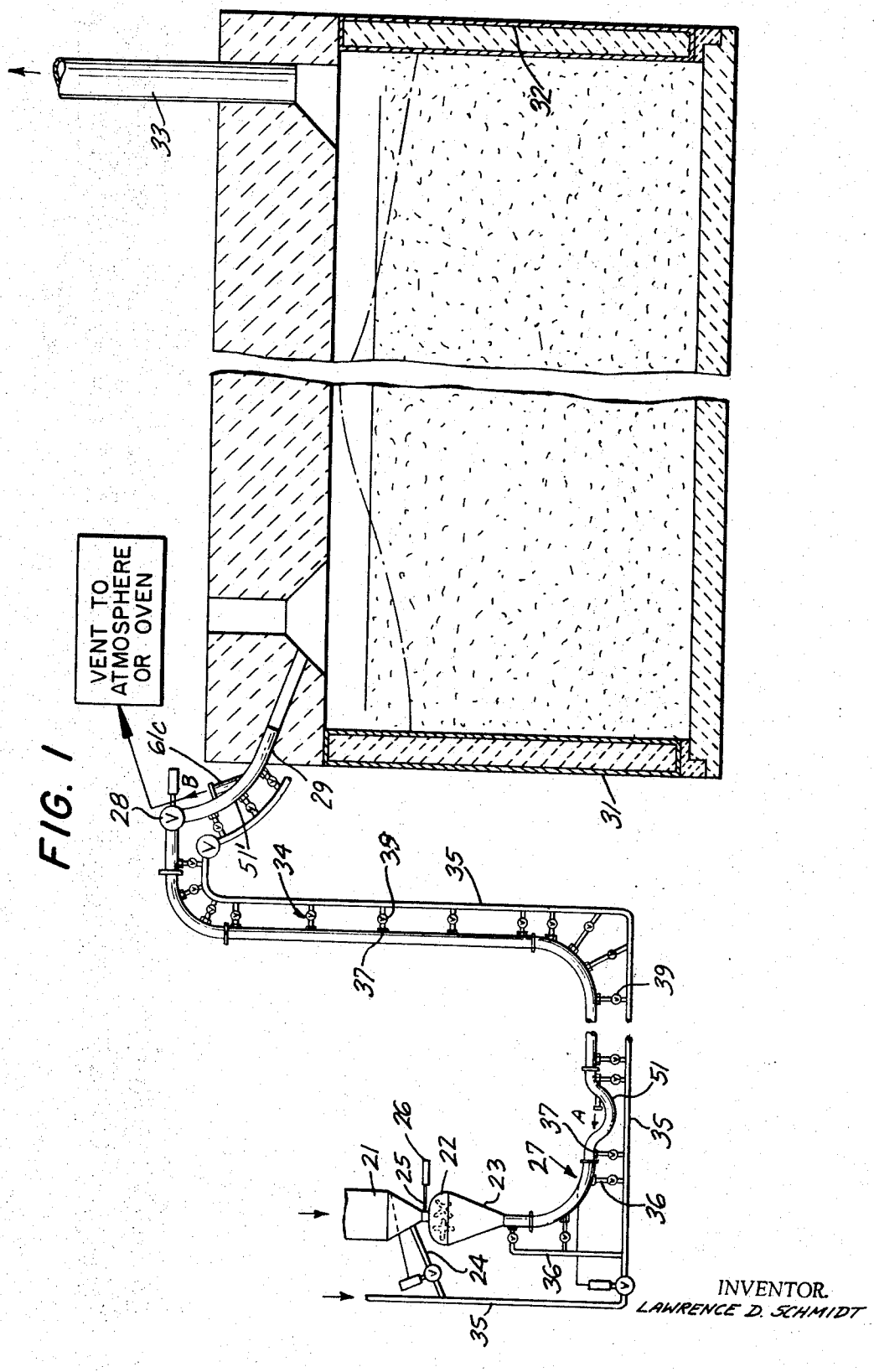
Nov. 3, 1970 L. D. SCHMIDT 3,537,755

CHARGING COKE OVEN WITH HOT COARSELY COMMINUTED COAL

Original Filed July 14, 1964 5 Sheets-Sheet 1

FIG. 1



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CHARGING COKE OVEN WITH HOT COARSELY COMMINUTED COAL

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FIG. 2

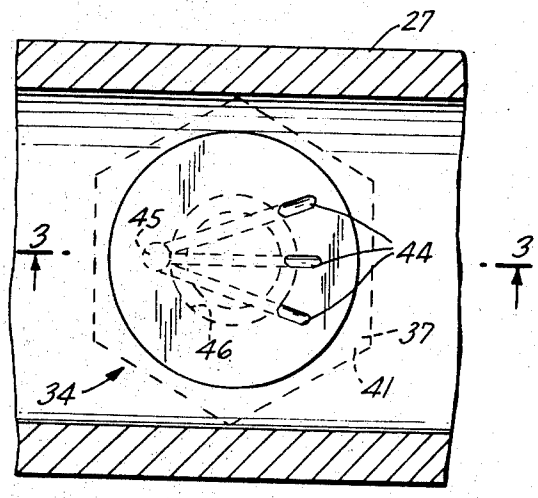


FIG. 3

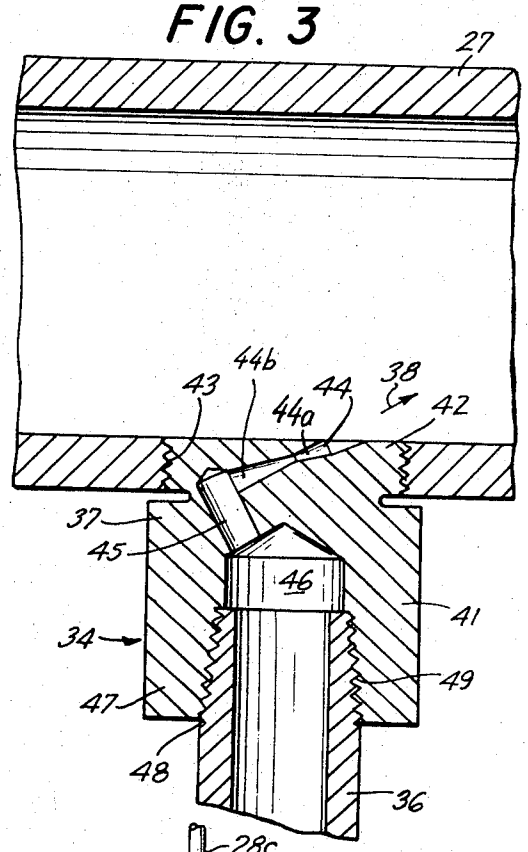
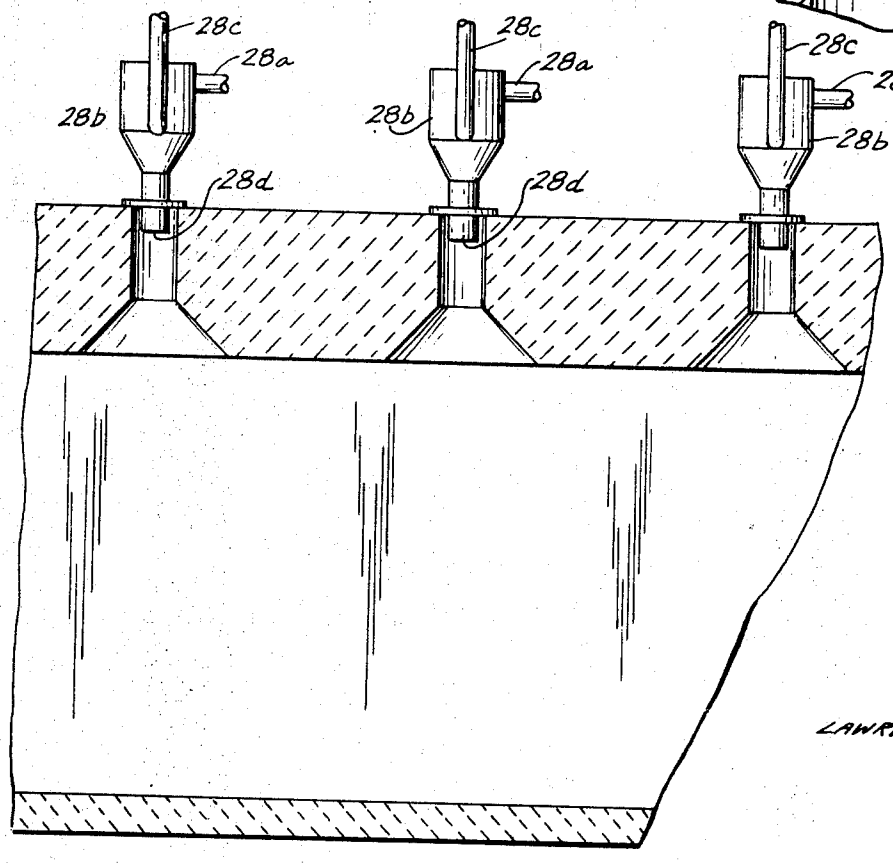


