# United States Patent [19]

**Moody**

[11] **3,871,839**

[45] **Mar. 18, 1975**


[54] **METHOD OF FEEDING SOLID CARBONACEOUS MATERIAL TO A HIGH TEMPERATURE REACTION ZONE**


[75] Inventor: **Burton E. Moody,** Allentown, Pa.

[73] Assignee: **Air Products and Chemicals, Inc.,** Allentown, Pa.



[22] Filed: **Oct. 12, 1972**

[21] Appl. No.: **296,959**

[52] **U.S. Cl.** ................ **48/197 R,** 48/210, 48/DIG. 7

[51] **Int. Cl.** ................ **C10j 3/06**

[58] **Field of Search**..... 48/197 R, 202, 210, DIG. 7, 48/206; 34/12, 22, 33; 110/7 R, 7 A, 7 S; 159/16 R, 29; 201/20; 252/373



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,595,234 | 5/1952 | Eastman | 48/202 |
| 2,946,670 | 7/1960 | Whaley | 48/206 |
| 2,987,387 | 6/1961 | Carkeek et al. | 48/197 |
| 3,250,016 | 5/1966 | Agarwal | 34/10 |
| 3,384,974 | 5/1968 | Alleman et al. | 34/31 |
| 3,652,454 | 3/1972 | Robin et al. | 252/373 |
| 3,715,195 | 2/1973 | Tassoney et al. | 48/197 R |



*Primary Examiner*—S. Leon Bashore
*Assistant Examiner*—Peter F. Kratz
*Attorney, Agent, or Firm*—James C. Simmons; Barry Moyerman



[57] **ABSTRACT**

A method of feeding solid carbonaceous material to a gasifier operating under conditions of high temperature and pressure by forming a slurry of the carbonaceous material and a liquid vehicle, raising the internal pressure of the slurry to the operating level of the gasifier, drying the carbonaceous material by entraining the carbonaceous material in a hot gas stream, and thereafter separating the carbonaceous material and feeding the carbonaceous material to the gasifier. The method is adaptable to using the gasifier effluent to dry the carbonaceous material and includes using process materials such as char accumulated from the process and condensing steam to provide a portion of the source of carbonaceous materials and vehicle for the slurry.


