Oct. 21, 1952 R. BERKEMEYER 2,614,823

PEBBLE HEATER APPARATUS

Filed Aug. 24, 1948 2 SHEETS—SHEET 1

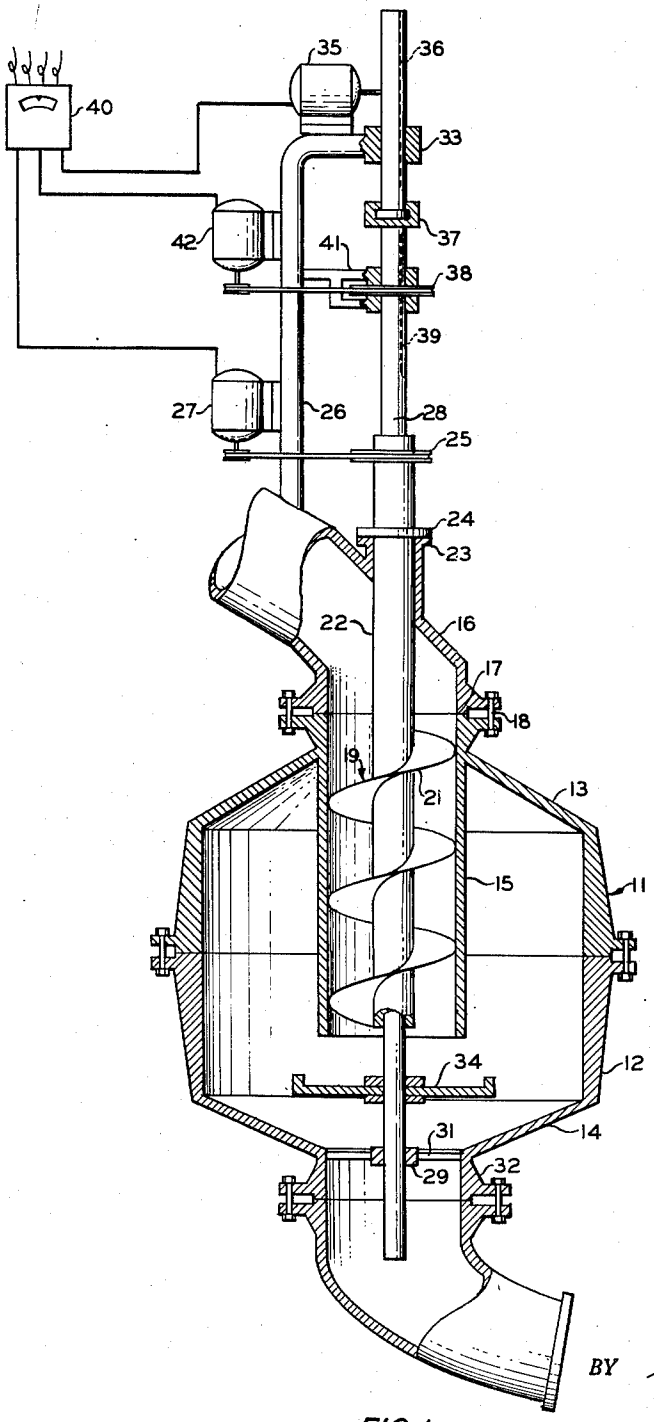


FIG. 1

INVENTOR.
R. BERKEMEYER

BY Hudson and Young

ATTORNEYS

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PEBBLE HEATER APPARATUS

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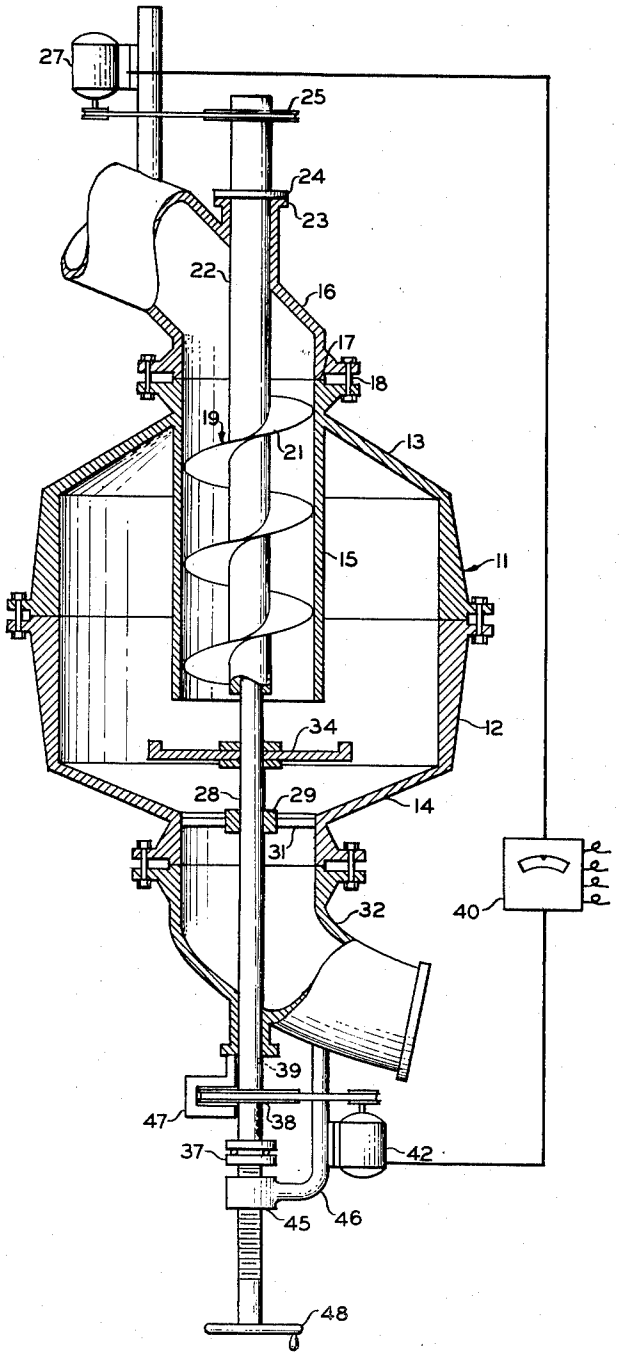


FIG. 2

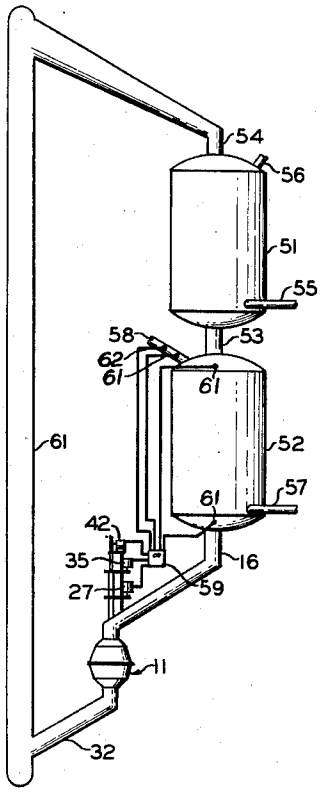


FIG. 3

INVENTOR.
R. BERKEMEYER

BY Hudson and Young

ATTORNEYS

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PEBBLE HEATER APPARATUS

Robert Berkemeyer, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

Application August 24, 1948, Serial No. 45,901

11 Claims. (Cl. 263—19)

1

This invention relates to a solid material feeder. In one of its more specific aspects, it relates to a pebble feeder in pebble heater apparatus. In another of its more specific aspects, it relates to an improved method for controlling the speed of pebble flow through pebble heater apparatus.

Thermal treating and conversion processes which are carried out in so-called pebble heater apparatus utilize a flowing mass of solid heat exchange material which mass is heated to a high temperature by passing hot gas therethrough in a first direct heat exchange step and is then caused to contact a second gaseous material furnishing heat to the second gaseous material in a second direct heat exchange. The conventional pebble heater apparatus generally comprises two chambers which may be disposed in substantially vertical alignment. The solid heat exchange material is introduced into the upper portion of the first or upper chamber. That material forms a moving or fluid bed of solid heat exchange material which flows downwardly as a contiguous mass through the chamber in direct heat exchange with hot gaseous heat exchange material. The solid heat exchange material is heated to a relatively high temperature in the heat exchange and is then passed to a second chamber in which the hot solid heat exchange material is caused to contact a second gaseous material in a second direct heat exchange relation furnishing heat for the treatment or conversion of the gaseous material.