FIG. 9



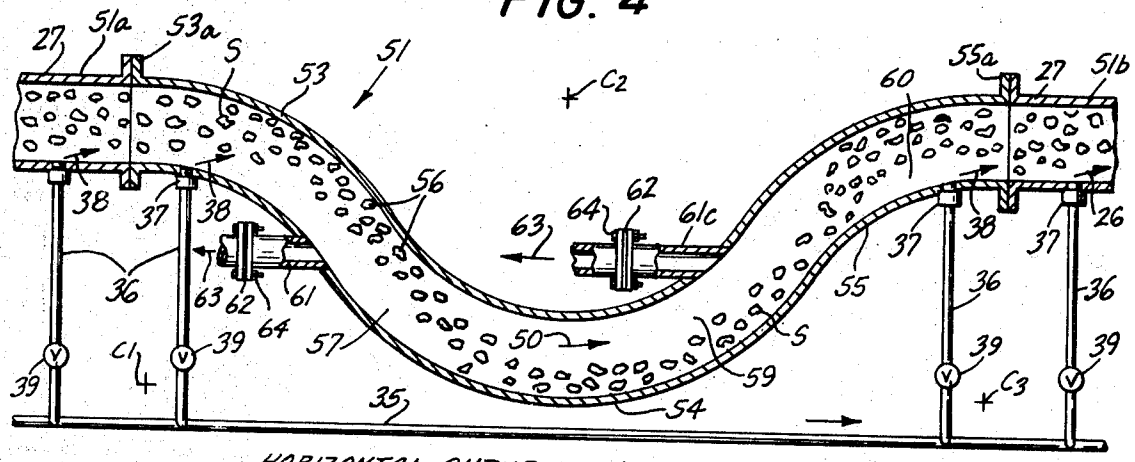
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Nov. 3, 1970 L. D. SCHMIDT 3,537,755

CHARGING COKE OVEN WITH HOT COARSELY COMMINUTED COAL

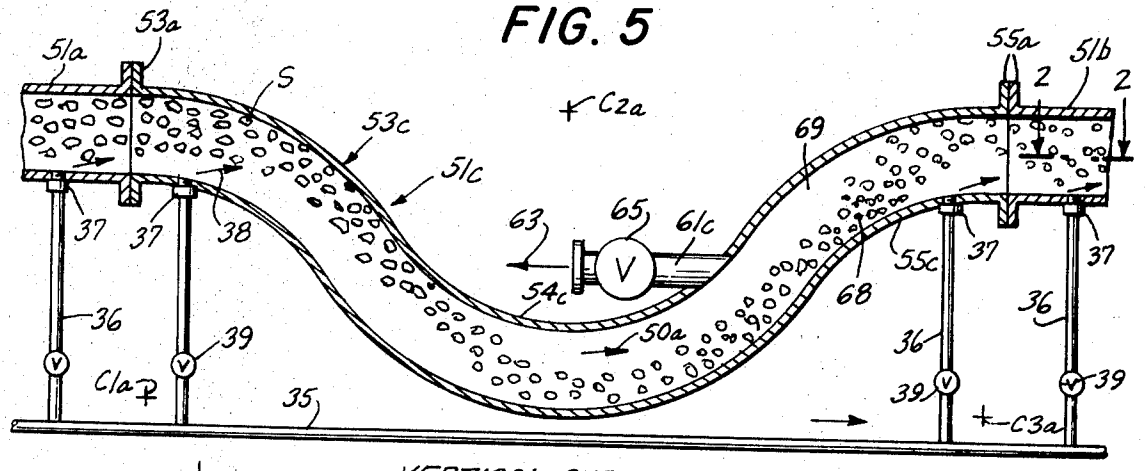
Original Filed July 14, 1964 5 Sheets-Sheet 3

