Aug. 4, 1970 L. D. SCHMIDT 3,523,065

CHARGING OF PREHEATED COAL INTO THE COKING CHAMBERS OF A COKE OVEN BATTERY

Original Filed July 20, 1964

3 Sheets-Sheet 1

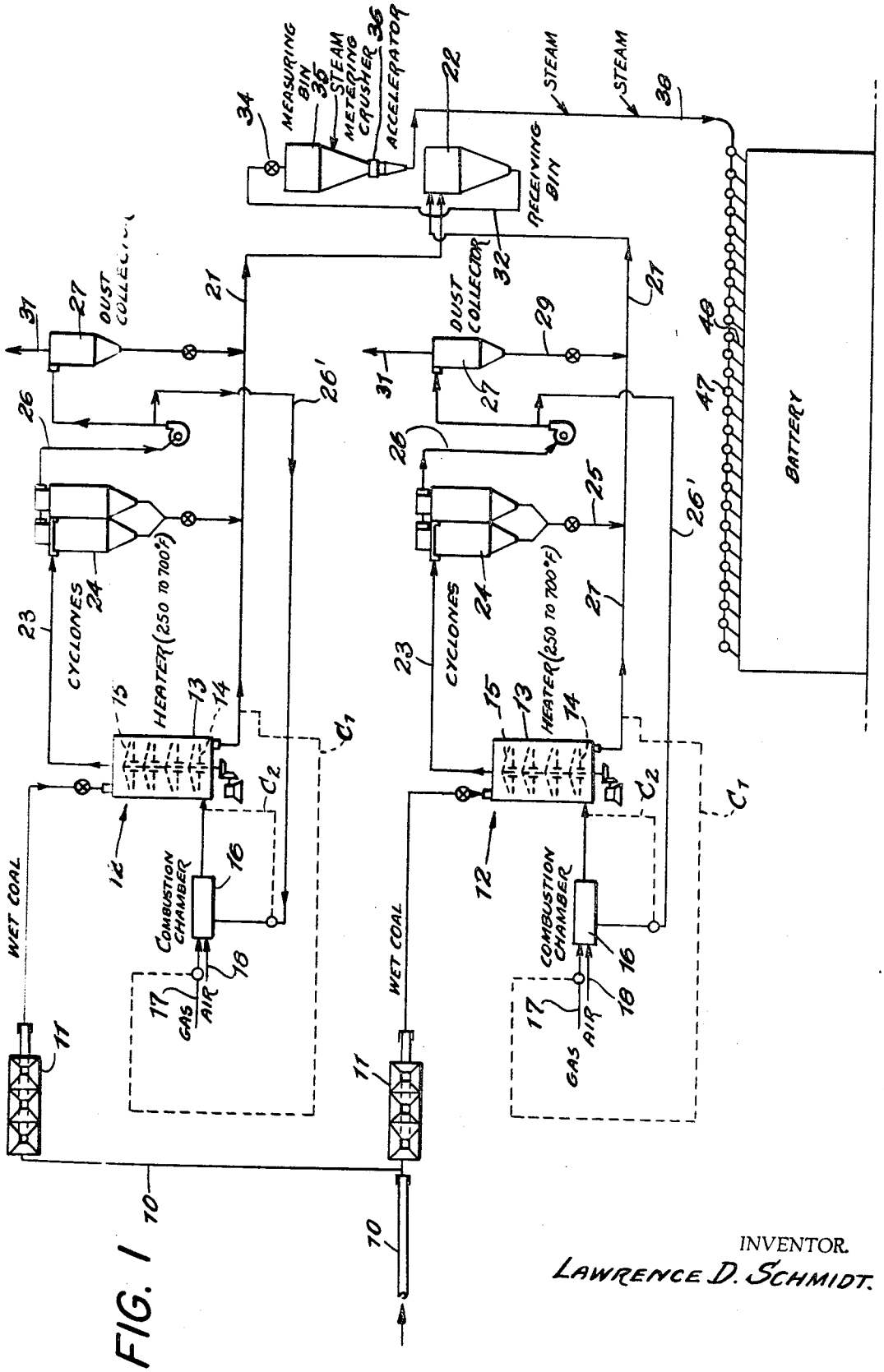


FIG. 1

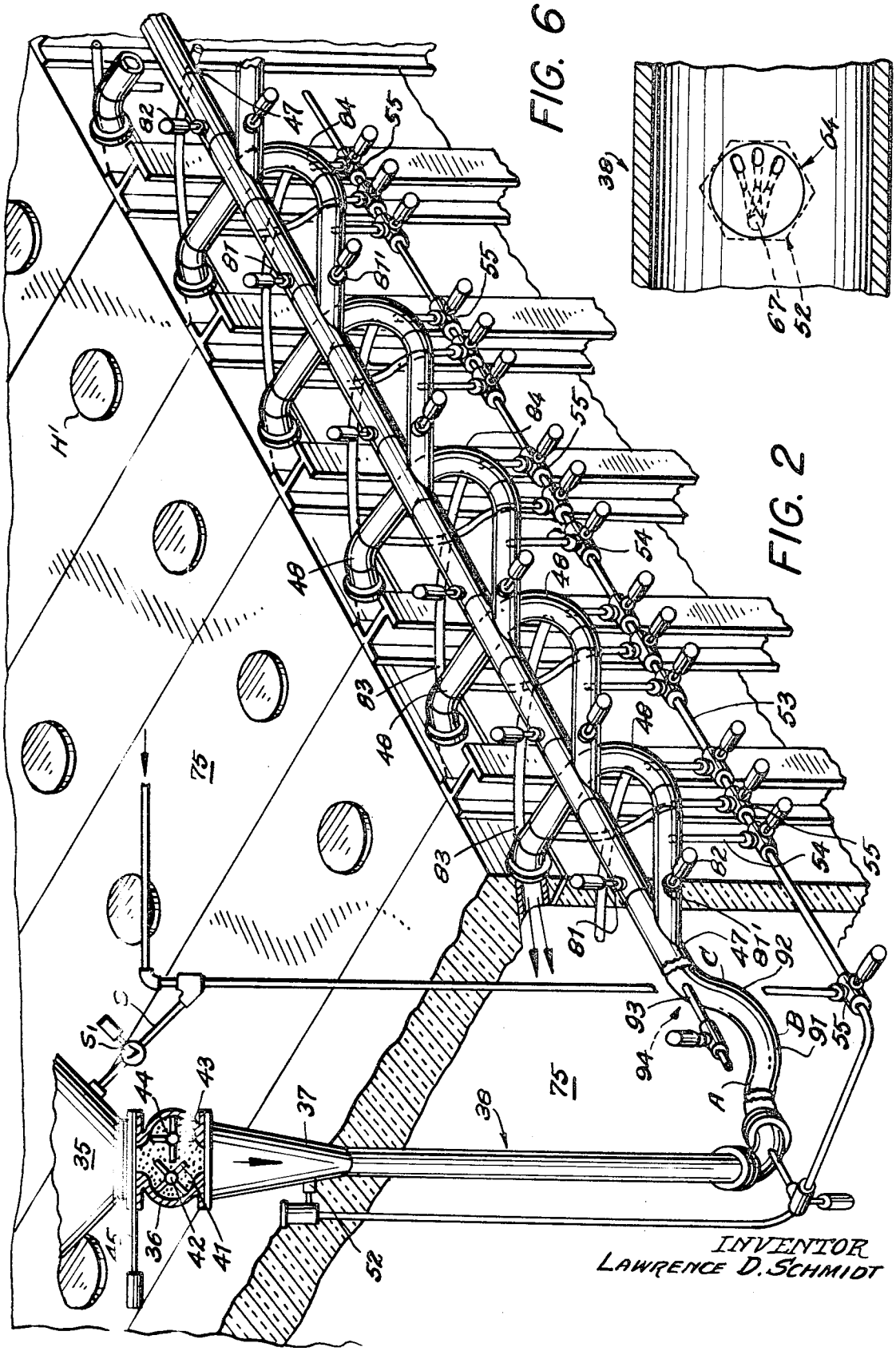
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FIG. 6



