

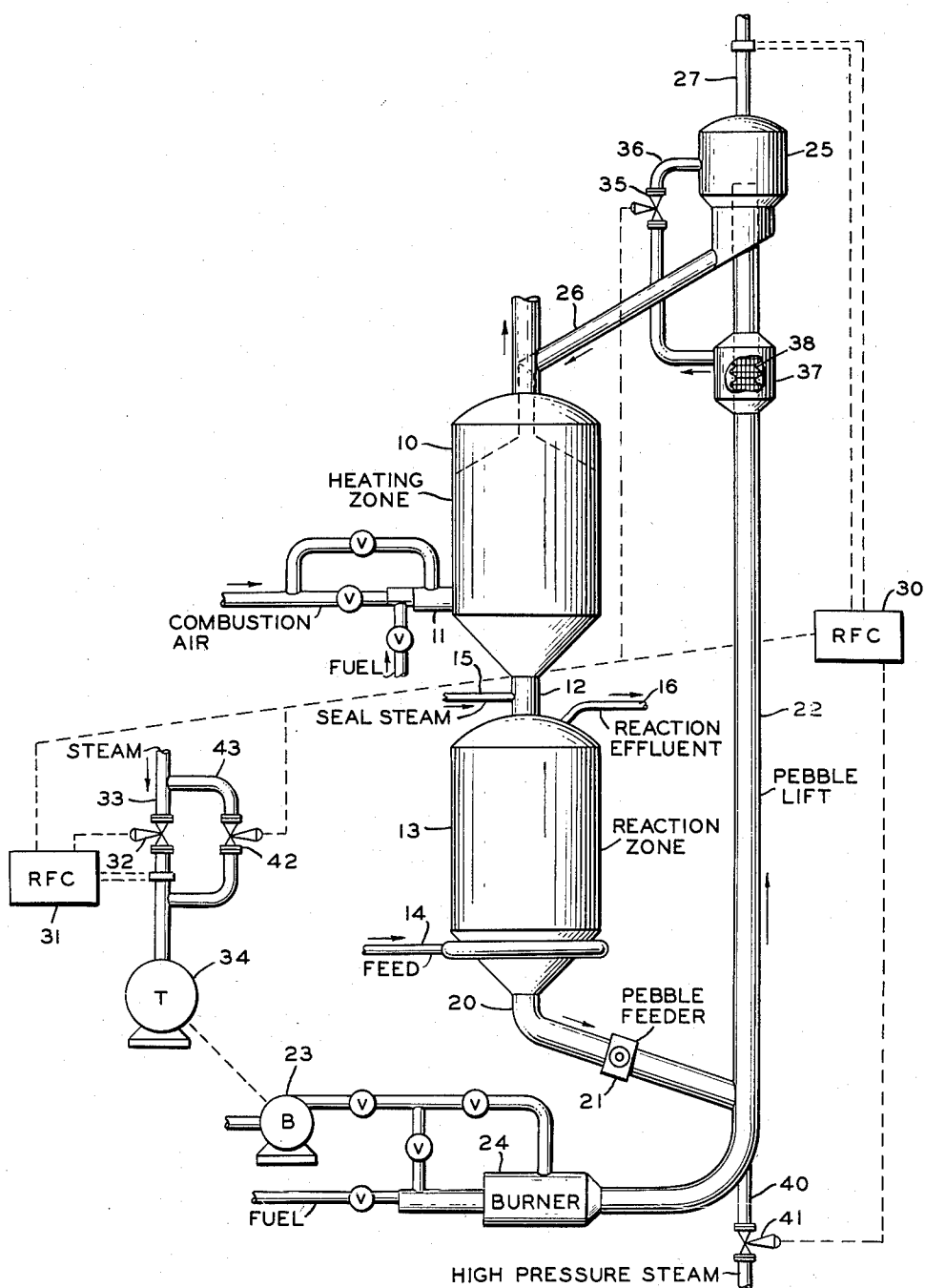
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PEBBLE GAS LIFT

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## PEBBLE GAS LIFT

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This invention relates to elevating solid particles by a gas lift in a pebble heater type system. In one of its aspects this invention relates to a method and apparatus for maintaining continuous flow in a gas lift in a pebble heater system. In a preferred embodiment this invention relates to apparatus for automatically relieving a blocked lift line in a gas lift in a pebble heater system.