FIG. 4



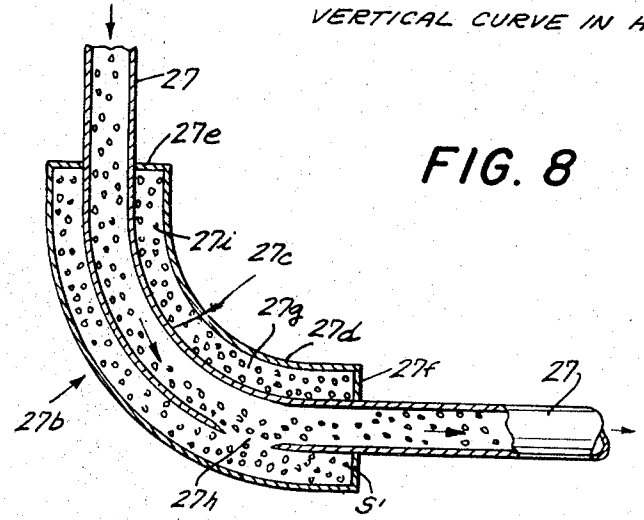
HORIZONTAL CURVE IN HORIZONTAL RUN

FIG. 5



VERTICAL CURVE IN HORIZONTAL RUN

FIG. 8



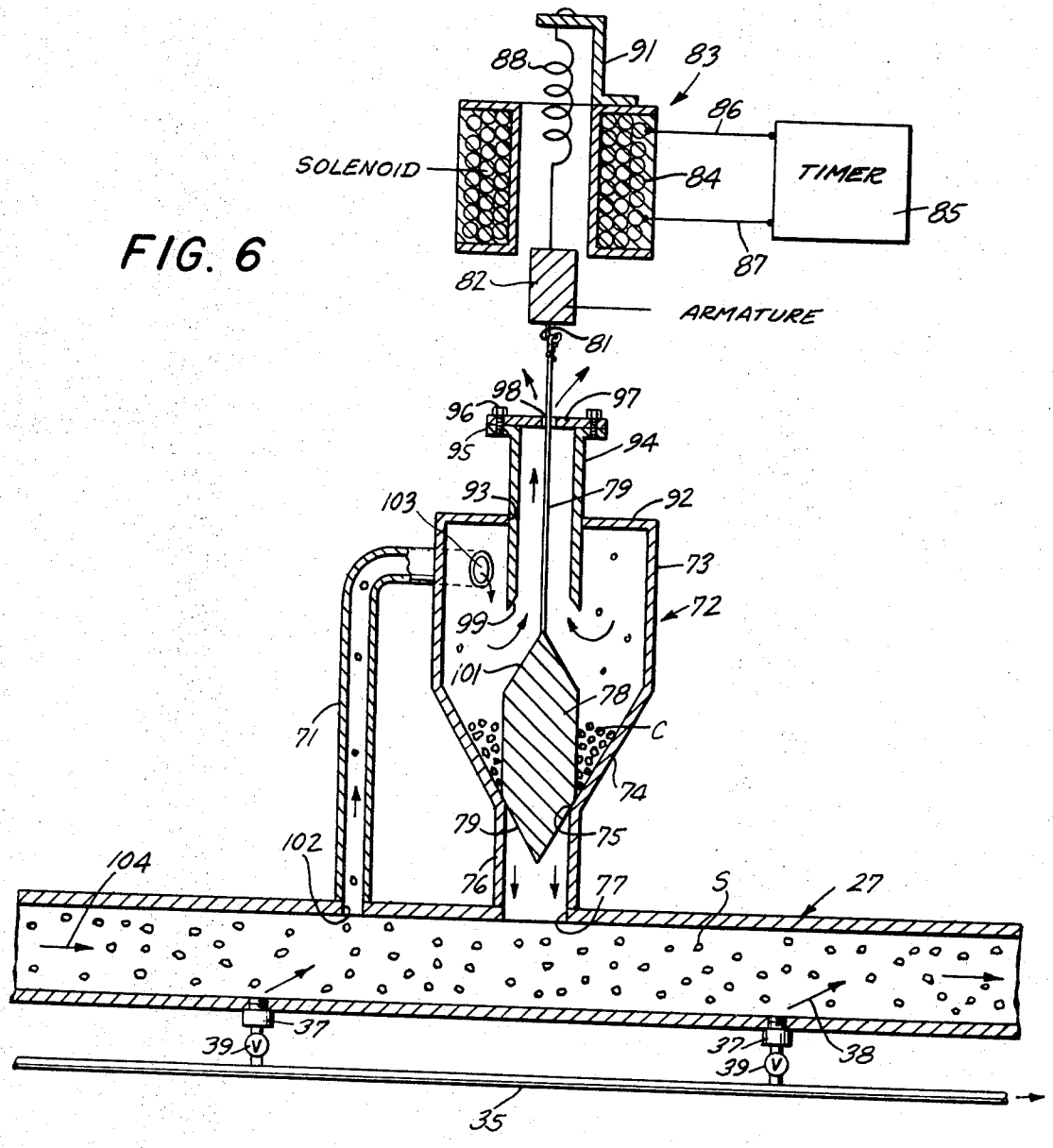
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CHARGING COKE OVEN WITH HOT COARSELY COMMINUTED COAL

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FIG. 6



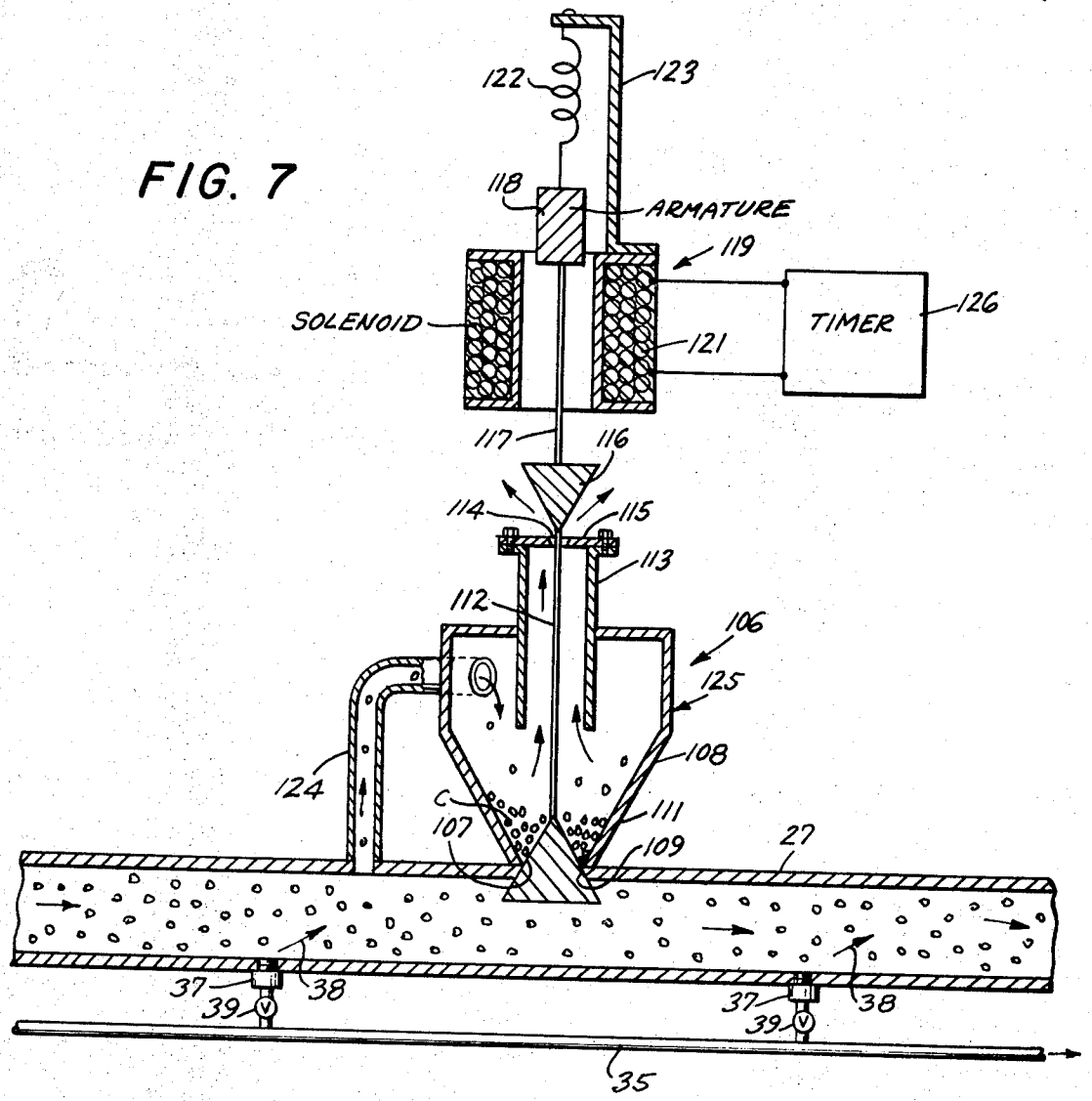
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FIG. 7



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United States Patent Office

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3,537,755

CHARGING COKE OVEN WITH HOT COARSELY COMMINUTED COAL

Lawrence D. Schmidt, New York, N.Y., assignor to Allied Chemical Corporation, New York, N.Y., a corporation of New York

Original application July 14, 1964, Ser. No. 382,609. Divided and this application Sept. 30, 1968, Ser. No. 785,414

Int. Cl. B65g 53/04

U.S. Cl. 302—24 11 Claims

ABSTRACT OF THE DISCLOSURE

A method of charging coking chambers or coke oven battery with hot coarsely comminuted coal particles, the particles being introduced into the chamber through a pipeline through which they are carried by a carrier gas under super-atmospheric pressure, the gas being the means for inducing flow of the hot coal through the pipeline, the pressure being controlled carefully to maintain a certain coal-to-carrier-gas weight ratio and venting the line at least once before the oven, so that the oven feels a charge which has a high coal-to-carrier-gas weight ratio, which is brought to the oven at a relatively low pressure.

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a division of application Ser. No. 382,609, filed July 14, 1964, now Pat. No. 3,432,398.

The advantages of charging the coking chambers with coal preheated to a temperature such that the coal is completely dried and below the temperature at which the coal is in a plastic state has long 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. 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. 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 about 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.

It has been proposed to preheat the coal in the 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 (U.S. 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 particle size such that it can be transported in fluidized condition, with the expense involved in so doing. The coking of coal particles fine enough to be readily transported in fluidized condition results in coke of poor quality, unsatisfactory for many metallurgical uses.

