May 18, 1937. C. E. LESHER 2,080,946

CARBONIZATION OF COAL

Original Filed July 20, 1933 5 Sheets-Sheet 1

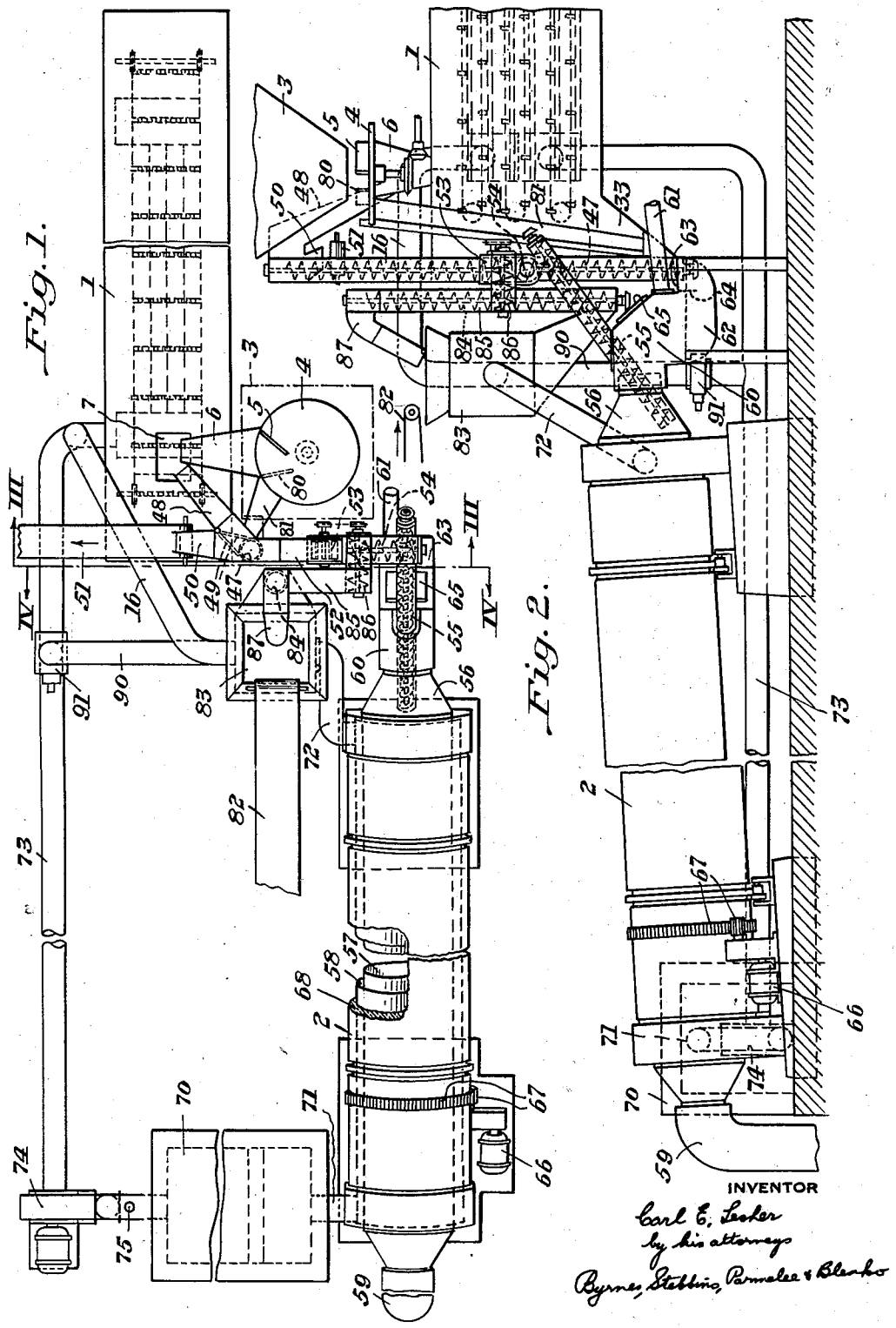

Fig. 1.

Fig. 2.

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CARBONIZATION OF COAL

Original Filed July 20, 1933 5 Sheets-Sheet 2

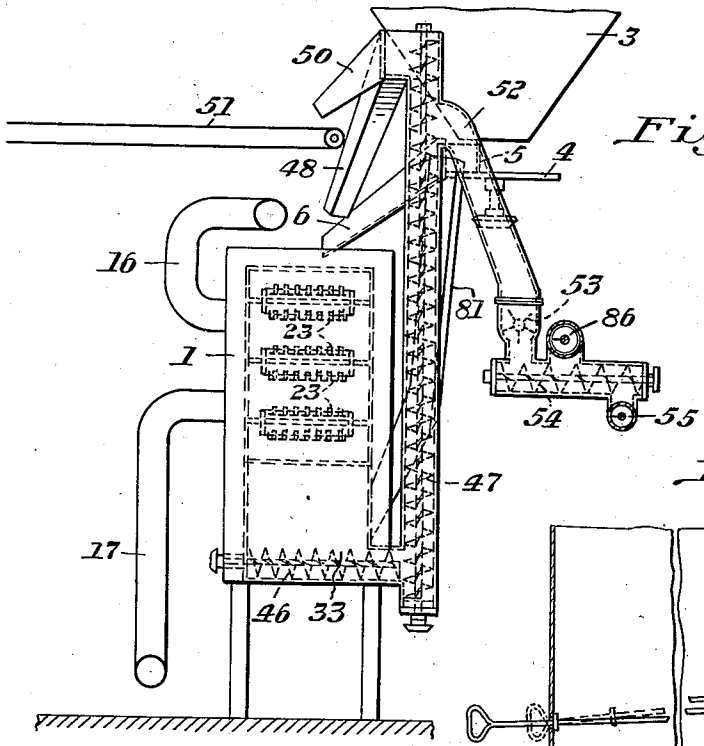


Fig. 3.

Fig. 9.

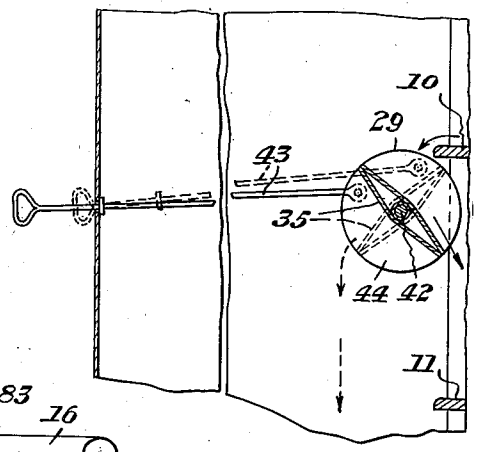
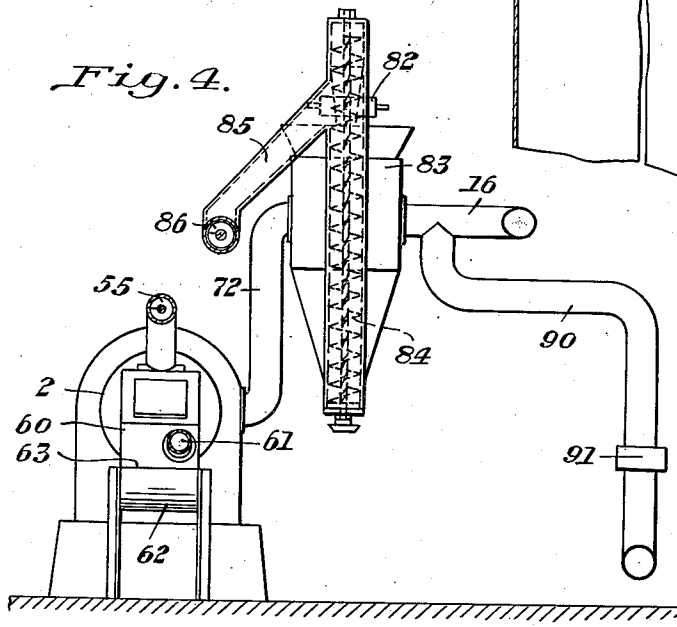


Fig. 4.