Pebble heater type apparatus is finding increasing commercial acceptance for effecting chemical reaction continuously at temperatures in the range of 1000 to 3500° F. The apparatus and process has many advantages when applied to hydrocarbon conversion reactions, such as thermal and catalytic cracking, reforming, dehydrogenation, dehydrocyclization or aromatization and the like. Some factors which favor the utilization of pebble heaters are the extremely sharp heating rates possible with this type of apparatus, and the avoidance of contamination of the reaction product with the combustion gases.

The circulation of pebbles in this system is effected, in part, by gravitational descent as a relatively compact mass of pebbles from an upper pebble heating zone where the pebbles are heated to a temperature in the range of 1000 to 3500° F. by contact with hot gases, usually combustion gases from a burner, down through a conduit or throat into a conversion or heat transfer zone, where they are directly and usually countercurrently contacted with a stream of hydrocarbon material. Such hydrocarbon material is heated by use of these said pebbles to a desired conversion temperature and subjected to the catalytic effect of such pebbles, if any. From the lower part of said conversion zone pebbles which have given up a portion of their heat to the material undergoing conversion, pass through a duct and a pebble feeder into the lower portion of an elevation zone which usually consists of a mechanical elevator or a gas lift by which means the pebbles are elevated into a pebble settling zone and hopper from whence they return to the pebble heating zone, thus completing the cycle.

Preferably the contact material or pebbles employed is in the form of small, substantially spherical particles. Their size, whether spherical or other regular or irregular shape, is sufficient that excessive pressure drop will not result when beds of substantial depths are employed in the heating and conversion zones. It is a further requirement, when a gas lift is employed rather than a mechanical elevator, that the solid particles be sufficiently small to facilitate their transportation by said gas lift in that part of the circuit through which they flow between the conversion and the heating zones. Usually pebbles in the size range of 1/8 inch to 3/4 inch in diameter, preferably 1/4 inch to 1/2 inch diameter are employed. Pebbles made of alumina, beryllia, magnesia, thorium, zirconia, mullite, periclase and other materials, preferably refractory materials may be employed. The presence in the system of substantial quantities of excessively fine particles of a powdery or dusty nature should be avoided so that they will not form "clinkers" or excessively fill the voids between the larger pebbles and give an excessive pressure drop for the reactants and combustion gases passing through the zones. For these reasons, the pebbles charged to the system are preferably of substantially uniform or well-graded size and any excessive quantity of fines produced by attrition of the larger pebbles within the system

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is preferably removed therefrom and replaced by larger pebbles. To avoid excessive attrition, the pebbles should have good structural strength to withstand extremely high temperature and shock conditions of temperature change, impact and abrasion to which they are subjected in the system. The use of substantially spherical pebbles will greatly assist in avoiding excessive attrition.

A special feature of my invention resides in the manner and means whereby continuous circulation of the solid particles of catalyst or contact material is maintained through the system. In most of the pebble heaters in commercial operation, the lifting or elevating means is comprised of a mechanical elevator which takes pebbles from the feeder below the reactor and elevates them to the top of the heating chamber. Some of the reactions which are carried out in pebble heater apparatus take place at exceedingly high temperatures and the temperature of the cooled pebbles is still above the effective operating range of mechanical elevators. In such instances, it is desirable and necessary to employ a gas lift. In elevating pebbles by means of a gas lift the pebbles leaving the lower part of the reactor pass through a duct and pebble feeder into the lower portion of the lift conduit through which is passed a gas at a flow rate sufficient to fluidize and elevate said pebbles into a pebble settling zone and hopper. From there they complete the cycle back to the pebble heating zone. In order to avoid thermally shocking the pebbles during their concurrent flow upward to the settling chamber the temperature of the lifting fluid is regulated to approximate that of the pebbles being lifted. In designing a gas lift for pebble heaters, many factors are taken into consideration such as the average density, size and shape of the pebble; the density of the lifting fluid; the terminal velocity of the gas necessary to freely suspend the pebbles; the total pressure drop in the lift including pressure drops due to gas friction on the wall, due to acceleration of the pebbles, due to friction of pebble on pebble, due to the head of pebbles in the lift and due to the velocity (i. e. kinetic energy) of the pebbles at the top of the lift pipe; pebble circulation rate; bulk density of the pebbles in the pipe; and the diameter of the lift pipe. In a well-designed gas lift there will be no blocking of the system due to a bridging in the pipe of the pebbles. However, in the normal operation of a gas lift, it has been found that if the flowing pebble density exceeds five pounds per cubic foot, the lift line will become blocked. Now, the flowing pebble density may approach and exceed this value due to several reasons such as, an inadvertent surge of pebbles through the pebble feeder or severe fluctuation in the rate of flow of the lifting gas. Usually when a blockage occurs in the lift the lift must be shut down and the pebbles drained therefrom in some way or other. The present invention is directed to overcoming blockages of pebbles in the lift line of the pebble heater.

