March 22, 1955 H. J. OGORZALY 2,704,704

SOLIDS PUMP APPLIED TO COAL GASIFICATION

Filed Oct. 22, 1949

2 Sheets-Sheet 1

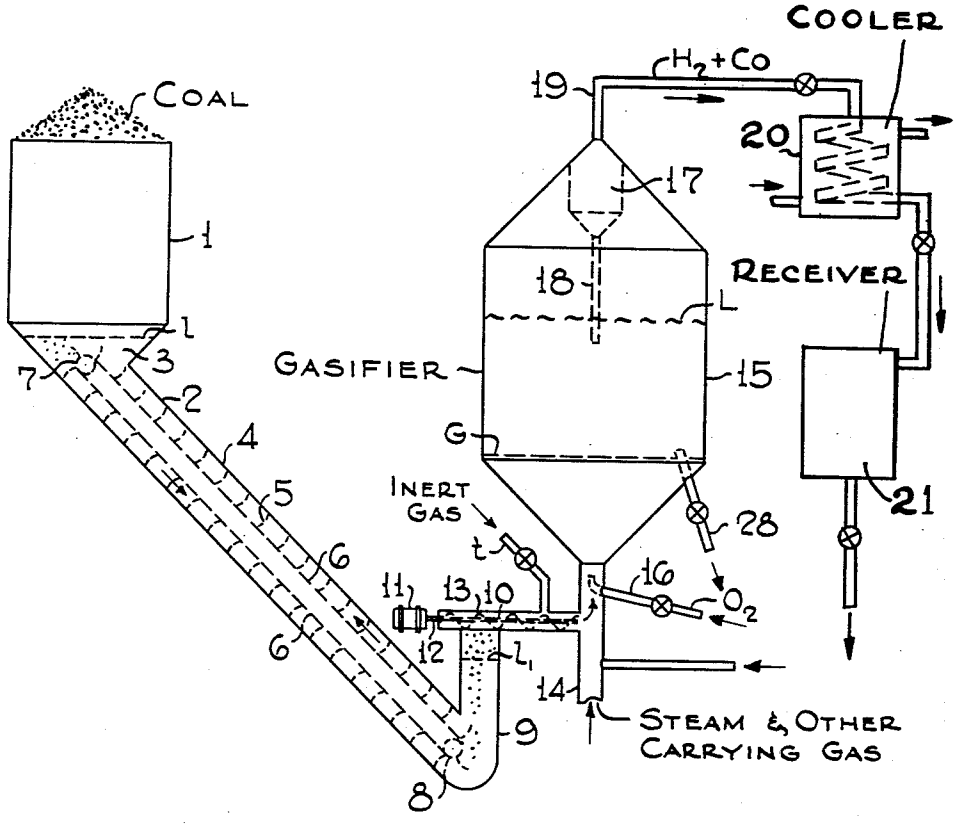


FIG. - 1

Henry J. Ogorzaly Inventor

By J. Cashman Attorney

March 22, 1955 H. J. OGORZALY 2,704,704

SOLIDS PUMP APPLIED TO COAL GASIFICATION

Filed Oct. 22, 1949 2 Sheets-Sheet 2

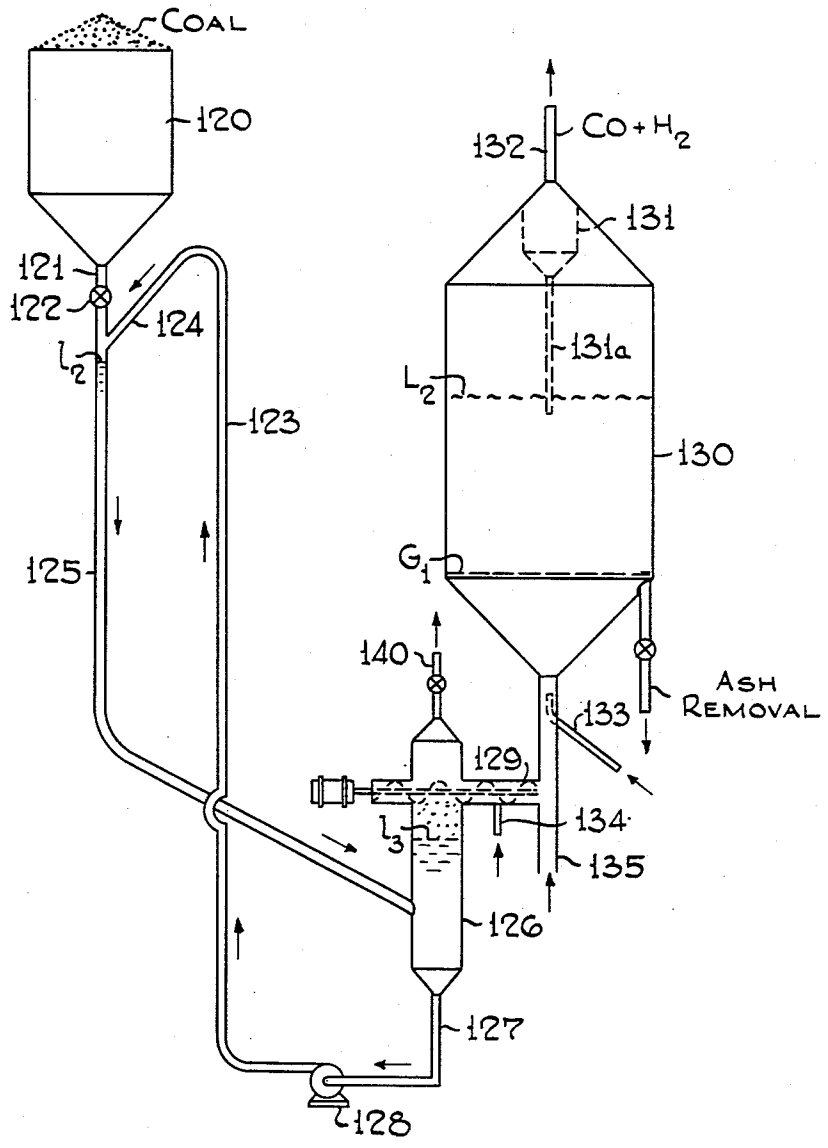


FIG.-2

Henry J. Ogorzaly Inventor

By J. Cashman Attorney

United States Patent Office 2,704,704 Patented Mar. 22, 1955

2,704,704

SOLIDS PUMP APPLIED TO COAL GASIFICATION

Henry J. Ogorzaly, Summit, N. J., assignor to Esso Research and Engineering Company, a corporation of Delaware

Application October 22, 1949, Serial No. 123,070

6 Claims. (Cl. 48—206)

The present invention relates to a method of gasifying carbonaceous solids in a zone of high pressure in conjunction with hydrocarbon synthesis gas production and utilization. More particularly, the invention relates to improvements in the transfer of the carbonaceous solids in a subdivided form from a zone at atmospheric or relatively low pressure to the reaction zone operating, as stated, at a high pressure.

Heretofore and prior to the present invention, it was a matter of record and commercial practice to transfer solids, such as catalysts, from a zone of lower pressure to one of higher gas pressure by employing a combination of so-called "lock-hoppers" or by means of the pressure developed by an elongated vertical column of aerated powdered solids.