Transport of the hot coal with a carrier gas under pressure has the serious objection that as the mixture of coal particles and the gas travels along the pipeline, the pressure within the pipeline continually decreases and the gas expands with the attainment of increasing velocities. In other words, the rapid increase in specific volume of the expanding gaseous mixture is accompanied by a correspondingly rapid increase in velocity in accordance with the mass continuity equation. Bearing in mind the length of a battery, it will be appreciated that relatively long pipelines are necessary to supply the preheated coal to all of the coking chambers of the battery. Excessively high velocities produce excessive friction losses with consequent lower efficiencies. It is known that friction and abrasion in a solid transport system varies proportionately to the cube of the velocity of the solid; hence a velocity should be used as low as is compatible with the smooth transport of the coal, in order to reduce wear on the pipeline. Moreover, employing known pneumatic conveyance and with the relatively high velocity of the carrier gas required for transport of the solids through a long pipeline, the solids to gas ratio at the exit end of the pipeline is relatively low. The charging of coking chambers with such low coal to gas ratio presents several problems, e.g., the difficulties involved in effecting disentrainment of the coal from the carrier gas in the coking chamber being charged and the prevention of excessive carryover of coal particles into the collector main.

Pulsating discharges of air at intervals along the length of a pipeline to advance solid material progressively from one zone to the next in a wave-like manner has been disclosed (U.S. Pat. 1,465,269). This transport procedure cannot be used for the transport of preheated coal because the coal would be oxidized destroying its coking properties. The flow of air into the hot coking chamber with the coal would result in combustion of the coal. Furthermore, such transport procedures cannot be used for relatively long distances such as are necessary in coke oven battery installations, and this even though an inert gas were used instead of air because the velocities of the stream would soon increase to a level rendering such procedure objectionable. Moreover, due to the periodic introduction along the length of the pipeline of inert gas under pressure, the coal to gas weight ratio would progressively fall along the length of the pipeline so that at the exit end thereof relatively low coal to gas weight ratio results, with the serious and thus far insolvable problems hereinabove noted in the charging of coking chambers with low coal to gas weight ratios.

Preheated coal by reason of its dry hot condition has substantially different properties from the standpoint of its handling and conveyance than the original wet coal from which it is produced and which wet coat is ordinarily charged into the coking chambers of a coke oven battery. Such preheated coal has a substantially reduced angle of repose and tends to disperse or "float" when flowed through

conveying systems and particularly when introduced into a confined space such as coking chamber at rates necessary in effecting the charging of a coking chamber. This tendency to disperse or "float" is accentuated by the property of the dry hot coal particles not to tend to adhere to each other as do the particles of wet coal normally employed for charging the coking chambers of a coke oven battery. This tendency of the hot coal produces conditions detrimental to efficient charging of coking chambers when attempts are made to charge preheated coal into the coking chambers by heretofore known methods. Thus when preheated coal is introduced into the charging holes of a coking chamber from the chutes of a larry car, the hot coal entering the hot coking chamber entrains air which reacts with the coal and the volatile matter evolved from the coal to form fires and explosions resulting in damage to the coking chambers, to the larry car and hazards to operating personnel.

When attempts are made to transport the coal of size desirable for coking, by a pneumatic conveying system from the preheater to the ovens, the amount of carrier gas required to effect movement of the coal over the distances involved, except possibly to the coking chambers immediately adjacent the preheater, is such that the introduction of the hot coal and carrier gas mixture into the coking chamber produces the undesired conditions and problems noted above. Moreover, these undesired conditions and problems become accentuated as the distance from the preheater to the coking chamber being charged, or the length of the pneumatic conveying line, becomes longer, e.g., in the case of relatively large batteries or where more than one battery is supplied with preheated coal from one locality.

It is a primary object of the present invention to provide a novel procedure of conveying coarsely comminuted preheated coal particles from a preheater to the coking chambers of a coke oven battery, which procedure results in the feed of a hot coal carrier gas stream having a relatively high coal to carrier gas weight ratio when introduced into the coking chamber and otherwise overcomes the difficulties and problems hereinabove noted.

Another object of this invention is to provide a novel pipeline construction for effecting such conveyance of preheated coal particles of a particle size conventionally used for charging the coking chambers of a battery, referred to herein as "coarsely comminuted coal particles."

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

In accordance with this invention, a carrier gas under superatmospheric pressure is employed to effect feed of preheated coarsely comminuted coal particles through a pipeline to the coking chambers of a battery, and at one or more points along the length of the pipeline and desirably at or just before the mixture of hot coal and carrier gas is discharged from this pipeline into each coking chamber, excess carrier gas is bled off or vented from the pipeline to produce at the exit end of the pipeline a hot coal carrier gas mixture at a relatively low pressure and having a relatively high coal to carrier gas weight ratio. The carrier gas can be superheated steam or coke oven gas; superheated steam is preferred. This relatively low pressure stream of hot coal and carrier gas having such relatively high coal to carrier gas weight ratio is introduced into each coking chamber to be charged to effect the charging thereof.

Since the weight ratio of preheated coal particles and carrier gas in the stream charged into the coking chambers is kept high and at an optimum level for facilitating the disentrainment of the coal from the gas in the coking chamber, ready separation of the coal from the gas in the coking chamber takes place. Moreover, the steam or coke oven gas employed as the carrier gas introduced into the coking chamber exits into the collector main. The steam condenses in the collector main, adding to the water

therein. In the case of coke oven gas, it mixes with the coke oven gas in the collector main. Thus the use of superheated steam or coke oven gas does not complicate the operation of the coke oven battery; in fact, it improves the operation, giving clean smoke-free charging, preventing the oxidation of the coal and minimizing charging difficulties.

In a preferred embodiment of the present invention, when employed for the transport of 1 to 3 tons per minute of hammer-milled preheated coal through a pipeline of six-inch diameter, the coal being unscreened and having a maximum particle size of about one inch, the hot coarsely comminuted coal particles and superheated steam are introduced into the upstream end of the pipeline. The superheated steam is supplied from a steam line at a pressure of from 25 to 600 p.s.i.g., preferably 250 to 350 p.s.i.g. The steam is introduced from this steam line through one or more steam jets and the steam expands upon introduction into the pipeline so that it has a velocity of at least sonic, preferably supersonic, at the point of introduction into the pipeline, i.e., as it leaves the steam jets. The pressure within the pipeline at the upstream end thereof is from 4 to 50 p.s.i.g. and the velocity of the steam, preheated coal mixture is from 10 to 200 feet per second. Jets for introducing additional superheated steam are positioned in the bottom of the pipeline to produce jets of steam at an angle of from five 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. 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 preferably of 6 feet or more and at the bottom on straight horizontal runs, the spacing of these jets is from 6 inches to 36 inches apart, preferably 12 inches to 18 inches apart. The closer the spacing of the jets, (a) the less pressure required entering the pipeline, (b) the less velocity required for smooth transport, (c) higher coal-steam weight ratios can be attained, and (d) higher rates of coal flow can be attained. 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. The closer the spacing the less the pressure drop per unit length of pipe at a given rate of coal flow.

In accordance with this invention 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 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 the body thereof substantially free of coal particles formed by subjecting the mixture to centrifugal force or from the side stream passed through the cyclone separator in this modification of this invention. Where a side stream is removed coal particles carried thereby are returned to the pipeline.

The venting of the stream 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 effect the propulsion of the coal particles through the pipeline and this without excessive buildup of velocity of mixtures of coal and superheated steam in the pipeline and with the delivery of the mixture to the coking chamber at a high solids to steam weight ratio and at a relatively low pressure not exceeding about 2 p.s.i.g. 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 and the quantity of steam jetted thereinto. 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 6 inches employing steam as the carrier gas supplied to the jets under a pressure of 25 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 the absolute pressure in the pipeline.

At least one venting unit should be positioned at the point near the discharge into the coking chamber. The branches leading from the main pipeline, each branch being individual to a coking chamber, may each 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 two or more adjacent coking chambers. Thus is created a high weight ratio (20 to 500) of preheated coal particles to steam with consequent desired low pressure not exceeding about 2 p.s.i.g. in the mixture which is discharged into the coking chamber. This high weight ratio greatly facilitates disentrainment of the coal particles from the steam within the coking chamber and hence minimizes carry-over of coal into the gas off-take.

