April 29, 1930. C. B. WISNER 1,756,896

COAL BALL AND PROCESS OF MANUFACTURING THE SAME

Filed Aug. 7, 1926 2 Sheets-Sheet 1

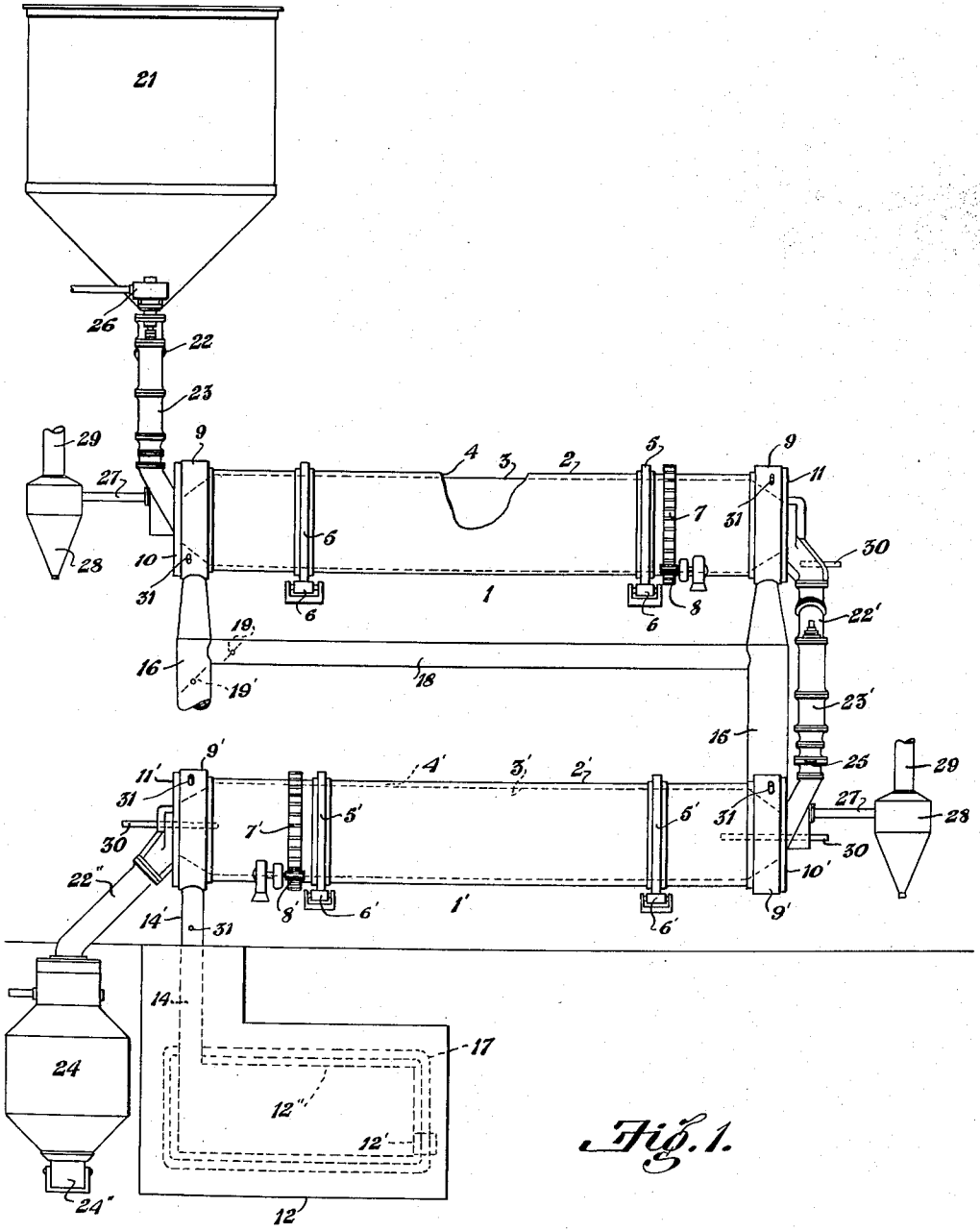


Fig. 1.

