outlet 56 is connected a pressure relief pipe 59 with valve 60 at its upper end. It will be seen that the fine coal and dust entering the hopper 52 from the bin 45 will be subjected to an upward blast of gas and the dust thus removed and conveyed by the fan to the dust settler, the same gas being continuously circulated upwardly through the hopper and then through the dust separator. The separator 47 has its gas inlet 61 so arranged that a supplemental current of inert or explosion-preventing gas, as hereinbefore explained, may be introduced and may serve to supplement the action of the dust separator, carrying with it up through the separator and through the bin 46 into the hopper 52 any dust which may have reached or been formed in the separator itself. The gas in the dust separator may thus be slowly or continually charged or maintained of an explosion-preventing nature. Any excess gas may escape through the outlet 59 to the atmosphere. While no source of inert gas is shown leading to the separators 12 and 47 it will be understood that furnace gas or gas from any other suitable source may be utilized, and that the atmosphere surrounding the separators and the screens can also be maintained of an explosion-preventing nature as already explained, and danger from coal dust explosions thus prevented.

While the screens 36, 42 and 41 have been described as 4, 8 and 16 mesh respectively so that the material separated is thus fractionated it will be understood that these sizes can be varied somewhat to accommodate the different fractions to the capacities of the machines and the number of screens and of fractions can also be varied.

In the foregoing description different types of apparatus have been described in which the novel process of the present invention can be carried out. It will be evident, however, that the process is not dependent upon any particular type of apparatus, but that it is of broad and general application. By this process it is possible to reduce the ash and sulfur content of the coal very materially and to such an extent that impure coals, which before treatment are too high in these inorganic impurities, are thereby rendered available for coking and other industrial purposes. The resulting coal moreover does not require subsequent drying to remove water as with the known washing processes. The rejected portion of the coal which contains most of the impurities admixed with more or less coal, and which in describing the foregoing process has been referred to as gangue coal can be used under boilers or for fuel or other purposes, either without further treatment or after it has been given one or more subsequent treatments to separate further the coal from the impurities contained in it.

The following analyses of a coking coal before and after separation indicates the results which have been obtained by the dry purification process of the present invention:

<table>
<thead>
<tr>
<th>Sizing test of coal</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>On 4-mesh...</td>
<td>21.3%</td>
</tr>
<tr>
<td>8-mesh...</td>
<td>28.3%</td>
</tr>
<tr>
<td>16-mesh...</td>
<td>29.4%</td>
</tr>
<tr>
<td>60-mesh...</td>
<td>14.2%</td>
</tr>
<tr>
<td>Through 60-mesh...</td>
<td>0.91%</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The percentages of each size under 4-mesh obtained in the rejected, intermediate and clean coal fractions was as follows, only three fractions being obtained and the so-called middlings or intermediate fraction...
and the rejected fraction not having been further purified:

<table>
<thead>
<tr>
<th>Mesh Size</th>
<th>Middlings</th>
<th>Reject</th>
<th>Clean Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-8 mesh</td>
<td>20.4%</td>
<td>22.4%</td>
<td>57.2%</td>
</tr>
<tr>
<td>8-16 mesh</td>
<td>6.0%</td>
<td>21.7%</td>
<td>72.3%</td>
</tr>
<tr>
<td>16-60 mesh</td>
<td>9.9%</td>
<td>20.5%</td>
<td>70.6%</td>
</tr>
</tbody>
</table>

The analyses of these fractions were as follows:

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4-8 mesh</td>
<td>8.34</td>
<td>2.23</td>
<td>8.90</td>
<td>2.94</td>
<td>18.86</td>
<td>4.63</td>
</tr>
<tr>
<td>8-16 mesh</td>
<td>9.56</td>
<td>3.96</td>
<td>14.65</td>
<td>4.24</td>
<td>23.86</td>
<td>6.22</td>
</tr>
<tr>
<td>16-60 mesh</td>
<td>12.95</td>
<td>3.44</td>
<td>18.47</td>
<td>3.88</td>
<td>31.96</td>
<td>6.97</td>
</tr>
<tr>
<td>Through 60 mesh</td>
<td>18.63</td>
<td>3.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The "middlings" or intermediate fraction and also the rejected impure fraction might have been further purified and the amount of clean coal correspondingly increased.