**7 Claims, 2 Drawing Figures**

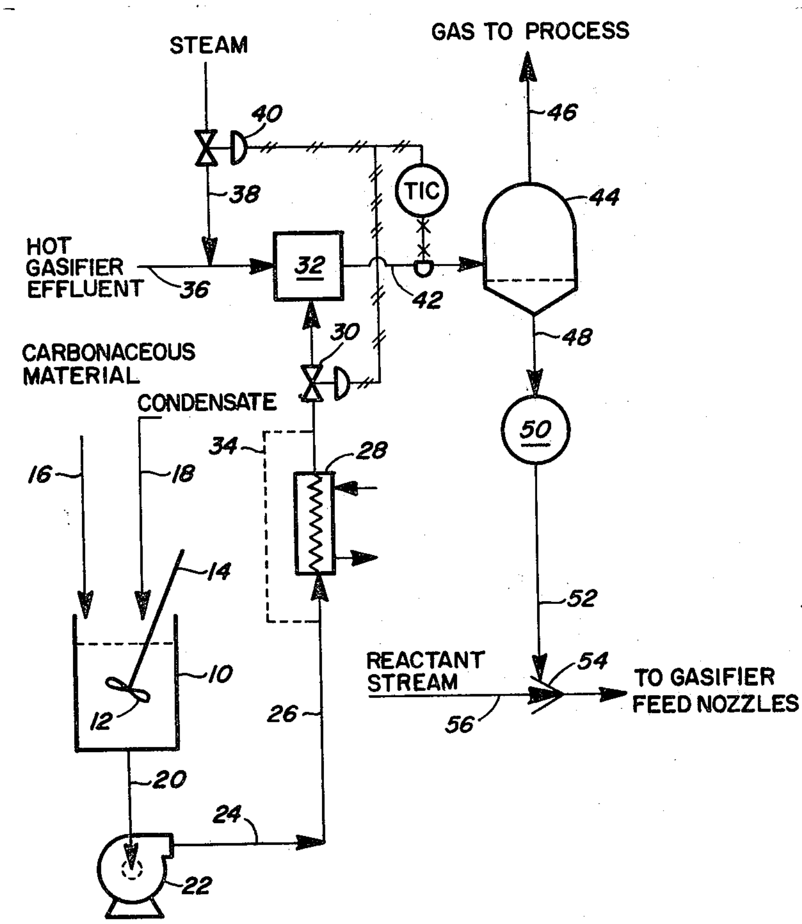

Fig. 2

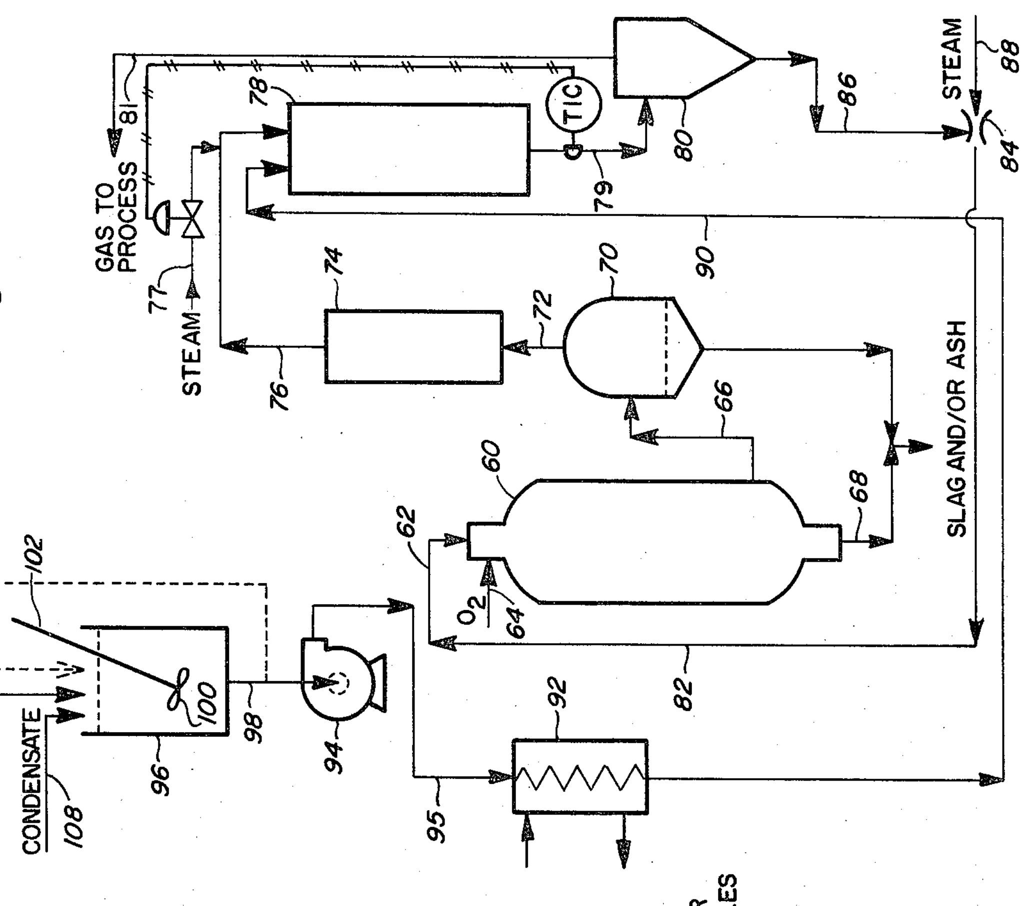
WET GRINDING ALTERNATE
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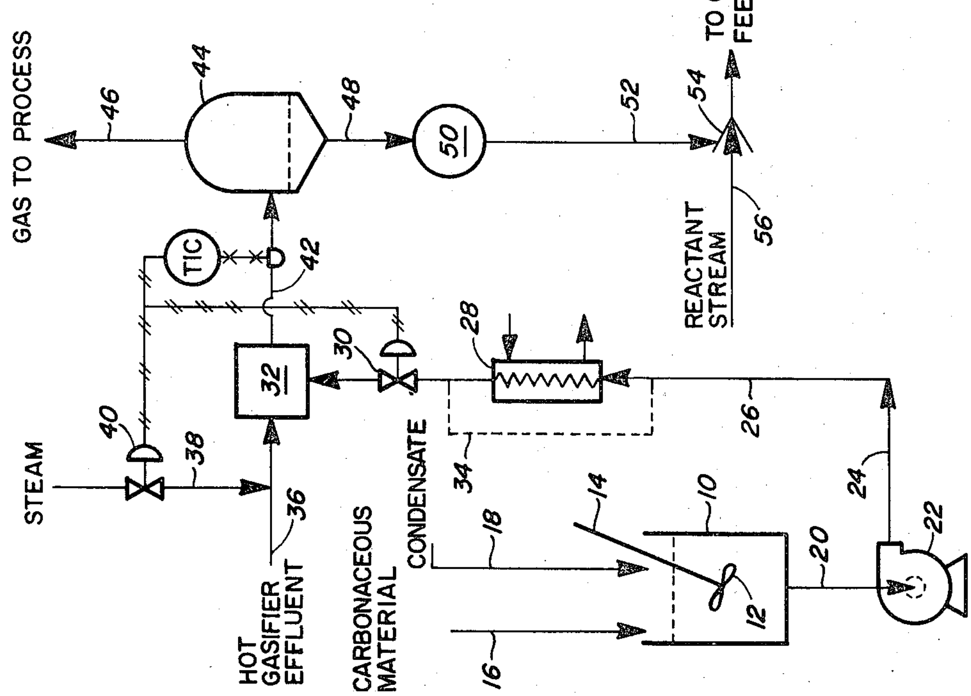
Fig. 1