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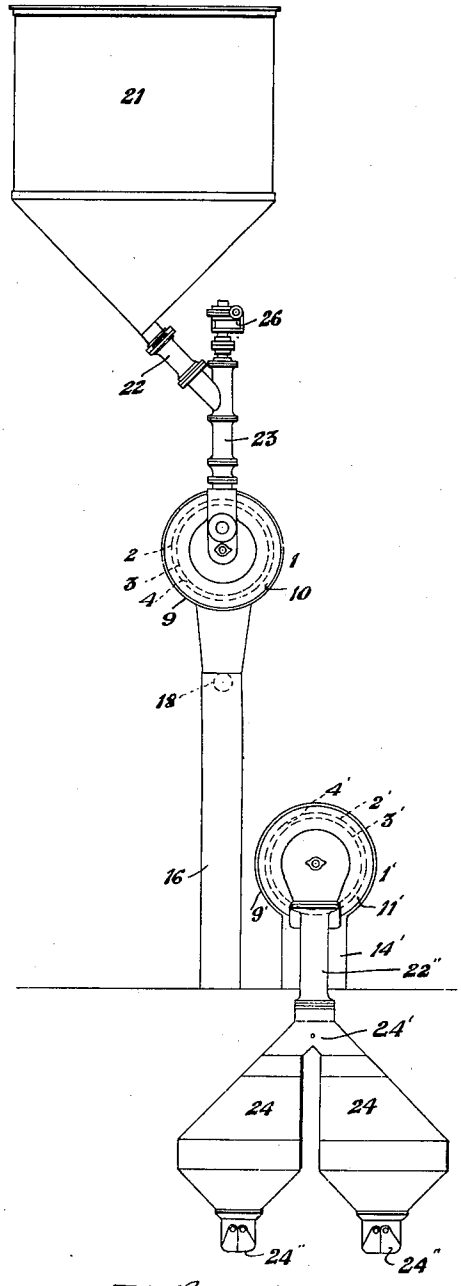
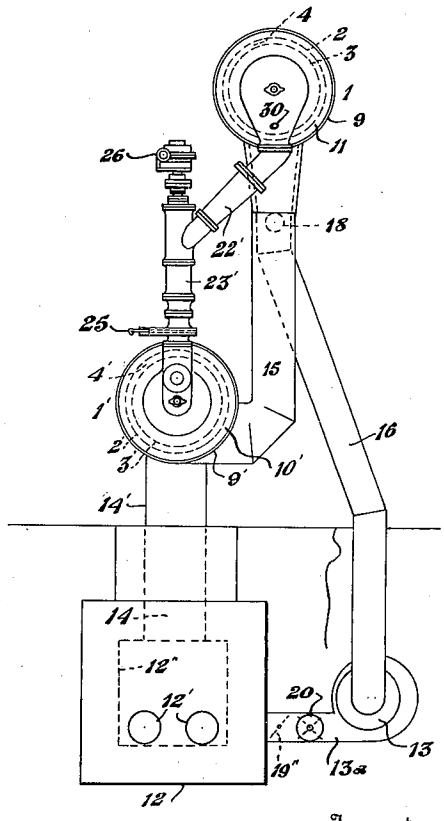


Fig. 2.

Fig. 3.



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Patented Apr. 29, 1930 1,756,896

UNITED STATES PATENT OFFICE

CLARENCE B. WISNER, OF CANTON, OHIO, ASSIGNOR, BY MESNE ASSIGNMENTS, TO COAL PROCESS CORPORATION, OF DOVER, DELAWARE, A CORPORATION OF DELAWARE

COAL BALL AND PROCESS OF MANUFACTURING THE SAME

Application filed August 7, 1926. Serial No. 127,942.

The invention relates to a smokeless fuel in the form of balls consisting of the residual product of low temperature carbonization of high volatile coals, made by tumbling and advancing the charge while in a plastic condition in a rotary retort; and the object of the improvement is to produce such a fuel in such a manner that (*a*) the volatile content, (*b*) the structural density, (*c*) the resistant strength, (*d*) the relative weight, and (*e*) the maximum size of the balls, along with (*f*) the uniformity of all of these characteristics, are such as will render coal balls commercially suitable for transportation and storage for domestic or steam fuel purposes.

A further object of the improvement is to produce such a fuel by a continuous process in steel shell rotary retorts heated externally, wherein the coal balls are formed naturally and freely by tumbling and rolling during carbonization, in different sizes of irregular and uneven shapes; as distinguished from mechanically made pressure molded carbonized briquettes, the expense of making which may prohibit the commercial use of such a product.