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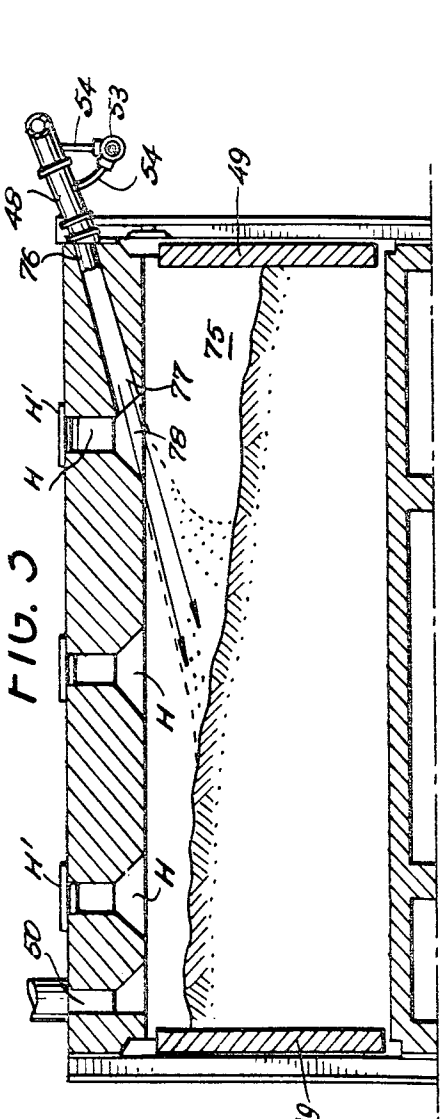


FIG. 3

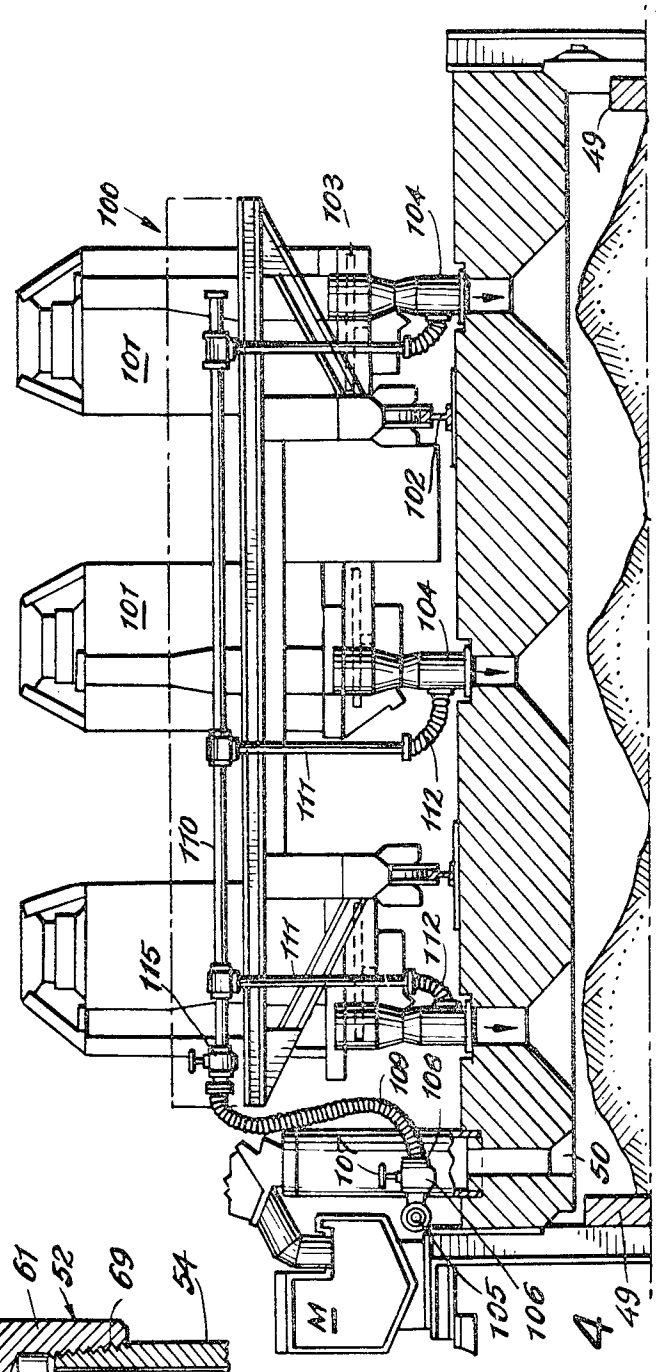


FIG. 4

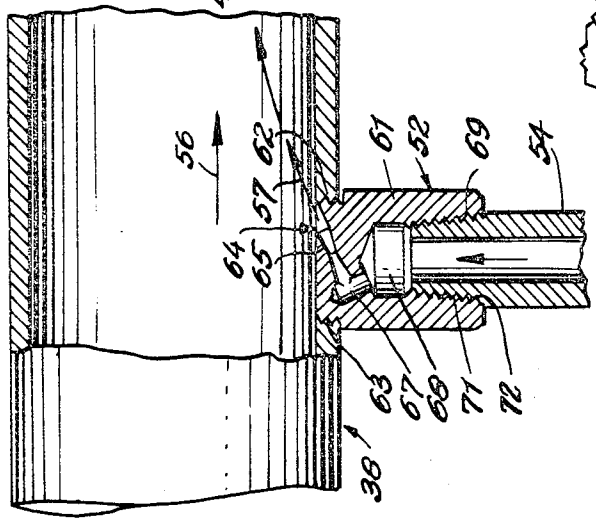


FIG. 5

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3,523,065

CHARGING OF PREHEATED COAL INTO THE COKING CHAMBERS OF A COKE OVEN BATTERY

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Original application July 20, 1964, Ser. No. 383,750. Divided and this application Jan. 14, 1969, Ser. No. 810,061

Int. Cl. C10b *31/04*

U.S. Cl. 201—40 2 Claims

ABSTRACT OF THE DISCLOSURE

A method of charging the coking chambers of a coke oven battery equipped with a larry car having charging hoppers, each of which are provided with drop sleeves for communication with respective charging holes in each coking chamber of the battery. Coarsely comminuted coal particles are preheated to a temperature within the range of from 250° to 700° F. and fed into the charging hoppers of the larry in an amount equal to a desired charge for a coking chamber. The larry is then moved into position to charge a coking chamber whereupon the preheated coal from the charging hoppers is discharged through the drop sleeves into the coking chamber at a rate to produce the desired charge within said coking chamber in not less than about 5 minutes, while a carrier gas from the group consisting of steam and coke oven gas is introduced into the drop sleeves to prevent aspiration of air into the coal streams falling through said drop sleeves into the coking chamber.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a division of application Ser. No. 383,750, filed July 20, 1964.