Such devices and apparatus are open to many objections, particularly where it is desired to transfer the solids into a zone of relatively high pressure, such as one in which the pressure is 400 pounds per square inch or higher. For instance, lock-hoppers are cumbersome, expensive to manufacture and operate, and introduce substantial added requirements for gas compression. A single standpipe would be of impractical height while the use of a number of standpipes in series involves an extremely delicate balancing of discharge rates.

According to the present invention, solids can be transferred from an open hopper to a reaction zone operating at pressures as high as 400 pounds per square inch and higher, through the device of operating means which are relatively inexpensive to construct and simple to operate. The ability to feed solids from a low to a high pressure zone is important, for example, where it is desired to produce a hydrocarbon synthesis gas from coal or coke. In the said synthesis, high pressure operation results in reduced cost of equipment, greater selectivity to liquid products when using promoted iron catalysts, and extended catalyst life. The costs of compressing synthesis gas to the desired operating pressure are, however, very substantial, and a considerable economic incentive exists to reduce the compression cost. Since between 4 and 5 volumes of synthesis gas are produced per volume of oxygen fed to a generator gasifying coal or coke with oxygen-steam mixtures, it is apparent that the volume of gas to be compressed can be very much reduced by operating the gas generator as well as the synthesis unit itself under elevated pressure. Similar advantages for gasification under substantial pressure exist where the produced gas is intended for delivery to high pressure fuel gas transmission or distributing lines.

