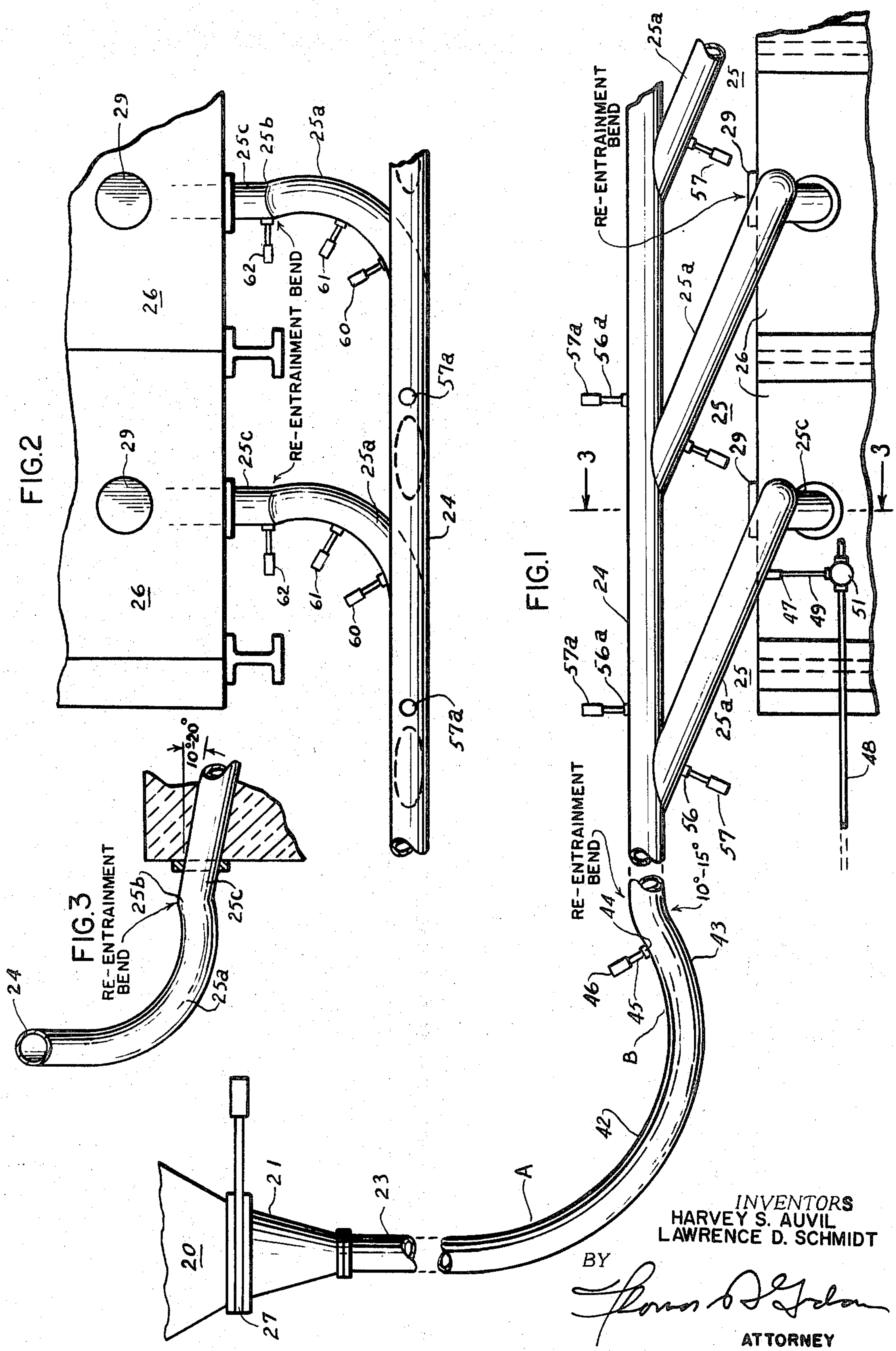
Sept. 25, 1973 H. S. AUVIL ET AL 3,761,360
RE-ENTRAINMENT CHARGING OF PREHEATED COAL INTO
COKING CHAMBERS OF A COKE OVEN BATTERY
Original Filed July 17, 1967 4 Sheets-Sheet 1



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Original Filed July 17, 1967 4 Sheets-Sheet 2

FIG. 4

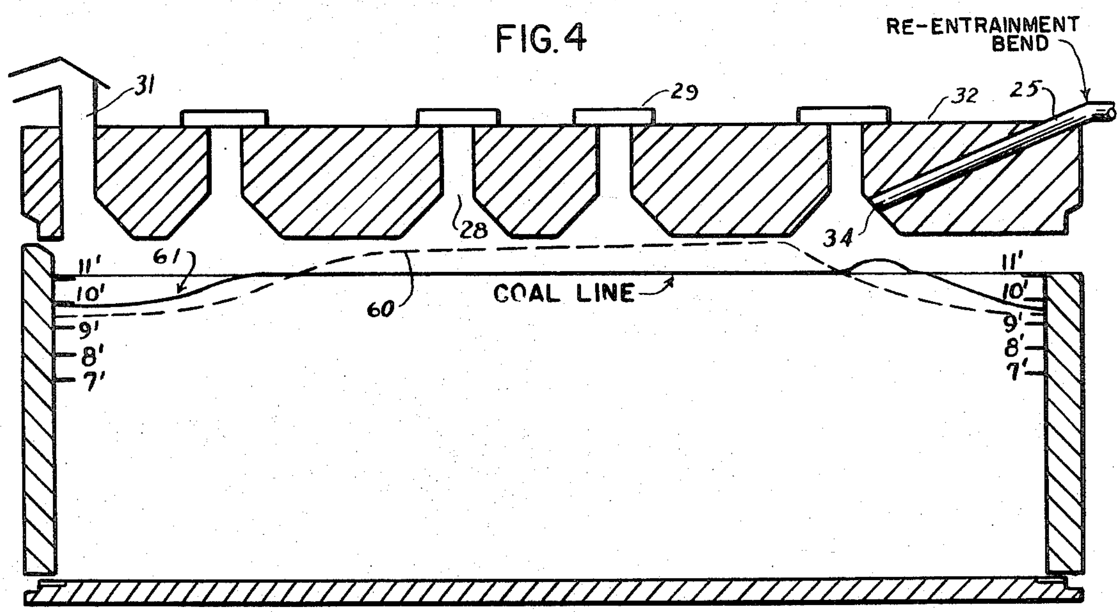
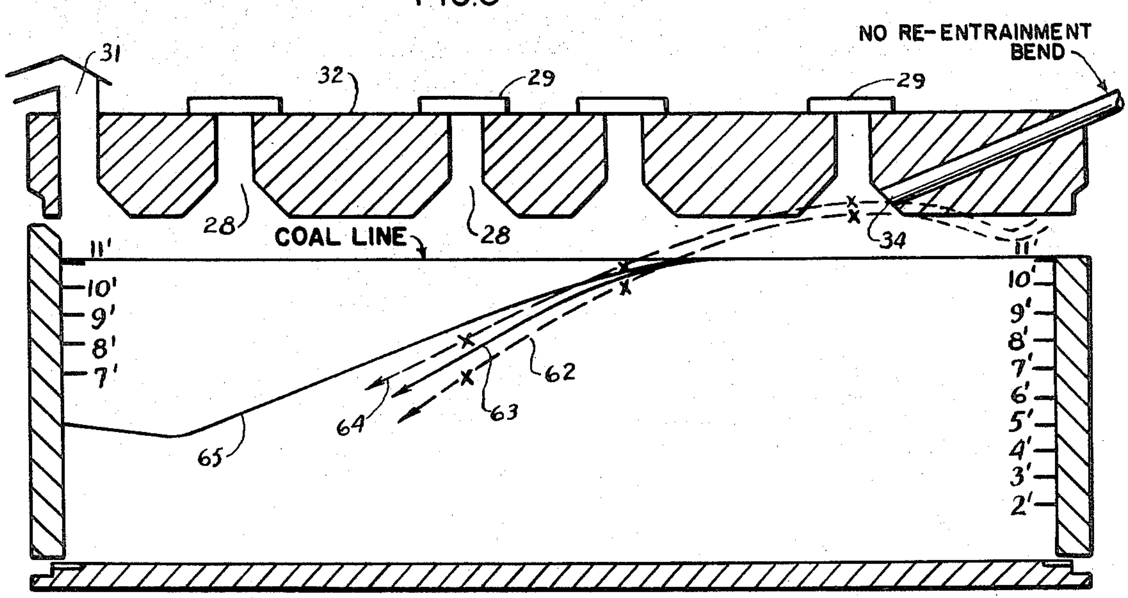