It is an object of this invention to provide an improved method and apparatus for elevating solid particles by a gas lift in pebble heater type system.

It is another object of this invention to provide a method and apparatus for maintaining continuous flow in a gas lift in a pebble heater system.

A further object of this invention is to provide apparatus for automatically relieving a blocked lift line in a gas lift in a pebble heater system.

Other objects and advantages will be apparent to those skilled in the art from the accompanying disclosure and discussion.

The accompanying drawing which is partly in elevation portrays diagrammatically one embodiment of my invention.

Referring now to the drawing in detail, substantially spherical pebbles 1/8 inch to 3/4 inch, preferably 1/4 inch

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to  $\frac{1}{2}$  inch, in diameter are gravitated as a relatively compact mass downwardly from an upper pebble heating zone 10 where they are heated to a temperature in the range of 1000 to 3500° F. by contact with hot combustion gases from burner 11, through pebble duct 12 and into conversion zone 13. The temperature to which the pebbles are heated in pebble heating zone 10 can be controlled by any one of a number of conventional control devices, or in any one of a number of conventional ways. Combustion air for burner 11 is supplied from a blower not shown. In conversion zone 13 hot pebbles are directly and countercurrently contacted with the hydrocarbon material undergoing conversion which enters that zone through line 14 at a flow rate correlated with the rate of pebble circulation so that said hydrocarbon material is heated by heat contained in said pebbles to a desired conversion temperature and for a desired time, also receiving the benefit of any catalytic effect which may be exercised by the pebbles. Leakage of combustion gases from pebble heating zone 10 into conversion zone 13, or effluent gases from zone 13 into heating zone 10, caused by small differences in pressure between the two zones can be alleviated by the injection through line 15 into pebble duct 12 of an inert gas such as steam. The said pressure differences may be kept small, thus cutting down on the amount of seal steam required, by controlling the rate of flow of reaction effluent leaving zone 13 through line 16.

Pebbles which have given up part of their heat to the material undergoing conversion leave conversion zone 13 through pebble duct 20 and pebble feeder 21 passing into a pebble lift conduit 22 usually at a temperature considerably less than the conversion temperature. As a preferred method of operating, and in order to avoid thermally shocking the pebbles entering conduit 22, the lifting gas supplied by blower 23 is heated to the approximate temperature of the pebbles entering conduit 22 by means of burner 24. This step can be controlled either manually or automatically. In the latter instance a differential temperature controller can be employed to compare the temperature of the gas leaving the burner with that of the pebbles leaving conduit 20 and, in response to a temperature differential, say no greater than 50° F., control a valve in either the air or fuel supply lines to the burner. The preferred way of operating the burner is to have the primary air aspirate the fuel. The hot lift gas is passed upwardly through conduit 22 at a velocity sufficient to maintain the desired pebble circulation rate, thus elevating the pebbles to the main pebble drop-out chamber, the pebbles passing through conduit 26 back to pebble heating zone 10, thereby completing the cycle.

