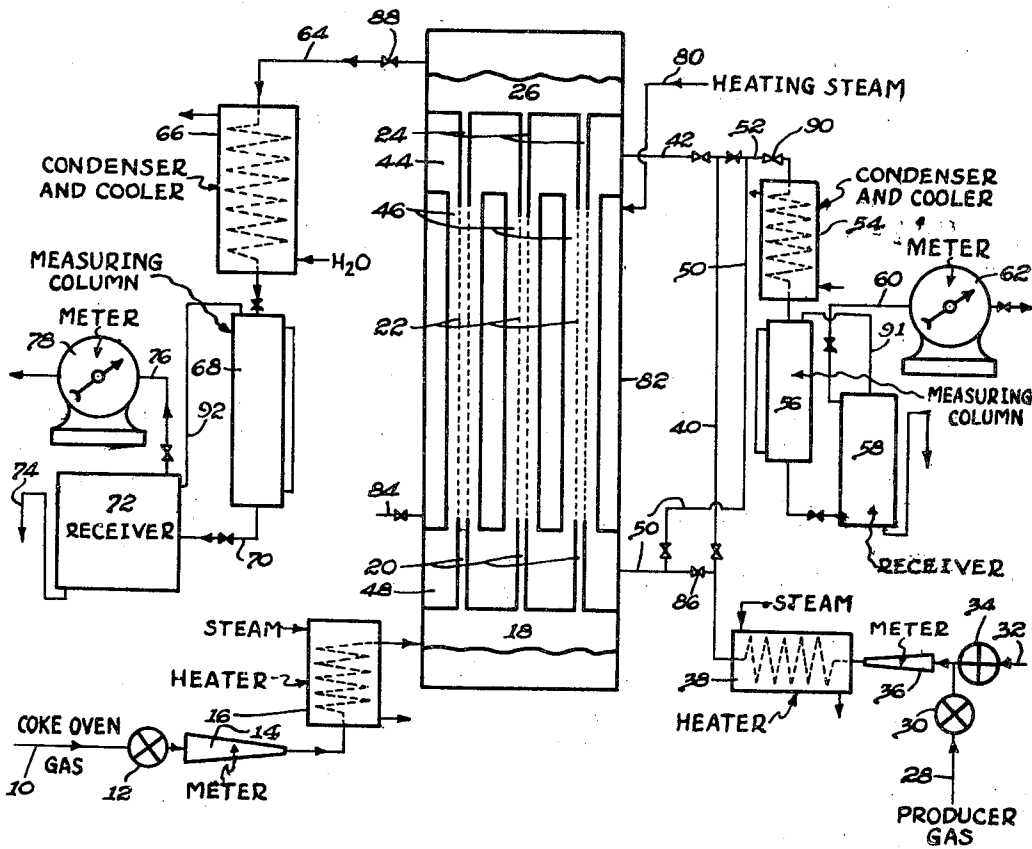


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GAS COMPOSITION REVISION

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GAS COMPOSITION REVISION

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11 Claims. (Cl. 48-197)

1 This invention relates to changing the composition of fuel gas by diffusion. More particularly the invention relates to revising the composition of coke oven gas by diffusion in which a combination of producer gas and steam is used as a sweep gas.

In a copending application of Gilbert V. McGurl, Serial No. 710,327, a method of revising the composition of coke oven gas by diffusion has been described in which producer gas is used as a sweep gas. This revising operation is carried out particularly for the purpose of adjusting the specific gravity and B. t. u. heating value to adapt the coke oven gas for use in domestic heating appliances.

The use of producer gas for revising coke oven gas is very desirable because the transfer of hydrogen from the coke oven gas to the producer gas acts to increase both the gravity and B. t. u. value of the coke oven gas. At the same time the B. t. u. value of the producer gas is increased. The diffusion treatment permits a transfer of constituents between the coke oven gas and the producer gas that will provide a wide variation in the composition of both of the gases. For example, a coke oven gas can be revised to have a heating value of 530 B. t. u.'s per cubic foot and a gravity of 0.55 to 0.7. The producer gas will have its heating value raised from 135 to as much as 175 B. t. u.'s per cubic foot and the molecular volumes of hydrogen and carbon monoxide in the gas may be rearranged to have a ratio of 1:1 to 2:1. A gas having such a content of hydrogen and carbon monoxide is well adapted as a synthesis gas for the hydrogenation of carbon monoxide by the Fischer-Tropsch process.