HOT GASIFIER EFFLUENT
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CONDENSATE
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# METHOD OF FEEDING SOLID CARBONACEOUS MATERIAL TO A HIGH TEMPERATURE REACTION ZONE

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to the feeding of solid carbonaceous material, e.g. coal, into a high-pressure, high-temperature reaction zone such as a coal gasifier. In coal gasification, finely pulverized coal is reacted in the presence of steam and air oxygen at elevated temperature and pressure to form an effluent gas. If the product is to be a low BTU content gas, it is subject to removal of hydrogen sulfide and then used directly. If a high methane content gas is to be produced, the effluent gas is then subjected to various process steps including water shift reaction, acid gas removal and methanation thereby yielding a synthetic natural gas.

One such process is disclosed in U.S. Pat. No. 2,840,462; another is the process referred to as the "BCR Two-Stage Super-Pressure Gasification Process" developed by Bituminous Coal Research Incorporated of Monroeville, PA; and a third pertains to generation fo a synthetic gas by electrothermal hydrogasification developed by the Institute of Gas Technology of Chicago, ILL.

In the above processes, the finely divided carbonaceous material (coal) is fed to the gasification vessel by a conventional lock hopper feeding system, a piston feeder, and a hydrocarbon liquid slurry respectively after the coal has been ground to size, screened, dewatered, and stored in storage hoppers.

2. Prior Art.

Although use of a water slurry feed system for feeding solid carbonaceous materials to a hydrogasification vessel has not been shown in the prior art, slurry feed systems for use with other high-temperature reaction vessels for finely divided solid carbonaceous material is known. For example, U.S. Pat. No. 3,116,143 discloses a slurry feeding system wherein a coal slurry is injected directly into the hot zone of a blast furnace for manufacturing iron. The Patentee discloses injecting the slurry directly into the blast furnace without dewatering or otherwise removing the moisture.

Another feed system for feeding dried coal to a blast furnace as shown in U.S. Pat. No. 3,250,016 wherein the Patentee discloses a fluidized bef for drying the coal by using blast furnace off gas prior to injection into the blast furnace.