FIG. 5



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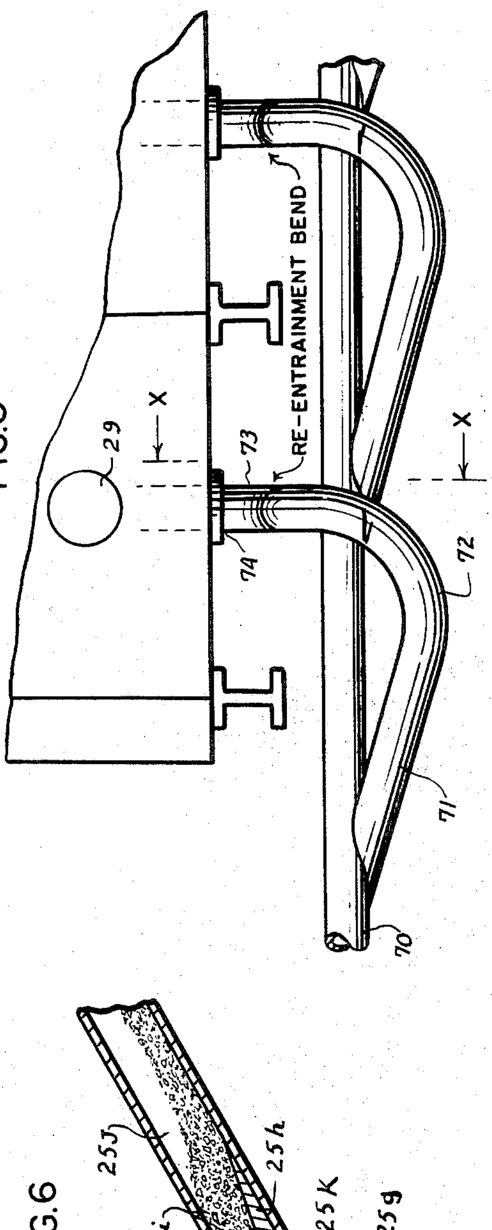


FIG.8

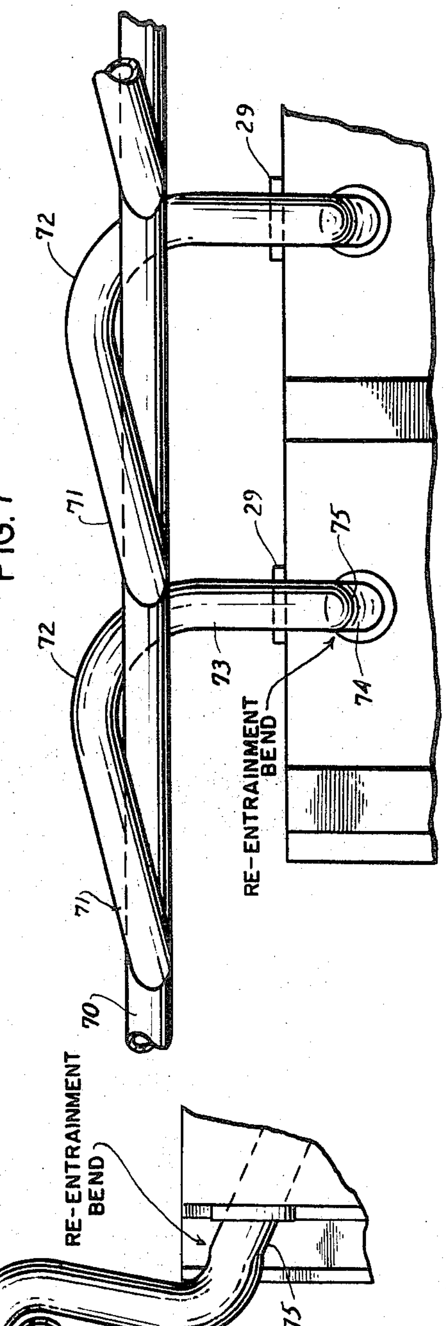


FIG.7

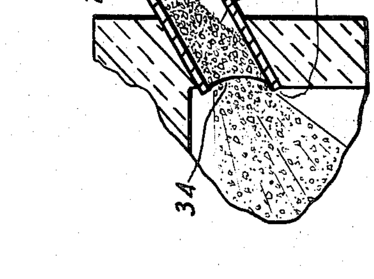
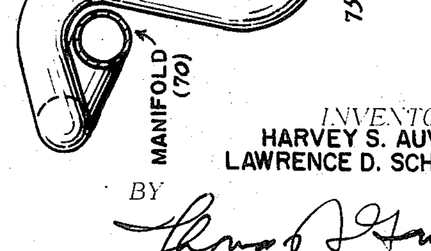