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CARBONIZATION OF COAL

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Fig. 5.

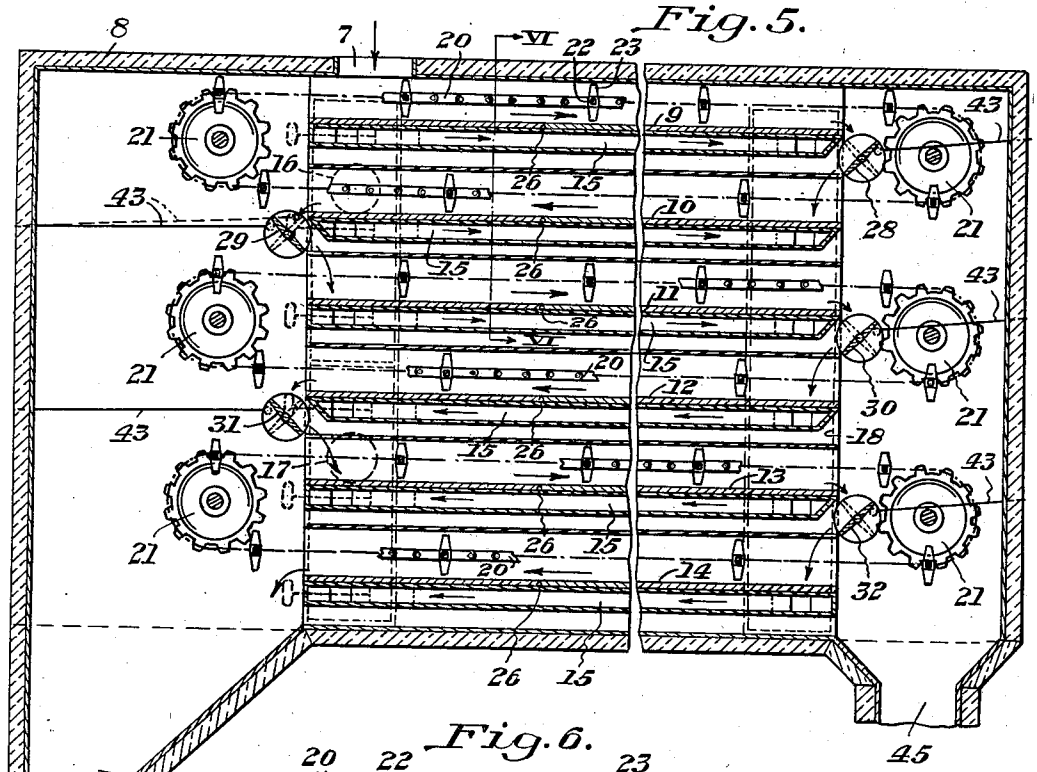


Fig. 6.

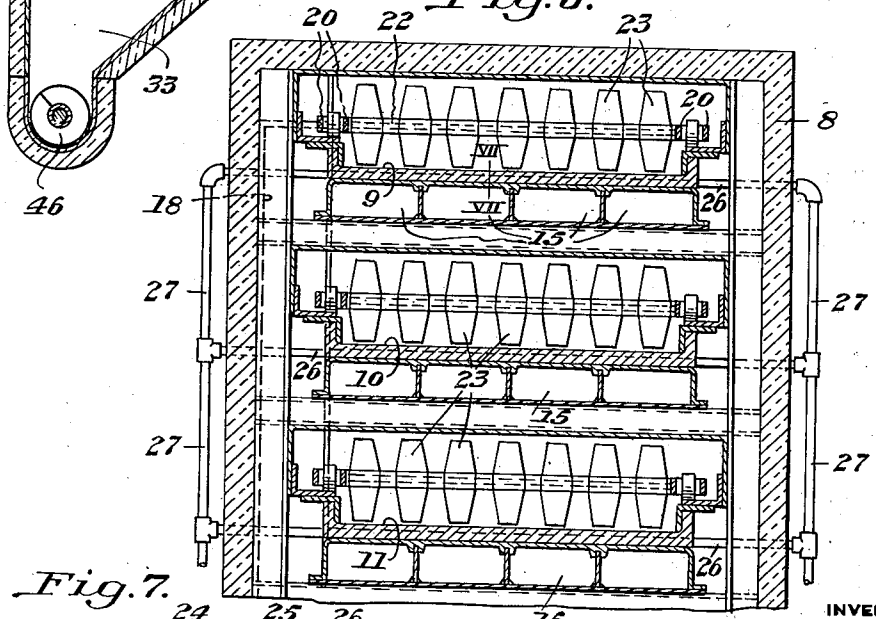
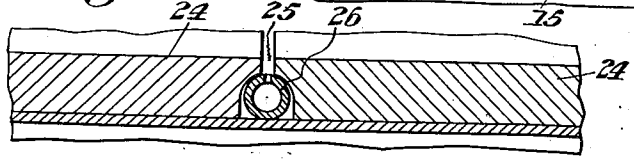


Fig. 7.



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CARBONIZATION OF COAL

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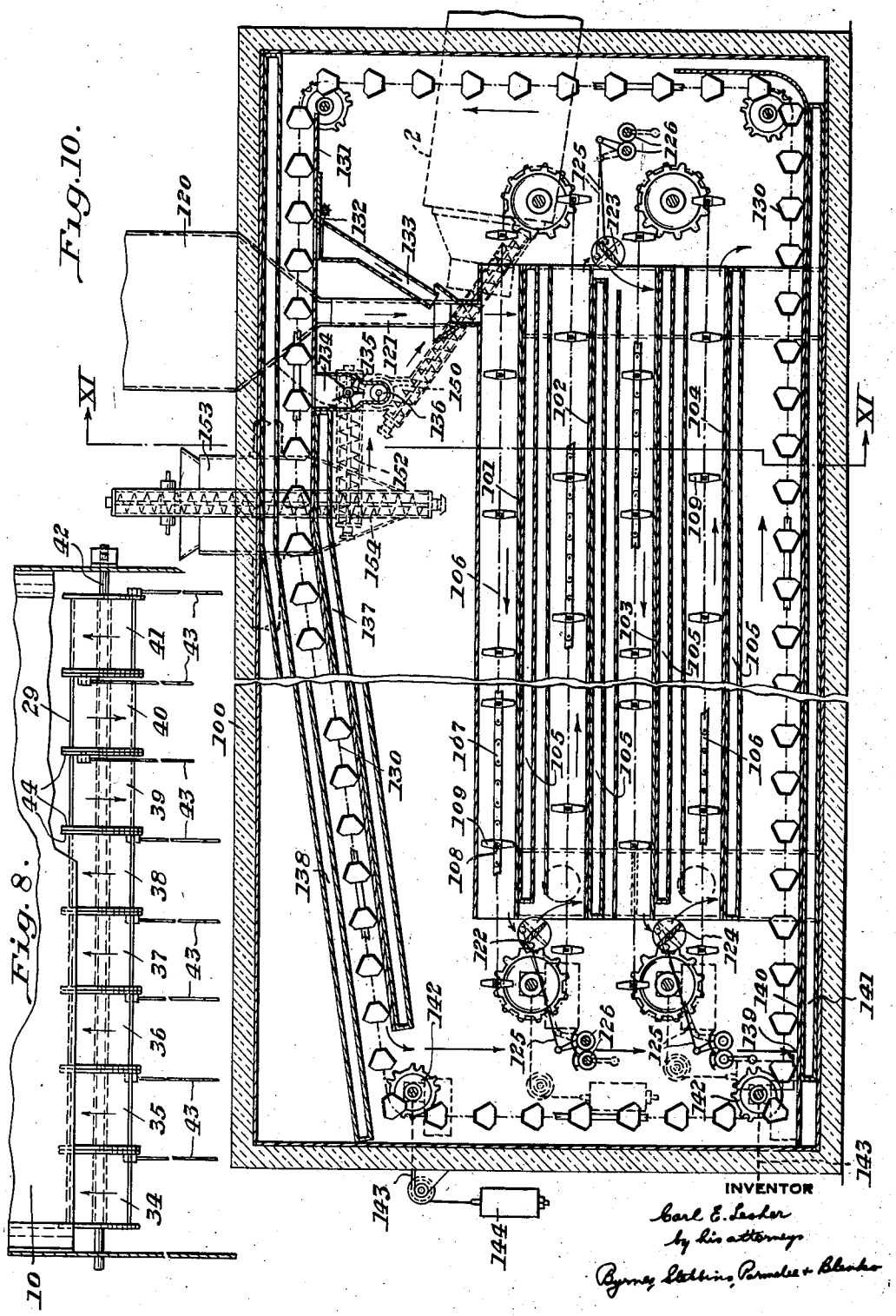

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CARBONIZATION OF COAL

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Fig. 11.