Flow of solid heat exchange materials through pebble heater apparatus is in many instances quite difficult to control. When the apparatus is utilized for the purpose of converting hydrocarbons, the flow rate of pebbles through the pebble heater apparatus is very critical to the efficient conversion of the hydrocarbons. It is only by the closest control of the pebble flow rate that it is possible to prevent the over-conversion of the gaseous hydrocarbons by reason of excessive temperatures within the conversion chamber, or to prevent the under-conversion by reason of insufficient temperatures within the conversion chamber. The flow rate of solid material has heretofore been partially controlled by the utilization of screw type conveyors disposed at any number of various positions. Flow controllers of this type, as heretofore utilized, have had very narrow limits of variance of the rate of pebble flow. Screw type conveyors which have heretofore been conventionally used for controlling the flow of solid materials have been constructed so that the helix about the inner stem has a relatively flat pitch. In order to completely stop the flow of the solid material, it is necessary that the angle of pitch of the helix be less than the angle of slide for the solid material which is being controlled. A screw type conveyor so constructed could impart only a relatively low maximum flow rate to the flow of solid material therethrough. In many instances, it may be desirable in heating apparatus such as pebble heaters to control the rate of flow of solid material so that it moves at one rate of flow through the apparatus over a given period of time for a given conversion and at other times considerably higher or lower rates of flow may be desirable.

2

An object of this invention is to provide an improved method for controlling the flow of solid materials through a solid material system. Another object is to provide an improved method for controlling the rate of flow of solid materials through a solid material system. Another object is to provide a means for controlling the rate of flow of pebbles through pebble heater apparatus. Another object is to provide an improved method for controlling the rate of flow of pebbles through pebble heater apparatus. Another object of the invention is to provide means for slowing and stopping the flow of solid material in contact chambers. Another object is to provide a device capable of increasing the rate of flow of solid material in a contact chamber above the rate of flow obtained by gravity. Other and further objects and advantages will be apparent upon study of this disclosure and the accompanying drawing.

Solid heat exchange material which is conventionally used in pebble heater apparatus is generally called "pebbles." The term "pebbles" as used herein denotes any solid refractory material of flowable size and form having the capacity to carry large amounts of heat from the pebble heater chamber through the gas heating or conversion chamber without rapid deterioration or substantial breakage. Pebbles conventionally used in pebble heater apparatus are substantially spherical and range from about ⅛ inch to about 1 inch in diameter. In a high temperature process, pebbles having a diameter between ¼ and ⅜ inch are preferred. The pebbles must be formed of a refractory material which will withstand temperatures at least as high as the highest temperature attained in the pebble heating chamber. The pebbles must also be capable of withstanding temperature changes within the apparatus. Refractory materials, such as metal alloys, ceramics, or other material having the properties

above described may be utilized to form such pebbles. Silicon carbide, alumina, periclase, beryllia, stellite, zirconia, and mullite may be satisfactorily used to form such pebbles or may be used in admixture with each other or with other materials. Pebbles formed of such materials, when properly fired, serve very well in high temperature operations, some withstanding temperatures up to about 3500° F. Pebbles which are used may be either inert or catalytic when used in any selected process.

Understanding of the invention will be facilitated upon reference to the diagrammatic drawing in which Figure 1 is a vertical partial section of a solid material feeder embodying the invention. Figure 2 is a vertical partial section of a solid material feeder embodying a modification of the invention. Figure 3 is a schematic view of a pebble heater apparatus showing the preferred positioning for a solid material feeder of this invention.