FIG.6



SECTION X-X

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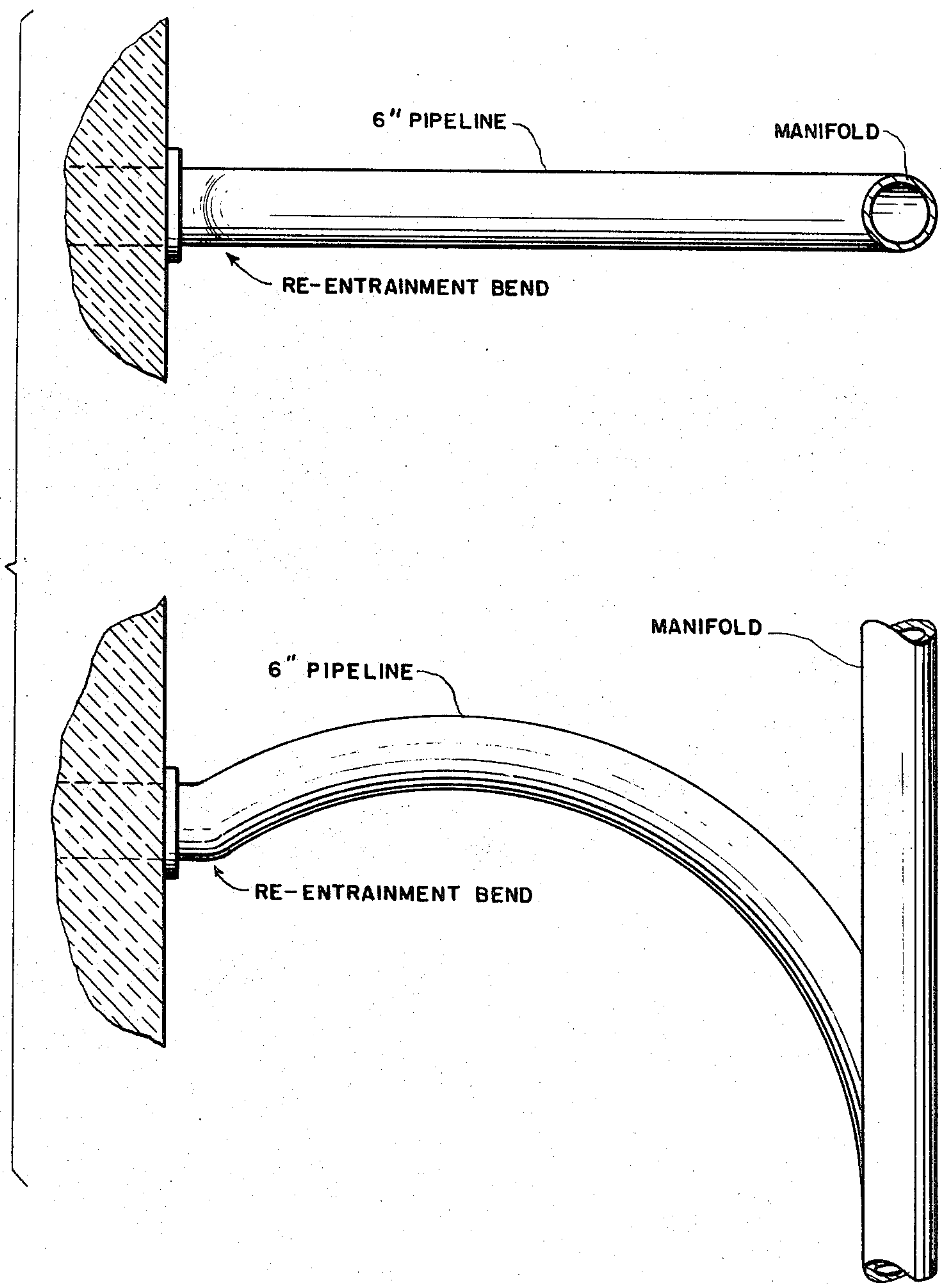

FIG. 9

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3,761,360

RE-ENTRAINMENT CHARGING OF PREHEATED COAL INTO COKING CHAMBERS OF A COKE OVEN BATTERY

Harvey S. Auvil, Ashland, Ky., and Lawrence D. Schmidt, New York, N.Y., assignors to Allied Chemical Corporation, New York, N.Y.

Continuation of abandoned application Ser. No. 653,693, July 17, 1967. This application Jan. 20, 1971, Ser. No. 108,207
Int. Cl. C10b 31/00
U.S. Cl. 201—40 8 Claims

ABSTRACT OF THE DISCLOSURE

The invention herein is concerned with a method and apparatus for charging preheated coal into coking chambers of a coke oven battery, wherein the coal is preheated, coarsely comminuted and conducted via pipeline under the force induced by a highly heated inert gas such as steam, with the assistance of a re-entrainment bend in the pipeline, adapted to effect sudden change in direction of the flow of coal so as to move upwardly and into the stream of gas, coal which settled out of the stream and onto the bottom, to re-enter the same.

This application is a continuation of application Ser. No. 653,693, filed July 17, 1967, now abandoned.

This invention relates to the charging of coal into the coking chambers of a coke oven battery.

THE INVENTION

The advantages of introducing coal preheated to a temperature within the range of from 250° F. 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, have been recognized. Paramount among these advantages is the reduction of coking times within the coking chambers, with consequent marked increased 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° F. o 700° F. In modern practice, with large coking chambers having a length (crosswise of the battery) of 30 to 40 feet or more and a capacity 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 relatively high oxygen content, such as Illinois coals.

THE NATURE OF THE CHARGING PROBLEM

The problems involved in effecting feed of the coal preheated to incipient gassing temperature in the 250° F. to 700° F. range from the preheater into the coking chambers to supply each chamber with 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, numerous. Necessary precautions must be observed to prevent hot coal particles

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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; i.e. the time interval should be shorter than that needed between pushing successive ovens; (c) be under conditions avoiding excessive carry-over of fine particles into the collector main; (d) avoid a smoke nuisance; (e) not interfere with the collection of coke oven gas in the collector main from other coking chambers at progressively different stages of coking; and (f) give reasonably uniform charging throughout the length of the battery, minimizing if not completely avoiding segregation of the different sizes of coal particles along the length of the coking chamber with consequent production of non-uniform and poor quality coke which results when segregation of coal particle sizes takes place in the charge.

RELATED APPLICATION

In co-pending application of Lawrence D. Schmidt, one of the applicants of this application, Ser. No. 383,750, filed July 20, 1964, is disclosed a process for charging the coking chambers of a coke oven battery with hot coarsely comminuted coal particles preheated to a temperature within the range of 250° F. 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, by charging this mixture into the coking chamber at a rate such that it takes at least about 5 minues to introduce the entire charge into the coking chamber which can have a capaciy of from about 15 to 25 tons or more. In accordance with the preferred embodiment of the invention disclosed and claimed in said application the preheated coal and 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. From 1 to 3 tons of preheated coarsely comminuted coal per minute are transported through a pipeline of 6 inch diameter.

DETAILED DESCRIPTION OF THE INVENTION

The coal is unscreened hammermilled coal and has a maximum particle size of about 1 inch in greatest dimension and usually 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 92% 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. They have an average particle size markedly greater than pulverized or powdered coals. As a practical matter pulverized and/or powdered coals cannot be used as the charge for the coking chambers of a coke oven battery where coke for metallurgical purposes is the desired product. Coking of pulverized and/or powdered coal results in coke of poor quality, unsatisfactory for metallurgical purposes.

The coal and superheated steam, at a pressure from 4 to 50 p.s.i.g. (pounds per square inch gauge), and usually from 5 to 30 p.s.i.g., are introduced into the upstream end of the pipeline. The pressure within the pipeline at the upstream end is such in practice that initial velocity of the steam and preheated coal mixture, within the pipeline of from 10 to 200 feet per second is attained. 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 convenient steam boiler pressures ranging from 25 to 600 p.s.i.g. Along the length of the pipeline, at the hydraulic "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 24 inches apart. The jets spaced somewhat closer in the bends, e.g., every 5 degrees to 9 degrees of arc. At least 5 jets are positioned in a 90 degree bend having a six foot radius which corresponds to one jet every 24 inches, although preferred spacing is one jet every 6 or 12 inches. A larger radius of curvature permits wider spacing of jets.

From each jet the steam exiting at velocity which may be sonic or supersonic imparts an impulse to the coal particles in the desired direction of flow through the pipeline, thus aiding the flow. In general sonic or supersonic jet velocities of the steam are obtained when the steam is supplied to the jet at absolute pressures more than twice the absolute pressure of the pipeline. The momentum of the steam moving at sonic or supersonic velocity is transferred to the solid coal particles moving them from one jet to the next and through the pipeline. The introduction of steam through jets spaced as herein disclosed avoids the necessity of excessively high pressures at the entry to the pipeline.