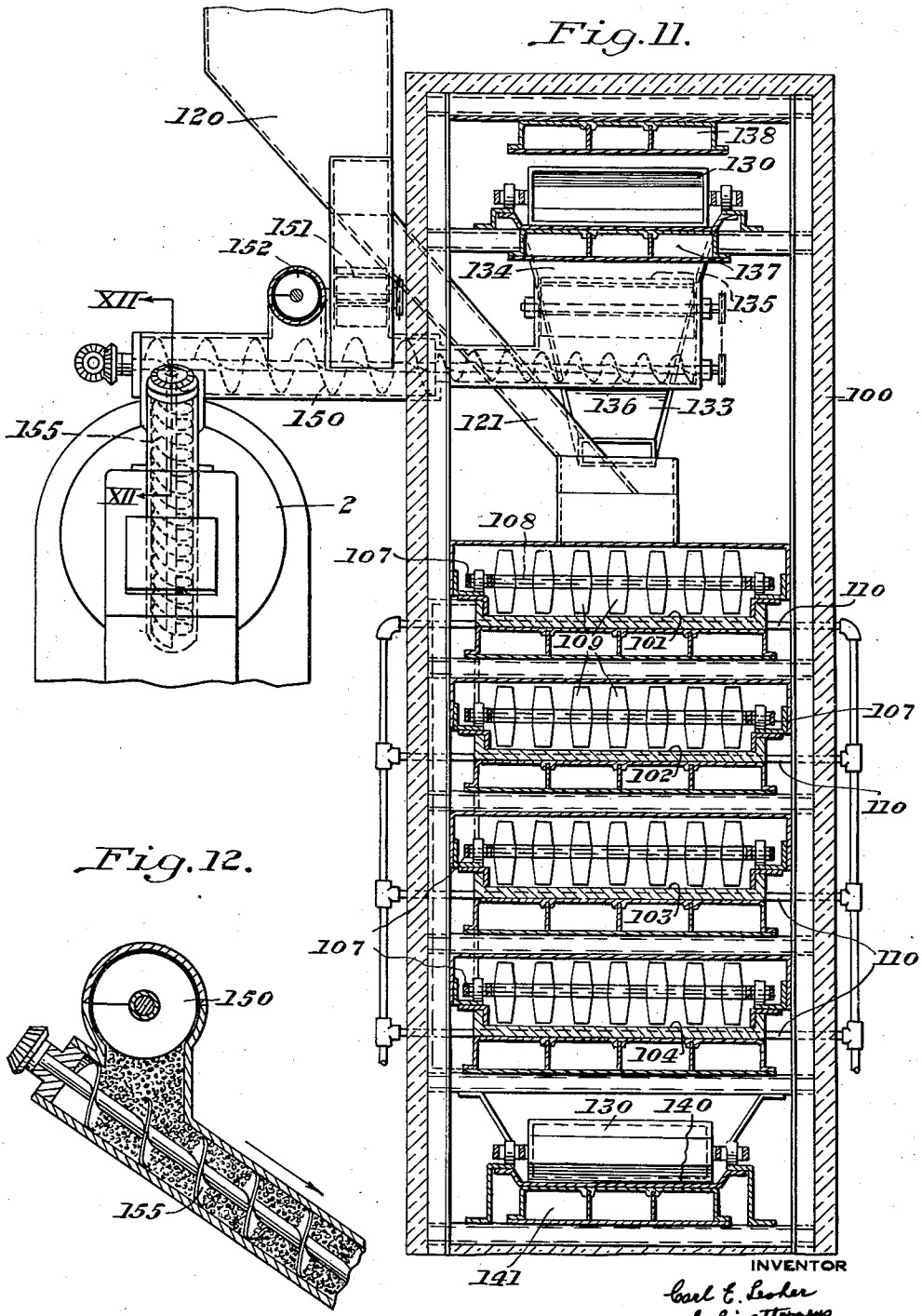

Fig. 12.

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Patented May 18, 1937 2,080,946

UNITED STATES PATENT OFFICE

2,080,946

CARBONIZATION OF COAL

Carl E. Lesher, Ben Avon, Pa., assignor to Pittsburgh Coal Carbonization Company, Pittsburgh, Pa., a corporation of Delaware

Application July 20, 1933, Serial No. 681,281
Renewed October 22, 1936

8 Claims. (Cl. 202—9)

The present invention relates to the carbonization of coal, and more particularly to a process of low temperature carbonization to produce balls of semi-coke.

The present invention is in the nature of an improvement in the process disclosed in the Wisner Patents 1,490,357 and 1,756,896. According to the Wisner process, crushed coal is first subjected to a "thermodizing" process in which the raw coal is roasted in contact with air. The effects produced are somewhat similar to the weathering of coal when held in storage for several months. The action is generally believed to be one of partial oxidation. It reduces the caking or agglutinating properties of the coal. The roasting treatment when properly carried out tempers and restricts the agglutinating properties of the coal so as to prevent the coal from sticking to the walls of the retort and forming large masses in the subsequent carbonizing operation, although enough of the agglutinating properties of the coal are preserved so that it is agglomerated into coal balls of the desired size in the carbonizing operation.

The roasted partially oxidized coal is then passed through a rotary retort where it is subjected to so-called low temperature carbonization. The temperature of the coal in the carbonizing retort is elevated from that at which it is delivered from the roasting or partial oxidation process sufficiently to soften the coal particles. Subsequent elevation of temperature in the carbonizing retort drives off condensible hydrocarbons and, to the extent desired, non-condensible gases. If the roasting pretreatment has been properly controlled for the particular coal in process, then the softened coal forms balls in the revolving carbonizer, which balls become consolidated and of fixed shape when the heating has progressed sufficiently to drive off the condensible hydrocarbons; that is to say, the coal is first softened by heat, then formed into ball-shaped masses, and finally solidified by carbonization into semi-coke. The extent to which the carbonization is carried and the volatile matter driven off, is a matter of choice, limited by the carbonizing equipment used.

The word "coal balls" is used in the Wisner patent to describe the product, which is a partly carbonized coal or semi-coke.

The balling action in the carbonizer is very sensitive to changes in the material reaching the carbonizer. It is a very delicate reaction requiring exact conditions for the production of coal balls of the proper character and size. If the roasting pretreatment does not sufficiently temper and restrict the agglutinating properties of the coal, the coal will form relatively large masses which cannot be discharged from the retort or will stick to the walls of the rotary retort. On the other hand, if the roasting treatment is carried too far and the agglutinating properties of the coal unduly restricted, the product, instead of forming properly shaped and sized coal balls, will consist of fine material together with possibly some irregular shaped pieces of coke—a product which is not suitable for fuel marketing. In practice it is found that there is a very delicate balance which must be maintained in the agglutinating properties of the coal fed to the carbonizer, in order to produce a commercially satisfactory product of coal balls.

This proper balance has been found very difficult to maintain. The present invention relates particularly to the continued and accurate control of the quality and quantity of the coal as delivered to the carbonizer, so as to always maintain the proper balance of the agglutinating or agglomerating qualities of the coal to produce continuously a satisfactory product of coal balls.