Sticking during carbonization

Difficulty has always been experienced in the low temperature carbonization of high volatile coals in rotating retorts, because of the tendency of the softened charge to stick to the walls of the container, when temperatures were carried high enough to rapidly drive off the liquid hydrocarbons; and with slightly reduced temperatures, the coal tumbling in the plastic stage, would form into chunks or balls too large to be removed through a gas-tight discharge from the retort; and because of the low heat conductivity of coal, the volatile content of the larger chunks or balls remains too high to make a smokeless fuel or to produce enough liquid hydrocarbons to make the operation profitable.

The sticking difficulty has been overcome to a certain extent, by the pretreating step set forth in my United States Patent No. 1,490,357, of April 15, 1924, according to which the coal is preheated in a current of air to a point just below the temperature at which hydrocarbon vapors are educed, which serves to stop the sticking of the softened coal to the walls of the retort.

It has been found, however, that if the temperature in a rotating retort during a continuous carbonization process, is permitted to rise high enough to cause a cracking of the hydrocarbon vapors while contained therein, this cracking releases free amorphous carbon which may deposit upon the walls of the retort in a sufficient amount to gradually build up a layer of carbon thereof and cause the fine coal charge rolling thereon to stick thereto and insulate the walls. This condition requires the use of an increasingly higher extraneous heat, and in a short time the steel shell of the container will be burnt and the retort rendered useless.

To avoid this difficulty, the uniform temperature which is maintained within the walls of the carbonizing retort, should never reach the critical temperature which causes a cracking of the hydrocarbon vapors contained therein; which cracking temperature may vary with different kinds of coal, from 900° to 1000° F.

Pretreating or thermodizing

The varying coking strength and degree of expansion in different high volatile coals is such that a naturally formed coal ball fuel cannot be successfully produced by low temperature carbonization in a rotary retort, unless the fuel is pretreated or thermodized usually in a current of air, in a predetermined manner for each kind of coal; not only to prevent a sticking and to facilitate the carbonizing process, but to predetermine and uniformly regulate and control the size, the strength and the weight, of the coal balls produced thereby.

For these additional purposes the raw coal must be ground fine enough to give the proper oxidizing surface contact with the air current for tempering and restricting the binding element so as to form coal balls of desired size, strength and weight; and the temperature of the extraneous heat must be adjusted to the requirements of the indi-

vidual coal being treated to bring the temperature of the same when discharged into the carbonizing retort, near to its critical point at which hydrocarbon vapors are driven off.

Furthermore, the time during which the coal remains at a given temperature in the pretreating container, and the volume of air at such temperature, must be coordinated with the size of the raw coal in the thermodizing retort.

As a general rule, it is preferred to grind the fuel to such a size that it will all pass through a screen having about three-eighth inch openings, and to subject the same for a period of some fifteen minutes for a non-coking coal, as Ohio No. 6, to some forty-five minutes for a coking coal, as Pittsburgh No. 8, while heating the fuel to just below the critical temperature at which the eduction of hydrocarbon begins, which may be from 450° to 550° F. and at the same time passing through or over the fuel from one-eighth of a cubic foot to some five cubic feet of air per pound of fuel, which air may be preheated to any degree up to that of the desired retort temperature.

Although the degree of fineness, the temperature, the time, and the amount of air will, of course, vary for the different kinds of fuel, and in turn must be varied in a predetermined manner to produce uniform coal balls of different sizes, strength and weight, to those skilled in the art the conditions mentioned above can be readily modified to meet the requirement of any particular kind of coal.

Coal ball carbonization

The normal product of the low temperature carbonization process set forth in my said patent, as well as of other processes which have been proposed, is a light-weight, pie-crust, type of coke. Such a product is too soft to stand transportation and storage, and is too light in weight for an efficient fuel, because of its relatively large porosity, which cuts down the strength of the cell structure and the amount of carbon contained in a given cubic content. If the maximum amount of air is used in my dual process, the product is of substantially the same size or fineness as the coal charged into the retort.

For these reasons, among others, it has generally been thought necessary to compress low temperature coke residue into briquettes, to render it suitable for domestic or steam fuel purposes.

It has been found, however, that when the process steps of my said patent are carried on in the manner and under the predetermined conditions set forth herein, carbonized coal balls can be produced from various kinds of raw coal, and such balls will have the required uniformity in the necessary volatile content, structural density, resistant strength, relative weight, and desired size, for transportation and storage for domestic and steam fuel purposes.