The advantages of introducing coal preheated to a temperature within the range of from 250° to 700° F. so that the coal is dry and below the temperature at which the coal is in a plastic state, necessary to permit introduction of the preheated coal into the coking chambers, has been recognized. Paramount among these advantages is the reduction of coking times within the coking chambers, with consequent marked increase in the capacity of the battery for this reason and also because the charging of dry coal enables the charging of more coal per unit volume of the coking chamber. When coal containing moisture is introduced into the coking chambers the amount of heat required to be transferred through the walls of each chamber to and through the stationary charge to evaporate the water content of the charge is indeed large. About 40% of the total coking time is spent, in prior conventional coking practice, to effect the necessary heat input throughout the charge to evaporate and remove the water content of the charge and to raise the temperature thereof to within the range of from 250° to 700° F. In modern practice, with large coking chambers having a capacity, say, of about 15 to 25 tons per chamber, the coking time is usually from about 15 to 30 hours depending on the type of the coke produced, namely, whether blast furnace coke or foundry coke. A saving of 40% of this time is indeed of vast economic importance. The charging of preheated coal also improves the quality of the coke, especially in the case of coals of higher oxygen content, such as Illinois coals.

It has been proposed to preheat the coal in a fluidized state in a fluidizing and heating chamber externally of the coking chambers of the battery to a temperature of

about 700° F. and then convey the preheated fluidized coal particles by the fluidizing gas into the coking chambers of the battery, where carbonization of the preheated coal is effected (United States Pat. 2,658,862), This procedure is objectionable for a number of reasons, among which may be mentioned that it requires the pulverization of the coal to reduce it to a particle size (65% minus 200 mesh) such that it can be fluidized and conveyed by the fluidizing gas. The coking of such fine coal results in coke of poor quality, unsatisfactory for many metallurgical uses. Because of the low bulk density of such fine coal, the charge per unit volume of coking chamber is much lower than the charge per unit volume of coarsely comminuted coal particles, such as are commonly used for charging the coking chambers.

The feed of preheated coal by means of an inert gas such as coal gas, as disclosed in my Pat. 3,047,473, leaves much to be desired from the standpoint of effecting the charging of the coking chambers reasonably smoothly and within a reasonable time, say not exceeding about 20 minutes for each coking chamber having a capacity of about 15 to 25 tons or more, without excessive carry-over of fine coal particles in the collector main of the oven battery and without excessive power requirements for the compressor or compressors required to compress the inert gas to the pressure necessary for effecting the transport of the preheated coal particles into the coking chambers.

The introduction of preheated coal employing a conventional larry as heretofore carried out involving the relatively rapid dumping of the charge into the coking chamber, usually in about one or two minutes, has the serious objection that as the mess of hot coal enters the hot coking chamber it may catch fire with consequent damage to the larry car. Such rapid charging has the disadvantage of introducing excessive quantities of suspended particles in the gas taken off from each coking chamber.

The problems involved in effecting feed of the preheated coal from the preheater into the coking chambers to supply each chamber with the desired charge of the order of 15 to 25 tons or more in the case of modern coke oven batteries, which may contain from 20 to 90 coking chambers, are indeed manifold. Necessary precautions must be observed to prevent hot coal particles from catching fire. Obviously, air or oxygen-containing gases cannot be used as the carrier gas and hence ordinary pneumatic transport employing air as the carrier gas is out of the question. The feed of the hot coal must (a) be smooth and free of interruption into the coking chamber being charged; (b) be reasonably rapid so that the charging can be effected within a reasonable time period, permitting successive charging of the chambers after pushing the coke therefrom to provide the empty chamber for charging; (c) be under conditions avoiding excessive carry-over of fine particles into the collector main; (d) avoid a smoke nuisance; and (e) not interfere with the collection of coke oven gas in the collector main from other coking chambers at progressively different stages of coking.

It is a principal object of the present invention to provide a novel procedure of charging the coking chambers of coke oven batteries with coarsely comminuted, preheated coal particles so as to effect such charging smoothly and efficiently.

The use of coarsely comminuted coal, rather than fine coal permits the attainment of a satisfactory bulk density of the coke oven charge.

Other objects and advantages of this invention will be apparent from the following detailed description thereof.

In accordance with this invention, coarsely comminuted

coal particles, of a particle size conventionally used for charging the coking chambers of a battery and preheated to a temperature within the range of from 250° to 700° F. along with a carrier gas, namely, steam or coke oven gas, preferably superheated steam, in amount to provide a relatively high weight ratio of coal to carrier gas, at least 20 to 1, are charged into an empty coking chamber at a rate such that it takes at least about five minutes to introduce the entire charge into the coking chamber, which, as noted, can have a capacity of from about 15 to 25 tons or more.

The coke oven gas used as the carrier gas can be the same type of coke oven gas as is employed in the heating flues of the battery. It is supplied to the preheated coal at ambient temperature. While coke oven gas can be used, steam is preferred for a number of reasons, including (a) steam reacts endothermically with carbon, thus reducing the temperature conditions during the charging with consequent reduction in evolution of volatiles during the charging, and (b) steam condenses in the hydraulic main, thus lessening the problem of maintaining proper pressure in the hydraulic main during charging. The description which follows will, therefore, be confined chiefly to the use of steam as the carrier gas with the understanding, however, that coke oven gas can be used instead of steam.

Desirably, before the charging of the coal-steam mixture is commenced, steam, preferably superheated steam, is introduced into the empty hot coking chamber to provide therein a steam atmosphere. Thereafter the preheated coarsely comminuted coal particles, along with additional steam at least during the initial stages of the charging, are charged into the steam containing coking chamber so that the weight ratio of coal to steam is at least 20 to 1 and can be from 20 to 500 to 1 in the case of the coal-steam mixture pipe-lined into the coking chamber. As the charging continues the amount of steam introduced with the coal particles can be reduced and during the latter stages of charging, the amount of steam can be the minimum amount required to obtain the transport or flow of the preheated coal. Employing mechanical transport such as a larry car, after introduction of about 10% of the charge, the amount of steam introduced with the coal can be reduced to a minimum, i.e., so much so that towards the end of the charging the flow of steam into the coal charge fed to the coking chamber can be discontinued.