Typical analyses of a coke oven gas and producer gas are shown in the following table:

TABLE I

Property	Producer Gas	Coke Oven Gas
Specific gravity.....	0.9	0.4
B. t. u./Cu. Ft.....	130	586
Analysis:		
Carbon dioxide.....	3.5	1.8
Hydrogen.....	30	3.7
Oxygen.....	0.5	0.2
Carbon monoxide.....	30	6.3
Methane.....	1.5	31.6
Hydrogen.....	10.0	53.0
Nitrogen.....	54.5	3.4

It will be seen from the table that producer gas is a heavy gas, i. e. higher molecular weight

2 than coke oven gas, so that its rate of diffusion through a porous boundary is not as rapid as the diffusion rate of hydrogen and some of the lighter hydrocarbons in the coke oven gas. I have found that if steam is used with the producer gas, as a sweep gas, the control of transfer of constituents between the gases on the opposite sides of the porous boundary may be greatly increased. Further the composition of the revised gases on opposite sides of the boundary may be much more widely varied than when producer gas is used alone as a sweep gas. Also the steam may be readily condensed and separated from the gases so that this provides another means of varying the composition of the gas being treated because the volume of steam as a dry vapor will function as a gas in diffusing through the boundary in the same way that the producer gas diffuses through the boundary and thus when the steam is extracted from the revised gas the chemical composition will be varied.

Tests have shown that the above-mentioned coke oven gas having a specific gravity of 0.4 may be revised by the method of the present invention to raise the specific gravity from 37.5% to 75% to have a specific gravity from 0.55 to 0.7 as mentioned above.

The primary object of the present invention is to provide a method of changing the composition of coke oven gas by diffusion in which a combination of a high gravity gas with a condensable vapor may be used as a sweep gas.

Another object of the invention is to provide a method of revising coke oven gas by diffusion in which steam with a high gravity gas such as producer gas or blast furnace gas may be used as a sweep gas.

A further object of the invention is to provide a method of revising coke oven gas by diffusion in which a high molecular weight gas is used in combination with a low molecular weight vapor as a sweep gas.

With these and other objects in view the invention consists in the method of revising coke oven gas by diffusion in which steam is used with a high specific gravity gas as a sweep gas.

The various features of the invention are illustrated in the accompanying drawing which is a diagrammatic illustration of an apparatus in which the preferred form of the diffusion method may be carried out.

Referring to the drawing, coke oven gas may be revised as follows:

Coke oven gas is introduced through a line 10 and passes through a flow regulating valve

12 into a meter 14. The metered gas passes through heater 16 into a chamber 18 at the bottom of a diffusion apparatus. The coke oven gas then passes upwardly through a series of tubes 20 which have cylindrical continuations 22 that are porous boundaries through which constituents of the gas may diffuse. From the porous boundary tubes 22 the gas flows through tubes 24 into an outlet chamber 26.

Producer gas for the diffusion operation is introduced into the system through a line 28 and flows through a flow regulating valve 30. The valve 30 is used for carefully adjusting the flow volume of the producer gas so that the desired volume of sweep gas will be provided for the diffusion revising of the coke oven gas. Steam for mixture with the producer gas is introduced through a line 32 and flow regulating valve 34 to mix with the producer gas and the mixture then flows through a meter 36. The metered mixture of steam and producer gas then flows through a heater 38 where it is heated to a temperature 10° C. above the dew point of the mixture, and then flows through a line 40 to a line 42 and enters a distributing chamber 44. The mixture of steam and producer gas acts as a sweep gas for controlling the diffusion operation. The gas is distributed into a series of tubes 46 and passes downwardly through the tubes around the diffusion boundaries 22 which are located within the tubes 46. The mixture of steam and producer gas passes in a parallel stream to the coke oven gas with countercurrent flow. After passing through the tubes 46 the revised producer gas enters a chamber 48 and then flows through a valved line 50 into a line 52. From the line 52 the mixture of revised producer gas and steam flows through a cooler and temperature conditioner 54 into a measuring column 56, and then into a water separator 58. The producer gas flows from the separator 58 through a line 60 to a meter 62. By this means the volume of revised producer gas is measured and the volume of water or condensed steam is measured.