In brief compass, one important aspect of the present invention is based on the principle that a vertical column of a high density liquid of sufficient length is adapted to develop a desired pressure differential between zones of low and high pressure, and at the same time granular or subdivided carbonaceous material may be transferred through the column of liquid from the said zone of low pressure to that of higher pressure. A satisfactory heavy liquid medium for providing a tight gas seal and a high pressure differential is mercury, although others may be used.

An important object of the present invention is to provide means of utilizing a high density liquid of the character indicated to balance a pressure differential of high degree between two zones and to effect the transfer through the high density liquid, of subdivided solid carbonaceous material from a zone of low pressure to a treating zone operating at higher pressure.

Another aspect of the present invention involves the formation of hydrogen and carbon monoxide under pressure by the gasification of a carbonaceous solid for use in a hydrocarbon synthesis gas.

Another object of the invention is to provide a relatively simple and inexpensive means for feeding subdivided carbonaceous solids continuously to a pressurized reaction zone operating continuously, and at the same time preventing gas leakage from the reaction zone.

Another object of the invention involves charging subdivided oil shale from a zone of low pressure to a zone of high pressure.

In the accompanying drawings there is shown in Fig. 1, diagrammatically, an apparatus layout in which one modification of the invention may be carried into effect; and in Fig. 2 a second modification of the invention is depicted diagrammatically.

Referring in detail to Fig. 1, reference character **1** represents an open hopper, which in the illustration shown, contains ground or lump coal and **2** represents a transfer line disposed as shown at an inclination, which line contains liquid mercury at substantially atmospheric temperature identified by reference character **3**. The level of the liquid mercury is shown by reference character *l*. There is also disposed within the line **2**, a bucket type conveyor **4**. In general, the conveyor is of conventional construction consisting of a plurality of receivers or buckets **5**, in fixed engagement with a driven chain or belt **6**, which is in operating engagement with shafts **7** and **8**, one of which may be driven by a suitable driving means, such as an electric motor (not shown). The line **2** terminates at its lower end in communication with vertical column **9**, partially filled with mercury to a level indicated by reference character l_1. There is disposed at the upper end of column **9** a screw conveyor **10**, the interior of the conveyor **10** and the column **9** being in open communication with each other. The discharge end of conveyor **10** projects into pipe **14**, which latter serves as an inlet to a treating vessel **15**.

In operation, the ground coal contained in hopper **1** floats on the mercury but is partially submerged by the weight of supported coal, so that the lower layer is swept by the buckets of conveyor **4**, which are thus filled with coal. The filled buckets responsive to driven chain **6**, carry the coal from the hopper downward through the body of mercury (which is at atmospheric temperature or thereabouts) in **4** to vertical pipe **9**; the coal in the bucket is discharged into the base of column **9** by inversion of the said buckets. The transport of coal through the mercury in **2** is such that there is no overall displacement of mercury so that the mercury remains confined within the limits indicated at *l* and l_1. The motion of the buckets through the mercury in **2** may be likened to the effect caused when one drags his fingers spaced apart through a basin of water. There may be internal circulation in **2** but the body of liquid in **2**, considered as a whole, will be static in the sense that there is no displacement beyond the limits indicated, and in that sense the word "static" will appear in some of the appended claims. Since the coal has a lower density than the mercury, the buoyant effect of the latter causes the coal to rise upwardly through the column of mercury which partially fills vertical pipe **9**, and collect at the top thereof. Accumulation of coal at this point fills the upper portion of pipe **9**, so that coal eventually passes into the barrel of screw conveyor **10**. Operation of driven pulley **11**, which is securely mounted on shaft **12**, to which are also fixedly mounted a plurality of flights **13**, causes the coal to be withdrawn from pipe **9** and discharged into inlet pipe **14**. In the present example, where coal is to be gasified, steam generated under pressure at some source (not shown) is charged to pipe **14** and passes upwardly, carrying the powdered coal in suspension into the reactor **15**. A small stream of inert gas such as product CO and H_2 is introduced through a tap *t* into conveyor **10** to prevent the condensation of steam on the cold charge. The reactor is of a form and construction conventional in the fluid solids type of operation, as for instance employed in oil cracking. As is conventional in this type of reactor, the suspension of coal and steam passes through a gas distributing means G, which may be a refractory grid or

other foraminous member, forming in the space above G, a dense fluidized mass of solids in steam. In order to support the reaction between the steam and the coal to form water gas, heat is, of course, necessary. Some of that heat may be supplied by superheating the steam. However, additional heat is required and to supply this heat by the partial combustion of coal, oxygen is also charged to the reactor **15**. Oxygen from some source (not shown) is introduced to the present system through line **16**.