The mixture of preheated coal and steam is introduced into the coking chamber to form therein the desired charge at a rate such that it requires at least five minutes and not more than 20 minutes, preferably from 5 to 12 minutes, to introduce the entire charge into the coking chamber. These values are for modern coke oven batteries having coking chambers each adapted to contain from 15 to 25 tons of coal and a volumetric capacity of from 600 to 1200 cubic feet. Thus the rate of feed of the preheated coal is such as to require at least 0.4 minute and not exceeding 3.3 minutes per 100 cubic feet of the volume of the coking chamber. Stated otherwise, the rate of feed of the preheated coal is such as to give a rise of level of coal in the coking chamber of from 0.5 to 3.5 feet a minute for modern coking chambers dimensioned approximately 40 to 45 feet long, from 12 to 18 feet high, and approximately 1½ feet wide.

As compared with the heretofore known and conventional practice of charging coking chambers employing a larry, the rate of feed of the coal into the coking chamber by the procedure of this invention is relatively slow. The charging time required is at least about five times that now employed involving the dumping of a charge from a larry through the charging holes into the coking chamber. Attempts to introduce the preheated coal relatively rapidly at rates corresponding to the rates now used for charging wet coal so that the time required for each coking chamber is of the order of one to two minutes results in a large evolution of gases from the mass of preheated coal thus fed into the hot coking chamber, which gases may catch fire with objectionable smoke nuisance and excessive carryover of coal particles into the collector main of the battery. Operating, on the other hand, under the recited conditions of relatively slow charging rate, yet not too slow to permit charging of successive coking chambers, in a practical time cycle and in the presence of superheated steam which, at least during the initial stages of the charging envelops the preheated coal particles introduced into the hot coking chamber, eliminates flaming of the charge and gives satisfactory charging.

It is not fully understood why observance of the conditions of this invention, involving relatively slow charging so as to require at least about five minutes for introducing the charge into the coking chamber, and the presence of superheated steam or coke oven gas, preferably steam, enveloping at least the preheated coal particles initially introduced into the hot coking chamber with a coal to carrier gas weight ratio of at least 20 to 1, results in satisfactory charging of the preheated coal. As the coal is initially introduced into the hot chamber, the coal tends to form an initial thin layer covering the hot walls and floor of the chamber. This black layer later becomes the outer portion of the mass of coke produced in the coking chamber but initially serves to retard the flow of heat from the hot walls of the battery into the remainder of the charge introduced. This factor plus the relatively slow rate of preheated coal introduction reduces the rate of volatile evolution from the preheated coal sufficiently to prevent objectionable flaming and permits the collector main or mains to accommodate the volatiles evolved during the charging.

In accordance with a preferred embodiment of this invention, the preheated coal, superheated steam mixture is fed to the coking chambers through a pipeline provided with branches with at least one branch leading into each coking chamber. The invention, however, is not limited to this mode of transport of the preheated coal into the coking chamber. Other modes of effecting the feed of the preheated coal into the coking chamber, such as larry feed with slow charging and the disclosed coal to carrier gas weight ratio can used.

In the preferred embodiment, transporting from one to three tons of preheated coal per minute through a pipeline of six inch diameter, the coal being unscreened and having a maximum particle size of about one inch, i.e., the coal being coarsely comminuted, the coal and superheated steam at a pressure of from 4 to 50 p.s.i.g., preferably 5 to 30 p.s.i.g., are first introduced into the upstream end of the pipeline. The pressure within the pipeline at the upstream end is from 4 to 50 p.s.i.g. and the velocity of the steam, preheated coal mixture within the pipeline is from 10 to 200 feet per second. Steam jets for impelling and dispersing the coal are positioned in the bottom of the pipeline to produce high velocity jets of steam at an angle of from 5 degrees to 20 degrees to the horizontal and in a direction the same as the desired direction of flow of the preheated coal through the pipeline. Steam is supplied to these jets at pressures ranging from 25 to 600 p.s.i.g. Along the length of the pipeline, at the "bottom" thereof, i.e., at the outside of the pipeline on curved sections desirably having a radius of curvature of at least about six feet and at the true bottom on straight horizontal runs, the spacing of these jets is from 6 inches to 36 inches apart, preferably 12 to 18 inches apart. The jets are spaced somewhat closer in the bends, e.g., every 5 degrees to 9 degrees of arc. At least 10 jets are positioned in a 90 degree bend having a six foot radius which corresponds to one jet every 12 inches, although preferred spacing is one jet every six or seven inches. A larger radius of curvature permits larger spacing of the jets.

In each jet the steam expands to at least sonic and preferably supersonic velocity, and thus imparts an impulse to the coal particles in the desired direction of flow through

the pipeline thus aiding the flow. In other words, the energy of the sonic or supersonic velocity of the jets is converted into impulses aiding the transport of the solid coal particles from one jet to the next and thus through the pipeline. Under the conditions herein disclosed, relatively low pressure conditions are maintained throughout the pipeline within the range of from 0 to 50 p.s.i.g. and velocities which do not exceed about 200 feet per second. The introduction of superheated steam through jets spaced as herein disclosed avoids the necessity of excessively high pressures at the entry to the pipeline.

I have found that the rate of flow of unscreened hammer-milled coal through a horizontal pipeline six inches in diameter and 130 feet long, equipped with triple holed jet plugs spaced 8 inches apart, is given by the following empirical relationship:

$$R=0.5+0.5\sqrt{P}$$

wherein

R=rate of flow of coal in tons per minute

P=pressure in p.s.i.g. in the measuring bin supplying the hot coal to the feed end of the pipeline (i.e., bin **35** in FIG. 1).

Employing a relatively long pipeline, in the case of large batteries or where one and the same pipeline supplies more than one battery, or where the coal preheater is so spaced relative to the battery that a long pipeline is necessary, excess steam is bled off from the mixture thereof with the preheated coal particles at one or more points along the length of the pipeline to maintain the steam velocity in the pipeline below 200 feet per second and yet permit the introduction of superheated steam at a plurality of closely spaced points along the length of the pipeline to aid the transport of the coal particles through the pipeline. Preferably, the excess steam is bled off by subjecting the mixture to centrifugal force, for example, by flow through a curved section of the pipeline or by passing a side stream of the mixture through a cyclone separator, to produce a body of steam substantially free of coal particles. Steam is vented from this body thereof substantially free of coal particles. Where a side stream is removed, coal particles carried thereby can be returned to the pipeline.

The venting or bleeding off of the steam from the pipeline as herein disclosed permits replacement thereof along the length of the pipeline by the steam introduced at sonic or supersonic velocities in the form of jets to aid the propulsion of the coal particles through the pipeline, and this without excessive build-up of velocity of mixture of coal and superheated steam in the pipeline. The number of such venting units employed in any pipeline will depend on the particle size of the coal particles transported, the length of the line, the quantity of steam jetted thereinto, and the pressure in the feed tank at the head of the pipeline. For any given pipeline, it is a comparatively simple matter to determine the number of such venting units which should be used for optimum flow of the preheated coal particles. In general, two units should be used per 100 feet of pipeline length when conveying preheated hammer-milled coal in a pipeline having an inside diameter of six inches employing steam as the carrier gas supplied to the jets under a pressure of from 150 to 600 p.s.i.g., the steam jets being spaced apart approximately 15 inches between adjacent jets. The steam upon entering the pipeline through the jets expands to at least sonic velocity when the absolute pressure of the steam supply is at least twice that of the absolute pressure in the pipeline.