It will be appreciated that the pipeline through which the coal is transported to the coking chambers and the branches therefrom leading into the coking chambers, with one branch individual to each chamber, extends generally in a horizontal direction along the length of the battery and from one end of the battery to the coal supply source, such as that disclosed in the aforesaid application of Lawrence D. Schmidt. In the transport of the coarsely comminuted coal through the horizontal or substantially horizontal passes of the pipeline and the branches leading therefrom there is a tendency for the larger particles to settle out of the carrier gas stream toward the "effective bottom" of the pipeline. By "effective bottom" is meant the portion of the interior wall of the pipeline toward which the coal particles tend to settle or toward which the moving coal particles tend to concentrate by reason of gravity and/or centrifugal force. On all bends, except those changing direction solely from downwardly to the horizontal, the effective bottom of the pipeline within and somewhat beyond the bend is above its actual bottom, at an angle above the bottom, depending upon the direction of bend curvature and velocity of the stream of coal and gas flow therein, ranging up to the top of the pipeline when the change in direction is from upward to the horizontal or from the horizontal downwardly. When the change in direction is solely from downwardly to the horizontal the effective bottom and the actual bottom are the same. In other words large particles of solids separate from the mixture of solids and gas and settle due to gravity in straight horizontal runs or are thrown by centrifugal force to the outside of any curves in the pipeline or conduit.

In conducting the mixture of carrier gas and coarsely comminuted coal particles from the pipeline or main through the individual branches to the oven being charged the mixture is subjected to change in direction when traversing bends interconnecting the pipeline and the charging inlet to the coking chamber. In these bends the solids content of the mixture classifies and the larger particles concentrate or stratify against the effective pipe bottom. The tendency toward classification and stratification or settling of the coarse comminuted coal occurs also in straight courses of pipeline as well as in bends other than those referred to. When the stratification occurs or persists adjacent to the inlet to the coking chamber a substantial portion of the coal enters the coking chamber as a dilute dispersion in carrier gas and the remainder as slugs or streams of highly concentrated solids. Therefore, undesirable charging invariably occurs open to one or more of the following objections:

(1) The coal in the charge is segregated according to particle size; such segregation results in non-uniform coke of poor quality;

(2) Filling of the chamber with reasonable uniformity throughout its length does not take place, chiefly because the larger particles tend to accumulate near the charging end of the chamber and the far end of the chamber does not receive its proportionate share of the charge;

(3) The portion of coal carried to the far end of the chamber in dilute suspension does not settle properly resulting in excessive carry-over of fine coal into the gas off-take; and

(4) With larger coal particles concentrated in the effective bottom of the exit portions of the branch leading into the coking chamber, a pyramidal pile of coal tends to form in the coking chamber being charged rather than a substantially level distribution of the coal along the length of the chamber; as the charging continues a dense streak of coal results where the entering coal impinges on the top of this pile of coal as the pile grows in the coking chamber during its charging.

Good transport through the pipeline equipped with steam jets is obtained when the ratio of preheated coal particles to steam on a weight basis is within the range of from 20 to 150; 60 pounds of preheated coal per pound of stream represents preferred density of the mixture containing particles as large as 1 inch conveyed through the pipeline. At the inlet end of the pipeline the coal-to-steam weight ratio can be from 20 to 350 to 1, preferably 100 to 1. At the point of discharge into the coking chamber this weight ratio can be 40 to 500 to 1, preferably 200 to 1.

It is a principal object of the present invention to provide a process for charging the coking chambers of a coke oven battery involving the pipeline transport of the preheated coarsely comminuted coal into the coking chambers, which process results in substantially uniform distribution of the coal charge within the coking chamber, i.e., the filling of the far end of the chamber as well as the rest of the chamber at a substantially uniform rate, and this with minimization, if not complete elimination, of the objections hereinabove pointed out, this being accomplished by creating and holding fluidized condition of the coal immediately before and after delivery to the oven. When the coal is uniformly dispersed in the carrier gas upon entrance into the coke oven the fluidized state yields *hindered* elutriation so that a minimum amount of fines is carried over out of the oven.

We have found that improved pipeline charging of the reltaively long chamber of the coke oven battery, which may be 30–40 feet long or longer, is obtained by leading the mixture of hot coarsely comminuted coal and carrier gas through a pipeline and branch off curve in which each eurve is followed by a re-entrainment bend to redisperse the coal in the gas stream. So doing enables us to convey smoothly and maintain a relatively high solids to gas ratio in the transport pipeline. If required to obtain dense or fluidized mass, carrier gas may be bled off to adjust to coal and carrier gas mixture entering the oven to a fluidized state. To permit adjustment of the coal to carrier gas ratio, just before the entry into the oven, the mixture is led around a curve where the mixture is somewhat segregated by centrifugal force, the desired amount of gas is bled off, and the denser mixture progresses through a reentrainment bend where an abrupt change in direction disperses the coal particles uniformly in the carrier gas and the uniform, well fluidized dense mixture enters the coke oven chamber.

A re-entrainment bend can be defined as an abrupt change in direction of the pipeline either: (1) downward in the case of a horizontal pipeline, or (2) outward in the case of a curve in the pipeline. In case (1), in a horizontal straight pipeline the effect of gravity is to cause a concentration of coal along the bottom of the pipeline, whereupon at a re-entrainment bend consisting of a sharp downward bend in the pipeline, coal, tending to continue on in a straight line, moves out across the stream of gas thus being re-entrained in the gas stream. In case (2), where the coal is going around any curve in the pipeline tends to be thrown outward by centrifugal force and be concentrated along the outward wall the re-entrainment bend consists in an abrupt change in direction, outward of the pipeline whereupon the coal moves across the stream of gas thus being re-entrained in the gas stream.

An alternate way of describing the action of a re-entrainment bend would be: the gas following exactly an abrupt change in direction of the pipeline, either downward or outward, moves across the dense coal stream which tends to continue on in a straight line, with the result that coal and gas are mixed overcoming any separation or disentrainment caused by gravity or centrifugal force.

In charging a coke oven by pipeline the coarsely comminuted coal prior to introduction into the pipeline is preheated to incipient gasification temperature and is introduced into an oven which, of course, is above the coal gassing temperature or at coking temperature. By introducing into the coke oven the hot coarsely comminuted incipient gassing coal in this manner, essentially in a fluidized condition, the fluidized condition is maintained in the oven chamber for a period of time and disentrainment of the coal particles from the carrier gas is induced slowly, causing the fluidized mixture to flow the length of the oven. Disentrainment takes place slowly enough and uniformly enough to disperse the coal particles from the entry gas along the length of the chamber. The disentrainment, however, takes place rapidly enough to avoid the coking chamber being charged to excessive or dangerous levels, or to the extent of causing fine particles to be blown out of the far end of the oven and the fluidized state of the coal hinders elutriation of fines into the gas off-take. Tolerable levels of carry-over of fines into the gas off-take are somewhat less than 100–300 pounds per charge. Operating under the present invention, using a proper re-entrainment bend "this blow-out" or carry-over can be kept to 50 pounds per oven charge.

In the embodiment of the oven described in copending application Ser. No. 554,735, filed June 2, 1966, it is possible to arrange to feed the thus-carried-over coal dust to an adjacent oven.