The revised coke oven gas leaves the chamber 26 through a line 64 and passes through a condenser, cooler and temperature conditioner 66 into a measuring column 68. The condensed steam then flows through a line 70 and the gas through a line 92 into a receiver 72 which acts as a separator. The water flows out through a line 74 and the revised coke oven gas passes through a line 76 and then through a meter 78. By this means the volume of the revised coke oven gas is measured and the volume of water separated is measured.

The temperature in the diffusion apparatus is maintained as nearly uniform as possible throughout the diffusion zone. This temperature is approximately 115° to 120° C. for coke oven gas but will be about 10° above the dew point of the gas and steam mixture, and is controlled by means of steam which is introduced through a line 80 into a chamber 82 of the diffusion apparatus that surrounds the tubes 46. Condensate steam may leave the chamber 82 through an outlet pipe 84. Both the coke oven gas being fed to the diffusion apparatus and the sweep gas are heated to a temperature at least 10° above the dew point of the gas and steam mixture in the heaters 16 and 38 respectively to prepare them for the diffusion operation. The temperature must be above the dew point of the gases being treated in the apparatus

so that no liquid is present in the boundary tubes 22.

The flow regulator 12 controls the volume of coke oven gas which is the feed gas to the diffusion apparatus to be revised. The flow regulating valves 30 and 34 control the volumes of producer gas and steam respectively, which acts as a sweep gas in the diffusion operation. The pressures of the feed and sweep gas on the opposite sides of the porous diaphragm or boundary tubes 22 are very important in controlling the diffusion of the gases through the boundaries from one stream to the other. The pressure of the coke oven gas inside of the boundary tubes is controlled by a pressure regulating valve 88 and the pressure of the sweep gas on the outside of the boundary tubes is controlled by a pressure regulating valve 90. These valves are carefully regulated to maintain the pressure distribution for the diffusion operation. The pressure distribution of the feed and sweep gases involves several factors:

First, the pressure of the sweep gas is sufficiently higher than the pressure of the feed gas so that there is a hydrodynamic flow of sweep gas through the pores of the boundary. This hydrodynamic flow is the flow of sweep gas through the boundary pores which is not due to diffusion but is due to the pressure differential across the boundary.

Second, the size of the pores which determine the porosity of the boundary or diaphragm should be many times larger than the mean free path of the molecules of the feed gas. The mean free path of the molecules is the average distance which a molecule travels before colliding with an adjacent molecule. Depending upon the length and the resistance to flow of the pore, the average length and width or diameter of the pore may be from 1 to 10,000 times the mean free path of the molecule.

Third, the pressure of the gas streams at opposite sides of the boundary or the average pressure differential across the pores of the boundary.

Fourth, the area of the boundary. This area takes into consideration the pressure differentials at the inlet and outlet ends of the boundary or the average pressure differential over the area of the boundary. When the feed and sweep gas streams flow concurrently or in the same direction, the pressure differential at the entrance end is dependent upon the difference in pressure of the two gas streams. With such a flow there will be a gradual lowering of the pressure differential as the two streams advance across the boundary area. If the feed and sweep gas streams flow countercurrently along the boundary, then the pressure differential across the boundary at the entrance end of the sweep gas is at its maximum because the resistance of flow and the diffusion of the feed gas through the boundary has lowered its pressure and the pressure of the sweep gas is at its maximum. Accordingly with countercurrent flow the diffusion rate will be lowest at the entrance end of the sweep gas and highest at the exit end of the sweep gas from the boundary area.

When carrying out the diffusion operation with a porous boundary to provide a hydrodynamic flow of the sweep gas there will always be a passage of sweep gas into the coke oven gas as well as the diffusion of some constituents of the sweep gas through the boundary into the coke oven gas. At the same time there will be a passage of constituents of the coke oven gas into the sweep gas, particularly those constituents which have a low

molecular weight (hydrogen and low boiling point hydrocarbons). The rate of diffusion of various gases through a porous boundary is roughly inversely proportional to the square root of the molecular weight of the gas passing through the porous openings. Therefore, those lower molecular weight gases have a higher velocity or rate of passage through the boundary than the heavy molecular weight constituents. In some cases the movement of sweep gas in one direction will entirely oppose the movement of heavy constituents from the coke oven gas in the opposite direction. By this means a selective separation of the gases may take place. The greater the resistance to flow through the boundary or the smaller the porosity the more concentrated will be the hydrogen gas passing through the boundary. This same principle applies to all of the gases and the higher the molecular weight the less the diffusion of such gases through the boundary.