At least one steam venting unit should be positioned at a point where the pipeline communicates with the branch leading into the coking chamber. Each branch leading into a coking chamber can itself be shaped to produce a curved bend subjecting the mixture flowing therethrough to centrifugal force to produce in the bend a body of steam substantially free of coal particles, which body is vented either to the atmosphere or to an adjacent coking chamber or to a condenser. Thus the mixture which is charged into the coking chambers has a high ratio of preheated coal particles to steam. This facilitates disentrainment of the coal particles from the steam within the coking chamber and hence minimizes carry-over of coal into the gas offtake.

Good transport through the pipeline is obtained when the ratio of preheated coal particles to steam on a weight basis at the inlet end of the pipeline, is 20 to 350, preferably about 80; in the pipeline, up to the discharge point into the coking chamber, is 20 to 150, preferably about 60, and upon discharge into the coking chamber is 20 to 500, preferably about 80.

The feature of venting the pipeline to remove excess steam to attain the aforesaid ratios and to permit the maintenance of steam velocities below 200 feet per second within the pipeline is disclosed and claimed in my copending application Ser. No. 382,609, filed July 14, 1964.

In the preferred embodiment, complete charging of the oven chamber is accomplished by imparting to the coal, carrier gas mixture, at the point of introducion into the coking chamber, a velocity adequate to distribute the coal throughout the length of the coking chamber.

Preferably during the charging, the pressure of the steam at the charging inlet end of the coking chamber (the end of the chamber where the preheated coal enters) is limited to the range of ½ to 2 p.s.i.g. The opposite end of the coking chamber can be vented to the collector main or to an adjacent coking chamber during the charging to insure that the pressure at that end is less than that on the charging end of the chamber. In the case of new batteries built to practice this invention, which can be built without charging holes in the roof and which have only one collector main at the opposite side of the battery from that containing the coal inlets, such differential pressure can be created by not venting the charging end of each coking chamber during the charging and letting the pressure build up to the desired extent while the opposite end of the chamber is in communication with the collector main. Existing batteries require the sealing of the charging holes at the charging end of the coking chambers to prevent leakage of gas through these charging holes which would prevent pressure build-up to within the range of from ½ to 2 p.s.i.g. This differential pressure within the coking chamber during charging tends to effect the distribution of the charge throughout the length of the chamber and gives a charge which does not require leveling. In other words, the pressure differential facilitates the charging of the far end of the oven chamber with disposition of the charge into the coking chamber throughout its length to a reasonably uniform height so that leveling of the charge with a leveling bar is not necessary.

In the accompanying drawings forming a part of this specification and showing for purposes of exemplification a preferred embodiment of this invention without limiting the claimed invention to such illustrative instance:

FIG. 1 is a flow sheet, diagrammatic in character, showing a preferred layout of equipment for supplying preheated coal to the coking chambers of a battery;

FIG. 2 is a fragmentary perspective of a coke oven battery showing the preferred technique for transporting the preheated coal to the coking chambers of the battery;

FIG. 3 is a fragmentary vertical section through a coking chamber of an existing battery modified for charging by the present invention;

FIG. 4 is a fragmentary vertical section through a coking chamber showing a charging larry in position to charge the coking chamber, which larry is designed to effect the charging in accordance with the present invention;

FIG. 5 is a fragmentary sectional view, on an enlarged scale as compared with the scale of the other figures, through a portion of the pipeline showing one of the jet nozzles; and

FIG. 6 is a fragmentary sectional view through the pipeline, at right angles to the section of FIG. 5 and showing a plan view of a jet nozzle in the pipeline.

Referring to FIG. 1, wet coal containing from 3% to 12% by weight of moisture, usually from 7% to 8% moisture, is supplied by a conveyor **10** to the coal bin **11**. This wet coal is the usual hammer-milled coal employed in charging the coking chambers of the coke oven battery, i.e., coarsely comminuted, the particles of which are less than one inch in size in their greatest dimension and usually of a particle size such that from 3% to 20% of the particles are larger than about ¼ inch; from 8% to 40% of the particles are larger than ⅛ inch; and over 50% of the particles are larger than 0.04 inch. In the trade this size of coal is referred to as 60% to 90% through a ⅛ inch screen. It is the particle size commonly used for charging the coking chambers of a battery to produce metallurgical coke. Coals of such particle size are referred to herein as coarsely comminuted coal.

In the embodiment of the invention shown in FIG. 1, a preheating installation is shown involving two preheaters, each with associated dust collectors. The number of preheaters used will, of course, depend on the capacity of the preheater as well as that of the coking chambers. For smaller installations where one preheater will produce preheated coal at a temperature within the range of from 250° to 700° F. in sufficient quantity to supply the coking chambers of the battery, then the installation need have only one such preheater or, if desired, a second as a standby unit. Larger installations will, of course, have more than one coal preheating unit.

Since both preheating units **12** of FIG. 1 are the same, only one will be described in detail. Each unit comprises a heater **13**, desirably in the form of the well-known Herreschoff furnace, comprising a series of superimposed hearths **14** over which rabble arms **15** rotate to effect the discharge of the coal from an upper hearth to a lower hearth. Hot combustion gases produced in the combustion chamber **16** supplied with fuel through line **17** and air through line **18** to support combustion enter the base of the heater **14** and flow upwardly countercurrent to the descending coal. The heaters **13** can be of any known type in which effective preheating of the coal is effected to a temperature within the range of from 250° to 700° F.; the Herreschoff type represents one such heater.

The preheated coal at a temperature within the range of from 250° to 700° F. is withdrawn from the base of the heater through line **21** which enters the top of receiving bin **22**. Hot combustion gases leaving the heater exit through line **23** into a cyclone separator **24**, desirably a dual unit of known type. Coal entrained in the hot gases settle out in this cyclone separator **24** and is discharged through valve controlled line **25** into the hot coal line **21**.

Exhaust gas from the cyclone separator **24** is pumped through line **26** into a dust collector **27** which can be of the cyclone separator type. In dust collector **27** solid particles are separated and are discharged through valve controlled line **29** into the coal feed line **21**. The substantially dust-free gas can be discharged into the atmosphere through line **31**.

C_1 is a control of known type which controls the amount of fuel supplied through line **17** responsive to the temperature of the preheated coal to maintain the temperature of the latter substantially constant, C_2 is a control of known type which controls the volume of exhaust gas recycled through line **26'** to the combustion chamber **16** where this exhaust gas mixes wth the combustion products and thus tempers the temperature of the combustion gases supplied to the heater **13** and maintains the temperature of the combustion gases at the desired value. Each heater is equipped with an oxygen analyzer unit of known type to insure that the combustion gases entering the heater are free of oxygen. The preheaters can be supplied with additional conventional temperature and pressure controllers and electrical interlocks to insure proper sequence of operation under selected conditions of temperature and pressure for optimum performance of the preheating equipment.