Slight variations in the amount of feed, in the character of the coal and its moisture content, and in the conditions maintained in the roaster, may each be sufficient to upset the delicate balance required of the agglutinating properties of the coal and interfere with the continued production of coal balls of the desired shape, size and density.

In accordance with the present invention, the quality and quantity of the pretreated coal as supplied to the carbonizer are continuously and accurately maintained, such that the carbonizer continuously delivers the proper product of coal balls. One of the factors in such control is the maintenance of a heated recirculating storage stream containing the pretreated or partially oxidized roasted coal. The storage stream may be supplied with the partially oxidized hot coal from the roaster, or the storage stream may be subjected itself to the roasting process and be supplied with raw coal. A minor and accurately regulated portion of the recirculating storage stream of coal is continuously withdrawn and fed to the carbonizer. The recirculating stream of coal furnishes a reservoir from which the partially oxidized coal is withdrawn. Since the amount of coal maintained in the recirculating storage stream or reservoir is relatively large compared to the amount of coal being fed to and withdrawn from the stream, accidental variations

in the quality and quantity of the coal fed to the roaster have a relatively slow effect upon the quality of the pretreated coal as withdrawn. This permits corrections to be made in the roasting process before the product has become sufficiently off-quality to detrimentally affect the product of the carbonizer. It may take from forty to sixty minutes for the coal to pass through the carbonizer. A change in the quality of the pretreated coal delivered to the carbonizer may therefore not be apparent in the product until it is too late to make any correction. However, by employing the recirculating storage stream reservoir of pretreated coal, variations in the quality of the pretreated coal as delivered to the carbonizer occur so gradually that their effect can be observed in the product of the carbonizer, and corrections applied in the roasting pretreatment before the variations have progressed to such an extent as to materially detrimentally affect the coal ball product.

Rapid corrections in the quality of the product delivered to the carbonizer may be made in the following manner:—If the product of the carbonizer shows a tendency for too much agglomeration, resulting in an undesirable increase in the size of the coal balls or a tendency of the coal to stick to the walls of the carbonizer, a quick correction can be made by feeding coke breeze into the pretreated coal as fed to the carbonizer. On the other hand, if the product shows evidence of excessive pre-oxidation, as by a tendency to produce too small coal balls and powdered material, the deficiency in the agglutinating properties of the pretreated coal can be supplied by feeding into the pretreated coal passing into the carbonizer either a regulated quantity of raw coal or a regulated quantity of the coal taken off at an earlier stage in the roasting operation where its agglutinating properties have not been so much reduced. Such material has a similar effect to raw coal as a corrective and has the advantage of being dry and hot.

In the drawings, which illustrate the preferred apparatus for carrying out the process,—

Figure 1 is a plan view showing the assembly of the roaster and carbonizer;

Figure 2 is a side elevation showing the carbonizer and one end of the roaster, and the connections between them;

Figure 3 is a section along the line III—III of Figure 1;

Figure 4 is a section along the line IV—IV of Figure 1;

Figure 5 is a vertical longitudinal section through the roaster;

Figure 6 is a section along the line VI—VI of Figure 5;

Figure 7 is an enlarged vertical sectional view showing the arrangement of air discharge pipes in the decks of the roaster;

Figure 8 is a top plan view of one of the deflectors of the roaster;

Figure 9 is a side elevation of said deflector; and

Figures 10, 11 and 12 illustrate a modified form of roaster, Figure 10 being a longitudinal vertical section partly in elevation, Figure 11 being a section along the line XI—XI of Figure 10, and Figure 12 being a detail view of one of the screw conveyors.

In the illustrated embodiment of the invention, reference numeral 1 designates the apparatus in which the coal is pretreated and which, for convenience, we will designate as the roaster or as the thermodizer, in accordance with Wisner's nomenclature. Reference numeral 2 indicates the rotary drum type retort in which the coal is given a low temperature carbonizing treatment to form coal balls, and which, for convenience, we will designate as the carbonizer. The roaster or thermodizer is an apparatus in which the raw coal, either alone or mixed with some finely divided coke, is heated under conditions such as to reduce and regulate the agglutinating or agglomerating properties of the coal, or, as expressed by Wisner, to temper and restrict the binding element of the coal, so that while it will not stick to the walls of the carbonizer or form large masses, it will become sufficiently agglomerated during the tumbling in the carbonizer to form coal balls of a size desired for fuel, preferably balls of a few inches in diameter. For this purpose the coal is roasted to a temperature at which the partial oxidation of the coal takes place with sufficient rapidity for commercial operations, and, as above stated, this action is similar to that of the weathering of coal when subjected to storage for several months in a coal pile. It is generally accepted in this art as being an oxidizing operation, although in many cases the amount of actual oxidation is too small to be definitely quantitatively determined. Its effect on the coal is known to reduce the caking or agglutinating properties.

For this purpose the coal may be roasted in the presence of air at a temperature of from 400° to 650° Fahrenheit. In order to heat the coal as much as possible before its introduction into the carbonizer to reduce the heating load on the carbonizer, the coal is preferably roasted at as high a temperature as possible without softening the coal so as to make it difficult to handle in the roaster or without producing a material evolution of hydrocarbon vapors in the roaster. Some coals will become sticky before reaching the temperature at which hydrocarbon vapors are evolved, while other coals will give off hydrocarbon vapors before they become softened. The coal should therefore not be heated above the softening temperature or the hydrocarbon vapor evolution temperature, whichever is lowest.

In subjecting the well-known Pittsburgh seam coal to the roasting operation, the temperature is preferably maintained at about 550° to 600° Fahrenheit, which is about the maximum temperature obtainable without danger of softening the coal or evolving hydrocarbon vapors.

The roasting of the coal at the temperatures above mentioned drives the free moisture from the coal, and tempers and restricts the agglutinating properties of the coal by what is generally accepted as a partial oxidation of some of the constituents of the coal. If the agglutinating properties of the coal were not thus tempered and restricted, the coal would not only form large unmanageable masses in the carbonizer, but would stick to the surfaces of the carbonizer.

On the other hand, if the agglomerating properties of the coal are unduly tempered and restricted, the treated coal does not have enough agglutinating properties to form coal balls of the proper size, shape and density, but the coal will form powder or small pieces of coke in the carbonizer.

The raw coal is first crushed or ground, preferably to a size of ⅛" mesh or smaller. The crushed raw coal, with which may be mixed some finely ground coke, if desired, is fed into a hopper

3 which is provided with a rotary discharge valve 4 spaced beneath the bottom opening of the hopper. The rotary valve 4 consists of a circular plate which is continually rotated and from which the coal is taken at a predetermined rate by a scraper or plow 5 which extends over the top of the plate and which may be adjusted to divert more or less coal from the rotary plate 4. The regulated amount of coal delivered by the plow 5 passes through a chute 6 and is delivered to the roaster 1 through the opening 7 in the casing 8 of the roaster.

The roaster has an insulated casing 8 and a number of heated decks 9, 10, 11, 12, 13 and 14 enclosed in the casing and over which the coal is passed to subject it to the roasting or oxidizing pretreatment.

As shown in Figures 5 and 6, there are six decks, 9 to 14 inclusive, located one below the other. These decks are arranged to be heated by flues 15 carrying heated products of combustion. The heated products of combustion enter the roaster through an intake pipe 16 leading from the heating jacket of the carbonizer and are discharged through an exhaust pipe 17. The products of combustion from the intake pipe 16 enter a header and are distributed to the flues beneath the decks 9, 10 and 11 through which the heated gases pass in parallel from the left to the right, as viewed in Figure 5, then down through a distributing header 18 at the right hand side of Figure 5, and then back through the flues 15 of the decks 12, 13 and 14 in parallel into a header discharging into the exhaust pipe 17. The hot gases of combustion in the flues 15 maintain the decks at the desired temperature for the roasting process. The coal from the feed chute 6 falls through the opening 7 onto the left hand end of the top deck 9, as shown in Figure 5, and is carried along the deck by a flight type of conveyor which consists of chains 20 carried by sprocket wheels 21 and carrying cross arms 22 upon which are supported the conveyor blades 23. The blades 23 of the alternate set of blades are preferably staggered with relation to each other, so that a blade 23 plows along through a ridge of coal left between the blades of the next previous set of blades of the conveyor. The coal is therefore subjected not only to the conveying action of the blades by which it is pushed along the decks, but is also subjected to a plowing action which serves to turn over the coal and present fresh surfaces to the action of the air.