For the primary purpose of producing a smokeless fuel, it is necessary to drive off all the hydrocarbon vapors which will condense to liquids, as for instance, tar oil, and to do so requires that the fuel be brought up to temperatures ranging from 750° to 900° F. for thirty to sixty minutes, depending upon the age of the coal deposit. In different coals these temperatures and this time will reduce the volatile content to from 8% to 15%, it being preferred to retain about 12% of volatile content in the fuel for general practice.

When the fuel has been thermodized so as to flow into the carbonizing container in a dry preheated condition, practically all of the vapors which will condense to liquid hydrocarbons at 100° F. at atmospheric pressure, will be driven off in from thirty minutes to one hour at temperatures below 900° F., which is referred to herein as the thermal end point of the liquid hydrocarbons, during which time the gas educed which will not condense at 100° F. at atmospheric pressure will approximate less than 2000 cubic feet per ton of coal charge of very high B. t. u. value.

If the charge is continued in the container for a further period of from thirty minutes to one hour at temperatures of from 850° to 900° F., it will continue to give off vapors which will condense to water and may produce a further 2000 cubic feet per ton, of non-condensible gas; but this longer period cuts down the capacity of the unit to such an extent, that unless a very high price can be obtained for the gas, it is more profitable to stop at about the thermal end point of the liquid hydrocarbons, thus leaving a little more volatile in the coal balls.

For this reason alone, it is desirable to limit the time and temperature of the carbonization process, to that required for educing practically all of the tar vapors; but the matters of structural density and resistant strength and relative weight, are of even more controlling importance in the production of commercial coal balls.

When the coal balls do not have sufficient density, with a resulting resistant strength and weight, they are, like the normal low temperature product, too soft to stand transportation and storage, and are too light for an efficient fuel. This condition results from the common practice of low temperature carbonization, wherein the temperature and the time may carry the coal beyond the critical intumescent stage, which results in a contraction and a splitting or fracturing of the coal balls, and a weakening of the fuel structure.

This difficulty is overcome by limiting the temperature and the time for the carbonization of different kinds of coal, so as not to carry the fuel beyond the critical thermal end point of swelling and expanding during the intumescent and softening period, which may be from 580° to 750° F. for a high volatile non-coking coal, as Ohio No. 6, or from 650° to 850° F. for a high volatile coking coal, as Pittsburgh No. 8. By thus limiting the temperature of the fuel during the carbonization operation, a detrimental splitting or fracturing of the coal balls is avoided and a stronger fuel structure is obtained in the resulting product.

It has been found, however, that when high volatile non-coking coals, such as Ohio No. 6, and those types of high volatile coals which do not soften during carbonization, are processed alone, after having been thermodized or preheated to prevent a sticking if any in the coking retort, or to facilitate carbonization, there is not a sufficient amount of binder to form coal balls. Moreover, such a coal as Ohio No. 6, carrying 40% volatile, when processed alone swells or expands to about four times its original size and sticks to everything it comes in contact with, and when treated with air to prevent the sticking, the product comes out the same size as the feed, and in either case with a weight of from 17 to 21 pounds per cubic foot.

These difficulties may be overcome by mixing with the non-coking coal a strong coking coal, as for instance some 15% of Pittsburgh No. 8, and then preferably thermodizing the mixture with a sufficient volume of air, whereupon coal balls are formed substantially the same as with a strong coking coal, and will weigh from 26 to 30 pounds per cubic foot.

In districts, such as the sub-bituminous and lignite districts of the West, where the cost of securing coking coal for the binder is excessive, an asphalt pitch or the pitch from the oil educed from the coal, of high melting point and powdered, or other suitable heavy hydrocarbon binding element, may be added to the coal as a binder, either in the thermodizing or in the carbonizing retort; in which case a carbonizing temperature of from 750° to 900° F. is sufficient to render such a binder smokeless.

The present improvement

The improved method of making carbonized coal balls, therefore, may and preferably does comprise a dual process, the steps of which may be referred to, respectively, as thermodizing and carbonizing steps, each one of which is carried on continuously while the coal is flowing through an externally heated, steel shell, rotary retort, wherein the coal is agitated by a tumbling and advancing action.

For the thermodizing step, the raw coal is reduced by grinding or otherwise to the size of about three-eighths of an inch, and is heated to just below the temperature required for educing hydrocarbons for a period of from fifteen to forty-five minutes in a current of air of from one-eighth of a cubic foot to some five cubic feet per pound of coal; for acting upon the binder content to the extent desired for preventing a sticking of the fuel in the carbonizing retort and for predetermining and uniformly regulating and controlling the size, the density, the strength and weight of the balls produced by the carbonizing process.