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 steam 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 80 to 1. At the point of discharge into the coking chamber this weight ratio can be 20 to 500 to 1, preferably 80 to 1. Where the coal particles are of smaller size a higher weight ratio of coal particles to steam can be employed.

Coke oven gas when used as the carrier gas can be introduced in the same manner as the steam into the pipeline, as herein disclosed, and also vented in the same manner except that coke oven gas, unlike steam, cannot be condensed and the coke oven gas is desirably vented into a coking chamber other than the one being charged from which it flows into the collector main. Since superheated steam is the preferred carrier gas, the description which follows, for the most part, will be limited to steam. It will be understood, however, that the invention is not limited to the use of steam as the carrier gas.

Other objects and advantages of the present invention will become apparent as the detailed description proceeds in connection with the accompanying drawings, wherein:

FIG. 1 is a diagrammatic elevational view, partly in section, showing one embodiment of the invention employed for the charging of the coking chambers of a coke oven battery;

FIG. 2 is a fragmentary sectional view through a pipeline taken in a plane and in the direction indicated by 2—2 on FIG. 5, showing one of the jet nozzles;

FIG. 3 is a fragmentary sectional view taken in a plane passing through line 3—3 on FIG. 2;

FIG. 4 is a fragmentary sectional view showing a horizontal curve in a horizontal run of a pipeline embodying a preferred form of the present invention in which a curvilinear section of the pipeline applies centrifugal force to the mixture flowing therethrough and thus effects separation of the coal particles from the steam;

FIG. 5 is a fragmentary sectional view showing a vertical curve in a horizontal run of a pipeline, i.e., a curve disposed in a vertical plane rather than in a horizontal plane as in the case of FIG. 4;

FIG. 6 is a vertical section through a modified form of bleed-off device of the invention involving a cyclone separator construction for effecting separation of coal particles from the steam in a side stream removed from the pipeline and flowing therefrom into the separator;

FIG. 7 is a vertical section showing still another modified form of the invention utilizing a cyclone separator for effecting separation of the coal particles from the steam;

FIG. 8 is a vertical section through a bend or elbow of the pipeline showing a preferred construction minimizing, if not completely avoiding, the effect of wear of the pipeline walls at the bends which are subjected to maximum erosion conditions by the solid particles in the mixture flowing therethrough; and

FIG. 9 shows another embodiment of the invention in which cyclone separators are used to bleed off steam at points of entry of coal into the usual charging holes of a coking chamber.

The drawings have been made not to scale in order to better illustrate the structure and principles of the present invention. The dimensions of the parts, it will be understood, will depend on the desired capacity of a given installation and can be varied as desired.

Referring first to FIG. 1 of the drawings, **21** is a pressurized bin of the type disclosed, for example, in applicant's co-pending application Ser. No. 282,351 filed May 22, 1963. Bin **21** receives dried preheated hammer-milled coal particles for feed to a crusher **22** in an accelerator chamber **23**. To facilitate flow of the coal particles from bin **21** to chamber **23** steam is introduced through line **24** into bin **21**. Flow of coal from bin **21** to the accelerator chamber **23** is controlled by a gate valve **25** operated by a pressure fluid cylinder **26**. It will be understood that the source of coal particles shown in FIG. 1 for the pipeline **27** represents one convenient and preferred source. Coarsely comminuated coal particles can be supplied to the pipeline **27** from any suitable source.

In the embodiment of the invention in FIG. 1, pipeline **27** has an inside diameter of from 4 inches to 8 inches, preferably about 6 inches, and leads from the exit end of the accelerator chamber **23** to a main **28** which extends along the length of the battery. Main **28** has individual to each coking chamber a discharge conduit **29** leading into that coking chamber, preferably at an angle less than about 23 degrees to the horizontal, so that the coal mixture is dicharged near one end of the coking chamber and flows therefrom as disentrainment from the steam takes place towards the opposite end of the coking chamber. As customary, the coking chamber, a section through one of which is shown in FIG. 1, are each provided with doors **31**, **32** at the opposite ends and an uptake pipe or gas offtake **33** at the end remote from the coal discharge conduit **29**. One of the doors **31** or **32** as customary can be provided with a levelling door for the levelling door opening through which the levelling ram is reciprocated to level the charge in the coking chamber. The present invention, however, lends itself to operations in which the charge is self-levelling, the superheated steam mixture introduced having substantially the flow characteristics of a liquid so that a relatively uniform charge of coal is produced during the disentrainment of the solid coal particles from the steam, which charge does not require levelling. It will be appreciated that the invention includes the transport of the coal-steam mixture into the coking chambers both with and without subsequent levelling of the charge with a conventional levelling bar.

Pipeline **27** is provided at closely spaced points along its length, as hereinabove described, with jets **34** for introducing steam, preferably superheated steam. These jets are supplied with steam from a steam line **35** running

parallel to the pipeline **27**. Extending from steam line **35** at spaced points therealong are a plurality of branches **36** each leading to a jet nozzle **37** which injects the steam into the coal-steam mixture flowing through the pipeline **27**. The steam is jetted in the direction of flow entering at sonic or supersonic velocities and imparting an impulse or velocity to the flowing mixture. The direction of the injected jets of steam is indicated by the arrow **38** (FIG. 3). Branches **36** can be provided with valves **39** which can be adjusted to give the desired velocity of flow into the pipeline or can be closed when it is desired to reduce the number of branches **36** supplying fresh steam to the pipeline.

A preferred form of jet nozzle **37** is shown in FIGS. 2 and 3 and comprises a hexagonal plug **41** having a threaded end **42** in threaded engagement within a bore **43** in the wall of th epipeline **27**. The top of threaded end **42** lies flush with the inner wall of the pipeline to provide a smooth interior where the jets enter the pipeline, free of obstructions to the flow of the steam-coal mixture and also free of pockets or "dead spaces." Plug **41** has a group of radiating nozzles **44**, each of venturi shape having a divergent or exit portion **44***a*, the included angle formed by the walls of which is between 5° and 7° and having an entrance portion **44***b* that is effectively convergent. In the embodiment shown in FIG. 2 each plug **41** has three such nozzles communicating with a common passage **45** leading into a central bore **46** in plug **41**. Preferably each nozzle **37** delivers a jet stream of steam at an angle of about 5° to 20° 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 horizontal pipeline, at an angle of about 5° to 20° with respect to the horizontal. The end **47** of each plug **41** is threaded at **48** to receive the threaded end **49** of a branch **36** leading from steam line **35**. This arrangement provides fan-like jets of gas imparting velocity or impulses to the flowing coal-steam mixture in the direction of flow indicated by the arrows **50** (FIG. 4).

In the embodiment of the invention show in FIG. 1, pipeline **27** is provided at one point along its length, indicated at A, with a curved portion **51** for subjecting the mixture of superheated steam and preheated coal particles flowing therethrough to centrifugal force. Each discharge conduit **29** is shaped to contain a curved portion **51'**.

In FIG. 1, portion **51** is a skew curve; it need not be in a single plane. In FIG. 5 the curvilinear portion **51** is disposed in a plane which can be tilted in any direction but is vertical as shown; FIG. 4 shows a curve arranged in a horizontal plane, but can be in any desired plane. The curvilinear portions can be skew curves not in a single plane and still operate in the same way.

Referring to FIG. 4, curvilinear portion **51** comprises a first curved section **53** having a center of curvature at C1 and leading into and smoothly continuous with a second curved section **54** having a center of curvature at C2. Section **54** leads into and is smoothly continuous with a third curved section **55** having a center of curvature at C3. The radii of curvature of adjacent sections **53** and **54**, and **54** and **55** are diametrically opposite each other, i.e., the center of curvature C1 is on one side of the pipeline, C2 on the opposite side and C3 on the same side of the pipeline as C1. For a 6" pipeline for transporting hammer-milled coal, the radius of curvature can be from 1 to 9 feet, preferably about 6 feet.