Air is blown through the coal as it passes over the decks by means of a number of air pipes which which are located in the floors of the decks, as shown in detail in Figure 7, in which reference numeral 24 indicates the floor of a deck having a transverse opening 25 through which air is discharged upwardly from a perforated air pipe 26. Any desired number of these air pipes may be located along the length of each deck, there being preferably several of them in each deck. As the coal is carried along the deck air is blown through it from the pipes 26. The action of air on the hot coal is believed to produce a small amount of oxidation, which produces the desired reduction in the agglutinating properties of the coal. While air is preferred because of its ready availability, other gases having oxidizing properties may be used, such, for example, as hot products of combustion which contain some oxygen.

The air is supplied to the several discharge pipes 26 through air supply pipes 27 at a pressure sufficient to blow the air up through the stream of coal which is being moved along the decks. The coal drops from the discharge end of the deck 9 at the right hand, as shown in Figure 5, onto a deflector 28 which deflects the coal onto the end of the deck 10 along which it is carried by the flight conveyor while it is being subjected to further agitation and oxidizing action. The coal falls from the discharge end of the deck 10 onto a deflector 29 which deflects it onto the deck 11 along which it is pushed by the conveyor and from which it is discharged to the deflector 30 which deflects the coal to the deck 12. The coal discharged from the deck 12 is deflected by the deflector 31 onto the deck 13, from which it is delivered to another deflector 32 which deflects it onto the lowermost deck 14. The coal from the lowermost deck 14 is delivered into a collecting hopper 33.

The deflectors 28 to 32, inclusive, are preferably formed in a number of sections, as indicated in Figures 8 and 9, in which the construction of one of the deflectors, say, the deflector 29, is shown in more detail. As shown in Figures 8 and 9, the deflector 29 consists of a number of deflecting blades shown as eight in number and numbered 34 to 41, inclusive. These blades are rotatably mounted on a supporting shaft 42. They may be turned by means of hand operated rods 43 so that a section of the deflector will deliver its coal either back onto the deck beneath or outwardly into the collecting hopper 33. The sides of each section are formed with circular plates 44 which serve as connecting means for the ends of the rods 43 and also as separators for the stream of coal passing to the respective deflector blades.

If it is desired to discharge all of the coal onto the deck beneath, all of the deflector blades are turned so as to discharge the coal backwardly onto the deck beneath. If, for any reason, it is desired to empty the roaster quickly, as in the case of fire, the deflectors may all be turned so as to discharge the coal into the end spaces of the casing 8 and into the hopper 33 at one end and through a discharge opening 45 at the other end of the roaster. Also, the deflectors can be arranged to cut out a deck or decks entirely in case less roasting action is desired or in case of trouble with one deck.

In case it may be desired, as hereinafter described, to withdraw a portion of the coal which has been subjected to but partial roasting only from one of the upper decks of the roaster, and to mix it with the completely roasted coal from the lowermost deck, some of the deflector blades may be turned to discharge the coal from an upper deck into the hopper 33, while the remainder of the deflector sections deflect the coal back onto the deck below. Such a condition is illustrated in Figure 8, in which the sections 39 and 40 of the deflector 29 are turned to discharge coal—in this case a quarter of the coal stream—into the hopper 33, while the remaining six sections 34, 35, 36, 37, 38 and 41 deflect the remaining three-quarters of the coal stream onto the deck 11. The deflectors may be made up of any desired number of sections, whereby any desired degree of fineness may be attained in a fraction of coal diverted from an upper roasting deck into the collecting hopper 33.

At the bottom of the collecting hopper 33 there is a conveyor screw 46 which delivers the hot pretreated coal to an elevator screw 47. The greater part of the stream of coal raised by the

elevator screw 47 is discharged at its upper end into a chute 48 and is redelivered through the opening 7 onto the top deck 9. A deflector 49, shown in dotted lines in Figure 1, is provided for deflecting the coal from the chute 48 into another chute 50 which delivers to a take-away belt 51 which can be employed in case it is desired to empty the roaster. Normally, however, the coal delivered at the upper end of the elevator screw 47 is delivered back again to the roaster for recirculation.

A portion of the stream of coal raised by the elevator screw 47 is tapped off and delivered to the carbonizer 2. For this purpose a downwardly directed conduit 52 is tapped off from the side of the casing of the elevator screw 47 a short distance below its upper end. The conduit pipe 52 is normally maintained full of coal, since the elevator screw 47 will keep the conduit pipe 52 full. At the lower end of the conduit pipe 52 is a star wheel 53 which serves as an accurate measuring device to deliver an accurately measured amount of coal to a horizontal conveyor screw 54. The conveyor screw 54 delivers the coal to a downwardly inclined feed screw 55 which delivers the coal into the upper end of the carbonizer 2.

By means of the accurate feed afforded by the star feed wheel 53, an accurately predetermined quantity of pretreated coal is always supplied to the carbonizer 2. This is a feature of importance since the carbonizer is relieved of having to handle variable quantities of coal which would be delivered to it if it were supplied with the entire output of the roaster, as in the Wisner patents. It has been found that it is practically impossible to maintain an accurate control of the quantity and quality of coal delivered to the carbonizer, if the carbonizer is supplied with the entire output of the roaster. By the feed arrangement herein shown, the carbonizer is always supplied with the exact amount of coal irrespective of any accidental variations in the delivery of the total quantity of coal from the decks of the roaster. Also, as hereinafter more fully described, by taking off a minor fraction of the coal from the coal stream in the roaster for delivery to the carbonizer, the quality as well as the quantity of the coal may be accurately controlled.

The feed screw 55 and its casing are preferably small enough so as to be substantially filled with coal and form its own seal in delivering the coal to the carbonizer 2. The feed screw 55 passes through the end closure 56 of the carbonizer and into the carbonizer chamber 57. The carbonizer is of the rotary drum type of retort shown in the Wisner patents. It consists of a long drum retort 50 feet or more in length having a cylindrical inner chamber 57 through which the coal to be carbonized is passed. Surrounding the carbonizing chamber 57 is an annular chamber 58 through which hot gases of combustion are passed to heat the coal to the proper carbonizing temperature.

The coal is preferably heated, as described in the Wisner Patent 1,756,896, to a temperature such that a considerable proportion of the liquefiable hydrocarbons are driven off from the coal, leaving a certain amount of the volatile constituents of the coal in order to form a semi-coke free burning fuel. During the passage of the coal along the carbonizer, which is inclined as shown in Figure 2, the coal is subjected to a semi-coking action therein while it is being tumbled by the rotary movement of the carbonizer and is formed into rounded compact masses of semi-coke which, for convenience, may be designated as "coal balls", following Wisner's nomenclature. The coal balls are raised by any suitable discharge vanes, not shown, at the lower end of the carbonizer 2, and discharged into the discharge chute 59 which leads to any suitable device for cooling and leading away the coal balls for storage.

The coal as it is fed from the roaster to the carbonizer is in a heated condition, preferably heated to a temperature but slightly below the point at which the coal would soften or begin to give off condensible hydrocarbon vapors. By thus supplying coal heated to such a temperature, the heating load on the carbonizer is minimized. When the heated coal enters the carbonizer its temperature is further raised to a point where it softens and begins to ball up. The continued heating of the coal as it passes through the carbonizer results in the driving off of condensible hydrocarbons and in transformation of the solid residue into shaped compact rounded masses of semi-coke which are termed "coal balls", and which constitute a convenient substantially smokeless free burning fuel for domestic and other purposes.