Receiving bin **22** discharges the preheated coal to an elevating conveyor **32** which delivers the preheated coal into a measuring bin **35**. Measuring bin **35** is of sufficient capacity to maintain therein preheated coal in amount to supply the desired complete charge for charging an empty coking chamber. Measuring bin **35** is periodically filled from the receiving bin **22** which has an apppreciably larger capacity than the measuring bin **35**. In storage or receiving bin **22** is stored enough of the preheated coal to insure smooth operation, i.e., to supply the measuring bin **35** at intervals depending upon the charging cycle with the correct amount of preheated coal to supply the desired charge to the coking chamber being charged. When this amount of coal is introduced into the measuring bin **35**, the valve **34** is closed to seal the measuring bin. Steam is then introduced into the measuring bin through line S (FIG. 2), having a valve S1 therein, to produce a mixture of steam and coal particles which will flow readily, e.g., a mixture under a pressure of from 4 to 50 p.s.i.g.

Measuring bin **35** has at its discharge end a crusher **36** which can be of any desired type, such, for example, as the crusher disclosed in my co-pending application Ser. No. 282,351 filed May 22, 1963, now abandoned, in favor of my continuation application therefrom, Ser. No. 588,217, filed Mar. 19, 1968, now Patent 3,374,151. The crusher when used, has the function of crushing any oversized particles or agglomerates, thus insuring the delivery to the accelerator chamber **37** of coal well dispersed in the carrier gas having a maximum particle size conducive to trouble-free transport through the pipeline into the coking chambers.

In the embodiment shown in FIG. 2, the crusher comprises one set of crushing arms **41** each mounted for rotation on shaft **42** and cooperating with a second set of crusher arms **43** mounted for rotation on shaft **44**. The arms **41** and **43** are arranged to rotate in interengagement relation as indicated diagrammatically in FIG. 2 so as to agitate the hot coal and crush oversize lumps. A valve **45** is mounted just above the crusher **36** and controls the flow of hot coal and steam from measuring bin **35** into the crusher **36**.

As shown in FIG. 2, the accelerator chamber **37** is of truncated conical shape and has a steam jet **52** near the lower end thereof. The base of this chamber where it joins the inlet end of the pipeline **38** is of the same diameter as this inlet end. The joint between the two is such that streamline flow takes place from the exit of the accelerator chamber **37** into the pipeline **38**. This joint is free of any obstructions to flow therethrough. The length of the portion of the accelerator chamber **37** from the exit of the crusher to the discharge end of this chamber is at least sufficient to permit accelerative fall of the mixture of coal particles and steam from the crusher **36** into the inlet end of the pipeline without any tendency for accumulation or packing of the coal particles to take place in the accelerator chamber. This is important because by having this distance so dimensioned, accumulation of coal particles in the lower end of the accelerator chamber, which if permitted to develop would tend to obstruct or clog the flow into the pipeline, is prevented. Acceleration of the coal in a gravity type accelerator has been shown in the drawing and described above. However, other types of accelerators can be used, such, for example, as the known mechanical slingers.

The dimensions of the accelerator chamber as well as of the pipeline, the drier and associated equipment will, of course, vary for each installation and in general depend on the capacity of the coking chambers, the charging cycle used and the size of the coal particles charged.

In the embodiment of the invention shown in FIGS. 2 and 3, pipeline **38** has an inside diameter of from 4 to 8 inches, preferably about 6 inches, and leads from the exit end of the accelerator chamber **37** to a manifold **47** which extends along the length of the battery. Manifold

47 has a discharge conduit or branch 48 individual to each coking chamber leading into one end of that coking chamber, preferably at an angle of less than about 23 degrees to the horizontal so that the coal-steam mixture is discharged into one end of the coking chamber and flows therefrom toward the opposite end of the coking chamber, disentrainment of the coal from the steam taking place as the coal is fed into the coking chamber.

As customary, the coking chambers, a section through one of which is shown in FIG. 3, are each provided with doors 49 at the opposite ends. The usual gas off-take 50 leads into a collector main M (FIG. 4) from the opposite end of the coking chamber from that into which the coal-superheated steam mixture is introduced. Existing batteries to which this invention may be applied customarily have charging holes H in the roof thereof which are equipped with the usual charging hole covers H' (FIG. 3).

Pipeline 38, manifold 47 and each branch 48 are each provided, at a plurality of closely spaced points along their lengths, with jet plugs 52 for introducing superheated steam. These jet plugs 52 are communicably connected with a steam line 53 through branches 54 each equipped with a valve 55. Steam line 53 is positioned adjacent pipeline 38, manifold 47 and each branch 48 to supply them with steam under a pressure of from 25 to 600 p.s.i.g. through the jet plugs 52 spaced as hereinabove disclosed. The steam is jetted into the line in the direction of flow therethrough. For example, in the case of the pipeline 38, as shown in FIG. 5, in which the arrow 56 indicates the direction of flow through the pipeline, and arrows 57 the direction of steam jet flow into the pipeline, the steam enters at sonic or supersonic velocities and imparts impulses to the flowing mixture, aiding the flow through the pipeline; thus the sonic or supersonic velocity of the steam at the point of entry is immediately transformed into the energy imparted to the hot coal-superheated steam mixture to aid flow from one jet to the next. The pressure within the pipeline 38 and manifold 47 remains within the range of from 0 to 50 p.s.i.g. and the velocity of the coal-steam mixture below 200 feet per second.

The valves 55 in branches 54 can be adjusted to give the desired sonic or supersonic velocity of flow into the pipeline or can be closed when it is desired to reduce the number of branches supplying fresh steam to the pipeline.

A preferred form of jet plug 52 is shown in FIGS. 5 and 6 and comprises a hexagonal plug 61 having a threaded end 62 in threaded engagement within a bore 63 in the wall of the pipeline 38 or manifold 47. The top of threaded end 62 lies flush with the inner wall of the pipeline to provide a smooth interior where the jets enter the pipeline or manifold free of obstruction to the flow of the steam-coal mixture and also free of pockets or "dead spaces." Plug 61 has a nozzle 64 or a group of such nozzles 64, each of venturi shape having a divergent or exit portion 65, the included angle formed by the walls of which is between 5 and 7 degrees and having an entrance portion that is effectively convergent. In the embodiment shown in FIGS. 5 and 6, each plug 52 has three such nozzles communicating with a passage 67 leading into a central bore 68 in plug 61. Preferably each nozzle delivers a jet of super-heated steam at an angle of about 5 to 20 degrees with respect to the axis of the pipeline at the point where the jet nozzle is positioned, e.g., in the case of a straightaway or horizontal pipeline, at an angle of about 5 to 20 degrees with respect to the horizontal. The end 69 of each plug 52 is threaded at 71 to receive the threaded end 72 of a branch 54 leading from the steam line. This arrangement provides fan-like jets of steam imparting velocity or impulses to the flowing mixture of preheated coal and superheated steam in the direction of flow indicated by the arrow 56 (FIG. 5).