The successive curved sections **53**, **54** and **55** are designed for streamline flow therethrough; section **53** is connected with its section of the pipeline through a suitable flanged coupling **53***a* for streamline flow thereinto from the pipeline. Similarly section **55** is connected through a flanged coupling **55***a* with the pipeline for streamline flow from section **55** into the pipeline section contiguous thereto.

As the mixture of preheated coal and superheated steam flows through the first curved section **53** having the center of curvature C1, the coal particles S are propelled by centrifugal force in a radially outward (outward relative to the center of curvature) direction away from C1 (upward and to the right as viewed in FIG. 4) so as to have a relatively dense concentration in the radially outward interior region **56** of curvilinear portion **51** whereas the radially inward interior region **57** of the latter contains steam which is relatively free of coal particles. Similarly in the continued flow of the mixture through curved section **54**, the coal particles are thrown by centrifugal force outwardly forming the relatively coal-free steam body **59**. As the coal-steam mixture flows through the next curved section **55**, the coal particles are thrown toward the outer region forming a relatively coal-free steam body **60**. Thus the curvature of conduits **51** act to apply centrifugal force to the coal-steam mixture flowing therethrough to separate the coal particles S from the steam.

In the embodiment of the invention shown in FIG. 4, relatively coal-free steam bodies **57** and **59** are vented to the atmosphere to bled-off from these regions steam which is discharged into the atmosphere or to a suitable disposal point. For this purpose there is provided a bleed-off tube **61** having one end threaded or otherwise connected to conduit **51** and in communication with the radially inward interior region **57** thereof. Bleed-off tube **61** extends from said connected end in a direction generally opposite the direction of flow of the coal-steam mixture, for example, at about 45° to the axis of the pipeline at the point the bleed-off tube projects therefrom. The opposite end of bleed-off tube **61** is provided with an orifice plate **62** for controlling the rate of discharge to the atmosphere of bleed-off steam indicated by the arrow **63**. Orifice plate **62** can be detachably secured to the exit end of bleed-off tube **61** as by bolts **64**. By changing the orifice plate to provide the bleed-off tube **61** with a desired size orifice opening, the flow rate of the steam bled off can be controlled as desired. Instead of an orifice plate a valve **65** (FIG. 5) can be used to control the discharge rate of the steam bled off from the pipeline. Alternatively, employing correctly sized bleed-off tubes, no valve or orifice plate is required.

Steam can be bled off from body **59** by a bleed-off tube **61***c* which operates in the same manner as bleed-off tube **61**. Tube **61***c*, as shown in FIG. 4, extends in a direction away from the pipeline **27** opposite to the direction of flow therthrough as in the case of bleed-off tube **61**. In this way little or no coal particles enter the bleed-off tubes **61** or **61***c*; the velocity of flow and the action of centrifugal force resist flow of coal particles into the bleed-off tubes **61** and **61***c*.

FIG. 5 is a side elevational view of a modified form of bled-off device in which the conduit **51***c* extends in a curvilinear path lying in a vertical plane, not in a horizontal plane as in the modification of FIG. 1. Hence, in the construction of FIG. 5 the centrifugal forces acting on the coal particles S to effect separation from the steam are augmented by gravitational force which aid in effecting such separation. Conduit **51***c* is interposed in communicating series relation between the adjacent sections **51***a* and **51***b* of the pipeline as in the case of the construction of FIG. 4 and is joined thereto at its opposite ends by suitable flanged couplings **53***a* and **55***a*.

Conduit **51***c* comprises a first curved portion **53***c* extending forwardly and downwardly in an arcuate path about the center of curvature C1*a*, a second curved portion **54***c* continuous with portion **53***c* and extending downwardly and then upwardly in an arcuate path about the center of curvature C2*a*, and a third curved portion **55***c* continuous with portion **54***c* and extending upwardly and forwardly in an arcuate path about the center of curvature C3*a*. As the steam-coal mixture flows through second conduit portion **54***c* in the direction indicated by arrow **50***a*, the combined centrifugal and gravitational forces

act to throw the coal particles S downwardly in a direction away from the center of curvature C2*a* so that the radially outward interior region **68** has a relatively high coal density whereas the steam in the radially inward interior region **69** is relatively free of coal particles. A bleed-off tube **61***c*, similar to the bleed-off tube **61**, bleeds off the relatively coal-free steam from the region **69**. Bleed-off tube **61***c* has a valve **65** therein for adjusting the bleed-off rate of the steam. Tube **61***c* extends away from the pipeline in a direction away from the direction of flow of the coal-steam mixture through the pipeline.

A typical illustration of the effectiveness of the bleed-off arrangement similar to that shown in FIG. 4 was obtained in charging a full scale coke oven with 13.3 tons of dry coal. The oven was filled in 6.3 minutes using a 6" pipeline with 8" spacing of the jets similar to those shown in FIG. 3; the jets were supplied wth steam at about 150 p.s.i.g. The coal was transported at the rate of 2.1 tons per minute using 88 pounds of jet steam per minute or 42 pounds of jet steam per ton of coal transported. The pressure at the head end of the pipeline was 8 p.s.i.g. and 3 p.s.i.g. at the end where it discharged into the coking chamber through a curved portion similar to **51'**, FIG. 1. This curved portion had three 2" I.D. bleed-off pipes spaced about 30° apart. These bleed-offs were throttled on and off according to the amount of visible carryover of coal at the riser pipe at the far end of the oven chamber. At 5 p.s.i.g. the calculated flow out one bleed-off pipe 2" in diameter, based on isentropic flow, is 80 pounds of steam per minute. No difficulty was encountered in bleding off sufficient steam to avoid carryover of coal out the far end of the coking chamber during the charging operation.

As in the case of the modification of FIG. 4, that of FIG. 5 is provided with steam line **35** having branches **36** leading to jet nozzles **37** flow through each of which is controlled by a valve **39**. The jet nozzles **37** inject jets of steam at sonic or supersonic velocities into the flowing mixture of coal and steam to propel the latter through the pipeline and to replace at least some of the steam bled off, in the same manner as described above with respect to the modification of FIG. 4.

In FIG. 6 the pipeline **27** is provided with a branch line **71** through which a portion of the steam-coal mixture flows tangentially into a cyclone separator **72**. This separator has a cylindrical upper portion **73** and a downwardly tapering conical portion **74**. The latter is provided at its lower end with a circular opening or port **75** communicating with the upper end of a return conduit **76** leading down to an opening **77** formed in the latter.

The opening **75** serves as a discharge port through which the collected coal particles indicated by the reference letter C are returned through return conduit **76** to the mixture flowing through pipeline **27**. Discharge port **75** is normally closed by a closure plug **78** having a lower conical surface **79** adapted to engage the periphery of discharge port **75** so as to close the latter when plug **78** is in its lowermost position.

The upper end of closure plug **78** is connected to the lower end of a vertical rod **79** having its upper end connected at **81** to the movable core or armature **82** of a solenoid **83** and comprsing a coil **84** into which armature **82** is drawn by the electromagnetic field when coil **84** is energized. This energization is effected periodically by an automatic timer switch **85** which supplies current to solenoid coil **84** through leads **86, 87** at predetermined intervals. Armature **82** is normally held in a lower position with respect to coil **84** by a spring **88** connected at its lower end to armature **82** and at its upper end to a bracket **91** mounted on solenoid **83**.

The upper end of cylindrical portion **73** of cyclone separator **72** is covered by a horizontal plate **92** having a central opening **93** through which extends a vertical tube **94**. The latter is provided at its upper end with a flange **95** to which is secured by bolts **96** and interchangeable orifice plate **97** having therein a bleed-off orifice **98**. Rod **79** extends upwardly through orifice **98**. Reciprocatory motion of rod **79** effected by energization and de-energization of solenoid **83**, exercises a cleaning action on the orifice **98** and maintains the latter substantially free of coal partcles which otherwise obstruct the flow of bleed-off steam therethrough. The rate of discharge of bleed-off steam may be controlled by selectively varying the size of orifice **98**. That is, orifice plate **97** can be removed and replaced with a different plate having an orifice of a larger or smaller size to vary the rate of bleed-off, as desired.