U.S. Pat. No. 3,207,102 discloses a slurry feed for a steam generating unit such as is found in a commercial electrical generating plant. Here again the slurry is not dewatered prior to injection into the furnace and the slurry is further comminuted by impingement against a breaker in the furnace zone. U.S. Pat. No. 3,229,651 discloses an alternate slurry feed means for conducting a finely divided solid carbonaceous material into a steam boiler or the like.

In a two-stage, super-pressure gasifier as developed by Bituminous Coal Research Incorporated, it is contemplated that coal will be fed to the gasifier by a pressurized piston feeder in conjunction with a star-wheel feeder. The coal will be pressurized by the piston feeder and fed into the gasifier by the star-wheel feeder.



As an alternative system of feeding the gasifier, it has been suggested to use a lock hopper system with and without staged pressure letdown. In the staged pressure system, a number of lock hoppers feed coal into a high-pressure surge vessel from which the coal would be fed to the gasifier. After the coal is transferred from a hopper into the surge vessel, the high-pressure gas in the hopper is vented to a series of receivers at different pressure levels down to atmospheric pressure. Gas is vented first to the highest pressure receiver and when pressure equalization is approached the venting is switched to the receiver at the next lower pressure and so on until the final venting is to atmospheric pressure. The lock hopper is then refilled with coal then pressurized in staged from each gas receiver in turn and the receivers are maintained at constant pressure by pumping gas from the receiver at the next lowest pressure. Final pressurization is made by pumping gas from the highest pressure receiver directly into the lock hopper.

In the non-staged lock hopper system, the coal is fed into one of several alternating hoppers, the hopper is pressurized, the coal is injected into the gasifier and the hopper is vented for receiving the next charge.

In each of the above systems, the cost of compressing the gas increases significantly with increases in operating pressure. The staged system while being more expensive to install operates at lower cost because of a lower required volume of pressuring gas and lower compressing costs.

## SUMMARY OF THE INVENTION

In order to avoid the foregoing problems and to provide an improved method of feeding solid carbonaceous material to a high-temperature, high-pressure reaction vessel, it has been discovered that the solid carbonaceous material can be dispersed in a liquid vehicle in the form of a slurry, the slurry can be raised to an elevated pressure by means of a slurry pump, the slurry can be dried using the high-temperature effluents from the gasification vessel and simultaneously entrained in a humidified gas, the solid carbonaceous materials can be separated from the gas into which it has been entrained, and fed at high pressure into the gasifier by means of a stream of hot recycled gas or stream. In addition, the separated gas can be sent to the further purification steps without loss of volume of production for the overall gasification process. It is further contemplated that char separated and collected in the gasification process and condensed steam from the process or boiler feed water can be used in making up the initial slurry.

Therefore, it is the primary object of this invention to provide an improved method for feeding solid carbonaceous material to a high-pressure, high-temperature reaction zone.

It is another object of this invention to provide a method for feeding solid carbonaceous material to a gasification vessel.

It is still another object of this invention to provide a method for feeding pulverized coal to a gasification vessel.

It is yet another object of this invention to provide a method for feeding solid carbonaceous material to a partial oxidation reactor.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic drawing of the method of the instant invention.

FIG. 2 is a schematic drawing of the method of the instant invention as applied to a process for producing a synthesis gas.

## DETAILED DESCRIPTION OF THE INVENTION

There is shown in FIG. 1 a schematic drawing of a coal feeding system that would be applicable to a coal gasification process. In a coal gasification process, finely divided coal is reacted at high temperature between 1,400° and 3,000° F and high pressure of approximately 15 to 100 atmospheres to form an effluent gas consisting of methane, water vapor, carbon monoxide, carbon dioxide, hydrogen, hydrogen sulfide, and char. The effluent gas is then subsequently treated to remove the unwanted constituents, and the other constituents are either recycled to the gasifier or futher processed so that the end product is a gas substantially methane that is suitable for pipeline use.