In Figure 1, solid material feeder 11 comprises a substantially vertically disposed shell 12 which is formed by upper and lower sections 13 and 14, respectively. Solid material inlet conduit 15 extends through the top of shell 12 and extends substantially coaxially a part of the distance through the chamber within shell 12. Solid material outlet conduit 16 provides communication between the lower portion of a gas heating, treating, or conversion chamber and solid material inlet conduit 15. Outlet conduit 16 and inlet conduit 15 may be joined at a point 17 and rigidly retained in place by fastener means, such as bolts 18. Screw type conveyor 19 comprises helix 21 which is mounted on hollow stem 22 and is disposed within conduit 15 so as to extend between stem 22 and the inner circumference of conduit 15, thereby closing conduit 15 to solid material flow except upon helix 21 about stem 22. Conduit member 16 is provided with a bearing member 23 in its upper wall. Ring bearing member 24 is rigidly affixed about the periphery of stem 22 and supports screw type conveyor 19 within conduit 15, bearing upon bearing member 23. Also rigidly affixed about the periphery of stem 22 is pulley member 25. Support member 26 extends upwardly from conduit 16. Reversible-variable speed motor 27 is mounted on support member 26 so that the drive wheel mounted on its rotor shaft is opposite pulley member 25. A belt member provides an operative connection means between the drive wheel and pulley, whereby rotation of conveyor 19 is provided. Table support member 28 extends coaxially through stem 22 and is supported at its lower end by bearing member 29 which is in turn supported by spider arms 31 extending between the walls of solid material outlet conduit 32 in the lower portion of shell 12 and bearing member 29. Support member 28 is axially supported at its upper end by bearing member 33 which is in turn supported by support member 26. Rigidly mounted on table support member 28, below the outlet from solid material inlet conduit 15, is rotatable table baffle 34. Table support member 28 may be raised or lowered by elevation means which may comprise a "Selsyn" motor 35 which may have a pinion mounted on its rotor shaft or may comprise a motor of the type which is conventionally used to operate large valves. The upper end of support member 28 is prevented from rotating by a key member in bearing 33 which slides in keyway 36. The non-rotatable portion of table support member 28 is connected to the rotatable portion of the table support member by thrust bearing 37. Pulley member 38 is slidably mounted on table support member 28 and is prevented from turning thereon by a key in pulley 38 which slides in keyway 39. Pulley member 38 is maintained in position by a retainer member 41 which extends from support member 26. Table support member 28 is allowed to slide through pulley member 38 in response to motor 35. Variable speed motor 42 is supported on support member 26 and is equipped with a drive wheel on its rotor shaft, the drive wheel being positioned opposite pulley member 38. A belt member provides an operative connection means between the drive wheel of motor 42 and pulley member 38.

In the operation of the device shown in Figure 1, solid material, such as pebbles, enters feeder 11 through inlet conduit 15 and flows downwardly around stem 22 over helix 21. The conveyor shown in Figure 1 is a righthand helix and as it is rotated in a clockwise direction pebble flow through conduit 15 is accomplished. As the rate of rotation of conveyor 19 is increased or decreased, the flow of solid material, such as pebbles, through conduit 15 is likewise proportionately increased or decreased until the rotation of conveyor 19 is stopped at which time the rate of solid material flow through conduit 15 is only that provided by gravity over the inclined surface of the conveyor. In one type of operation, conveyor 19 may be reversed in its direction of rotation and may in that manner approach the function of a screw type elevator. The reverse rotation of conveyor 19 may be brought to such a rate that it will bring about a complete stoppage of solid material flow through conduit 15. Complete control of solid material flow may be controlled in that manner in accordance with one of the variable phenomena of gas heating, treating, or converting.

Table 34 is spaced a predetermined distance below the outlet end of conduit 15, thereby providing a baffle means for solid material flowing downwardly through conduit 15. Table 34 is preferably spaced at such a distance below conduit 15 that the solid material which piles up on the table forms a cone, the apex angle of which is small enough that the slope of the sides of the cone slightly exceeds the angle of repose of the solid material utilized in the system. Each of the motors 27, 35 and 42 are preferably regulated in accordance with one of the variable phenomena of gas heating, treating, or conversion in the system. A synchronizer control 40 is provided to synchronize the operation of the three motors. Conveyor 19 may be driven by motor 27 at such a rate and in such a direction as to provide the desired rate of flow of solid material through the solid material system. In many cases, it may be desired to maintain a sharp line of control over the temperature within the solid material system. In some cases, total control of solid material flow rate by conveyor 19 which is operated in accordance with one of the phenomena of gas heating, treating, or conversion may have a tendency to over-control the flow rate and suddenly throw the phenomena of heating, treating, or conversion too far in the opposite direction. It may be desirable, therefore, to utilize baffle table 34 as a check or counter-control. Table 34 may, therefore, be spaced from the end of conduit 15 in accordance with another of the phenomena of gas heating, treating, or conversion. In that manner, if the rate of rotation of conveyor 19 should be changed so suddenly as to

cause the conditions of heating, treating, or conversion to fall out of line with the desired results, the synchronizer control 40 may cause motor 35 to operate in accordance with another of the phenomena of gas heating, treating, or conversion so as to counteract a part of the change in variable phenomena by reason of the change of rate of rotation of conveyor 19.