In the carbonizing step, the preheated coal is raised to and maintained at a temperature for educing all the liquid hydrocarbon vapors during a period of some thirty minutes to one hour, without exceeding at any time the critical thermal end point of swelling and expanding during the intumescent and softening period, or beyond the critical temperature which causes a cracking of the hydrocarbon vapors contained therein, and without continuing the heating beyond the thermal end point of the liquid hydrocarbons, whereupon the solid residue is cooled in the form of carbonized coal balls.

Such limitation of the temperature serves the manifold purpose of educing all the liquid hydrocarbon vapors without further formation of hydrocarbon gas, of preventing a contraction and a cracking of the coal balls thus giving them the maximum density, strength and weight, and of preventing a cracking of the hydrocarbon vapors thus avoiding a deposit of amphorous carbon in the container.

The carbonized coal balls may be made in the apparatus which is illustrated more or less diagrammatical in the accompanying drawings, forming part hereof wherein—

Figure 1 is a side elevation of the apparatus;

Fig. 2, a left end elevation thereof; and

Fig. 3, a right end elevation thereof.

Similar numerals refer to similar parts throughout the drawings.

The thermodizing retort 1 and the carbonizing retort 1′ may be made substantially alike, in the form of an axially elongated cylinder with an outer steel shell or tube 2 or 2′, and an inner steel shell or tube 3 or 3′, spaced apart to form an annular flue 4 or 4′ through which heating gases may flow for heating the inner tube of the retort; it being understood that the outer tube will be covered with a casing of asbestos or other heat insulating material, not shown, in well known manner.

Each retort may be provided with ring tracks 5 and 5′ mounted for rotating on roller bearings 6 and 6′, and with a ring gear 7 or 7′ meshing with a gear pinion 8 or 8′,

connected with suitable power means for rotating the retort.

The ends of the inner tubes are preferably tapered as truncate cones and are enclosed in fixed heads 9 and 9′ provided with suitably sealed swivel joints with the ends of the outer and inner tubes.

Extraneous heat for the retort may be supplied from the furnace 12 provided with gas burners 12′ and combustion chamber 12″ from which hot gases may be driven or circulated by a blower 13 by way of a flue 14 and pipe 14′ through the peripheral wall and into the rear head 11′ of the carbonizing retort; whence the hot gases may flow forward through the annular flue 4′ between the tubes of the carbonizing retort into the head 10′ at the forward end thereof; thence upward by way of the pipe 15 through the periphery and into the rear head 11 of the thermodizing retort; thence forward through the annular flue 4 between the tubes of the thermodizing retort into head 10 at the forward end thereof; and thence returning through the pipe 16, the blower 13 and its discharge pipe 13ª to a reheating flue 17 formed around the combustion chamber 12″ and communicating with the outlet flue 14 leading therefrom.

A by-pass pipe 18 may connect the pipes 15 and 16 to reduce the temperature of heating gases going to the thermodizing retort from the heating circuit, if it is desired to do so. Suitable dampers 19, 19′ and 19″ are provided in the various pipes to control the circulation of hot gases therethrough, and a valve controlled outlet flue 20 may be provided in the blower discharge pipe 13ª for the escape of excess gases from the heating system, thus creating a closed heating circuit supplying enough new heat to keep the desired flue temperature and wasting an equal amount of spent heating gas.

Crushed coal may be supplied from a hopper 21 through a delivery pipe 22, and a disk screw feed pipe 23 leading through the forward end of the head 9 into the forward end of the inner tube 3 of the thermodizing retort 1; whence the charge flows rearwardly through the thermodizing tube by the rotation, volume and downward inclination thereof and flows from the rear end thereof through a discharge pipe 22′ and a disk screw feed tube 23′ leading through the forward end of the head 9′ into the forward end of the carbonizing tube 3′; whence the charge flows forward through the carbonizing tube by the rotation volume and downward inclination thereof, and flows from the rear end thereof through a discharge pipe 22″ into one or the other of a pair of receiving hoppers 24 provided with a controlling grate 24′ at their upper end and an undercut discharge grate 24″ at their lower ends.