Referring now to FIG. **1**, there is shown a slurry tank **10** with an impeller **12** mounted on shaft **14** rotated by a suitable motor or other rotating device not shown. The tank **10** receives the pulverized carbonaceous material from a feed hopper or pipe that is shown by arrow **16**. The pulverized carbonaceous material generally is coal but can include coke, char or low grade volatile materials such as lignite. Arrow **18** designates a source of supply of water which can be fresh water from utility, boiler feed water, or condensed steam from the process generally referred to as condensate. The slurry tank **10** is connected via conduit **10** to a slurry pump **22** which in turn is connected through conduits **24, 26,** heat exchanger **28,** and valve **30,** to a mixing chamber **32.** The heat exchanger **28** is included in the process stream and can be bypassed if not needed as by conduit **34.** If used, the heat exchanger **28** can be used to heat the slurry by means of heat exchange with steam, hot condensate, hot gas from the gasifier or hog gas from an independent gas heater (not shown). The mixing chamber **32** contains an inlet conduit **36** for receiving hot gas, which in turn is connected to another conduit **38** having disposed therein temperature indicating control valve **40.** An outlet conduit **42** is connected to a separator **44,** which in turn has an outlet gas conduit **46** and a solids removal device shown as **48.** Removal device **48** in turn is connected to a coal feeder **50,** which in turn is connected to a conduit **52** to a venturi nozzle **54.** A conduit **56** is connected to the venturi nozzle **54** in order to entrain the coal into a reactant gas for injection of the reactant and gas and coal into the gasifier.

In the above process shceme, solid carbonaceous material, e.g. coal is fed through conduit **16** and condensate through conduit **18** into the slurry tank **10.** The impeller **12** is used to agitate the coal and condensate in tank **10** to form a slurry having approximately **50** percent by weight solids. The slurry is then pumped under pressure to the mixing chamber **32** which chamber is maintained at the pressure of the gasifier vessel as the slurry is sprayed therein. In the mixing chamber **32,** the slurry is contacted by the hot gasifier effluent entering through conduit **36.** The action of the hot gasifier effluent and the spraying of the slurry causes the water to be driven off and the solid carbonaceous material (coal) becomes dried and entrained in the humidified hot gasifier effluent. The evaporated water humidifies the effluent gas to enhance subsequent reactions in the shift convertor where the gas is used. Steam conduit **38** is included to maintain the temperature of the spray drying chamber and to adjust the humidity of the effluent gas with the entrained solid carbonaceous material which is passed through conduit **42** to a cyclone separator and solid carbonaceous storage vessel **44** wherein the solid carbonaceous material is separated from the gas ans stored for use as needed with the solid carbonaceous material being withdrawn through a solids removal device, e.g., conduit **48,** into feeder **50** for feeding into the gasification vessel. The dried carbonaceous material is fed under pressure from conduit **52** into centuri feed nozzle **54** for pneumatic feeding to the reactor or gasifier. It may be advantageous to entrain the coal in a reactnat stream **56** which can be either hot recycled gas or steam used in the gasifier reaction vessel as in U.S. Pat. No. 2,840,462. Alternatively, the coal can be fed through conduit **52** directly to the gasifier nozzles. The gas separated in separator **44** is conducted through conduit **46** to subsequent processing steps (e.g. water gas shift reactor, acid gas removal, and methanation) in the overall gasification scheme so that none of the gasifier effluent is sacrificed in feeding the coal or other solid carbonaceous material to the gasifier.

The foregoing process provides a method for feeding dried preheated coal to a gasifier. It is possible to preheat the coal during drying to a temperature of approximately 500°F thereby achieving overall process economies in the production of synthetic natural gas by reducing oxygen requirements.

The foregoing basic method can be modified for application to other gasification schemes. For example, there is a proposed coal gasification process developed by Bituminous Coal Research Incorporated wherein a synthetic natural gas will be produced at the rate of 250 MM SCF/SD. The gasification vessel for such a process requires heated coal at 80 atmospheres pressure for gasifier feed and requires process gasifier effluent temperature of 660°F with a 1:1 steam to dry gas ratio for feed to the shift converter, which is the step after the gasifier.