The present process furthermore can be used as supplemental to, or in combination with, other purification processes, as well as a substitute for, or partial substitute for them, e.g., pneumatic, washing, and other processes. Thus it may be mentioned that material which cannot be economically treated by washing processes, such as the finer particles of slack or culms, can be subjected to the present process and the electrostatic purification may be thus supplemental to the washing process. Again, there occurs in some grades of bituminous coal a disagreeable constituent known as mineral charcoal which is of a friable nature and possesses no coking properties. When the coal is pulverized this as well as other softer and more friable constituents tend to become more readily and more finely pulverized than the harder and more valuable coal so that most of such constituents may be found in the fine coal dust and among the finer coal particles. In such cases the pulverized coal can be advantageously screened to remove this fine powder or dust, or it can be subjected to pneumatic separation by exposure to a blast of air or inert gas to remove the finer and lighter particles. Again screening for the purpose of removing the larger particles, e.g., above 4-mesh, and also for removing the finer particles can be both used, the intermediate fraction or fractions only being subjected to electrostatic separation.

With some coals the finer particles, e.g., below 1/100" may be removed as completely as possible; with others it may be advantageous to remove all below 1/60", or even larger size. In such cases only those particles passing e.g., a 4-mesh screen and retained or an 8 or 16-mesh screen may be treated electrostatically or fractions of these particles such as those between 4 and 8 mesh, 8 and 16 mesh, and 16 and 60, etc. Such fractions can be varied with different coals, and only such fractions obtained by screening, washing, or pneumatic or other processes treated electrostatically as the nature of the coal and the relation of the coal components e.g., coking and non-coking, may render advantageous.

When the coal resulting from the process of the present invention is to be used for coking it is advantageous that the coal be protected from oxidation during its previous treatment, since even atmospheric oxidation tends to lessen the coking qualities of the coal. The further addition of oxygen to the coal which readily takes place with many coals when exposed to the air causes a decrease in the heat value of the coal in much the same manner as do ash and moisture since oxygen itself is also incombustible. Viewed from another standpoint the prevention of oxidation serves to protect the oxidizable constituents of the coal and to preserve these constituents in an unoxidized condition in which they appear to be most valuable, particularly for coking purposes.

In order that this protection from oxidation may be as complete as possible it is advantageous that the coal be protected from atmospheric oxidation during the electrostatic separation as well as during the previous crushing, screening, pneumatic and other preliminary processes which may be carried out. Such protection can be readily effected by the use of an inert atmosphere such as flue gas or nitrogen. Preliminary pneumatic separation using a current of inert gas can be also effected. With other steps of the process either a relatively stationary ambient atmosphere or a current of the inert gas can be used such as has been already described in connection with the prevention of explosion.

The electrostatic separation can also be used in combination with electromagnetic separation by a suitable combination of electrostatic and electromagnetic fields or apparatus, or by charging the particles electrostatically and subjecting the charged particles to such fields: Again electrostatically charging particles may be subjected to pneumatic treatment while under the influence of an electrostatic field or electrode and particles not affected electrostatically thus separated; or the pneumatic treatment may supplement the electrostatic treatment by passing a current of air or inert gas through the particles undergoing electrostatic separation and through the electrostatic field as has been hereinafore briefly indicated. Also various other modifications can be made in the process described and in combinations and variations of the same without depart-
ing from the spirit and scope of the invention as set forth in the accompanying claims.

1. The process of separating lustrous and non-lustrous coal constituents from each other, which comprises subjecting coal containing lustrous and non-lustrous constituents in a suitably crushed condition to electrostatic separation, and thereby differentially affecting the lustrous and non-lustrous coal constituents, and separately collecting the so differentiated components.