In employing the pneumatic charging of the coke oven, it is important that as the gas-coal mixture passes out of the main pipeline carrying the gas-coal mixture into the branch line leading directly into the oven being charged that any excess carrier gas be bled off from the line to develop the fluidized gas-coal phase at the re-entrainment bend feeding the oven and for discharging the dense fluidized phase into the oven. This produces uniform filling of the oven to the far end thereof and avoids both (1) the piling of coal to the oven roof with consequent development of excessive pressures of 2 pounds per sq. in. or more within the oven chamber between the point where the oven is filled and the entry and (2) avoids excessive carry-over of fines into the gas off-take.

The usual preferred loading rate for an oven is of the order of 2000 pounds or more of coal per minute and the ratio of coal to steam, or carrier gas, entering the oven should generally be greater than that in the pipeline approaching the final curve into the oven.

Thus, steam is at about 5 pounds per square inch gauge just upstream of the final curve and re-entrainment bend before entering the oven. On a weight basis, the range of the weight of coal to steam entering the oven is more than 100 pounds of coal per pound of steam. The coal thus enters a very hot oven and being itself preheated, it enters with carrier gas (steam) and is itself in incipient gas-releasing condition. The combined effect of the entering gas or steam cushion keeps the coal mixture floating as it descends toward the oven bottom and commences to release gas. The total gas, including carrier and released gas, combines to keep the coal mixture floating in the oven for at least a few seconds thereby providing sufficient time to have the coal pass from the entry end to the discharge end to produce a good, relatively level fill line.

The coal pipeline approaching an oven, is of course, generally a straight line. To direct the coal into an oven, the pipeline is provided with a feed line gradually branching off for a particular oven, the branch line curving to lead the coal into the oven at one end of the oven. The line of the curve is down from the main straight pipeline then around to change direction of movement of the coal and then to incorporate a re-entrainment bend and direct the coal-gas-mixture into the individual oven.

The inlet pipe or orifice to each individual oven is set at an angle of 15–20° downward toward the oven floor. This latter inlet orifice is built into the oven and thus it is preceded by a re-entrainment bend incorporating an abrupt change of direction downward or outward just before the coal enters the oven, thereby inducing a thorough mixing of carrier gas and coal to induce a fluidized condition. The radius of the arcuate curve in taking the coal from the straight line in the horizontal pipeline approach apparatus to the oven is about 6 feet. To induce the formation of a dense phase appropriate for the fluidized condition, any excess propelling carrier gas brought to the oven by the straight pipeline is bled off from the mixture as the coal rounds the curve in its approach to the oven. In typical conditions, the mixture traveling in the straight pipeline comes at a rate of 40–150 feet per second, carrying about 40–150 pounds of coal per pound of steam. Actually, at the oven mouth itself, preferably, the ratio is about 200 pounds of coal per pound of steam.

By balancing the pressure conditions in the straight section of the pipeline coupled with the dynamic charging conditions in the curved approach to the oven and taking advantage of the momentum of the coal and the geometry of the pipeline requiring a change of direction of the travel of the coal from a line parallel to the battery to an oven perpendicular to the line, we pass the coal through the complex curve bringing it through several changes of plane so that the effective bottom of the pipeline changes position with the top several times, thereby inducing separation of coal from steam in the line, simultaneously bleeding off excess steam, so that in the curved section between the straight pipeline and the oven, concentration of coal to a dense uniform mixture with carrier gas is formed to give a coal-gas mixture in fluidized state for introduction into the oven.

In another embodiment of the invention, the flow path has a baffle member along the effective bottom thereof forming a restricted opening in the branch just prior to its exit and leading into the top of one end of the coking chamber, which baffle member and restricted opening cooperate to subject the coal particles flowing along, or which tend to settle onto, the effective bottom, to an abrupt change of direction to form a dense uniform mixture with the carrier gas, which mixture is discharged into the coking chamber.

In still another embodiment of the invention the coarsely comminuted coal particles at or settling onto or towards the effective bottom of the pipeline are subjected to an abrupt change of direction by jetting carrier gas into the effective bottom of the branch leading into the coking chamber to form a uniform dense mixture of coal and carrier gas at the exit end of the branch, i.e., at the point of entry into the coking chamber.

The preferred embodiment of this invention involving an abrupt change of direction outward or downward in the branch leading into the coking chamber finds particular application in the handling of the coarser grades of hammermilled coal employed in charging coking chambers. In general, the larger the coal particles, the more difficult it is to obtain and maintain a uniform dispersion of coal-in-gas. With grades of hammermilled coal having from 75% to 80% of the coal particles smaller than about 1/8 inch, a fairly uniform mixture of coal and carrier gas can be produced by subjecting the coal particles on or near the effective bottom of the pipeline to an abrupt change of direction by jetting carrier gas into the effective bottom of the branch leading into the coking chamber and this without introducing excessive carrier gas into the coking chamber, which excess would create excessive pressures therein and excessive carryover of fine coal into the collector main. With coarser grades of hammermilled coal, e.g., less than 75% of the coal particles being smaller than 1/8 inch, subjection of the carrier gas to an abrupt change of direction causing re-entrainment of coal particles on the effective bottom of the pipeline can best be accomplished by flowing the stream of coal and carrier gas through a path having therein an abrupt change in direction outward or downward at a point just before introduction of the mixture into the coking chamber.

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

FIG. 1 is a fragmentary front elevation of a coke oven battery showing a preferred technique for the pipeline transport of the preheated coal to the coking chambers of a battery with the branches leading into the coking chambers, each individual to a coking chamber, and with the portion of each branch containing an entrainment bend by a generally outward and downward bend in the pipe;

FIG. 2 is a fragmentary top plan of a coke over battery illustrating the arrangement of FIG. 1 in which the re-entrainment bend extends in a generally outwardly and downwardly inclined direction from the curved branch;

FIG. 3 is a fragmentary vertical section showing an end view of an oven showing a branch leading into a coking chamber as indicated in FIG. 1 incorporating a re-entrainment bend extending downwardly and outwardly from the curved branch;

FIG. 4 is a vertical section through a coking chamber showing the contour of the coal in the chamber before and after levelling when the coal is introduced in a dense phase dispersion in the carrier gas in accordance with the present invention; the contour lines are based on an actual test in a coke oven battery, the coking chambers of which are 40 feet long, 12 feet high and 1½ feet wide. The solid horizontal line labelled COAL LINE shows ideal charging and levelling;

FIG. 5 is a vertical section through a coking chamber of the same battery showing the contour of the coal in the chamber when the coal is introduced through a branch not having a re-entrainment bend therein and showing the contour of the coal before and after two successive periods of feed of the coal into the coking chamber with levelling of the coal after each such period of introduction;

FIG. 6 is a fragmentary vertical section through a modified form of branch leading into a coking chamber illustrating an alternative construction for producing a uniform dense phase of coal-carrier gas mixture in the branch leading into the coking chamber at the exit end thereof;

FIGS. 7 and 8 are analogous to FIGS. 1 and 2 and are fragmentary elevations showing pipeline branching horizontally then up, over and into the oven putting reentrainment bends in the line as it approaches the oven; and

FIG. 9 shows a horizontal branch and a horizontal re-entrainment bend.

In the description which follows, steam, the preferred carrier gas, will be, for the most part, referred to as the carrier gas. The invention, however, is not limited to steam as the carrier gas. Coke oven gas can be used under the same conditions, except that coke oven gas is not condensible as is steam. When coke oven gas is used, it passes off from the coking chambers into the collector main and mixes with the coke even gas obtained from the coking of the coal. The steam, of course, is condensed in the collector main and/or in the subsequent gas treating equipment, agumenting the gas liquor in the process.