Different methods can be employed to determine the existence of a blocked lift line, or an impending block in the lift line. By "impending block" I mean that point in the deviation of a selected variable beyond which a block is inevitable unless corrective measures are taken. For the purpose of describing this embodiment of my invention I will assume that lift conduit 22 is 10 inches in diameter and 90 feet long from the point of pebble entry to the point of pebble discharge into drop-out chamber 25. I will assume also that 90,000 pounds per hour of pebbles at 1000° F. are to be elevated in said lift. Under these conditions 2190 S. C. F. M. of air at a delivery pressure of 3.11 p. s. i. g. will be required. The calculated pressure drop of such a system will amount to 2.39 p. s. i. g. Thus in the operation of the lift under the conditions hereinbefore described it will be necessary for 2190 S. C. F. M. of air to leave pebble drop-out chamber 25 through vent 27 and pebble conduit 26. If pebble conduit 26 is 10 feet long and 7 inches in diameter and is maintained pebble full there will be approximately  $3\frac{1}{2}$  per cent of the air lost through said leg or approximately 65 S. C. F. M. Thus approximately 2125 S. C. F. M.

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must pass through vent 27. The rate of flow of gas through vent 27 may fluctuate for several reasons. However, when the rate drops to about 1800 S. C. F. M. a block in conduit 22 is inevitable. When the said drop is detected by rate of flow controller 30, said controller 30 automatically resets rate of flow controller 31 controlling valve 32 in steam line 33 to turbine 34 driving blower 23, thus increasing the rate of flow of lift gas. Another method consists in having controller 30 open and close a valve 42 in a by-pass line 43 so that the extra steam to speed up turbine 34 would not be metered by rate of flow controller 31 which controller would be set to maintain a normal rate of flow and hence speed for turbine 34. The amount of steam which would flow through the by-pass line would be sufficient to speed blower 23 to capacity, or slightly more, and then would be shut off by controller 30 when no longer needed. The degree of this increase will depend upon the available capacity of blower 23. It is desirable to operate blower 23 at 50 to 75 per cent of rated capacity so that the extra capacity is available when needed to overcome blocking tendencies. Another method of increasing the rate of flow of lift gas involves using an electrically driven blower so that speed changes can be made by means of a rheostat. At the same time that controller 30 increases the speed of blower 23 it also automatically opens valve 35 in by-pass conduit 36 thus causing deceleration of the pebbles lifted at the resultant increased velocity due to the increased rate of flow of lift gas at an increased pressure. This is accomplished by disengaging part of the lift gas at a point below drop-out chamber 25 while keeping constant the cross-sectional area of the pebble lift conduit. This step is necessary to prevent the pebbles from smashing themselves in drop-out chamber 25. Actually, by-pass conduit 36 is connected to a closed, expanded concentrically attached section of lift pipe 37. Screen 38 provides the means for maintaining the cross-sectional area of the upwardly flowing pebble stream constant. Alternately, conduit 22 may merely be perforated to accomplish the same purpose. The expanded section 37 of the lift line, for nominal pebble surges, can be located a short distance below the drop-out. For violent surges this distance must be increased to decrease the pebble velocity into the drop-out. In the latter case two to ten times the normal minimum height of drop-out 25 will be required for the location of expanded section 37 below drop-out 25, depending on the velocity of pebble flow in line 22 and the distance of travel in 25 beyond the top of conduit 22. In the former instance when the length of drop-out 25 is nominal based on normal operation with moderate pebble velocities in conduit 22 a distance of one half to one and one half times the length of drop-out 25 would be required.

When blower 23 is being operated at capacity it may not be desirable to speed it up over capacity, even for only short intervals of time when an incipient block, or actual block, in the lift line is detected. Thus, as an alternative way of operating, or in addition to increasing the speed of blower 23, controller 30 can be made to automatically open a valve 41 in line 40 to admit a sufficient amount of superheated steam into the bottom of conduit 22 to increase the rate of flow of upwardly flowing lift gas to the degree necessary to overcome any impending or actual blockage in the lift line. If this alternative or conjunctive method is employed it is desirable that the temperature difference between the steam and pebbles be as small as possible to minimize thermal shock to the pebbles. However, the advantages to be gained by the increased rate of flow of lift gas to overcome incipient or actual blockage could more than offset any loss due to thermal shock to the pebbles.