The gases evolved from the coal into the carbonizer and which include condensible hydrocarbon oils, pass out at the right hand end of the carbonizer, as shown in Figure 2, and into a dust collecting chamber 60 and to a discharge pipe 61 which leads the gases to any suitable apparatus wherein the condensible hydrocarbon oils may be recovered as a valuable by-product. The dust chamber 60 is relatively large and allows the dust to settle down and fall into a water pocket 62 from which the dust may be removed as a sludge through the opening 63 at the right hand end of the water pocket, as shown in Figure 2. A downwardly projecting plate 64 forms a water seal beneath which the sludge may be scraped out. A door 65 provides access to the dust chamber 60. Since the operation of the carbonizer is substantially that described in the Wisner patent, it need not be described here in great detail. The carbonizer itself, as in the Wisner patent, is inclined downwardly, as shown in Figure 2, to cause the coal to be fed along the tubular carbonizer chamber as it is being subjected to the carbonizing and tumbling action to form the coal balls. The carbonizer is rotated by means of a suitable motor 66 and gearing 67. The outside of the carbonizer is preferably provided with an insulating jacket 68.

The hot gases of combustion for heating the carbonizer are supplied from a furnace 70 from which the gases pass through a flue 71 into the heating jacket 58 of the carbonizer. The hot gases of combustion are discharged at the other end of the carbonizer into a flue 72 and are passed through the connections hereinafter described into the deck heating flues of the roaster and are passed through the coke heater hereinafter described into the pipe 16 which leads to the roaster. The exhaust heating gases from the roaster pass through the discharge pipe 17 into the flue 73 to a circulating fan 74 and are redelivered into the furnace 70. Ordinarily, there is sufficient leakage in the various connections so that the amount of exhaust gases delivered by the fan 74 to the furnace 70 will, with the products of combustion, supply the necessary amount of heating gases to the carbonizer. Any excess gas delivered by the fan 74 can be vented through the vent pipe 75. By recirculating the gases there is a conservation of heat.

Having now described the course of the pretreated coal which is diverted from the roaster to the carbonizer, I will return to the roaster to describe the recirculation of the coal therein.

At the upper end of the elevator screw **47** the stream of coal taken from the discharge hopper **33** is divided into two parts. A portion of the coal, preferably from about one-third to one-sixth of the total stream, is diverted into the conduit **52** and is delivered in an accurately controlled quantity to the carbonizer **2**. All of the excess coal not so diverted to the carbonizer is discharged at the extreme top of the screw elevator **47** through the chute **48** back into the roaster. Ordinarily from two-thirds to five-sixths of the coal passing through the elevator **47** is thus recirculated back into the roaster.

The roaster may be sixty or seventy feet long and have several decks as illustrated, so that it has considerable storage capacity and acts as a recirculating reservoir from which a minor fraction of the hot recirculated stream of pretreated coal is diverted to the carbonizer. The roaster may have a capacity of, say, ten tons, and may deliver about three tons per hour to the carbonizer. The average time of the coal in the roaster may be in the neighborhood of two hours.

The heating of the roaster, the amount of coal supplied to it, the thickness of the coal bed on its decks, and the rate at which the coal is recirculated, are regulated so that the coal as delivered from the roaster to the carbonizer has its agglutinating properties so tempered and restricted that the coal in the carbonizer will form coal balls of the proper size, shape and density.

Since the recirculating storage stream of coal in the roaster forms a relatively large reservoir of coal to which a relatively small amount of coal is constantly fed and from which a relatively small amount of coal is constantly withdrawn, variations in the quality of the raw coal fed to the roaster will cause gradual variations in the quality of the coal delivered to the carbonizer. The action of this recirculating reservoir of coal is to smooth out and make very gradual any changes in the quality of the coal delivered to the carbonizer, and thus make possible the correction of such variations before the operation of the carbonizer is materially detrimentally affected. However, if the operation of the carbonizer cannot be regulated with sufficient rapidity to correct such variations in the quality of its output, supplemental provision is made whereby a quick adjustment of the agglutinating properties of the pretreated coal delivered to the carbonizer may be secured. For this purpose, as will now be described, provision is made whereby there may be added to the pretreated coal as delivered to the carbonizer a small quantity of either coke breeze, or finely ground raw coal or but partially roasted coal.

If the coal in the roaster is over-oxidized and its agglomerating properties unduly restricted, correction can be made by adding a small amount of raw coal to the stream of pretreated coal diverted from the roaster to the carbonizer. For this purpose a second plow or diverting blade **80** is arranged to be swung over the rotary plate **4** of the valve beneath the coal hopper **3** to divert a small amount of raw coal to a chute **81**, delivering such raw coal into the hopper **33** at the end of the roaster where it is mixed with the roasted coal which is being raised by the elevator screw **47**.

If the coal delivered from the roaster is sufficiently over-oxidized to require any considerable addition to it as a corrective, it is preferred to supply such corrective mainly from the but-partially roasted coal from one of the upper decks of the roaster, since such partially roasted coal will act similarly to raw coal to restore the desired agglutinating properties to the coal delivered to the carbonizer. For this purpose the desired number of sections of the deflector **29** or the deflector **31** may be turned, as indicated by the sections **39** and **40** on Figure 8, to divert a fraction of the but-partially roasted coal from the deck **10** or **12** into the collecting hopper **33** to be there mixed with the fully roasted coal from the deck **14**. Such a procedure has the advantage over supplying raw coal as the corrective, in that the partially roasted coal is already dried and hot, and consequently has less chilling effect upon the material delivered to the carbonizer. When the incompletely roasted coal from one of the upper decks of the roaster is utilized as the corrective, the diverting blade **80** may still be employed to supply a small amount of raw coal as a finer adjustment in conjunction with the coarser adjustment afforded by diverting the fraction of the stream by utilizing one or more of the sections of the deflector **29** or **31**.

If, on the other hand, the agglutinating or agglomerating properties of the coal are not sufficiently tempered and restricted in the roaster, correction may be made by introducing into the coal fed to the carbonizer a small amount of coke breeze or finely ground coke. Such coke breeze is supplied by a belt conveyor **82** to a coke heater **83** which is heated by the gases delivered by the offtake pipe **72** from the carbonizer. The coke heater **83** delivers the coke to the lower end of an elevator screw **84** which raises the coke past a conduit **85** which is tapped off downwardly from the casing of the elevator screw **84** near its upper end. The action of the elevator screw **84** will be to maintain the conduit **85** normally filled with the coke breeze. An accurately regulated quantity of the coke breeze is fed from the bottom of the conduit by means of a horizontal screw conveyor **86** into the top of the casing of the horizontal screw conveyor **54** which carries the roasted coal to be delivered to the carbonizer. The screw conveyor **54**, which is relatively large compared to the screw conveyor **55**, serves as a mixer to thoroughly mix the coke breeze with the roasted coal before it is delivered to the conveyor **55** which feeds it into the carbonizer. Since the coke breeze is dry and easy to handle, the screw conveyor **86** will give an accurate feed and it is not necessary to use a star feed wheel such as is desirable in handling ground coal. Any excess of the coke breeze which is not fed through the conduit **85** and feed screw **86** passes to the top of the screw conveyor **84** and is redelivered through a chute **87** back into the hopper of the coke heater **83**.

It is generally desirable to utilize a certain amount of coke in connection with the process for two reasons. There is always a certain production of coke from the process which is too small in size for commercial use and which would represent waste unless returned to the process. Also, it has been found that a certain percentage of finely ground coke in the mixture being carbonized has advantages in increasing the density and strength of the coal ball product. This finely ground coke may be added to the stream of raw coal fed to the roaster, or it may be added to the roasted coal prior to its delivery to the carbonizer with or without utiliz-

ing it as a method of controlling the agglutinating properties of the pretreated coal. The addition of the coke to the raw coal has the advantage of utilizing one piece of apparatus, namely, the roaster for heating the coke as well as the coal. On the other hand, the addition of the coke through a coke heater to the roasted coal as delivered from the roaster to the carbonizer, has the advantage of conserving the capacity of the roaster for the treatment of raw coal without being loaded with the inert coke. Preferably, finely divided coke may be added from 10 to 25 percent of the raw coal used, although more coke can be employed up to 30 or 35 percent of the raw coal.