For such a gasification vessel, the coal slurry is prepared as a 50 percent by weight mixture by adding coal at approximately 60°F, hot condensate at approximately 212°F and a low pressure steam at 50 psig and 298°F into the slurry tank **10.** The slurry is pumped at the desired pressure (**80** atmospheres) and preheated by hot condensate in heat exchanger **28.** Finally, the slurry is dried (32) and the coal and process gas separated in the cyclone **44.** In order to accomplish this, it is proposed that the overall system will appear as follows. The first section of the process will encompass multiple train slurry preparation consisting of "make-down" tanks and mixers," low-pressure, centrifigal slurry pumps, holding tansk with mixers, and circulation pumps. In this section, coal sized at approximately 70 percent less than 200 mesh and hot condensate direct from deaerators will be combined to produce a 50 weight percent coal water slurry in the make-down tanks. Each tank will have a 10-minute residence time and be of 16,500 gallon capacity. The slurry mixer will employ an axial flow, constant velocity discharge impeller with the shaft and impeller covered with rubber to minimize erosion. There will be provision in these tanks for steam sparging for heating of the slurry and to free the mixer and impeller for start up under unusual circumstances where the coal may have settled to the bottom of the tank. After the slurry is throughly mixed, it will flow into a manifold from which it will be pumped to the holding tanks. Low pressure centrifugal pumps each rated at 50 percent of plant capacity will be used to pump the slurry into the holding tanks which will each have a capacity of approximately 65,000 gallons and will provide 40-minute residence time for the slurry. As with the make-down tanks, the mixers will require protection from erosion; however, the horsepower needed will be less since they will only be required to agitate the slurry enough to maintain the coal in the form of a slurry. Circulating pumps will be provided to circulate the slurry through a manifold and return it to the pressurized slurry tanks in order to maintain the stability of the slurry.

The next section of the process contains of the slurry pumping and hot condensate heat exchangers. The slurry pumps will develop the system pressure of approximately 80 atmospheres using reciprocating single-acting Triplex plunger pumps. The slurry will be discharged from the pumps at 1,200 psi and approximately 230°F into a heat exchanger wherein the slurry will be raised to approximately 430°F before feeding into the dryer. The temperature of 430°F is required in order to obtain the desired gas and coal temperature with a 1 to 1 steam to dry gas ratio in the process gas from the dryer. Care must be taken in constructing special inlet channels and distribution in the heat exchanger to prevent or minimize erosion due to the abrasive characteristics of the slurry.

The next section of the overall process will consist of slurry drying wherein there is employed a spray dryer, a cyclone, and a pair of coal receivers. The coal slurry is dried and the water is vaporized in a spray dryer which will operate at approximately 80 atmospheres pressure with exit gas temperatures of 660°F. Gas used for heating the slurry will be effluent gas from the gasifier. In the BCR Process, the effluent gas from the gasifier is at a temperature of 1,750°F but before being used is subjected to a char separation in a cyclone separator. The char is then recycled to the gasifier. In the BCR Process, a second cyclone separation is effected to eliminate the balance of the char from the gaas and lower the gas temperature to approximately 1,100°F. A portion of the gas from the first and second cyclone is combined with a net temperature of about 1,600°F which gas is used in the spray dryers to content the slurry which is pumped into the dryer and atomized. If required, steam can be added to increase the atomization of the slurry or it can be added later to achieve the desired steam to dry gas ratio. The dried coal and humidified gas is then taken over into a cyclone where the coal is separated and conducted into a pair of receivers, which will operate on a switching cycle to eliminate back surging through the cyclone. The separated gas will be taken and fed to the carbon monoxide shift converters for further processing into the required pipeline gas. At this stage, the coal can be withdrawn from the storage hoppers under pressure and fed to the gasifier for reacting.