When the rate of flow of gaseous effluent through vent 27 in drop-out chamber 25 increases to about 2125 S. C. F. M., the normal rate of flow for the particular embodiment being described, the pebble flow will also

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have been restored practically to normal. At that time controller 30 automatically closes valve 35 in line 36 and automatically resets rate of flow controller 31 to its normal operating point thus closing valve 32 in steam line 33. It will also close valve 41 in line 40, if that particular means for increasing the rate of flow of lift gas is being employed, or valve 42 in by-pass line 43 if that embodiment is employed.

As hereinbefore noted different methods can be employed to detect the existence of at least an impending pebble block in conduit 22. For example, another embodiment of my invention involves the use of a pressure controller instead of rate of flow controller 30. Here as the pressure builds up in the bottom of the lift to a predetermined value of magnitude such to indicate at least an impending block in conduit 22, the pressure controller would cause the same chain of events as hereinbefore described. It would be advantageous in this embodiment to employ a positive displacement blower, although a centrifugal type blower can be employed in this embodiment as well as others mentioned. When the pebble circulation rate is returned to normal the value of the pressure which had built up when the rate of flow of lift gas was increased will fall to a point below that which caused the rate to be increased, and said pressure controller will then automatically close valves 35 and 41 and reset flow controller 31 to normal.

Another modification involves the use of a differential pressure controller connected between the bottom of conduit 22 and expanded section 37. For any given pebble flow rate the differential pressure across conduit 22 between the two points will remain substantially constant. However, when the said differential pressure increases a predetermined amount of magnitude sufficient to indicate at least an impending pebble blockage in conduit 22, the differential pressure controller will cause the same chain of events described hereinbefore and reverse them when the differential pressure returns to normal. An advantage to operating my invention according to these last two embodiments is that pebble conduit 26 need not be kept pebble full and the lift gas is vented directly to the atmosphere. Also, in these two embodiments by-pass conduit 36 need not connect into drop-out chamber 25 but can be vented right to the atmosphere since it is not necessary to meter all the lift gas.

A further modification of my invention involves the use of a pressure controller connected to detect a drop of predetermined magnitude in a normally fixed back pressure maintained in drop-out chamber 25 sufficient to indicate at least an impending block in conduit 22, and in response thereto cause the chain of events described. When normal pebble flow has been restored in conduit 22 the value of said back pressure will increase over that normally maintained due to a decrease in the number of pebbles in the lift pipe and the increased delivery pressure. The pressure controller will then reverse the chain of events, also as described hereinbefore.

It will be appreciated that the degree of variation in the variable selected for observation which will indicate at least an impending block in lift conduit 22 will be dependent upon many factors, the most important of which is the pebble circulation rate to be maintained.

While this invention has been described and exemplified in terms of its preferred embodiment, it will be appreciated that modifications may be made without departing from the spirit of the invention as hereinbefore described.

I claim:

1. A method for maintaining continuous flow in a gas lift in a pebble heater system, which comprises, detecting at least an impending block in the lift conduit by detecting a predetermined variation in a preselected variable and in response to said variation increasing the

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rate of flow of lift gas upwardly through said conduit sufficient to overcome the objectionable conditions of pebble flow, decelerating the pebbles lifted at the resultant increased velocity before entry into a pebble drop-out chamber to minimize mechanical shock thereto by disengaging part of the lift gas from the pebble stream at a point below said drop out chamber, and decreasing said rate of flow of lift gas to normal and stopping deceleration of pebbles as hereinbefore described when the value of the preselected variable indicates that the conditions which caused said objectionable pebble flow no longer obtain.

2. A method for maintaining continuous flow in a gas lift in a pebble heater system, which comprises, maintaining a normally fixed back pressure in the pebble drop-out chamber and in response to a drop in said back pressure of magnitude such to indicate at least an impending block, increasing the rate of flow of lift gas by increasing the speed of the blower supplying lift gas, decelerating the pebbles lifted at the resultant increased velocity before entry into the pebble drop-out chamber to minimize mechanical shock thereto by disengaging part of the lift gas from the pebble stream at a point below said drop-out chamber and decreasing the rate of flow of lift gas to normal and stopping deceleration of said pebbles as hereinbefore described when the value of the back pressure in the drop-out chamber returns to normal.