Another method in which feeder 11 may be operated is to regulate the rate of flow of solid material through the solid material system by regulating the rotation of conveyor 19 in accordance with one of the phenomena of gas heating, treating, or conversion. A predetermined rate of rotation range may be set for the conversion and upon that rate being reached, the synchronizer control may cause motor 35 to shift table baffle 34 so as to relieve conveyor 19 of a partial amount of its control of the solid material flow rate. Conveyor 19 would thereupon be varied within its predetermined rotation rate by the synchronizer control.

An even sharper line of control may be accomplished by the apparatus of this invention. The speed of rotation of conveyor 19 may be varied in accordance with one of the variable phenomena of gas heating, treating, or conversion. Table 34 may be spaced from the end of conduit 15 in accordance with another of the above mentioned variable phenomena and table 34 may be rotated by drive member 42 at a rate in accordance with yet another of the variable phenomena above mentioned. By this method of operation three variable phenomena may be utilized as checks against one another in controlling the solid material flow rate through the solid material system. The additional feature of control of this method, i. e., rotation of table baffle 34, would provide a greater flow of solid material over table 34 than the flow which would be secured for a given position of baffle 34 if it was not rotated. It will thus be seen that if conveyor 19 should over-control in one direction and the spacing of table 34 should cut back a slight degree too far in the opposite direction, it would be possible to more accurately check the flow rate of the solid material by rotating table 34, thus partially eliminating one chance for error and providing a finer line of control for solid material flow through the solid material system.

The device shown in Figure 2 of the drawing is similar to that shown in Figure 1. Solid material feeder 11 comprises shell 12 which is made up of upper and lower sections 13 and 14, respectively. Solid material inlet conduit 15 extends through the top of section 13 and is connected to solid material outlet conduit 16 which extends from a solid material system similarly to the device shown in Figure 1. The connection between conduits 15 and 16 at point 17 may be made by bolts 18, also similarly to the connection made in Figure 1. Conveyor 19 comprises helix 21 which extends between a stem 22 and the wall of conduit 15. Stem 22 is hollow in at least its lower portion and extends upwardly through conduit 15 and through the wall of conduit 16. Bearing member 24, which is rigidly affixed to the circumference of stem 22, supports stem 22 as it bears on bearing 23 of conduit 16. Pulley member 25 is rigidly affixed to stem 22 and is driven by a belt member which operatively connects the pulley with a drive wheel on motor 27. In the device shown in Figure 2 of the drawing, table support member 28 extends upwardly through the wall of solid material outlet conduit 32 and into the hollow portion of stem 22. Support member 28 is supported laterally by bearing member 29 which is in turn supported by spider arms 31 which extend between the walls of conduit 32 and bearing member 29. The lower end of table support member 28 is threadably retained in guide member 45 which is in turn supported by support frame 46 extending from solid material outlet conduit 32. Pulley member 38 is slidably retained on table support member 28 by a key moving in keyway 39 in table support member 28. Pulley 38 is retained in position by retainer frame 47. Pulley member 38 is driven by a belt member which operatively connects pulley member 38 with a drive wheel mounted on the rotor shaft of variable speed motor 42. Hand wheel 48 is provided on the lower end of table support member 28, thus providing drive means for spacing table baffle 34 from the outlet end of conduit 15. The lower end of table support member 28 is connected to rotating portion of table member 26 by thrust bearing member 37.

The operation of the device shown in Figure 2 of the drawing is similar to that shown in Figure 1, the main difference being that the spacing and driving of table baffle 34 is accomplished from below feeder 11 rather than from above. The manual adjustment, i. e., hand wheel 48, is provided for spacing table baffle 34 from conduit 15.