The porous boundary tubes 22 which are illustrated in the drawings are of a material which is known on the market as "Lektromesh" which is a copper screen coated with nickel to make it corrosion resistant. Many other types of boundaries may be used for this purpose, the effectiveness of the boundary depending upon the size and uniformity of the porous openings in the boundary through which the gases may diffuse.

In Tables II and III below are shown examples of the revision of coke oven gas with a mixture of producer gas and steam as a sweep gas when using seven Lektromesh tubes, 1½ inches inside diameter and 24 inches in effective length. The Lektromesh barrier has 6400 openings per square inch, each opening being substantially square, the length of a side of the opening being 0.0035 inch. The flow rates of feed and sweep gases are corrected to 30 inches of mercury at a temperature of 60° F.

TABLE II

Diffusion pilot plant

Producer gas + steam countercurrent to coke oven gas flow.

Boundary: 80 x 80 x 0.0035" Lektromesh—7 tubes
1½" in diameter x 24"

Effective length—547.9

Flow rates at 30" Hg+60° F.:

Feed coke oven gas in=390 cu. ft./hr.

Feed coke oven gas out=517 cu. ft./hr.+24.4
lbs./hr. steam

Sweep (prod. gas) in=482 cu. ft./hr.+65.9
lbs./hr. steam

Sweep (prod. gas) out=355 cu. ft./hr.+41.5
lbs./hr. steam

	Sweep Prod. Gas		Feed	
	In	Out	In	Out
	Per- cent	Per- cent	Per- cent	Per- cent
H ₂ by Conductivity Cell.....	11.6	26.0	54.3	37.7
Orsat:				
CO ₂	4.9	3.5	1.7	4.9
Unsat.....	0.0	0.0	2.6	1.7
O ₂	0.2	0.1	0.7	0.7
H ₂	12.4	26.2	54.9	36.9
CO.....	28.5	24.3	6.3	14.1
CH ₄	1.4	0.2	24.6	17.3
C ₂ H ₆	1.2	2.3	0.6	1.1
N ₂ by difference.....	51.4	43.4	8.6	23.3
Specific gravity.....	0.889	0.751	0.394	0.595

TABLE III

Diffusion pilot plant

Producer gas + steam countercurrent to coke oven gas flow.

Boundary: 80 x 80 x 0.0035" Lektromesh—7 tubes
1½" in diameter x 24"

Effective length—547.9

Flow rates at 30" Hg+60° F.:

Feed coke oven gas in=390 cu. ft./hr.

Feed coke oven gas out=495 cu. ft./hr.+9.1
lbs./hr. steam

Sweep (prod. gas) in=473 cu. ft./hr.+24.5
lbs./hr. steam

Sweep (prod. gas) out=368 cu. ft./hr.+15.4
lbs./hr. steam

	Sweep Prod. Gas		Feed	
	In	Out	In	Out
	Per- cent	Per- cent	Per- cent	Per- cent
H ₂ by Conductivity Cell.....	11.6	29.8	54.3	37.3
Orsat:				
CO ₂	4.9	3.6	1.7	3.1
Unsat.....	0.0	0.2	2.6	2.0
O ₂	0.2	0.2	0.7	0.5
H ₂	12.4	28.5	54.9	36.3
CO.....	28.5	23.4	6.3	14.8
CH ₄	1.4	0.6	24.6	18.9
C ₂ H ₆	1.2	1.1	0.6	0.8
N ₂ by difference.....	51.4	42.4	8.6	13.6
Specific gravity.....	0.889	0.727	0.394	0.489

Similar runs have been made with the same coke oven gas and sweep gas wherein the flow through the diffusion apparatus is in concurrent paths as distinguished from the flow in countercurrent paths as shown in Tables II and III. When the gas flows in concurrent paths the sweep gas flows from the line 40 through a valved line 36 into the chamber 48, then up through the tubes 46 into the chamber 44, then out through the lines 42 and 52 into the cooler 54. The passage from the cooler is then through the measuring column 56, separator 58 and meter 62.