Slide grates 25 are provided in the various pipes for controlling the flow of coal; motors 26 are provided for operating the disk screws; pipes 27 lead from the forward ends of the thermodizing and carbonizing tubes to dust collectors 28 for receiving dust and vapors therefrom, the vapors being discharged through pipes 29 into the open or to condensers, not shown, as the case may be, and finally a valve controlled pipe leads through the head 9 into the rear end of the thermodizing tube 2 for supplying the moving air, under pressure if necessary, for the thermodizing process.

Such apparatus may be operated to carry out the low temperature carbonization of fossil fuels which is set forth very generally in my said former patent, as the process of educing hydrocarbon oils from solid fuel, which consists in first maintaining the fuel above steam producing temperature and below hydrocarbon volatilizing temperature in the presence of moving air until the agglomerating content is rendered inert to the extent desired, and then confining, tumbling and advancing the fuel within a closed container having a relatively large free space for volatile matter, flooding the fuel with extraneous heat so as to rapidly raise the temperature entirely to that at which hydrocarbon vapors are actually educed, and then continuously decreasing and maintaining the rate of supply and extraneous heat only sufficient so that the extraneous heat and the heat of formation of the vapors being evolved at a temperature not exceeding 900° F., will rapidly permeate the pieces of fuel and suddenly bring every particle thereof to the temperature for evolving hydrocarbon vapors.

In the operation of said patented process the thermodizing step has been very usefully employed for preventing a sticking of the fuel in the carbonizing process, but the resulting product is either a soft friable semi-coke, too low in density and not resistant enough for transportation and storage to make a merchantable fuel, except as a powdered fuel for steam plants, or if the coal contains an excessive amount of binding element, the softened mass forms into one or many balls of such a size as to prevent the necessary control of the carbonizing process to produce the most efficient character of fuel.

It has been discovered, however, that by varying the time during which the coal remains at the thermodizing temperature, and the volume and temperature of the moving air, with respect to different coals or mixtures thereof, the binding element therein can be tempered and restricted in a manner to definitely determine the size and character of the balls formed during carbonization.

And in the operation of said patented process the carbonizing step has been very usefully employed for making an ordinary low temperature or semi-coke product, and although there may possibly be some coals in

existence having exactly the character and amount of binding content to produce a satisfactory coal ball product at carbonizing temperatures in the fuel running as high as 900° F. without any thermodizing treatment, such a coal has not yet been found.

Although such a maximum temperature of the charge within the retort may not always cause a cracking of the hydrocarbon vapors contained therein, it will in the case of all fuels exceed the critical end point of swelling and expanding during the intumescent and softening period, and if continued long enough will carry the charge beyond the thermal end point of the liquid hydrocarbons.

These critical temperatures and thermal end points no doubt vary in themselves and also as to each other, with reference to each particular kind of coal, and for that reason it may be desirable, if not necessary, to limit the temperature of the charge during the carbonizing process so as not to exceed any one of these limits, with respect to the particular coal under treatment, to produce coal balls having all of the characteristics described herein.

In the operation of apparatus to carry out the improved process the coal flows from the preheating container into the carbonizing container at from 450° F. upward, depending upon the critical point of the particular coal. The temperature of the walls of the carbonizing container may be maintained at about 900° F. and the coal is allowed to flow through this heated zone just fast enough to absorb all of the free heat possible to deliver through the steel wall to the coal, for producing the predetermined heat in the coal at the discharge end of the container, as shown by a pyrometer-thermocouple 30 located therein. Extraneous heating temperatures are indicated by pyrometer-thermocouples 31 and controlled by the dampers in the heating pipes. The annular flues are of narrow cross section, and a high velocity of a thin sheet of external heating gases is maintained by forced or induced draft along the container in the annular flue around the same.

The peripheral speed of the carbonizing container wall will usually be from forty to seventy-five feet per minute, and the heat transferred to the coal will increase as the difference in velocity between the flow of the coal and the thin sheet of the heating gases traveling countercurrent to the flow of the coal. Because of the difference in specific gravity the hottest gases will flow to the top of the flue, and as the container wall moves out from under the coal its temperature is raised. In other words, the coal lying on the hot wall has absorbed its heat, and as it revolves its sensible heat is again brought up to a maximum to again be given up in part, based on the temperature difference between the heating gases and the coal as it passes through its cycle. This heating of a small peripheral portion of the charge to the softened temperature in advance of the remainder of the charge, is of importance in the formation of coal balls.

The coal flowing through the carbonizing container preferably fills about one-sixth of the space therein and covers something more than one-fourth of the peripheral wall surface. The speed of revolution of the container carries the charge up the side of the wall until a portion rolls over the top toward the center of the charge, and the balance slides back, but a small portion flows over with each movement forward.