3. A method for maintaining continuous flow in a gas lift in a pebble heater system which comprises, maintaining a normally fixed pressure at the bottom of the lift conduit and in response to a predetermined buildup in said pressure of magnitude such as to indicate at least an impending block, increasing the rate of flow of lift gas and decelerating the pebbles lifted at the resultant increased velocity before entry into the pebble drop-out chamber to minimize mechanical shock thereto by disengaging part of the lift gas from the pebble stream at a point below said drop-out, and decreasing the rate of flow of lift gas to normal and stopping deceleration of said pebbles as hereinbefore described when the value of said pressure at the bottom of the lift conduit falls below the point at which the flow rate was caused to be increased.

4. A method according to claim 3 wherein the rate of flow of lift gas is increased by increasing the speed of the blower supplying same.

5. A method according to claim 3 wherein the rate of flow of lift gas is increased by admitting superheated steam to the lift conduit at a point below the point of pebble entry into said conduit.

6. A method for maintaining continuous flow in a gas lift in a pebble heater system, which comprises, maintaining a normally fixed rate of flow of gaseous effluent through the vent pipe of the pebble drop-out chamber, and in response to a predetermined drop in said rate of flow of magnitude such as to indicate at least an impending block, increasing the rate of flow of lift gas upwardly through said conduit, decelerating the pebbles lifted at the resultant increased velocity before entry into the pebble drop-out to minimize mechanical shock thereto by disengaging part of the lift gas from the pebble stream at a point below said drop-out, and decreasing the rate of flow of upwardly moving lift gas to normal and stopping deceleration of said pebbles when the rate of flow of the gaseous effluent through said vent pipe in said pebble drop-out chamber returns to its normal value so as to indicate that the conditions which caused the objectionable pebble flow no longer obtain.

7. A method according to claim 6 wherein the rate of flow of lift gas upwardly through said conduit is increased by increasing the speed of the blower supplying same.

8. A method according to claim 6 wherein the rate

of flow of lift gas upwardly through said conduit is increased by admitting superheated steam to the bottom of the lift conduit below the point of pebble entry.

9. A method for maintaining continuous flow in a gas lift in a pebble heater system, which comprises, maintaining a normally fixed differential pressure across the lift conduit, and in response to a predetermined increase of said differential pressure of magnitude such as to indicate at least an impending block in said conduit, increasing the rate of flow of lift gas upwardly through said conduit, decelerating the pebbles lifted at the resultant increased velocity before entry into the pebble drop-out to minimize mechanical shock thereto by disengaging part of the lift gas from the pebble stream at a point below said drop-out, and decreasing the rate of flow of lift gas upwardly to normal and stopping deceleration of said pebbles when the differential pressure across said lift conduit returns to normal.

10. A method according to claim 9 wherein the rate of flow of lift gas upwardly is increased by increasing the speed of the blower supplying said lift gas.

11. A method according to claim 9 wherein the rate of flow of lift gas upwardly in said conduit is increased by admitting superheated steam at the bottom of the lift conduit at a point below the point of pebble entry.

12. A gas lift for a pebble heater which comprises, in combination, a source of lift gas; a conduit system connected at the bottom to said source; means for varying the rate of flow of said lift gas through said conduit system; a pebble drop-out chamber connected to the top of said conduit system; a closed expanded concentrically attached section of lift conduit connected over the main lift conduit below said drop-out chamber; means under said expanded section for disengaging lift gas into said expanded section while keeping constant the cross-sectional area of the pebble stream; a valved by-pass conduit connecting said expanded section of lift conduit to said drop-out chamber; and control means for detecting at least an impending block in the lift by detecting a predetermined variation in a preselected variable, and in response to said variation automatically operating said first-mentioned means to increase the rate of flow of lift gas and to automatically open the valve in said by-pass conduit, and to automatically close said valve and decrease said rate of flow to normal when the value of the preselected variable indicates that the conditions which caused at least said impending block no longer obtain.