It will be understood that valves are placed in the lines 40, 42 and 50 to direct the flow of sweep gases through the diffusion apparatus in either concurrent or countercurrent directions of flow with reference to the direction of flow of the coke oven gas.

By this means a selective removal or separation of predetermined constituents in the various gas streams may be made to get practically any desired revision of the gas. The hydrogen passing most rapidly from the coke oven gas to the producer gas acts to increase the B. t. u. value of the producer gas and at the same time increases the B. t. u. value of the coke oven gas. Furthermore, this diffusion movement of constituents through the boundary permits an increase in the specific gravity in the coke oven gas and a slight lowering of the specific gravity of the producer gas.

A typical blast furnace gas has a specific gravity of about 9.0 and a B. t. u. value of about 85. Carbon dioxide is 11.5%, hydrogen 1%, carbon monoxide 27.5%, and nitrogen 60%. It will be seen that with a blast furnace gas a comparatively large amount of hydrogen may be transferred by diffusion to build up its B. t. u. value and change its specific gravity. On the other hand, a typical producer gas which contains 10% of hydrogen would not require the transfer of as much hydrogen by diffusion in order to increase its B. t. u.

value and change its specific gravity. The use of steam with these gases gives an excellent control for the modification of the composition of the gases in that, when part of the sweep gas flowing through the boundary is a condensable vapor which is later removed from the revised coke oven gas, the addition of producer gas or blast furnace gas to the coke oven gas stream relative to the amount of hydrogen transferred to the sweep gas side by diffusion is reduced.

The preferred form of the invention having been thus described, what is claimed as new is:

1. A method of simultaneously changing the composition and specific gravity of coke oven gas and producer gas comprising: feeding coke oven gas as a stream along one side of a porous boundary, passing producer gas in mixture with steam to sweep across the other side of the boundary, controlling the area and length of the boundary and the rate of flow of gas on each side of the boundary to secure a diffusion of hydrogen from the coke oven side to the producer side of the boundary and to cause a flow of nitrogen, steam and carbon monoxide from the producer gas to the coke oven gas side of the boundary to increase the specific gravity of the coke oven gas from 37.5 to 75%, and removing steam from each of the gas streams.

2. The method of changing the composition of fuel gases defined in claim 1 in which the gas streams pass along the porous boundary in countercurrent paths.

3. The method of revising fuel gases as defined in claim 1 in which the steam passing across the boundary is dry steam and in which the temperature of the gas streams at each side of the boundary is maintained above the dew point of steam.

4. The method of revising the composition of fuel gases defined in claim 1 in which the gases are circulated across the boundary in concurrent paths.

5. The method defined in claim 1 in which a slightly higher pressure is maintained on the sweep gas side of the boundary than on the coke oven gas side of the boundary to cause a hydrodynamic flow of producer gas and steam through the pores of the boundary to the coke oven gas side of the boundary.

6. The method defined in claim 1 in which the volume of producer gas passing across the boundary is at least 20% greater than the volume of

coke oven gas passing across the boundary and the volume of steam flowing with the producer gas is from 3% to 25% by volume of the volume of producer gas.

7. The method defined in claim 1 in which the composition of the coke oven gas producer gases are brought to a finished composition in a single pass across the boundary.

8. A method of simultaneously changing the composition and specific gravity of coke oven gas and a fuel gas of high molecular weight comprising: feeding coke oven gas as a stream along one side of a porous boundary, passing a high molecular weight gas in admixture with steam to sweep across the other side of the boundary, controlling the area and length of the boundary and the rate of flow of the gases on each side of the boundary to secure a diffusion of hydrogen from the coke oven gas to the high molecular weight fuel gas stream and to cause a flow of nitrogen, carbon monoxide and steam from the high molecular weight gas side of the boundary to the coke oven gas side of the boundary to increase the specific gravity of the coke oven gas from 37.5 to 75%, and removing steam from each gas stream.

9. The method defined in claim 8 in which the volume of high molecular weight fuel gas is greater than the volume of coke oven gas.

10. The method defined in claim 8 in which the volume of high molecular weight gas is greater than the volume of coke oven gas and the volume of steam is from 3% to 25% by volume of the high molecular weight gas.

11. The method defined in claim 8 in which the high molecular weight gas is blast furnace gas.

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