The use of other servo-mechanisms such as thrusters etc. would serve as well as the solenoid mechanism described above.

The lower edge of tube **94** is tapered at **99** to coact with the tapered surface **101** at the upper end of closure plug **78** when the latter is in its raised position. Engagement of surface **101** with edge **99** closes off the bottom of tube **94** and thereby shuts off flow of bleed-off steam through orifice **98**. Conduit **71**, it will be noted from FIG. 6, extends from port **102** in pipeline **27** upwardly to the upper region of separator **72** communicating with a coal-steam entry port **103** tangentially positioned in the side wall of the upper cylindrical portion **73** near the top thereof as shown in FIG. 6.

As the coal-steam mixture flows through pipeline **27** in a direction indicated by arrow **104** a portion of the mixture flows upwardly through conduit **71** as indicated by the arrow in conduit **71** and flows through the entry port **103** tangentially into the top of cyclone separator **72**. Centrifugal forces thus generated act to separate the coal particles from the steam. The separated coal particles collect at C in the conical lower portion **74** of separator **72**. Closure plug **78** is normally in its lowermost position to close discharge port **75** and thereby prevent the collected particles C from flowing downwardly through return conduit **76**. The separated steam flows upwardly through tube **94** and discharges to the atmosphere through bleed-off orifice **98** which is maintained clear by the reciprocatory movement of rod **79** therethrough. Orifice **98** controls not only the bleed-off rate of the steam but also the amount of coal-steam mixture withdrawn from the pipeline. Utilization of an orifice plate having the necessary size orifice gives the desired rate of withdrawal from the pipeline into the cyclone separator and bleed-off of steam.

The expanded steam is thus continuously bled off and the coal particles are collected at the bottom of separator **72** until solenoid **83** is energized by automatic timer **85**, at which time the electromagnetic field of solenoid **83** acts upon armature **82** to raise the latter into coil **84** and thereby pull closure plug **78** upwardly to its uppermost position where discharge port **75** is opened and the lower end of tube **94** is closed. The coal particles C collected at the bottom of separator **72** are then free to fall through discharge port **75** and return conduit **76** back into the flowing mixture within pipeline **27**. After a predetermined time interval sufficient for the collected particles to flow through discharge port **75**, timer **85** de-energizes solenoid **83** permitting closure plug **78** to move downwardly back to its lowermost position under action of spring **88** closing discharge port **75** and the cycle is then repeated at periodic intervals. Timer **85** can be adjusted to effect periodic opening of port **75** at time intervals to avoid excessive accumulation of coal particles in separator **72**.

Jet propulsion of the coal-steam mixture through pipeline **27**, in FIG. 6, is effected by the jets of superheated steam introduced through jets **37** as hereinabove described in connection with the embodiments of the invention of FIGS. 1 to 5, inclusive.

In the modification of FIG. 7 the cyclone separator **106** has a discharge port **107** formed in the lower end of conical portion **108**. Port **107** is in direct communication with an opening **109** in the wall of pipeline **27**. Closure

plug **111** is of conical configuration and tapers upwardly to an apex which is connected to the lower end of a rod **112** extending upwardly through hollow tube **113** and through a bleed-off orifice **114** formed in an interchangeable bleed-off plate **115**. The upper end of rod **112** is connected to the apex of a downwardly tapering bleed-off plug **116** which has its upper portion connected to a second rod **117** which in turn has its upper end connected to the armature **118** of a solenoid **119** having a coil **121**. Armature **118** is normally maintained in an upper position projecting outwardly of coil **121** by a spring **122** secured to a bracket **123** mounted on solenoid **119**.

Opening **109** tapers upwardly so as to coact with the control surface of plug **111** when the latter is in its uppermost position thereby closing off opening **109** and discharge port **107** to prevent flow therethrough of coal particles which collect at C as separator **106** separates them from the coal-steam mixture entering through conduit **124**. The latter is connected tangentially to upper cylindrical portion **125** of the cyclone separator. The separated gas, relatively free of coal particles, flows upwardly through tube **113** and discharges to the atmosphere through bleed-off orifice **114**. The latter is tapered downwardly to coact with bleed-off plug **116** when the latter is in its lowermost position to close bleed-off orifice **114**. This occurs at periodic timed intervals determined by timer **126** which automatically energzes solenoid coil **121** to lower armature **118** against the action of spring **122** thereby lowering bleed-off plug **116** into its closed position and lowering closure plug **111** into its open position permiting the collected coal particles C to fall downwardly through discharge port **107** into the coal-steam mixture flowing in pipeline **27**.

In the FIG. 7 modification, when orifice **114** is closed by plug **116**, pressure builds up in separator **106**. This pressure aids in effecting return of the coal particles from the separator to the pipeline. In the FIG. 7 modification the steam is vented periodically to the atmosphere or other suitable disposal point, i.e., only when orifice **114** is open which is the case during the major portion of each cycle of operation. Orifice **114** is closed only momentarily to effect return of coal particles to the pipeline. It is closed often enough to prevent excessive accumulation of coal particles in the base portion of the separator **106**. Optimum cycle of opening and closing orifice **114** and closing and opening return port **109** will depend on the pressure conditions employed. The timer **125** can, of course, be adjusted to give the desired time cycle.

The number and type of bleed-off devices employed in any given pipeline and the spacing thereof in the pipeline will depend on the length of the pipeline, the pressure conditions employed within the disclosed range and the temperature of the superheated steam. The number should be such as to bleed-off enough steam substantially free of solids, at points spaced apart along the length of the pipeline to maintain the steam velocity within the pipeline within relatively narrow limits, say from 50 to 200 feet per second and to produce at the point of charging each coking chamber, a relatively high coal to carrier gas weight ratio at a relatively low pressure.

While control of the coal steam weight ratio can be effected by venting steam from the pipeline at one or more points spaced from the discharge end of the pipeline branches leading into the coking chambers, it is preferred to control the coal to steam weight ratio of the mixture entering the coking chamber to facilitate disentrainment of the coal particles from the steam within the coking chamber by providing a venting unit in the pipeline or a branch therefrom just prior to the point of discharge into the coking chamber. FIG. 1 shows one such venting unit at B in the form of a curvilinear portion **51'**. In FIG. 9 main **28** (FIG. 1) which extends along the length of the battery is provided with branches **28*a***, leading to a cyclone separator **28*b***. Each charging hole of the battery is equipped with such cyclone separator. Steam is vented from the cyclone separator through vent line **28*c*** and the coal particles discharged from exit port **28*d*** into the charging hole.

The bends or elbows of the pipeline are the portions thereof which wear most rapidly, i.e., the portions where maximum wear takes place. FIG. 8 discloses an elbow construction which minimizes, if not completely avoids, the effect of wear of the elbow. In this figure **27*b*** is an elbow or curved portion of the pipeline comprising the elbow or curved portion **27*c*** of the pipeline enclosed in a sleeve **27*d*** concentric with the curved portion **27*c***. This sleeve **27*d*** extends the full length of the curved portion **27*c*** and has its ends sealed to the pipeline by closure plates **27*e*** and **27*f***. These plates can be welded or otherwise sealed to the outer periphery of the pipeline and the ends of sleeve **27*d*** to provide an annular space **27*g*** surrounding the curved portion **27*c***. Space **27*g*** can be filled with the coal particle S' to be transported during the fabrication of the pipeline or just prior to placing the pipeline in operation or left empty to become filled should wear of the walls of curved portion **27*c*** take place with formation of one or more openings **27*h*** through which the coal flows into space **27*g***. The layer **27*i*** of coal particles S' thus formed provide a protective layer for the walls of sleeve **27*d*** minimizing if not completely preventing erosion thereof.