Referring first to FIG. 1, **20** is a measuring bin, fragmentarily shown, arranged to receive preheated coarsely comminuted coal from any suitable source. Bin **20** communicates with the flared end **21** of a pipeline **23** communicating with a main or manifold **24** extending along the length of the battery at one side thereof. Branches **25** lead from manifold **24** into each coking chamber **26**; one such branch **25** is individual to each coking chamber **26**. A valve **27** controls flow of preheated coarsely comminuted coal from bin **20** to pipeline **23**.

The drawings show the present invention applied to an existing battery comprising coking chambers **26** having charging holes **28** closed by lids **29** and an uptake **31** (FIG. 4) at one end of the battery communicating with a gas collector main (not shown). In the case of new batteries, the roof **32** can be free of the charging holes **28**, i.e., solid except for the uptake opening at one end and coal charging inlet **34** at the opposite end, which can extend through the roof **32** as shown in FIG. 4 or through the side of the battery near the top of each coking chamber as shown in FIGS. 1 and 2.

In the embodiment of the invention shown in FIGS. 1 and 2, pipeline **23** and main or manifold **24** can have an inside diameter of from 4 inches to 8 inches, preferably about 6 inches. In the case of long pipelines, say exceeding 100 feet in length, turns or curves may be required. These can be in the form of horizontal or vertical bends in the long runs, approaching the ovens. In FIG. 1, curved portion **42** is typical of such bend and is in a vertical plane. Curved portion **42** can be in the form of a horizontal curve, i.e., lying in a horizontal plane as more fully described in co-pending application Ser. No. 382,609, filed July 14, 1964. This curved portion **42** is a long radius curve exceeding a 90° bend by 10–15° shown, as successive curved sections A and B, designed for efficient flow therethrough. The momentum of solid particles in the gas stream causes the particles to continue to flow longitudinally while settling, and the gas follows the contour of the bend. To overcome the settling effect, therefore, re-entrainment bends are put in the conduit to move the solids past the axis twice. The radii of curvatures of adjacent portions A and B, are diametrically opposite each other. For a 6-inch pipeline the radius of curvature is preferably about 6 feet. As the mixture of preheated coal and steam flows through the curved portion **42** it is subjected to centrifugal force in section A causing the coal particles to concentrate beyond the bend in the locality of portion **43** and forming opposite this locality at side **44** a body of steam substantially free of coal particles. A bleed-off or vent **45** in the form of a valve arranged to be actuated by a solenoid or pressure cylinder **46** is provided for bleeding off steam from the body thereof formed at **44**. By employing one or more such bleed-offs, the number depending on the length of the pipeline **23**, enough of the steam, to avoid excessive velocities in the pipeline, can be removed from the pipeline; this enables the introduction of additional steam through the subsequent steam jets, hereinafter described, in the direction of flow of the steam-coal mixture without creating excessive velocities within the pipeline **23**, the main or manifold **24** and the branches leading from the manifold **24** into the coking chamber.

Steam bleed-offs **60**, **61** and **62** are installed in curves in the piperline feeding to individual ovens to provide for forming the appropriate coal-gas-mixture.

Pipeline **23**, manifold **24** can each be provided, at a plurality of closely spaced points along their lengths, with jet plugs **47** for introducing steam. These jet plugs **47** are communicably connected with a steamline **48** through branches **49** each equipped with a valve **51**. Steamline **48** is positioned adjacent pipeline **23** and manifold **24** to supply them with steam under a pressure through the jet plugs **46**, as disclosed more fully in co-pending application Ser. No. 383,750, filed July 20, 1964. The valves **51** in branches **49** can be adjusted to furnish steam to the jet at the desired pressure or can be closed when it is desired to reduce the number of branches supplying fresh steam to the pipeline **23** or manifold **24**.

In the modification of FIG. 1, each of the branches **25** individual to each coking chamber comprises a first arcuate portion **25***a* extending down from the manifold **24**, a second portion **25***b* extending outwardly and downwardly from curved portion **25***a* and toward the oven to give the coal mixture a new direction from the first portion **25***a* and leading into a third straight discharge portion **25***c* which extends downwardly into the upper end of the coking chamber at an angle of 5 to 20 degrees to the longitudinal axis of the coking chamber. Where portions **25***a* and **25***c* join at **25***b* a re-entrainment bend is produced by the sudden downward and outward turn of the piping. The longitudinal axis of portion **25***c* is positioned relative to the longitudinal axis of portion **25***a* at an angle of from 5 to 60 degrees, preferably about 15 degrees, to form the re-entrainment bend **25***b*. When the angle between the longitudinal axis of portion **25***a* and **25***c* is 15 degrees, the carrier gas is subjected to an abrupt change of direction while the coal particles at the effective bottom of the pipe at the 15 degree re-entrainment bend are thrown into the carrier gas with formation of a uniform mixture of coal and carrier gas in the exit portion of the branch which is located just beyond the 15 degree bend. However, the 60 degree re-entrainment bend is not preferred because it tends to throw coal across to the opposite side of the pipe where it separates from the carrier gas again and thus more steam is required per unit weight of coal to obtain the desired throw of the coal charge into the coking chamber. Hence this technique is less efficient than the utilization of an angle bend of less than 60 degrees. Most efficient introduction is obtained with angle bends of from 10 to 20 degrees.

FIGS. 1, 3, and 4 show diagrammatically the action of the re-entrainment bend **25***b* to illustrate the operation using a 15° approach or inlet to the oven. The bend commencing at the manifold **24** is at the angle bringing about separation of the pipeline downwardly. It is then curved gently to the areas indicated as the re-entrainment bend **25***b* before the actual straight inlet **25***c* to the oven. It will be noted from this that as the mixture of coal and steam flows from the manifold in this generally downward direction first, then curving as shown in the diagram toward the entry of the oven, there are such changes of direction that the coal tends to be separated from the carrier gas by centrifugal force permitting bleed-off of excess carrier gas. The ultimate end mixing occurs at the re-entrainment bend **25***b* when the abrupt change in direction from the curved approach to the downwardly inclined inlet of the oven is reached. Since the curve commences at the manifold where the coal is travelling relatively rapidly, a dilute mixture of steam and coal will enter the curve. To avoid having too large a volume of steam enter the oven and also to reduce the velocity of the coal to a reasonable level for charging into the oven, steam is bled out of the pipeline as the mixture progresses around the curve. Since the radius of curvature of the curve is preferably about 6 feet for the six inch pipeline, it can be seen that there is ample space for the installation of a plurality of steam discharge or bleed valves indicated as numbers **60–61–62** in the diagram. With a plurality of bleed-off points in the bend, the dilute dispersion of coal in steam thus entering the bend being bled of steam becomes a relatively concentrated dispersion of coal particles by the time it reaches the abrupt change of direction constituting the re-entrainment bend. As the concentrated dispersion flows through the re-entrainment bend, the carrier gas and coal are subjected to this abrupt change of direction. The coal particles tend to move in a straight line and, thus, a relatively uniform dense phase dispersion enters the final phase of the entry of the oven **25***c*. This uniform dense phase which is formed in the bend reaches a fluidized condition at or just before the actual inlet of the oven and is discharged into the oven and being at incipient gassing temperature, maintains a fluidized condition for a number of seconds after entering the oven, so that the coal as it settles out manages to flow substantially evenly across the full length of the 40 feet of the oven with hindered elutriation of fines.