In the device shown in Figure 3 of the drawing, a pebble feeder of this invention has been utilized in connection with pebble heater apparatus. Pebble heating chamber 51 communicates with gas heating chamber 52 through pebble throat 53. Pebbles are injected into pebble heating chamber 51 through pebble inlet conduit 54 in the upper end portion of chamber 51. Combustible material is injected into chamber 51 through inlet conduit 55 and is burned so as to form combustion gases within chamber 51 to heat the contiguous, downwardly flowing mass of pebbles therein. Gaseous effluent material is removed from chamber 51 through effluent outlet conduit 56. The heated pebbles enter chamber 52 through communicating throat 53, maintaining the contiguous flow of pebbles downwardly through chamber 52 and out of chamber 52 through outlet conduit 16. Gaseous material which is thereby heated, treated, or converted, is injected into chamber 52 through inlet conduit 57 and passes upwardly through the contiguous mass of heated pebbles in chamber 52. Effluent materials are removed from chamber 52 through effluent outlet conduit 58. If the temperature of pebbles in chamber 52 is too low, insufficient heating, treating, or conversion of the gaseous materials may be accomplished. On the other hand, if the pebbles in chamber 52 are too hot the gaseous materials may be over-heated, treated, or converted. It will thus be seen that with a relatively constant rate of heating pebbles in chamber 51, it is very necessary that the flow rate of pebbles through pebble heater apparatus be rigidly controlled. Some of the variable phenomena upon which control of the rate of pebble flow may be based are the temperature differential between the pebble inlet and outlet of chamber 52, the gravity of effluent material taken at effluent outlet conduit 58 when chamber 52 is utilized as a conversion chamber, the temperature of effluent material taken from effluent outlet conduit 58, and the temperature of pebbles removed from chamber 52 through pebble outlet conduit 16. Control lines extend from ther-

mocouples at 61 and gravity measuring means at 62, positioned at points at which the variable phenomena may be measured within chamber 52 to synchronizer control 59. Control lines also extend from controller 59 to motors 35, 42, and 27, which regulate the position, rate of rotation of the table baffle, and rate and direction of rotation of the screw conveyor. Flow of pebbles through conduit 16 is thereby controlled by solid material feeder 11. Pebbles which flow downwardly from feeder 11 through pebble outlet conduit 32 are picked up by elevator means 61 and are passed upwardly to pebble inlet conduit 54 through which they are injected into the upper portion of pebble heater chamber 51.

Synchronizer controllers, such as controller 59; variable speed motors, such as motor 42; and reversible-variable speed motors, such as motor 27, are in common use and are available in commerce. A detailed description thereof is therefore deemed unnecessary. A controller such as the "Atcotran" control of the Automatic Temperature Control Company may be used to control the speed and direction of rotation of motors 27 and 42 and the direction and extent of movement of motor 35.

Treating and conversion processes in pebble heater and other solid material apparatus ordinarily require the addition of heat. Gas heating chamber, as recited in the claims, is deemed to include gas treating and conversion chambers.

As will be evident to those skilled in the art, various modifications of this invention can be made or followed in the light of the foregoing disclosure and discussion without departing from the spirit or scope of the invention.

I claim:

1. An improved pebble heater apparatus which comprises in combination a substantially vertically disposed closed pebble heater chamber, said chamber having a pebble inlet and an effluent outlet conduit in its upper end portion, and a gas inlet and a pebble outlet in its lower end portion; a closed gas heating chamber having a pebble inlet and an effluent outlet in its upper end portion and a gas inlet and a pebble outlet in its lower end portion, said gas heating chamber being in substantially coaxial alignment with said pebble heating chamber and said pebble inlet of said gas heating chamber communicating with said pebble outlet of said pebble heating chamber; a pebble feeder which comprises in combination an outer shell, a pebble inlet conduit communicating with the pebble outlet conduit of said gas heating chamber and extending downwardly into the chamber within said shell, a screw conveyor rotatably mounted in said pebble inlet conduit on a hollow stem which extends upwardly through the upper end wall of said shell, table support means rotatably extending coaxially through and out of each end of said hollow stem, a table rigidly mounted on said support means and spaced below the outlet end of said pebble inlet conduit, elevation means operatively connected to the upper end portion of said table support means, reversible-variable speed rotation means operatively connected to said screw conveyor, and a pebble outlet conduit in the lower portion of said shell; gravity measuring means operatively connected to said effluent outlet of said gas heating chamber and said elevation means; first temperature measuring means in the pebble outlet of said gas heating chamber and operatively connected to said reversible-variable speed rotation means; and elevator means connected at its lower end to said pebble outlet conduit of said pebble feeder and at its upper end to said pebble inlet conduit to said pebble heater chamber.