The superficial velocity of the gasiform material in **15** may be fixed within the limits of, say, ½ to 1½ to 2 feet per second in order to form the ground carbonaceous material into a fluidized mass. The feed material may have a particle size of from, say, 20 microns up to particles passing through 10 mesh screen; preferably, the feed shall all pass through a 30 mesh screen. By superficial velocity one has reference to the velocity of the gasiform material through the expanded section of reactor **15** assuming there were no solids in the reaction vessel. Depending upon the superficial velocity of the gasiform material and the actual mass or weight of carbonaceous solids in the reactor, the fluidized bed will have an upper level at L, above which there will be a dilute suspension of the carbonaceous solid in the reaction gases. The reactor **15** may be provided with one or more solids-gas separators **17**, through which the gasiform product is forced in order to separate therefrom entrained material, which is returned to the dense phase by one or more dip pipes **18**; or similar separators may be provided externally to reaction vessel **15**, e. g. after cooler **20**.

In the case where the reaction occurring in **15** is the gasification of coal or coke, the temperature maintained therein is from 1400° to 2000° F. It is desired in the present example to operate under a pressure in the vessel **15** which may be of the order of 200 to 600 pounds per square inch, for example, 475 pounds per square inch above atmospheric pressure. The differential in height of the levels l and l_1 required to balance a differential pressure of 475 p. s. i. is about 80 feet when mercury is employed as the balancing fluid.

Referring again to the reactor **15**, provision is made for withdrawing ash constituents through a valved line **28**. Furthermore, it is desirable to include an alkaline reacting compound such as sodium carbonate in the charge to the gasifier **15**. The presence of such compounds and the like service to catalyze the gasification reaction.

Referring to the modification of the invention illustrated in Fig. 2, **120** represents an open hopper containing a mass of subdivided carbonaceous material, from which said material may be withdrawn through a line **121** at a rate controlled by feeder **122** which may be a rotary valve as indicated or a noncompression screw or any other suitable feed device. It is not required to build up a pressure differential. In this modification a high density liquid, for example, mercury circulates continuously in the system consisting of lines **123**, **124**, **125**, the elongated vertical receptacle **126**, a line **127** and a pump **128**. The coal discharged from feeder **122** onto the level of mercury indicated by l_2 is continuously entrained by the flowing stream of mercury and carried in suspension through line **125**, which discharges into receptacle **126**. Receptacle **126** serves as a coal disengaging zone, the coal moving upwardly to the surface of the mercury indicated at l_3 because of the buoyant effect of the latter. By employing high velocity turbulent flow through line **125**, the buoyant effect is overcome in this vertical column, and the coal particles are caused to flow downwards in line **125**. In receptacle **126**, the upper layer of mercury above the point of introduction of line **125** does not circulate and in the lower section the velocity of the liquid is sufficiently low so that the buoyant effect exceeds the drag on the particles, and they rise as a result. As before explained in connection with the operation of Fig. 1, the carbonaceous material accumulated above the mercury level l_3 is forced by the operation of the screw **129** into gas inlet line **135** of gasifier **130**. As before, steam generated under pressure from some source (not shown) is introduced into the system through line **135** and passes upwardly therethrough, acquiring the coal or carbonaceous material in suspension. The suspension is then forced into the bottom of gasifier or reactor **130**, thereafter passes through a foraminous member G_1 into the reactor **130** where it forms a fluidized bed of subdivided solids in gasiform material by controlling the superficial gasiform velocity, as explained in connection with the operation of the similar part shown in Fig. 1. By thus controlling the superficial velocity of the gasiform material and the actual amount of solids therein, the bed will have an upper dense phase level in **130** at a desired level L_2. The treatment of the solids with the gasiform material is such as to effect the desired conversion as where carbonaceous solids are treated with steam or steam and oxygen to form water gas. The product is recovered through line **132** from the reactor **130** after having first passed through one or more cyclone separators **131** provided with one or more dip pipes **131***a*, serving to return separated solids to the dense suspension. Oxygen utilized to maintain the desired temperature in **130** by causing combustion of some of the carbonaceous material may be introduced into pipe **135** from some source (not shown) through line **133**.

The screw for feeding coal from the disengaging zone **126** into the inlet pipe **135** of reactor **130** is preferably of the non-compression type. However, in order to prevent leakage of steam from the pipe **135** into the barrel of the screw, with which it is in communication, it is preferable to force gas under pressure into said barrel as, for example, through line **134** of Fig. 2. In the operation of the system illustrated in Fig. 2, air entering with the coal through feeder device **122** will be carried with the coal into disengaging receptacle **126**. If desired, it may be vented through line **140**.