When the coke is added to the raw coal feed to the roaster, the stream of raw coal containing such minor proportion of coke is subjected to the roasting treatment as hereinbefore described, and if an additive corrective is required, a small amount of either raw coal or partially roasted coal may be added to increase the agglutinating properties of the roasted coal, or a small amount of coke may be introduced through the coke heater to reduce the agglutinating properties of the roasted coal.

When I speak of roasting the coal or the raw coal without further restriction, I intend to include the roasting of either the raw coal alone or raw coal which may contain some coke added to it.

When the finely divided coke which it is desired to utilize in the normal operation of the process is supplied through the coke heater **83**, an amount of coke which it is desired to feed may be constantly supplied, and the agglutinating properties of the coal delivered to the carbonizer may be corrected by increasing or decreasing such normal coke feed, or by adding some raw coal or but-partially oxidized coal as a corrective.

I wish, therefore, to particularly distinguish between the coke which may be normally and constantly added either to the raw coal or to the oxidized coal for the purpose of utilizing such coke and increasing the density and strength of the coal balls, and the amount of coke used perhaps intermittently as a corrective for the degree of preoxidation of the coal.

The remainder of the piping connections for handling the gases of combustion will now be described. The hot gases of combustion after passing through the heating jacket **58** of the carbonizer **2** are led through the flue **72** to a heating jacket around the hopper **83** which constitutes the coke breeze heater. From the coke breeze heater run two flues **16** and **90**. The flue **16** leads the gases of combustion to the roaster **1**. The flue **90** is provided for by-passing some of the combustion gases around the roaster **1** in case it is desired to cut down its heat supply, the flue **90** leading directly from the jacket of the coke heater to the flue **73**. The bypassing of the gases through the flue **90** is controlled by the valve **91**.

In Figures 10, 11 and 12 is illustrated a modified form of roaster. It has an outer insulating shell **100**. Mounted within this shell are a number of heated decks **101**, **102**, **103** and **104**. The decks are heated by flues **105** beneath the decks supplied with the hot combustion gases from the heating jacket of the carbonizer **2**. The coal is carried along the decks while it is stirred by means of the flight conveyors **106** which consist of conveyor chains **107** carying cross bars **108** having attached thereto the conveyor blades **109** which engage the coal and drag it along the decks with a plowing action. Air is blown through the loose coal which is carried along the decks by means of the air pipes **110**. The arrangement of the decks, the deck heating ducts, the conveyors, and the air pipes is substantially the same as that illustrated in Figures 1 to 7.

Raw coal is fed by a suitably regulated feed into a feed hopper **120** from which it falls through a chute **121** onto the upper deck **101**. The coal is dragged along this deck and is subjected to the heating and oxidizing action. The coal which falls from the end of the deck **101** is deflected by the deflector **122** onto the deck **102** along which it passes for further roasting treatment. The coal is discharged from the deck **102** by means of the deflector **123** onto the deck **103** for further roasting treatment. The coal is discharged from the deck **103** onto the deck **104** by means of the deflector **124**.

The deflectors **122**, **123** and **124** are preferably made in sections, as illustrated in Figures 8 and 9, so that part of the coal may be deflected to the next lower deck and part of the coal discharged to the bottom of the roaster chamber. The several sections of the deflectors may be manually turned to either deflect the coal back onto the next lower deck or outwardly to fall to the bottom of the roaster chamber by means of operating rods **125** which are operated by suitable connections **126** to the outside of the roaster chamber.

The coal as discharged from the last deck **104** falls to the bottom of the roaster chamber where it is engaged by the bucket conveyor **130** and lifted onto the deck **131** at the top of the chamber along which it is pushed by the buckets. The coal on the deck **131** first passes by a slide valve **132** which is opened to a limited extent to allow a minor portion, say, about one-fourth of the coal stream, to be diverted into the chute **133** to mix with the raw coal from the hopper **120** and pass with it onto the roasting decks, for the purpose of securing a more thorough mixing. The greater part of the coal is carried along the deck **131** and over the opening of the conduit **134**, in the bottom of which is a star feed wheel **135** which serves to feed an accurately regulated quantity of coal to the horizontal screw conveyor **136** for delivery to the carbonizer. The remainder of the coal, which constitutes the greater portion of the coal stream, is carried along the deck **131** onto the downwardly sloping portion of the deck beneath which is a heating chamber **137** to preserve the coal in the heated condition. Another heating chamber **138** may be provided above the deck for the same purpose. The coal is discharged from the left hand end of this deck, as shown in Figure 10 and falls to the bottom of the chamber at the point indicated by reference numeral **139** where it is again engaged and carried along by the bucket conveyor **130** over a bottom deck **140** which is provided with the heating chamber **141** to maintain the coal hot. The sprocket wheels **142** of the conveyor **130** are preferably slidably mounted and are yieldably drawn by cables **143** and weights **144** so as to take care of expansion in the chain. A similar arrangement of sliding bearings and weights and cables is provided for the chains of the conveyors which carry the coal over the heating decks.

The form of roaster shown here may have a length of sixty to seventy feet and provides a considerable storage capacity for the coal. The

greater part of the recirculated coal is carried around by the bucket conveyor 130 along the decks 131 and 140 and is not recirculated over the heating decks. In the arrangement illustrated in Figure 10 the coal may have a considerable depth of, say, 6 to 8 inches on the decks 131 and 140 so that the greater part of the coal storage is provided by these decks. The recirculated coal on these decks is not plowed and agitated and subjected to air as is the coal on the heating decks 101, 102, 103 and 104. This arrangement allows the raw coal to be first passed over the heating decks where it is subjected to the roasting treatment and then to pass into the circulating storage on the decks 131 and 140 where it is maintained in heated condition but without subjecting it to further oxidation.

The accurately measured quantity of coal which is diverted from the main stream through the feed wheel 135 passes to the horizontal screw conveyor 136 which delivers the coal to a larger mixing screw 150. If desired, a regulated amount of raw coal may be delivered from the hopper 120 through a star feed wheel 151 to the mixing screw 150 if it is desired to increase the agglutinating properties of the roasted coal fed to the carbonizer. The agglutinating property of the coal as fed from the roaster may be adjusted by diverting some of the coal from the upper deck 101 instead of passing it over the lower roasting decks, thus adding to the coal carried by the bucket conveyor 130 coal which is but partially roasted, although it is heated and dried. The deflector 122, since it is made in sections, may deflect a fraction of the coal stream to the bucket conveyor 130 while deflecting the remainder of the coal stream onto the deck 102. The deflectors 123 and 124 are similarly arranged in case it is desired to deflect coal away from the bottom or next to the bottom heating decks.

If it is desired to feed coke breeze to the coal going to the carbonizer, coke can be fed by the feed screw 152 to the mixing screw 150. The coke is supplied from a coke heater 153 by means of an elevator screw 154, the arrangement of coke heater and elevator screw being substantially the same as that of the coke heater 83 and elevator screw 84 shown in Figures 1 to 7.

The feed screw 150 is relatively large and operates in a relatively large casing which serves as a mixing chamber to mix the raw coal or coke breeze as the case may be, with the coal coming from the roaster. The coal is fed from the mixing screw 150 to a feed screw 155 which delivers the coal into the end of the carbonizer 2, this arrangement being substantially the same as the feed screw arrangement 55 shown in Figure 2. The screw 155 and its casing are sufficiently small so that it is substantially filled with coal and forms its own seal.