The manifold 47 extends the full length of the battery, along one side thereof, desirably the side opposite to that on which the collector main is positioned. Each branch 48 leading from the manifold 47 is individual to a coking chamber 75 of the battery. Each branch 48 is of arced or curved shape; the radius of curvature is preferably about six feet. The exit end 76 of the branch extends into the refractory roof of the battery and leads into a downwardly inclined passageway 77 (FIG. 3) in open communication with a coking chamber 75. The angle of inclination to the horizontal of the exit end 76 and the passageway 77 is such as to direct a flowing stream of superheated steam and preheated coarsely comminuted coal particles in a downwardly inclined direction toward the opposite end of the coking chamber. An angle less than about 23 degrees to the horizontal (i.e., the angle formed between the axis of the passageway 77 and the horizontal) gives satisfactory charging. While in FIG. 3 the passageway 77 is shown leading into the lower end 78 of a charging hole H, the passageway 77 need not communicate with a charging hole. FIG. 3 shows a construction applied to an existing oven battery having charging holes H, three in number, speed across the top of each coking chamber. In the case of new batteries, to which this invention is applied, the roofs of the coking chambers need not have any charging holes therein.

As noted, each branch 48 has a plurality of closely spaced steam jet plugs 52 therein. The spacing of the jets is the same as in a curved section of the pipeline. For the sake of clarity of illustration, all of the jets in the pipeline 38, manifold 47, and each branch 48, have not been shown on the drawing.

Flow through each branch 48 from the manifold 47 is controlled by a pair of valves 81 and 81'. Valves 81 are positioned in the manifold 47 and control flow through this manifold to the branch 48 leading into the coking chamber to be charged. Thus all valves 81 in the portion of manifold 47 leading up to the branch 48 communicating with the coking chamber to be charged are open and at least the valve 81 in the manifold 47 immediately following the branch leading into the coking chamber to be charged is closed. Thus the coal-superheated steam mixture must flow into the branch communicating with the coking chamber to be charged. Each branch 48 has a valve 81' at the inlet end thereof which controls the flow from manifold 47 thereinto. Each valve 81 and 81' is equipped with a pressure fluid cylinder 82 for egecting actuation thereof. Valves 81 and 81' controlling flow into a coking chamber to be charged are opened when that coking chamber is empty and in condition for charging; these valves are closed when the charge has been introduced into that chamber. Valves 81 and 81' of the respective branches 48 and the rest of the equipment can be operated through suitable timing mechanism so that automatic introduction takes place of superheated steam into the successive empty hot chambers, followed by the feed thereinto of preheated coal-steam mixture, as well as the feed of the preheated coal into the measuring bin 35 from the receiving bin 22 and into the latter from the preheater 12.

Preferably, but not necessarily, each branch 48 is equipped with a bleed-off 83 leading from the inner curved portion 84 of the branch into an adjoining coking chamber 75, i.e., the bleed-off leads into a coking chamber adjoining the chamber receiving the charge. As the mixture of superheated steam and preheated coal flows through the curved portion 84, it is subjected to centrifugal force so that substantially all of the coal particles tend to concentrate in the locality of the outer wall of the curved portion 84, i.e., the wall remote from the port or opening leading into the bleed-off 83. Hence in the vicinity of the inlet to the bleed-off 83, the superheated steam is substantially free of coal particles. This superhetaed steam flows through the bleed-off 83 into the adjoining chamber which

is in an advanced stage of the coking and hence can readily accommodate the carrier gas which flows from that coking chamber into the collector main.

The bleed-off of superheated steam from the coal-steam mixture flowing into the coking chamber being charged increases the coal to steam weight ratio of the mixture charged into the steam-containing coking chamber. This facilitates disentrainment of the coal from the steam. The steam entering the chamber being charged upon disentrainment from the coal particles exists through the uptake leading into the collector main. The steam entering the adjacent chamber or a pair of chambers on the opposite sides of the coking chamber being charged, if desired, flows across the open space above the coke in these chambers and exits from these chambers through the gas off-takes into the collector main. Any solid coal particles therein, for the most part, settle out and become part of the coke charge in the adjacent chambers.

In operation, after the preheated coal is introduced into the measuring bin **35** in amount to supply a charge for a coking chamber, valve **34** is closed. Valve **45** had been closed previously. The valves **81** and **81'** controlling flow to the branch leading to the coking chamber to be charged are opened while closing the valves **81** in the coal manifold downstream of the coking chamber being charged. Steam is turned on to the jets upstream of this coking chamber. The crusher is actuated; valve **45** is opened and steam is supplied, preferably, to the lower part of bin **35** to raise it to desired pressure, e.g., 4 to 50 p.s.i.g. The steam jets upstream of the coking chamber being charged serve to produce a steam atmosphere in the coking chamber to be charged. The formation of such steam atmosphere in each coking chamber before introduction of the hot coal charge thereinto represents preferred operation, although satisfactory charging can be effected by not filling the coking chamber to be chargged with steam prior to the commencement of the feed of the coal-steam mixture into that coking chamber. Thereafter coal flow to the oven begins and continues at a rate to introduce the charge in from abou t5 to 12 minutes.

In the case of a long pipeline, say exceeding 100 feet in length, the line is provided with a curved portion **91** which can be in the form of a horizontal curve, i.e., lie in a horizontal plane as shown in FIG. 2, or a vertical curve, i.e., lie in a vertical plane, as more fully described in my copending application Ser. No. 382,609 filed July 14, 1964. This curved portion **91** desirably is made up of successive curved sections A, B and C designed for streamline flow therethrough. The radii of curvature of adjacent portions A and B, and B and C are diametrically opposite each other. For a six-inch pipeline the radius of curvature is preferably about six feet. As the mixture of preheated coal and superheated steam flows through the curved portion **91**, it is subjected to centrifugal force causing the coal particles to concentrate in the locality of portion **92** and forming opposite this locality at **93** a body of steam substantially free of coal particles. A bleed-off or vent **94** is provided for bleeding off steam from this body, thus removing enough of the superheated steam to avoid excessive velocities in the pipeline and to enable the introduction of superheated steam through the subsequent jets in the direction of flow of the superheated steam-preheated coal mixture without creating excessive velocities within the pipeline, the manifold **47** and the branch **48** leading from the manifold into the coking chamber to be charged.

After initiation of the introduction of the mixture of preheated coal and superheated steam into the coking chambers, the pressure of the steam released from the mixture can be permitted to build up in the end of the coking chamber where the mixture is introduced. That is to say this end of the coking chamber is not vented. In the case of an existing battery having charging holes, modified to practice this invention, precautions are taken to insure that the charging hole covers at the end of the coking chamber which receives the charge are tightly sealed to enable the pressure in that end of the chamber to build up to within the range of from ½ to 2 p.s.i.g. The opposite end of the coking chamber communicating with the usual gas off-take at the opposite end of the coking chamber is thus at a lower pressure. This opposite end of the coking chamber is usually vented through the off-take to the collector main during the charging. The differential pressure thus created between the respective ends of each chamber during the charging thereof facilitates the flow of the coal-steam mixture from the end of the chamber where it is introduced to the opposite end and gives a distribution of the coal within the coking chamber so as to produce a reasonably uniform level of coal throughout the length of the coking chamber, i.e., a disposition of the charge requiring no leveling. Hence while the present invention is not confined to charging without leveling, it enables such charging to be effected.

When the measured charge has been delivered from the measuring bin **35**, valve **45** is closed. When this charge has been introduced into the chamber being charged, the steam jets **52** are turned off and the operation of the crusher **36** interrupted. Valve **34** is then opened and a fresh charge of preheated coal introduced from the receiving bin **22** into the measuring bin **35**. Once this charge has been introduced into measuring bin **35**, the operation hereinabove described is repeated for the next coking chamber to be charged.