The coal lying on the steel wall naturally is heated and becomes plastic slightly in advance of the remainder of the charge and as this flows over the top it picks up particles of the cooler coal and immediately begins to form into small agglomerating chunks which by the continuous tumbling on the steel walls are automatically formed and eroded into round balls. These balls may be regulated to a predetermined maximum size by the preliminary thermal treatment described herein, and for domestic and other fuel purposes coal balls produced may vary in size from one-fourth inch to a maximum of three inches in diameter; of which the balls from one-fourth to one-half inch will include some 5%, the balls from one-half to three-fourths inch will include some 5%, and the balls from three-fourths inch to three inches will include some 75% of the residual fuel; the remainder of some 15% will be fines made by erosion against the walls of the apparatus. These fines may be screened out and either carried back into the fresh coal charge or powdered for steam fuel.

Coal balls made in this manner and of the general sizes mentioned will carry from eight to fifteen percent of volatile gases, which makes a free burning fuel and an ideal substitute for other domestic fuels. Such balls will weigh about twenty-seven pounds per cubic foot, while the carbonized residue from the same coal without the preliminary thermal treatment weighs from seventeen to twenty-one pounds. Moreover, the varying sizes and shapes of the automatically formed balls, permit them to pack closer together for burning in a fuel bed, and gives greater opportunity for controlling the rate of the combustion of the fuel.

The irregularity in the size and shape of the coal balls, gives to them an identity which distinguishes them from mechanically formed briquettes, which are made in molds of one size and shape.

When a fuel bed is formed of briquettes, large spaces are left for the presence and passage of air, and it is difficult to control combustion within close limits. With coal balls,

however, the smaller sizes tend to fill the voids between the larger sizes, and the high volatile nature of the fuel renders possible an accurate control of combustion.

I claim:

1. The method of making carbonized coal balls which includes the initial step of heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of desired size, strength and weight, and then carbonizing the coal while tumbling it in a closed container so as to form such balls.

2. The method of making carbonized coal balls which includes carbonizing high volatile coal at a temperature required for educing tar vapors without heating the charge beyond the thermal end point of swelling and expanding during the intumescent and softening period, and then cooling the solid residue, the charge being tumbled in a closed container throughout the carbonizing process.

3. The method of making carbonized coal balls which includes carbonizing high volatile coal by extraneous heat at a temperature required for educing tar vapors without continuing the heating beyond the thermal end point of the liquid hydrocarbons, and then cooling the solid residue, the charge being tumbled in a closed container throughout the carbonizing process.

4. The method of making carbonized coal balls which includes carbonizing high volatile coal at a temperature required for educing tar vapors without heating the charge either to the critical temperature which causes a cracking of the hydrocarbon vapors contained therein or beyond the thermal end point of swelling and expanding during the intumescent and softening period and then cooling the solid residue, the charge being tumbled in a closed container throughout the carbonizing process.

5. The method of making carbonized coal balls which includes carbonizing high volatile coal at a temperature required for educing tar vapors without heating the charge to the critical temperature which causes a cracking of the hydrocarbon vapors contained therein and without continuing the heating beyond the thermal end point of the liquid hydrocarbons, which is from 750° to 900° F., and then cooling the solid residue, the charge being tumbled in a closed container throughout the carbonizing process.

6. The method of making carbonized coal balls which includes carbonizing high volatile coal at a temperature required for educing tar vapors without heating the charge beyond the thermal end point of swelling and expanding during the intumescent and softening period and without continuing the heating beyond the end point of the liquid hydrocarbons, which is from 750° to 900° F., and then cooling the solid residue, the charge being tumbled in a closed container throughout the carbonizing process.

7. The method of making carbonized coal balls which includes carbonizing high volatile coal at a temperature required for educing tar vapors without heating the charge to the critical temperature which causes a cracking of the hydrocarbon vapors contained therein or beyond the thermal end point of swelling and expanding during the intumescent and softening period, and without continuing the heating beyond the end point of the liquid hydrocarbons, which is from 750° to 900° F., and then cooling the solid residue, the charge being tumbled in a closed container throughout the carbonizing process.

8. The method of making carbonized coal balls from high volatile, non-coking coal, which includes mixing coking coal therewith to supply a binding element thereto, then heating the mixture from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of desired size, strength and weight, and then carbonizing the mixture while tumbling it in a closed container so as to form such balls.