The mode of operation of the various modifications of this invention should be evident from the above description. The flowing stream of mixture of coal particles and steam is propelled through the pipeline by the jets of steam introduced at closely spaced points along the length of the pipeline at sonic or supersonic velocities to impart impulses or momentum to the mixture in the direction of flow and thus maintain continuous flow of the mixture. At least a portion of the carrier gas is vented to control the pressure and the coal to steam weight ratio, preferably by subjecting the mixture to centrifugal force at at least one intermediate point along the length of the pipeline to separate coal particles from the steam and produce a body of steam substantially free of coal particles, which body or a portion thereof is vented, as herein disclosed.

In the transportation of coal particles for charging the coking chambers of a battery, as shown in FIG. 1 at B, preferably at least one venting or bleed-off device is positioned following the feed main **28** in the conduit leading into the discharge conduit **29**, one individual to each coking chamber. In this way the coal entering the coking chamber has a high coal to steam weight ratio, desirably about 80 pounds of coal per pound of steam. This facilitates disentrainment of the coal particles from the steam in the coking chamber, prevents carryover of coal particles into the collector main, and speeds up the charging.

The steam employed to impart the impulses or momentum to the coal and effect its flow into the coking chambers, aids the charging. The steam atmospheres surrounding the hot coal particles entering the hot coke oven prevent the hot coal from flash coking. With the relatively high coal to steam weight ratio as the coal-steam mixture is introduced into the coking chamber rapid disentrainment of the coal from the steam takes place; the steam exits through the gas offtake into the collector main and the coal accumulates in the coking chamber to form the desired charge.

While it is preferred to have a multiplicity of closely placed steam jets along the length of the pipeline as herein disclosed, the invention is not limited thereto. With the hot coal-steam mixture introduced into the inlet of the pipeline with the coal dispersed in the steam, flow of the coal under the pressure of the steam introduced at the inlet end where the pressure is high enough, say of the order of 4 to 50 p.s.i.g., takes place to the branches from the pipeline leading into the coking chambers, steam being vented at or near the point of introduction of the mixture into the coking chambers to obtain the high coal to steam weight ratio and low pressure of the coal-steam mixture at

the point of introduction of each charge into the coking chambers.

As noted, the preferred embodiment of the invention is in the transport of hot coarsely comminuted preheated particles of coal from the preheater to the coking chambers of a coke oven battery to effect the charging thereof. The invention, however, is not limited to this preferred embodiment. It can be used to convey coal from a coal drying plant to the point of comsumption and can also be used for conveying other materials than coal; it is especially valuable in the conveyance of hot coal. In uses other than the charging of the coking chambers of a battery, instead of steam and coke oven gas, other carrier gases inert to the solids conveyed can be used, e.g., nitrogen and other inert gases.

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.

What is claimed is:

1. A pipeline for conveying solid particles mixed with a carrier gas comprising a plurality of carrier gas injectors along the pipeline constructed and arranged to inject a carrier gas in the direction of solid particle flow through the pipeline and at least one bleed-off device in said pipeline comprising a curved conduit in said pipeline, said conduit consisting of three curvilinear components in series with the radii of curvature of each component extending in a direction diametrically opposite that of its adjacent curvilinear components, whereby upon flow of the mixture through said curved conduit the mixed particles are subjected to centrifugal force and moved radially outwardly from the center of curvature of each curvilinear component in succession producing a stream of gas substantially free of mixed particles at the radially inward interior region of said conduit, and said bleed-off device additionally comprising means for withdrawing at least a portion of said gas substantially free of solid particles from the radially inward region of said conduit, said gas withdrawing means comprising a tube having one end in communication with said curved conduit at a radially inward region thereof, said tube extending from said one end in a direction generally opposite to the flow of gas in said curved conduit, and means for controlling the rate at which the gas discharges therethrough.

2. A pipeline as defined in claim 1, in which said curved conduit is positioned in a vertical plane with the radially outward region extending downwardly whereby when the mixture of solid particles and gas passes therethrough, the action of the centrifugal force on the solid particles is augmented by gravitational force to effect the separation of the solid particles from the carrier gas.

3. A pipeline as defined in claim 1, in which said curved conduit is positioned with the curved portion in a horizontal plane.

4. A pipeline as defined in claim 1 in which the controlling means is an orifice plate removably mounted on the opposite end of said tube and having therein an orifice through which the gas discharges to the atmosphere at a rate controlled by the size of the orifice.

5. The pipeline of claim 1 wherein said pipeline includes at least two portions extending at an angle to each other and connected by a curved portion for streamline flow therethrough, said curved portion having a sleeve surrounding same and extending substantially the full length thereof, the inner walls of said sleeve being spaced from the outer walls of said curved portion and the ends of said sleeve being sealed to the walls of said pipeline to provide a sealed protecting space for said curved portion, said space containing a body of solid particles conveyed by the pipeline, which body provides a protective layer for the inner walls of said sleeve after the curved portion of said pipeline has worn through.

6. A pipeline for conveying solid particles mixed with a carrier gas comprising a plurality of gas injecting means at spaced points along the pipeline and at least one bleed-off device comprising a cyclone separator having a solid-gas entry port, a solid discharge port, and a bleed-off gas orifice, conduit means extending from said pipeline to said entry port for conveying a portion of the solid-containing carrier gas from the pipeline to the separator, said discharge port communicating with said pipeline for returning to the latter solids separated from the carrier gas, closure means normally closing said discharge port and movable to open the latter to permit said separated solids to return to the pipeline, closure-actuating means operable to move said closure means to its open position, and means for periodically operating said closure-actuating means.

7. A pipeline as defined in claim 6, comprising a second closure means movable to a closed position closing said bleed-off gas orifice, means normally maintaining said second closure means in an open position to permit gas within the separator to escape through said orifice, and means connecting said closure-actuating means and said second closure means to move the latter to its closed position in response to operation of said closure-actuating means.

8. The pipeline of claim 6 wherein said pipeline includes at least two portions extending at an angle to each other and connected by a curved portion for streamline flow therethrough, said curved portion having a sleeve surrounding same and extending substantially the full length thereof, the inner walls of said sleeve being spaced from the outer walls of said curved portion and the ends of said sleeve being sealed to the walls of said pipeline to provide a sealed protecting space for said curved portion, said space containing a body of solid particles conveyed by the pipeline, which body provides a protective layer for the inner walls of said sleeve after the curved portion of said pipeline has worn through.

9. A pipeline for conveying solid particles mixed with a carrier gas comprising a plurality of gas injecting means at spaced intervals along the pipeline and a plurality of bleed-off devices at spaced intervals along the pipeline, each of said bleed-off devices comprising a separator having an entry port for solid-gas mixture, a discharge port for separated solids, and a bleed-off gas orifice, each of said ports communicating with said pipeline, closure means actuable to open said discharge port, and automatic timer means for periodically actuating said closure means at predetermined time intervals.

10. The pipeline of claim 9 wherein said pipeline includes at least two portions extending at an angle to each other and connected by a curved portion for streamline flow therethrough, said curved portion having a sleeve surrounding same and extending substantially the full length thereof, the inner walls of said sleeve being spaced from the outer walls of said curved portion and the ends of said sleeve being sealed to the walls of said pipeline to provide a sealed protecting space for said curved portion, said space containing a body of solid particles conveyed by the pipeline, which body provides a protective layer for the inner walls of said sleeve after the curved portion of said pipeline has worn through.

11. A pipeline for conveying solid particles mixed with a carrier gas comprising a plurality of jet nozzles for injecting gas into the pipeline at spaced intervals therealong for effecting propulsion of said mixture through said pipeline, a plurality of bleed-off devices at spaced intervals along the pipeline, each of said bleed-off devices comprising a cyclone separator having a gas-solids entry port and a solids discharge port, and a bleed-off gas orifice, conduit means extending from said pipeline to said entry port for conveying a portion of the solids-containing carrier gas from the pipeline to the separator, said discharge port

communicating with said pipeline for returning to the latter solids separated from the carrier gas, closure means normally closing said discharge port and movable to open the latter to permit said separated solids to return to the pipeline, solenoid means actuable to move said closure means to its open position, and automatic timer means for periodically actuating said solenoid means.

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