The differential in height between mercury levels l_2 and l_3 in Fig. 2 provides the required head of dense liquid to balance the super-atmospheric pressure maintained in reactor **130**. Approximately 80 ft. of differential height will be required to balance a 475 p. s. i. g. pressure level when mercury is employed as the circulating fluid. It will be appreciated that the pump **128** is not required to generate a pressure differential of this magnitude, since liquid-filled column **125** substantially balances column **123**. The pump provides only the pressure drop resulting from circulation of the fluid, plus a small added pressure head to compensate for the somewhat lower density of the fluid and solid mixture in column **125**.

Although the examples have referred to liquid mercury as the confining fluid, other liquids are also suitable, a principal requirement being that the fluids should have a high density capable of balancing the desired pressure by a column of reasonable height. Low melting point metal alloys, such as conventional lead-tin solders, melting at about 350° F. are suitable. Where normally solid materials are employed, suitable provision for maintaining temperatures in safe excess over the melting point must be provided.

An important modification of the invention involves treating shale in the form of a fluidized bed under pressure in, say, a vessel of the type illustrated by **15** in Fig. 1. The advantages of retorting shale under pressure are, among others, that a smaller vessel may be employed to process the same charge in the form of a fluid bed than if the same charge were retorted under, say, atmospheric pressure. Also the light ends recovery is simplified where the retorting is carried out under pressure. Furthermore, if the retorting is carried out in the presence of added hydrogen, under superatmospheric pressure, the process is improved as to product distribution, as to quality of product in that less sulfur is found in the product and the process generally is operated in a more satisfactory manner.

The present invention relates, therefore, generally to transporting carbonaceous material from a zone of lower pressure to one of higher pressure according to the means hereinbefore described in detail, and thereafter treating the thus transported material in the form of a fluidized bed to yield gasiform material under superatmospheric pressure.

Many modifications of the invention will be apparent to those familiar with the art without departing from the spirit thereof.

What is claimed is:

1. In the process of continuously gasifying subdivided carbonaceous material which comprises contacting said carbonaceous material with steam and oxygen in a reaction zone at elevated temperature and pressure and while

the said carbonaceous material is in the form of a dense, fluidized mass, the improvement which comprises feeding subdivided carbonaceous material to said gasifying zone from a zone of substantially atmospheric pressure by withdrawing carbonaceous material from a feed hopper, introducing it at substantially atmospheric pressure into the top of an elongated column of a non-reactive liquid of high density and of such height as to develop a hydrostatic pressure at the lower end thereof exceeding the pressure in the reaction zone, disposing said lower end of the column of high density liquid in communication with a vertical receiver also containing said high density liquid, causing the said liquid to flow in high velocity turbulent flow downwardly through an elongated column carrying entrained carbonaceous material and to discharge into a portion of said receiver intermediate between its top and bottom, maintaining said high density liquid relatively quiescent in the top and bottom sections of said receiver, permitting the carbonaceous material to rise as a result of its buoyancy in the high density liquid in said receiver to the top of the liquid in said receiver, while keeping the bottom section below said intermediate portion substantially free of carbonaceous materials, withdrawing carbonaceous material at substantially reaction zone pressure from a point near the top of said receiver, transporting said pressured carbonaceous material into a bottom portion of the aforesaid fluidized mass of carbonaceous solids in said gasifying zone, withdrawing high density liquid substantially free of carbonaceous materials from said bottom section and returning liquid so withdrawn through impelling means to the top of said column.

2. The process set forth in claim 1 in which said elongated column is substantially vertical.

3. The process set forth in claim 1 in which said elongated column is at least partially inclined.

4. The process set forth in claim 1 in which said nonreactive liquid is mercury.

5. The process set forth in claim 1 in which said carbonaceous material is coal.

6. The process set forth in claim 1 in which said carbonaceous material is coke.

References Cited in the file of this patent

UNITED STATES PATENTS

1,857,799	Winkler	May 10, 1932
2,187,872	Winkler et al.	Jan. 23, 1940
2,357,694	Schutte	Sept. 5, 1944
2,453,458	Reed et al.	Nov. 9, 1948
2,547,015	Kirkbride	Apr. 3, 1951
2,585,472	Kennedy	Feb. 12, 1952
2,613,832	Ogorzaly et al.	Oct. 14, 1952