9. The method of making carbonized coal balls from high volatile, non-coking coal, which includes mixing a heavy carbonaceous binding element therewith, then heating the mixture from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the carbonaceous element in the coal which causes sticking and swelling to form balls of desired size, strength and weight, and then carbonizing the mixture while tumbling it in a closed container so as to form such balls.

10. The method of making carbonized coal balls from crushed coal, which includes heating high volatile coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of the desired size, strength and weight, and then tumbling and advancing the same while in a plastic state in a closed container during the carbonizing process so as to form such balls.

11. The method of making carbonized coal balls which includes first heating high volatile coal from fifteen to forty-five minutes in a current of air to just below the temperature at which the eduction of hydrocarbon vapors begins, for tempering and restricting the binding element to form balls of the de-

sired size, strength and weight, then carbonizing the coal by tumbling it in a closed container at a temperature required for educing tar vapors without heating the charge to the critical temperature which causes a cracking of the hydrocarbon vapors contained therein while forming such balls, and then cooling the solid residue.

12. The method of making carbonized coal balls which includes first heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapors begins, for tempering and restricting the binding element to form balls of the desired size, strength and weight, then carbonizing the coal by tumbling it in a closed container at a temperature required for educing tar vapors without heating the charge beyond the thermal end point of swelling and expanding during the intumescent and softening period while forming such balls, and then cooling the solid residue.

13. The method of making carbonized coal balls which includes first heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapors begins, for tempering and restricting the binding element to form balls of the desired size, strength and weight, then carbonizing the coal by tumbling it in a closed container at a temperature required for educing tar vapors, without continuing the heating beyond the thermal end point of the hydrocarbon vapors which condense to tar, and then cooling the solid residue.

14. The method of making carbonized coal balls which includes first heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of desired size, strength and weight, then carbonizing the coal by tumbling it in a closed container at a temperature required for educing tar vapors without heating the charge either to the critical temperature which causes a cracking of the hydrocarbon vapors contained therein, or beyond the thermal end point of swelling and expanding during the intumescent and softening period, and then cooling the solid residue.

15. The method of making carbonized coal balls which includes first heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of desired size, strength and weight, then carbonizing the coal by tumbling it in a closed container at a temperature required for educing tar vapors without heating the charge to the critical temperature which causes a cracking of the hydrocarbon vapors contained therein, and without continuing the heating beyond the thermal end point of the hydrocarbon vapors which condense to tar, and then cooling the solid residue.

16. The method of making carbonized coal balls which includes first heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of the desired size, strength and weight, then carbonizing the coal by tumbling it in a closed container at a temperature required for educing tar vapors without heating the charge beyond the thermal end point of swelling and expanding during the intumescent and softening period, and without continuing the heating beyond the thermal end point of the hydrocarbons which condense to tar, and then cooling the solid residue.

17. The method of making carbonized coal balls which includes first heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of desired size, strength and weight, then carbonizing the coal by tumbling it in a closed container at a temperature required for educing tar vapors, without heating the charge either beyond the thermal end point of swelling and expanding during the intumescent or softening period, or to the critical temperature which causes a cracking of the hydrocarbon vapors contained therein, and without continuing the heating beyond the thermal end point of the hydrocarbons which condense to tar, and then cooling the solid residue.

18. The method of making carbonized coal balls which includes the initial step of heating coal from fifteen to forty-five minutes in the presence of air to just below the temperature at which the eduction of hydrocarbon vapor begins, for tempering and restricting the binding element to form balls of desired size, strength and weight, and continuously carbonizing the coal while tumbling it in a closed container so as to form such balls.

19. A carbonized-coal ball of from one-fourth inch to three inches in diameter, having volatile content burning without smoke, and having substantially the density, strength and weight of the residue at the thermal end point of the expanding stage of carbonization of the coal.

20. A carbonized-coal ball having volatile content burning without smoke and having substantially the density, strength and weight of the residue at the thermal end point of the expanding stage of carbonization of the coal.

21. A carbonized-coal ball of from one-fourth inch to three inches in diameter, and

having substantially the density, strength and weight of the residue at the thermal end point of the expanding stage of carbonization of the coal.

22. A carbonized-coal ball having substantially the density, strength and weight of the residue at the thermal end point of the expanding stage of carbonization of the coal.

In testimony that I claim the above, I have hereunto subscribed my name.

CLARENCE B. WISNER.