FIG. 3 shows the approach to the oven in idealized condition. Thus, in FIG. 3, the manifold **24** may be visualized as being above the branch of the pipe marked **25***a*. This is the portion which first separates coal-steam from that in line **24**. The first separation from the manifold leads downward to the section of the pipeline marked **25***a* wherein the pipeline takes its curve as the arc **25***a* connecting further to a straight section **25***c*, which is the direct approach to the oven. Actual physical connection with the oven inlet **25***c* is made in a bend marked **25***b*.

In the FIG. 6 modification the branch **25** has just before its discharge port **25***g* a baffle member **25***h* which slopes upward towards discharge port **25***g* to form a restricted passageway **25***i*. Baffle member **25***h* desirably covers about one-third to one-half of the interior cross-sectional extent of branch **25**. When the coal-carrier gas mixture reaches the baffle member **25***h*, the coal particles at and near the effective bottom of the pipeline are subjected to a change of direction upward into the coal-poor carrier gas stream as indicated by the reference character **25***i* (i.e., the coal particles are caused to move away from the effective bottom of the pipeline). A uniform dense phase **25***k* is thus formed which is discharged into the coking chamber and flows the full length of the coking chamber discharging its burden of coal uniformly throughout the chamber length.

The bleed-off of 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 coking chamber, i.e., results in an increase in the amount of coal relative to steam in the dense phase introduced into the coking chamber. The steam bled-off may enter the adjacent chamber, or a pair of chambers at 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 charged in the adjacent chambers.

To allow for selective oven charging, each branch **25** as shown in FIG. 1 may be provided with a valve **56** actuated by a pressure cylinder or solenoid **57**. The manifold **24** has a valve **56***a* actuated by a pressure cylinder or solenoid **57***a* for each valve **56** in each branch **25**. Thus by opening all of the valves **56***a* in the manifold **24** leading up to a given branch **25** and closing the valve **56***a* immediately following that branch and opening the valve **56** in that branch while closing the valves **56** in the other branches flow of coal-carrier gas mixture from the pipeline **23** into and through the manifold **24** and into and through the branch **25** communicating with the coking chamber to be charged can be effected. The operation of the valves **56** and **56***a* by their pressure fluid actuating cylinders **57** and **57***a*, respectively, is effected automatically from suitable control mechanism to open in timed sequence the necessary valves for effecting the charging of an empty coking chamber as herein disclosed and when the charging of that chamber has been completed closing the valves controlling the flow of coal-carrier gas mixture to the charged chamber and opening the valves which control the flow of coal-carrier gas mixture to the next empty chamber to be charged. In another modification 2-way valves are used to direct the flow of coal and gas to the desired oven chamber.

Inn FIG. 4 dotted line **60** shows the coal contour in a coking chamber 40 feet long after introduction of the coal-steam mixture in a dense phase by flow through a pipeline, the branch **25** of which had therein a re-entrainment bend having an angle of 15 degrees. In the typical run involving this re-entrainment bend the steam jets in pipeline **23** and manifold **24** were spaced 8 inches apart, steam was supplied at a pressure of 120 p.s.i.g., the pressure in bin **20** was 2.5 p.s.i.g. total conveying steam used was 513 pounds, and the average conveying rate of coal was 1.7 tons per minute. The solid line **61** shows the typical coal contour after one pass of the leveler bar through the coking chamber.

FIG. 5 is a diagrammatic representation of the charging of a coking chamber of the same size in the same battery as the chamber of FIG. 4, but in which the coal was introduced through a branch, not provided with a re-entrainment bend and not designed to subject the carrier gas to an abrupt change of direction causing re-entrainment into the carrier gas of the coal particles on the effective bottom of the branch. In the run of FIG. 5 the spacing of the steam jets in the pipeline **23** and manifold **24** were the same as in the run of FIG. 4, namely, 8 inches apart; the pressure in bin **20** was 3.3 p.s.i.g. In order to introduce the charge it was found necessary to use substantially more conveying steam than in the run of FIG. 4. In the run of FIG. 5, 1113 pounds of conveying steam was used and the average conveying rate of coal was 0.7 ton per minute.

Dotted line **62** on FIG. 5 shows the coal contour after the first pipeline introduction of coal into the chamber; this first period was of 14.5 minutes duration. It will be noted from FIG. 5 that the pile of coal thus introduced reached the top of the coking chamber at the right-hand end, viewing FIG. 5, necessitating interruption of the introduction of the coal-steam mixture and levelling of the pile of coal within the chamber in order to enable the introduction of a further quantity of coal into the chamber. Solid line **63** shows the coal contour after levelling after this first pipeline introduction of coal into the chamber. Immediately after this first levelling the coal-steam mixture was again introduced into this chamber for two minutes, at the end of which time the coal contour in the chamber was as represented by the dotted line **64**. It will be noted that a pile of coal was again formed extending to the top of the chamber at the right-hand end thereof where the coal-steam mixture was introduced interfering with the further introduction of the coal-steam mixture into the chamber. This pile was again levelled and solid line **65** shows the coal contour after this second levelling. It will be noted that the far end of the oven was not adequately charged; the oven was filled to 78.8% of coal-line full in 16.5 minutes involving two charging periods, the first of 14.5 minutes and the second of two minutes with an intermediate levelling of a 0.5 minute duration.

The comparison between FIGS. 4 and 5 demonstrates unexpected and marked improvement effected by causing an abrupt change of direction to effectively disperse the coal particles on the effective bottom of the pipeline caused to flow into the carrier gas and thus form a uniform phase of coal-carrier mixture which is introduced into the cokink chamber being charged.

It will be noted that the present invention provides a process for charging the coking chambers of a coke oven battery involving the pipeline transport of the preheated coarsely comminuted coal into the coking chambers and the substantially uniform distribution of the coal charge within the coking chambers without segregation of the different particle sizes of coal. Such charging is accomplished by pipeline transport of the hot coarsely comminuted coal particles dispersed in the carrier gas and subjecting the carrier gas to an abrupt change of direction causing the coal particles on the effective bottom of the pipeline branch leading into the coking chamber to effectively disperse within the carrier gas and form a uniform dense phase of coal-carrier gas mixture which is introduced into the coking chamber being charged. The result of this action is that in the coke oven disentrainment of the coal particles from the carrier gas takes place positively yet slowly enough to permit complete and uniform disentrainment of the coal from the carrier gas while avoiding pressure build-up in the coking chamber to excessive levels.