2. An improved method of regulating the rate of flow of pebbles through pebble heater apparatus which comprises the steps of removing said pebbles from the lower end of a gas conversion zone of pebble heater apparatus as a contiguous pebble stream; passing said pebble stream into a pebble flow control zone of a pebble feeder zone; mechanically feeding said pebble stream through a tortuous path in said flow control zone; regulating the velocity of said pebble stream in said control zone in accordance with the temperature of pebbles at the pebble outlet of said gas conversion zone; regulating the size of the communication space between a pebble collection zone of said pebble feeder zone and said control zone in accordance with the gravity of effluent material from said gas conversion zone taken at an effluent outlet zone in the upper portion of said gas conversion zone, whereby the volume of pebble flow through said pebble feeder zone is controlled; additionally controlling the rate of distribution of pebbles from said control zone to said collection zone in accordance with the temperature of effluent from said gas conversion zone taken at said effluent outlet zone in the upper portion of said gas conversion zone; and passing said pebbles from said collection zone through an elevation zone to a pebble heater zone of said pebble heater apparatus.

3. An improved method of regulating the rate of flow of pebbles through pebble heater apparatus which comprises the steps of removing said pebbles from the lower end of a gas conversion zone of pebble heater apparatus as a contiguous pebble stream; passing said pebble stream into a pebble flow control zone of a pebble feeder zone; mechanically feeding said pebbles through the length of said pebble flow control zone at a rate variable in response to one of the variable phenomena of gas conversion in said gas conversion zone; controlling the size of a pebble outlet zone from said pebble flow control zone in response to another of the variable phenomena of gas conversion in said gas conversion zone; varying the rate of pebble removal from said pebble flow control zone in response to still another variable phenomena of gas conversion in said gas conversion zone; and passing said pebbles upwardly from said pebble feeder zone through an elevation zone and downwardly through a pebble heating zone to said gas conversion zone.

4. The method of claim 3, wherein the rate of mechanically feeding of pebbles through the length of said pebble flow control zone is controlled in response to the temperature of pebbles at the pebble outlet of said gas conversion zone.

5. The method of claim 3, wherein the size of the pebble outlet zone from said pebble flow control zone is controlled in response to the gravity of effluent material from said gas conversion zone.

6. The method of claim 3, wherein the rate of pebble removal from said pebble flow control zone is controlled in response to the temperature of effluent material from said gas conversion zone.

7. The method of claim 6, wherein the rate of mechanical feeding of pebbles through the length of said pebble flow control zone is controlled in response to the temperature of pebbles at the pebble outlet zone of said gas conversion zone.

8. The method of claim 3, wherein the rate of mechanically feeding of pebbles through the

length of said pebble flow control zone is controlled in response to the temperature of pebbles at the pebble outlet zone of said gas conversion zone; and the size of the pebble outlet from said pebble flow control zone is controlled in response conversion zone.

9. The method of claim 3, wherein the size of the pebble outlet zone from said pebble flow control zone is controlled in response to the gravity of effluent material from said gas conversion zone; and the rate of pebble removal from said pebble flow control zone is controlled in response to the temperature of effluent material from said gas conversion zone.

10. The heater apparatus of claim 1, wherein second temperature measuring means are provided in said effluent outlet of said gas heating chamber, and rotation means are operatively connected to said table support means and said second temperature measuring means.

11. A solid material feeder which comprises in combination an outer shell, a solid material inlet conduit extending through the upper end portion of said shell and downwardly into the chamber within said shell; a solid material outlet conduit extending downwardly from the lower portion of said shell; a first shaft, hollowed throughout at least a portion of its length, axially positioned and rotatably mounted in said downwardly extending portion of said solid material inlet conduit; a helix rigidly affixed and closely fitted to said first shaft and extending outwardly to the wall of said downwardly extending conduit portion; first drive means operatively connected to said first shaft; a second shaft slidably and rotatably supported in the hollow portion of said first shaft and extending from outside said shell through at least a portion of said chamber below said solid material inlet; a laterally extending table rigidly affixed to said second shaft below the lower lip of said inlet conduit; longitudinal displacement means operatively connected to said second shaft for spacing said table from said inlet conduit; and second drive means operatively connected to said second shaft.

ROBERT BERKEMEYER.

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