13. A gas lift for a pebble heater which comprises, in combination, a blower; a conduit system connected at the bottom to said blower; means for varying the speed of said blower; a pebble drop-out chamber connected at the top of said conduit system; a closed expanded concentrically attached section of lift conduit connected over the main lift conduit one-half to one and one-half times the length of said drop-out chamber below said drop-out chamber; means under said expanded section for disengaging lift gas into said expanded section while keeping constant the cross-sectional area of the pebble stream; a valved by-pass conduit connecting said expanded section of lift conduit to said drop-out chamber; and a rate of flow controller connected to detect the rate of flow of gaseous effluent vented from said pebble drop-out chamber, and in response to a predetermined drop in said rate of flow of magnitude such as to indicate at least an impending block in the lift conduit to automatically operate said means to increase the speed of said blower and to automatically open the valve in said by-pass conduit, and to automatically close said valve and decrease the speed of said blower to normal when the rate of flow of gaseous effluent from said pebble drop-out chamber returns to normal.

14. A gas lift for a pebble heater which comprises, in combination, a centrifugal blower; means for varying speed of said blower; a conduit system connected at the bottom to said blower; a pebble drop-out chamber con-

nected at the top of said conduit system; a closed expanded concentrically attached section of lift conduit connected over the main lift conduit one-half to one and one-half times the length of the drop-out chamber below said drop-out chamber; means under said expanded section for disengaging lift gas into said expanded section while keeping constant the cross-sectional area of the pebble stream; a valved by-pass conduit connecting said expanded section of lift conduit to said drop-out chamber; and a differential pressure controller connected to detect a normal differential pressure between the bottom of the lift and said expanded section of lift pipe, and in response to an increase in said differential pressure the magnitude of which is such as to indicate at least an impending block in said lift line to automatically operate said means to increase the speed of said blower and to automatically open the valve in said by-pass conduit, and to automatically close said valve and decrease the rate of speed of said blower to normal when the value of the differential pressure returns to normal.

15. A gas lift for a pebble heater which comprises, in combination, a positive displacement blower; means for varying the speed of said blower; a conduit system connected at the bottom to said blower; a pebble drop-out chamber connected at the top of said conduit system; a closed expanded concentrically attached section of lift conduit connected over the main lift conduit one-half to one and one-half times the length of said drop-out chamber below said drop-out chamber; means under said expanded section for disengaging lift gas into said expanded section while keeping constant the cross-sectional area of the pebble stream; a valved by-pass conduit connecting said expanded section of lift conduit and said drop-out chamber; and a pressure controller connected to detect a normal operating pressure in the bottom of said lift and in response to a predetermined build-up of said pressure of magnitude sufficient to indicate at least an impending block in the lift to automatically operate said means to increase the speed of the blower and to automatically open said valve in said by-pass conduit, and to automatically decrease the speed of the blower to normal and automatically close said valve in said by-pass conduit when the value of said pressure at the bottom of the lift conduit falls below the point at which the speed of the blower was caused to be increased.

16. A gas lift for a pebble heater which comprises, in combination, a centrifugal blower; means for varying the speed of said blower; a conduit system connected at the bottom to said blower; a pebble drop-out chamber connected at the top of said conduit system; a closed expanded concentrically attached section of lift conduit connected over the main lift conduit one-half to one and one-half times the length of said drop-out chamber below said drop-out chamber; means under said expanded section for disengaging lift gas into said expanded section while keeping constant the cross-sectional area of the pebble stream; a valved by-pass conduit connecting said expanded section of lift conduit and said drop-out chamber; and a pressure controller connected to detect a normally fixed back pressure in said drop-out chamber, and in response to a predetermined drop in said back pressure of magnitude such as to indicate at least an impending block in said conduit to automatically operate said means to increase the speed of said blower and to automatically open said valve in said by-pass conduit, and to automatically close said valve and decrease said speed of blower to normal when the value of the back-pressure in said drop-out chamber returns to normal.

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