There is shown in FIG. **2** a method of using a slurry feed in conjunction with a commercial partial oxidation unit. The partial oxidation unit is shown in U.S. Pat. No. 2,595,234 and is used to produce a synthesis gas consisting mainly of water vapor, hydrogen, carbon dioxide, and carbon monoxide, which can be subsequently shift converted to carbon dioxide and hydrogen. The hydrogen is then separated out and used for various processes including gasification of crude oil or as product hydrogen for other manufacturing operations.



The partial oxidation reactor is shown as **60** in FIG. **2** and has an inlet conduit **62** for receiving the solid carbonaceous material to be reacted, a second inlet conduit **64** for receiving oxygen that reacts with the solid carbonaceous material and outlet conduit **66** for conduiting the synthesis gas out of the reactor and a bottom clean out **68** for removing slag and/or ash from the gasifier. The product gas is conducted from conduit **66** to a separator **70** and from separator **70** through conduit **72** to a waste heat boiler **74,** from waste heat boiler **74** through conduit **76** to a dryer **78,** from dryer **78** to separator **80** and from separator **80** through to purification (shift) through conduit **81.** Coal is fed to the reactor **60** through conduit **82** which is in turn connected to a pneumatic injectionm device **84** which receives the coal feed from conduit **86** and carries the coal into the reactor **60** by means of steam shown by arrow **88.** Conduit **86** is connected in turn in reverse order to separator **80** and dryer **78.** From dryer **78** a conduit **90** is connected to preheater **92** which in turn is connected to slurry pump **94** through conduit **95** for receiving the coal slurry. Slurry pump **94** is connected to the slurry tank **96** by conduit **98.** Slurry tank **96** includes an impeller **100** and a drive shaft **102,** which are connected to a suitable source of power such as a motor (not shown). Alternatively, the slurry can be made as the result of wet grinding of the carbonaceous material in which event tank **96** is bypassed through conduit **104** directly to the slurry pump **94.**

In operating the method of FIG. **2** in the one alternative solid carbonaceous material in the form of coal, char, coke, or combinations thereof are introduced into the slurry tank **96** and are designated as arrow **106.** Condensate is added to tank **96** as indicated by arrow **108,** e.g., condensate from the process in the form of boiler feed water, condensed steam, or fresh water. The impeller is activated to provide the proper mixing of the solid carbonaceous material and condensate to form the slurry. Alternatively as shown by arrow **104,** the slurry can be formed as the coal is wet ground to size and passed directly to the slurry pump **94** through conduit **104.** The preferably slurry is one that consists of 40 to 60 percent by weight water with the rest solid carbonaceous material. The slurry is passed to the slurry pump **94** where its pressure is raised to that above the operating pressure of the gasifier **60** and is then preheated in heat exchanger **92** if the overall heat balance of the system requires additional heat into the system. The slurry is then injected into the dryer **78** where it is contacted by the hot effluent from the waste heat boiler **74** and the water is driven off and the solid carbonaceous material is raised in temperature and entrained in a gas. As described in connection with FIG. **1,** a source of steam can be provided through conduit **77** to control the humidity and temperature of the effluent in conduit **79** from dryer **78.** The gas solid mixture is then conducted to the cyclone separator **80** wherein the coal and gas are separated, the gas going from conduit **81** on to further purification and the coal being conducted through conduit **86** into the gasification vessel by means of the injection nozzle **84.** Waste heat boiler 74 is included in this system to recover heat and at the same time to produce high-pressure steam for the overall reaction and for injecting into the gasifier itself.

The foregoing method of feeding a partial oxidation unit accomplishes the following:

1. The process provides a dry preheated carbonaceous solid fuel to the gasifier thereby increasing gasifier efficiency.

2. In the drying preheating step, the water is evaporated without the use of additional oxygen and simultaneously provides steam required for subsequent shift operations of the effluent.

3. The process provides a method for utilizing a high-sulfur fuel such as coal, petroleum, coke or the like by producing sulfur as hydrogen sulfide because of the overall reducing atmosphere.

Having thus described my invention, what is desired to be secured by Letters Patent of the United States is contained in the following claims.