2. The process of purifying or separating coal from admixed conductive parts which comprises crushing the coal sufficiently to separate the better conductive particles from the less conductive particles, and thereafter separating the conductive particles from the freshly crushed coal by electrostatic means.

3. The process of purifying or separating coal from pyrites-containing gangue which comprises crushing the coal sufficiently to separate the gangue particles from the coal particles, and thereafter separating the gangue from the freshly crushed coal by electrostatic means.

4. The process of purifying or separating coal from pyrites-containing gangue which comprises crushing the coal sufficiently to separate the gangue particles from the coal particles without separating the gangue from its contained pyrites, and thereafter bringing the crushed coal into contact with an electrostatically charged electrode whereby the conductive pyritic gangue after contact is repelled and thus separated from the non-conductive coal.

5. The process of purifying bituminous coals and of separating coking and non-coking constituents from each other, which comprises subjecting bituminous coal containing coking and non-coking constituents in a suitably crushed condition to electrostatic separation, and thereby differentially affecting the coking and non-coking coal constituents and separately collecting the so differentiated components.

6. The process of purifying coal from mineral charcoal, which comprises subjecting non-conductive coal containing mineral charcoal in a suitably crushed condition to electrostatic separation, and thereby differentially affecting the mineral charcoal and the more valuable coal constituents, and separately collecting the so differentiated components.

7. The process of purifying or separating coal which comprises subjecting the coal in a granulated condition to electrostatic separation under explosion-preventing conditions.

8. The process of purifying or separating coal which comprises subjecting the coal in a granulated condition to electrostatic separation in an atmosphere of an inert gas.

9. The process of purifying or separating coal which comprises subjecting the coal in a granulated condition to electrostatic separation in an atmosphere containing less than 18.5% of free oxygen.

10. The process of purifying or separating coal which comprises subjecting the coal in a granulated condition to electrostatic separation in a current of an explosion-preventing gas.

11. The process of purifying or separating coal which comprises subjecting the coal in a granulated condition to electrostatic separation in a current of hot flue gas.

12. The process of purifying or separating coal which comprises crushing the coal, separating from the crushed coal the finer particles of dust, and subjecting the resulting dust-free coal to electrostatic separation.

13. The process of purifying or separating granulated coal which comprises separating from such coal the finer particles of dust and subjecting the resulting coal to electrostatic separation in the presence of an inert gas.

14. The process of purifying or separating granulated coal which comprises subjecting to electrostatic separation in a current of a heated gas.

15. The process of purifying or separating granulated coal which comprises separating from such coal the finer particles of dust and subjecting the resulting coal to electrostatic separation in a current of a heated gas adapted to remove dust therefrom.

16. The process of purifying or separating granulated coal which comprises heating the coal, and subjecting the heated coal to electrostatic separation in a current of a heated gas adapted to remove dust therefrom.

17. The process of purifying or separating granulated coal which comprises heating the coal, and subjecting the heated coal to electrostatic separation in a current of a heated explosion-preventing gas.

18. The process of purifying or separating granulated coal which comprises subjecting the coal to electrostatic separation in the presence of a current of heated gas, and utilizing the same current of heated gas to heat and dry the coal previous to its separation.

In testimony whereof I affix my signature in the presence of two witnesses.

FREDERIC W. C. SCHNIEWIND.

Witnesses:
G. KLINGELHEFFER,
ROBERT C. METCALFE.
It is hereby certified that in Letters Patent No. 1,153,182, granted September 7, 1915, upon the application of Frederic W. C. Schniewind, of Englewood, New Jersey, for an improvement in "The Purification of Coal," an error appears in the printed specification requiring correction as follows: Page 8, line 118, for the word "charging" read "charged"; and that the said Letters Patent should be read with this correction therein so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 5th day of October, A. D., 1915.

[SEAL.]  
R. F. WHITEHEAD,  
Acting Commissioner of Patents.