During the charging of each chamber, in the embodiment shown in FIG. 2, branch **48** is vented into an adjacent coking chamber through bleed-off **83**, thus reducing the steam input into the chamber being charged, i.e., increasing the weight ratio of coal to steam introduced into the coking chamber being charged. Higher coal to steam ratios facilitate disentrainment of the coal from the steam and tends to reduce the charging time. It also tends to prevent carry-over of fine coal particles by the steam introduced into the chamber being charged from that chamber into the collector main. Bleed-off **83** can be provided with a valve to control flow therethrough or to permit optional use of this bleed-off.

Bleed-off **83** can be designed to connect with two adjoining coking chambers to vent steam into these two chambers. Operating in this manner facilitates recovery of coal particles carried by the steam thus vented into the adjacent chambers, which coal particles form part of the coal charge in these adjacent chambers and are eventually converted to coke.

With relatively high coal to steam ratios, the venting of the steam-coal mixture introduced through branch **48** into the chamber being charged can be eliminated entirely. As a general rule, venting into one adjacent coking chamber is useful in minimizing carry-over of coal particles by the steam from the chamber being charged into the collector main and also in facilitating dissentrainment of the coal from the steam in the chamber being charged in that it reduces the amount of steam introduced into the chamber being charged.

The following example of charging a coke oven battery, the coking chambers of which are approximately 12 feet high, 40 feet long and 18 inches wide, is given for illustrative purposes. The equipment used is substantially that shown in FIG. 2. The measuring bin **35** after introduction of the charge of preheated coal (15 tons) at a temperature of about 650° F. was pressurized with superheated steam to a pressure of 9.8 p.s.i.g. The crusher **36** was driven at approximately 93 r.p.m. Steam was introduced into the coking chamber to form therein a steam atmosphere. Steam was then introduced through the jets spaced along the length of the pipeline 8 inches apart in the horizontal stretch and somewhat closer in the bends of the pipeline. The total conveying steam used was 506 pounds equivalent to 79 pounds per minute. The steam pressure was 287 p.s.i.g.; on the average 65.6 pounds per minute of steam was supplied to the jets in the pipeline.

The charging of the chamber required 6.4 minutes. At

the end of this time the coal was disposed in the chamber in a mound with the level of the coal at the ends of the chamber about a foot below the level in the middle of the chamber. Upon leveling the coal was disposed at a substantially uniform height throughout the length of the chamber. The chamber which as noted was 12 feet high was filled to a height of 11.2 feet.

Such charging is repeated for each chamber of the battery by manipulation of the valves.

In the battery of FIG. 4, a charging larry **100**, having three charging hoppers **101**. one for each charging hole travels on rails **102** on the roof of the battery. Each of the hoppers has a covered top which prevents access of air to the hot coal in the hopper. The cover, of course, can be removed to permit filling the hopper with hot coal. This larry **100** can be of a known type involving a rotary discharge plate **103** at the base of each charging hopper **101**. Each plate **103** is rotated by a motor drive (not shown) as conventional, the speed of which is adjustable to give discharge of coal at the desired rate. Each discharge plate delivers the coal to a discharge chute which, as conventional, communicates with a drop sleeve **104**. These sleeves in their lowered position bridge the spaces between the discharge ends of the discharge chutes and the inlet ends of the charging holes communicating therewith. Larry **100** travels along the top of the battery, receives a charge of preheated coarsely comminuted coal, preheated to a temperature within the range of from 250° to 700° F. at the loading station for the larry and then is moved into charging position over the empty chamber to be charged.

Positioned at one side of the battery running the length thereof is a steam line **105**. This line has branches **106**, one individual to each coking chamber provided with a valve **107** to control flow therethrough and equipped with a conventional quick attachable and detachable coupling **108** for connection to flexible steam conduit **109** carried by the larry. Conduit **109** communicates with a steam line **110** having three branches **111**, one for each charging hopper **101**. Each branch **111** has a flexible lower end **112** which leads into a drop sleeve **104** as shown in FIG. 4. Conduit **109** has a flow control valve **115** therein.

When the larry is spotted over the empty chamber to be charged, conduit **109** is coupled to steam line **105**. Valves **107** and **115** individual to the chamber being charged are turned on to fill the chamber with superheated steam. The steam flow is continued during the charging which is carried out at a rate such that from 5 to 12 minutes are required to introduce the charge into the coking chamber; such charging is effected by rotating the discharge plates **103** at a rate to give the necessary slower feed of the hot coal through the drop sleeves into the coking chamber. The flow of steam into the coal passing through the drop sleeve prevents aspiration of air into the falling coal stream and thus avoids fires and explosion hazards which would be involved in charging hot coal from a larry into a hot coking chamber by dumping same from the larry into the coking chamber at the relatively rapid rates normally used. The steam, with the slow charging as hereinabove described, thus serves a dual purpose. Its presence in the coking chamber when hot coal first enters protects the dry hot coal from excessively fast carbonization which, were it to occur, would result in excessive evolution of volatiles which carry fine coal particles up through the gas off-take; also, the steam blankets the falling coal from the air thus avoiding fires and explosions.

The amount of steam introduced should be as hereinabove described to provide a relatively high coal to steam weight ratio, so that rapid disentrainment of the coal from the steam takes place in the coking chamber. The coal to steam weight ratio can be from 20 or more to 1. Coke oven gas can be used instead of steam, supplied to the larry from a coke oven gas main at ambient temperature, in amount such as to provide about the same weight ratio as in the case of steam.

While preferred embodiments have been disclosed herein and illustrated in the drawings, it will be understood this invention is not limited to this disclosure including the showing of the drawings because many variations and other modifications will occur to those skilled in the art.

What is claimed is:

1. A method of charging the coking chambers of a coke oven battery equipped with a larry car having charging hoppers, one for each charging hole in each coking chamber of the battery, the larry car having drop sleeves, one for each charging hopper, which sleeve, when the larry is spotted in charging position is lowered to place the discharge outlet of the charging hopper with which the sleeve is associated in communication with the charging hole bridging the space between said discharge outlet and said charging hole, which method comprises preheating the coal particles in coarsely comminuted condition to a temperature within the range of from 250° to 700° F., feeding the preheated coal into the charging hoppers of the larry in an amount equal to a desired charge for a coking chamber, moving the larry containing the charge of preheated coal into position to charge a coking chamber to be charged, discharging the preheated coal from the charging hoppers of the larry through the drop sleeves into the coking chamber to be charged at a rate to produce the desired charge within said coking chamber in not less than about 5 minutes while introducing a carrier gas from the group consisting of steam and coke oven gas into the drop sleeves to prevent aspiration of air into the coal streams falling through said drop sleeves into the coking chambers.

2. The method of charging the coking chambers of a coke oven battery as defined in claim **1**, in which steam is introduced into the drop sleeves during at least the initial portion of the discharge of the preheated coal therethrough into the coking chamber and the rate of discharge of the preheated coal from the charging hoppers of the larry into the coking chamber is such as to fill each 100 cubic feet of volume of the coking chamber in from 0.4 to 3.3 minutes.

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