As will be apparent from the foregoing description, my method and apparatus for controlling the quantity and quality of the roasted coal delivered to the carbonizer is an improvement over the Wisner patents. As shown in the Wisner patents, the coal is roasted or thermodized in a rotary roaster. All of the coal which is discharged from the roaster in the Wisner patents is fed directly into the carbonizer. In actual plant operation it is virtually impossible to maintain an exactly regulated quantity of feed from the Wisner roaster to the carbonizer. In my arrangement the coal in the roaster is carried around in a recirculating stream and an exactly measured quantity of coal is diverted from this stream to the carbonizer, which insures an unvarying quantity of coal delivered to the carbonizer. This completely overcomes the difficulties which have been encountered with variations of feed of the coal from the roaster to the carbonizer in the Wisner apparatus.

Also, in the Wisner apparatus a variation in the quality of the coal delivered to the roaster causes a variation in the same direction in the quality of the roasted coal as delivered from the roaster to the carbonizer, making it difficult to maintain the delicate balance of the agglutinating properties required in making coal balls. In my apparatus a considerable body of coal is always maintained in the recirculating storage stream in the roaster. A variation in the quality of the coal delivered to the roaster therefore causes a very gradual change in the quality of the large body of coal which is being recirculated in the storage stream. Such changes are therefore gradually reflected in the quality of the portion of the coal stream which is diverted from the storage stream into the carbonizer. By thus smoothing out the variations and making their effect very gradual upon the quality of the coal delivered to the carbonizer, it is possible to correct such variations by manipulating the various controls of the roaster so as to maintain a substantially constant quality of the coal delivered to the carbonizer, and thus continuously maintain the delicate balance required in the agglutinating properties of the coal. If it is desired to decrease the roasting effect and get less reduction in the agglomerating properties of the coal, the speed of the conveyors may be increased to cut down the roasting time, and the temperature may be decreased, or both. Similarly, if it is desired to increase the roasting effect to further cut down the agglutinating properties of the coal, the speed of the conveyors may be decreased to allow more roasting time or the temperature may be raised, or both. Some regulation is possible by controlling the air supply; the greater the amount of air, the greater the tendency for oxidation. Also, if it is desired to decrease the roasting effect to give greater agglutinating properties, the deflectors may be manipulated to shunt coal past a heating deck or decks.

In each form of apparatus illustrated there is maintained a recirculating storage stream of coal which contains the roasted coal. In the form of apparatus illustrated in Figures 1 to 7, this storage stream of coal is maintained on the heating decks 9 to 14 in the collecting hopper 33 and elevator screw 47, so that the coal which is recirculated in the storage stream is subjected to further roasting as it is repassed over the heating decks. In this form of apparatus the raw coal is fed into the recirculating storage stream. In the form of apparatus shown in Figures 10 to 12, the recirculating storage stream is maintained principally upon the decks 131 and 140 where it is maintained hot, but is not subjected to the oxidizing roast. In this form of apparatus the raw coal is not fed to this recirculating storage stream but is fed to the heating decks 101 to 104, inclusive, and is roasted before it is added to the recirculating stream on the decks 131 and 140. In each case the effect is similar in that the raw coal is roasted so as to temper and restrict its agglutinating properties and there is maintained a recirculating storage stream of coal which contains the thus-roasted coal, and from which storage stream a minor fraction is diverted to the carbonizer.

Supplemental provision is made for adjusting the agglutinating properties of the coal as delivered to the carbonizer by the arrangements shown for feeding in to such coal regulated quantities of raw coal, partially roasted coal or coke. While it is preferred to combine the advantages of accurate control resulting both from the provision of the recirculating storage stream of coal and from the provision for further adjusting the agglutinating properties by adding raw coal, partially roasted coal, or coke breeze, as correctives, either of these features may be employed alone. For example, good control may be secured by employing the recirculating stream principle without the additive corrective feature of the regulated additions of coal or coke, or the coal may be passed through a roaster without recirculation, and the variations in its agglutinating properties may be compensated for by feeding in regulated amounts of coal or coke.

While I have specifically illustrated and described the preferred apparatus and method used in carrying out my invention, it is to be understood that the invention is not limited to such preferred structure and process, but may be otherwise embodied and practiced within the scope of the following claims.

I claim:

1. Apparatus for making carbonized coal balls, comprising means for roasting crushed coal having agglutinating properties so as to modify but retain some of its agglutinating properties, including a chamber having heated decks and means for moving the coal along the decks while subjecting it to oxidation and mixing, means for repassing the greater part of the stream of coal over the decks, means for continually diverting from the stream of coal a minor portion thereof, and a rotary kiln for subjecting the diverted portion of the coal stream to low temperature carbonization while tumbling it so as to form coal balls.

2. Apparatus for making carbonized coal balls, comprising means for roasting crushed coal having agglutinating properties so as to modify but retain some of its agglutinating properties, including a chamber having heated decks and means for moving the coal along the decks while subjecting it to oxidation and mixing, a conveyor for recirculating a stream containing roasted coal delivered from the decks while maintaining the coal in a heated condition, means for delivering the coal from the roasting decks to the recirculating stream, means for continually diverting from the recirculating stream a minor portion thereof, and a rotary kiln for subjecting the diverted portion of the coal stream to low temperature carbonization while tumbling it so as to form coal balls.

3. The process of making carbonized coal balls, which comprises passing crushed coal having agglutinating properties along heating contact surfaces while it is subjected to oxidation and mixing so as to temper and restrict but still retain some of its agglutinating properties, transferring the thus roasted coal to a storage body in which the coal is thoroughly mixed and maintained in agitated condition while it remains hot, continually withdrawing a controlled amount of the coal from such storage body, and subjecting the withdrawn coal to low temperature carbonization in a rotary kiln so as to tumble it and form coal balls.

4. The process of making carbonized coal balls, which comprises roasting crushed coal having agglutinating properties by passing the coal along and in contact with heating surfaces while subjecting it to oxidation and mixing so as to temper and restrict but still retain some of its agglutinating properties, transferring the thus roasted coal to a coal storage in which the coal is continually subjected to mixing and agitation, continually withdrawing a controlled amount of the coal from the storage, and subjecting the withdrawn coal to low temperature carbonization while tumbling it so as to form coal balls.

5. The process of making carbonized coal balls, which comprises roasting crushed coal having agglutinating qualities while subjecting it to oxidation and mixing so as to temper and restrict but to still retain some of its agglutinating properties, transferring the thus roasted coal to a coal storage in which the coal is continually subjected to mixing and agitation, continually withdrawing a controlled amount of coal from the storage, and subjecting the withdrawn coal to low temperature carbonization in a rotary kiln so as to tumble it and form coal balls.

6. The process of making carbonized coal balls, which comprises roasting crushed coal having agglutinating properties by passing the coal along and in contact with heating surfaces while subjecting it to oxidation and mixing so as to temper and restrict but still retain some of its agglutinating properties, transferring the thus roasted coal to coal storage in which the coal is continually subjected to mixing and agitation, continually withdrawing a controlled amount of the coal from the storage, subjecting the withdrawn coal to low temperature carbonization while tumbling so as to form coal balls, and adding to the roasted coal prior to its carbonization a regulated amount of a material of the group composed of raw coal, partially roasted coal and coke.

7. The process of making carbonized coal balls, which comprises roasting crushed coal having agglutinating properties by passing the coal along and in contact with heating surfaces while subjecting it to oxidation and mixing so as to temper and restrict but still retain some of its agglutinating properties, transferring the thus roasted coal to a coal storage in which the coal is continually subjected to mixing and agitation, continually withdrawing a controlled amount of the coal from the storage, subjecting the withdrawn coal to low temperature carbonization while tumbling so as to form coal balls, and adding to the roasted coal prior to its carbonization a regulated amount of finely divided coke.

8. The process of making carbonized coal balls, which comprises passing crushed coal having agglutinating properties along heated contact surfaces while it is subjected to oxidation and mixing so as to temper and restrict but still retain some of its agglutinating properties, transferring the thus roasted coal to a storage body in which the coal is thoroughly mixed and maintained in agitated condition while it remains hot, continually withdrawing a controlled amount of the coal from such storage body, and subjecting the withdrawn coal to low temperature carbonization in a rotary kiln so as to tumble it and form coal balls, the storage body being large compared with the amount of coal in the roaster and in the carbonizer.

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