In recapitulation, it should be noted that the operation of the pipeline for charging coal to the coke ovens involves rapid accomplishment of a sequence of steps and unless the variables are properly balanced, it can lead to complications. In accordance with the invention, advantage is taken of the fact that the coal is coarsely comminuted and heated to incipient gasification temperature. Thus, it moves from the bin **20** into pipeline **23**, being carried as a relatively dilute mixture of coal and steam as it is accelerated around the bend. The first bend shown in FIG. 1 indicated as **42**, will generally be in a vertical plane to swing the coal-gas mixture into the horizontal pipeline **24**. In accomplishing this change of direction, advantage is taken of the centrifugal force developed in the coal as it passes around the bend to re-entrain and mix it generally in the gas stream. Visually, it is easy to see that the centrifugal force would tend to cause the ground coal to accumulate in the bottom of the bend. For this reason we make the bend somewhat larger than 90°, generally finding 100–110° a very useful curvature. This is shown at area B where there is essentially a first re-entrainment or mixing bend in the pipeline. Separation of coal-gas mixture for entry into an oven is accomplished at individual branches by appropriate valve control. Here, the separation must be first from the main stream of the pipeline and having slightly altered the direction of flow of the coal, re-entrainment is likely to become desirable. In the preferred version shown in FIG. 1, the first separation therefore takes advantage of the natural direction of separation of the mixture, namely the fact that it would be settling downwardly. Hence the branch is directed downward at a small angle and, again, in directing the coal, which is still moving generally in the direction of pipeline **24** into the oven, it is necessary to alter the direction of flow by 90°, because the ovens are generally perpendicular to pipeline **24**. The bend accomplishing the change of direction of the coal movement into alignment with the oven is again preferably a 100° bend having a form of curvature closely approximating that shown at **42**. This brings the coal to a point where it is travelling in the direction desired and has been, once again, re-entrained in the gas mixture. Also, immediately prior to entry into the oven, an abrupt change of direction dropping the coal from more nearly horizontal approach to an approach toward the bottom of the oven at an angle about 10–15° is accomplished to develop another re-entrainment immediately prior to the entry into the oven. The re-entrainment device illustrated in FIG. 6 constitutes essentially a baffle in the bottom of the pipeline immediately prior to entry into the oven and is optional, but quite useful and very simple to install.

FIG. 7 illustrates an alternative structure for feeding coal into the oven, taking advantage again of separating the coal from the main stream, changing its direction of flow to 90° to the main stream and then directing it downward into the oven with a re-entrainment bend immediately prior to entry. Thus, in the figure, **70** represents the main line carrying the coal from a hopper such as **20** as shown in FIG. 1 and in this instance the first separation of coal in the main stream is in a horizontal section 71 which is then curved upward at bend 72 to point 73, after completing its 100° turn, where it is then turned horizontally toward the oven at 74, where it is bent downwardly to approach the oven, and at 75 where there is a re-entrainment bend. Geometrically, the separation accomplished in this manner is quite as effective as that shown in FIGS. 1 and 2 in that the coal is first separated from the main stream and brought through the wide bend re-entraining it and changing its direction and then finally directing it into the oven. In the same manner as explained in connection with FIGS. 1, 2 and 3, steam discharge outlets can be provided for removing steam from the coal-steam mixture prior to the oven entrances and also the valves are similarly placed to permit the selective flow of the coal-gas mixture into the empty oven which is to be charged.

Thus, in the process involved in practicing the instant invention, it should be noted that a fluidized bed of coal is the objective sought immediately upon discharge of the coarsely comminuted coal and steam into the oven to give the coal a time lag interval in which it can flow from one end of the oven to the other and level itself into an approximately level bed before cohering in the first stage of coking.

A fluidized bed is one in which the upward velocity of an individual particle in the bed may be as much as 3–6 feet per second. This is characterized by observation of a fluidized bed wherein the entire material appears to be at rest, but random puffs appear in the surface representing this upward velocity. Fluidized conditions are not maintained in the pipeline used in this invention to move coal. Here, the purpose is to move the coal as rapidly as is consistent with charging of the oven. Thus, a very dilute mixture of comminuted coal and steam is forced through the pipeline at a high rate of speed and converted to fluidized coal-gas ratio just prior to entry to the oven.

The density of solid coal may be taken as an average of 88 pounds per cubic foot. It may be considered to be fluidized when it is being mixed with gas to give a bulk density of about 10–30 pounds per cubic foot. In this fluidized condition there are several hundred pounds of coal per pound of steam. In our pipeline operation, we generally move 60 pounds of coal per pound of gas or steam, or maintain a ratio approximately of that level. Thus, a very considerable amount of steam must be bled off at the curve just before the final re-entrainment bend in order to arrive at a final bulk density of about 10–30 pounds per cubic foot on entering the oven.

The location of the bleed valve in the curve or the locations of the bleed valves in the curves are preferably in the final third of the curve which feeds the oven, on the side of the pipe away from the bottom in which centrifugal force has caused the coal to settle.

While preferred embodiments have been disclosed herein and illustrated in the drawings, it will be understood that 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. For example, the entire quantity of carrier gas needed for transport of the preheated coarsely comminuted coal to each coking chamber can be supplied to the measuring bin or at the inlet end of the pipeline.

What is claimed is:

1. In a method of charging the coking chambers of a coke oven battery with hot coarsely comminuted coal particles through a pipeline, which method comprises, feeding a stream of a dispersion of hot coarsely comminuted coal particles in a carrier gas first through a main pipeline wherein the weight ratio of coal to carrier gas is between 20 to 150:1, passing said coal-carrier gas dispersion into a substantially-horizontal arcuate chamber-charging branch off pipeline communicating at its inlet end with said main pipeline and at its distal end with a charging inlet located at the upper end of the coking chamber to be charged, said branch off pipeline of a length such that at least some of the coal particles settle out toward the effective bottom of said pipeline, venting the coal-carrier gas dispersion in said branch off pipeline approaching the coking chamber to be charged to release excess carrier gas before entry of said dispersion into said charging inlet and feeding the coal particles dispersed in the carrier gas into the coking chamber through said charging inlet; the improvement which comprises re-entraining the coal particles which settle out towards the effective bottom of said coal-carrier gas stream in said branch off pipeline by subjecting said coal-carrier gas stream at the distal end of said branch off pipeline and at the point of entry just prior to introduction of the dispersion into the charging inlet of the coke oven to a change in flow of direction of the coal particles sufficient to cause the coal particles on the effective bottom of the branch off pipeline to be uniformly dispersed within the carrier gas to produce a uniformly dense phase fluidized dispersion of said coal in the said carrier gas having a weight ratio of coal to carrier gas of 40 to 500:1 and feeding said uniformly dense dispersion through said charging inlet into the coking chamber at a velocity of from 10 to 200 feet per second, wherein the particles flow substantially the full length of the coking chamber before significant disentrainment of the coal particles from the carrier gas takes place, and gas release from hot coal deposited in said oven maintains fluidized condition of carrier gas, whereby the coking chamber is charged throughout substantially its full length at substantially the same rate and without substantial carry-over of solids beyond the oven chamber.

2. The method of claim 1 wherein the weight ratio of preheated coal to carrier gas at the point of discharge into the coking chamber is about 200:1.

3. The method of claim 1 wherein the carrier gas is selected from the group consisting of steam and coke oven gas.

4. The method of claim 1 wherein the dispersion after re-entrainment is uniformly distributed throughout the entire cross-sectional area of the stream entering the coking chamber.

5. The method of claim 1 wherein re-entrainment of the coal in the carrier gas is effected by a baffle member positioned along the effective bottom of the distal end of the branch off pipeline.

6. The method of claim 1 wherein the coal particles at the distal end of the branch off pipeline are subjected to a change in flow of direction to an angle of from 5 to less than 60 degrees on the longitudinal axis of the charging inlet relative to the longitudinal axis of the distal end of branch off pipeline.

7. The method of claim 6 wherein re-entrainment of the coal in the carrier gas is effected by a downward change of about 10 to 20 degrees in the direction of flow of the coal-carrier gas stream in the distal end of the branch off pipeline.

8. The method of claim 6 wherein re-entrainment of the coal in the carrier gas is effected by an outward change of about 10 to 20 degrees in the direction of flow of the coal-carrier gas stream in the distal end of the branch off pipeline.

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