I claim:

**1.** A method of feeding carbonaceous particles to a gasifier operating at elevated temperature and pressure comprising the steps of:

forming a slurry of solid carbonaceous particles with water as a liquid vehicle;

pumping the slurry into a drying chamber, said drying chamber being separated from said gasifier, maintained at approximately the operating pressure of the gasifier wherein the slurry is mixed with hot effluent gases from the gasifier so that the carbonaceous particles without substantial reaction are dried and heated and entrained in the effluent gas;

substantially immediately separating the entrained carbonaceous particles from the effluent gas which effluent gas includes evaporated water vehicle in the form of steam; and injecting the separated carbonaceous particles into the gasifier.

**2.** A method according to claim **1** wherein the slurry is preheated by indirect heat exchange with a hot gas prior to entering the drying chamber.

**3.** A method according to claim **1** wherein steam is added to the drying chamber containing the slurry and gasifier effluent gas to adjust the temperature of the effluent gas thereby controlling the humidity of the effluent gas.

**4.** A method of feeding solid carbonaceous particles to a gasifier operating at high temperature and high pressure comprising the steps of:

providing a feed stream of solid carbonaceous particles suspended in water;

raising the internal pressure of the feed stream to a pressure above the operating pressure of the gasifier;

introducing the pressurized feed stream to a drying chamber, said drying chamber being separated from said gasifier, wherein it is contacted by hot gaseous effluent from the gasifier without substantial reaction so that, the water is evaporated, and the dried solid carbonaceous particles are entrained in the gaseous effluent;

substantially immediately separating the dried solid carbonaceous particles from the gaseous effluent; and

entraining the separated solid carbonaceous particles in a stream of reactant being fed into the gasifier.

**5.** A method according to claim **4** wherein the feed stream is a slurry of 40% by weight solid carbonaceous particles selected from the group consisting of coal, coke, char or mixtures thereof in water prepared in a mixing tank.

**6.** A method according to claim **4** wherein the slurry is preheated prior to being introduced into the drying chamber.

**7.** A method according to claim **4** wherein the gaseous effluent separated from the solid carbonaceous particles consists essentially of water vapor, carbon monoxide, and hydrogen, and is subjected to a subsequent shift step wherein carbon dioxide and hydrogen are produced.

* * * * *

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(5/69)

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,871,839 Dated March 18, 1975

Inventor(x) Burton E. Moody

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 26, "fo" should be--of--

Column 1, line 48, "bef" should be--bed--

Column 2, line 15, "staged" should be--stages--

Column 3, line 34, after "conduit","10" should be--20--

Column 3, line 41, "hog" should be--hot--

Column 3, line 54, "shceme" should be--scheme--

Column 4, line 10, "ans" should be--and--

Column 4, line 15, "centuri" should be--venturi--

Column 4, line 17, "reactnat" should be--reactant--

Column 4, line 57, after "down" delete--quotation marks--

Column 4, line 58, "tansk" should be--tanks--

Column 5, line 18, "contains" should be--consists--

Column 5, line 45, "gaas" should be--gas--

Column 5, line 49, "content" should be--contact--

Column 6, lines 11-12, "con-duiting" should be--conducting--

PO-1050
(5/69)

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,871,839 Dated March 18, 1975

Inventor(s) Burton E. Moody (CONTINUED)

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:



Column 6, line 21, after "injection" delete--m--

Column 6, line 48, "preferably" should be--preferable--

Column 7, lines 34-35, after "entrained" and before "carbonaceous" insert--dried--

**Signed and Sealed this**

*second* **Day of** *December 1975*

[SEAL]

*Attest:*

**RUTH C. MASON**
*Attesting Officer*

**C. MARSHALL DANN**
*Commissioner of Patents and Trademarks*

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,871,839 Dated March 18, 1975

Inventor(s) Burton E. Moody

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 47, "stream" should read -- steam --.

Column 5, line 3, "throughly" should read -- thoroughly --.

Signed and Sealed this

*sixth* Day of *January 1976*

[SEAL]

*Attest:*

**RUTH C. MASON**
*Attesting Officer*

**C. MARSHALL DANN**
*Commissioner of Patents and Trademarks*