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[54] **PRODUCTION OF WATER GAS**

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[52] **U.S. Cl.** **48/204,** 48/202, 48/210
[51] **Int. Cl.** **C10j 3/00**
[58] **Field of Search** 48/202, 204, 210, 215

[56] **References Cited**

UNITED STATES PATENTS

2,662,816	12/1953	Kalbach	48/202
2,687,950	8/1954	Kalbach	48/210 X
2,690,384	9/1954	Schutte	48/204 X
2,840,462	6/1958	Gorin	48/202 X
3,194,644	7/1965	Gorin et al.	48/202 X

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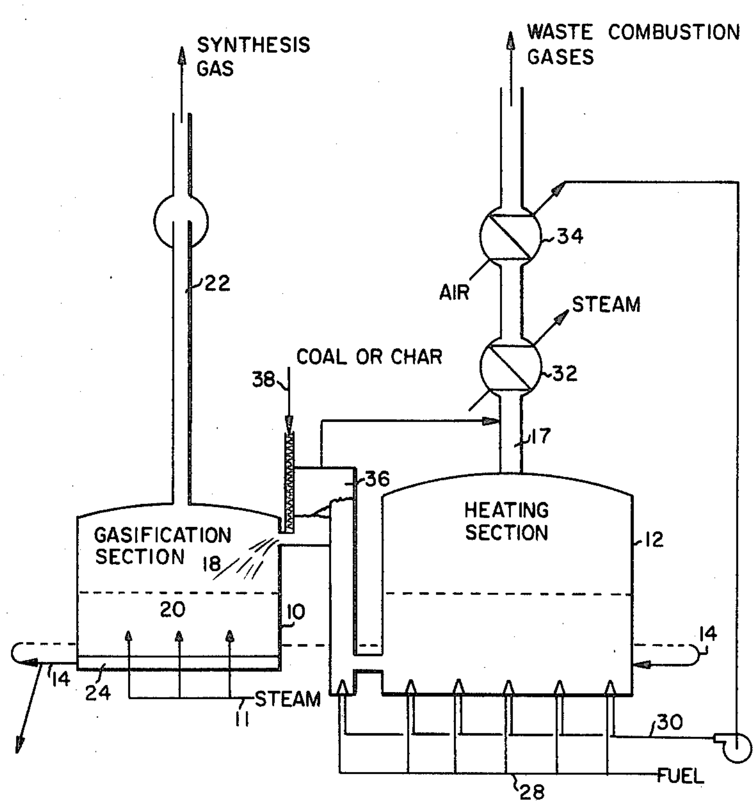
[57] **ABSTRACT**

Water gas is produced by blowing steam through carbon suspended in a coal ash melt in a gasification section, the endothermic heat of reaction being supplied by the ash melt, which is continuously recirculating through a separate superheating section where the ash is superheated by burning fuel separately introduced into that section; the superheated ash is then conveyed to the gasification section, substantially free of oxidative gas, preferably by means of a heated gas lift.

3 Claims, 2 Drawing Figures

CIRCULATING SLAG GASSIFIER



CIRCULATING SLAG GASSIFIER

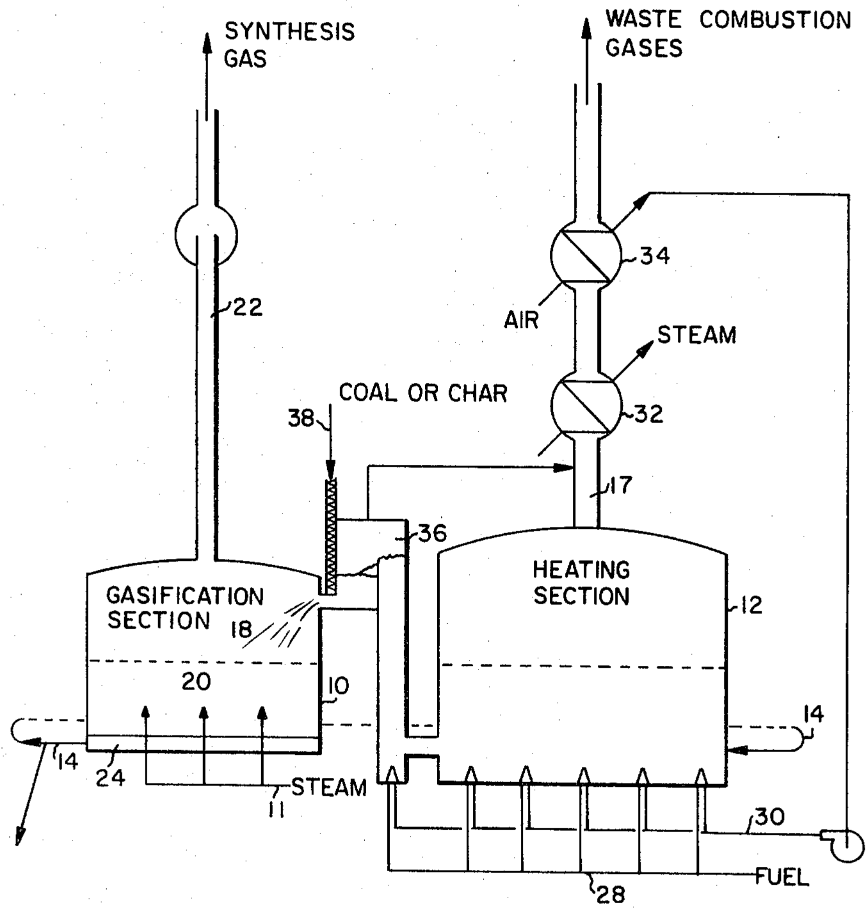


FIG. 1

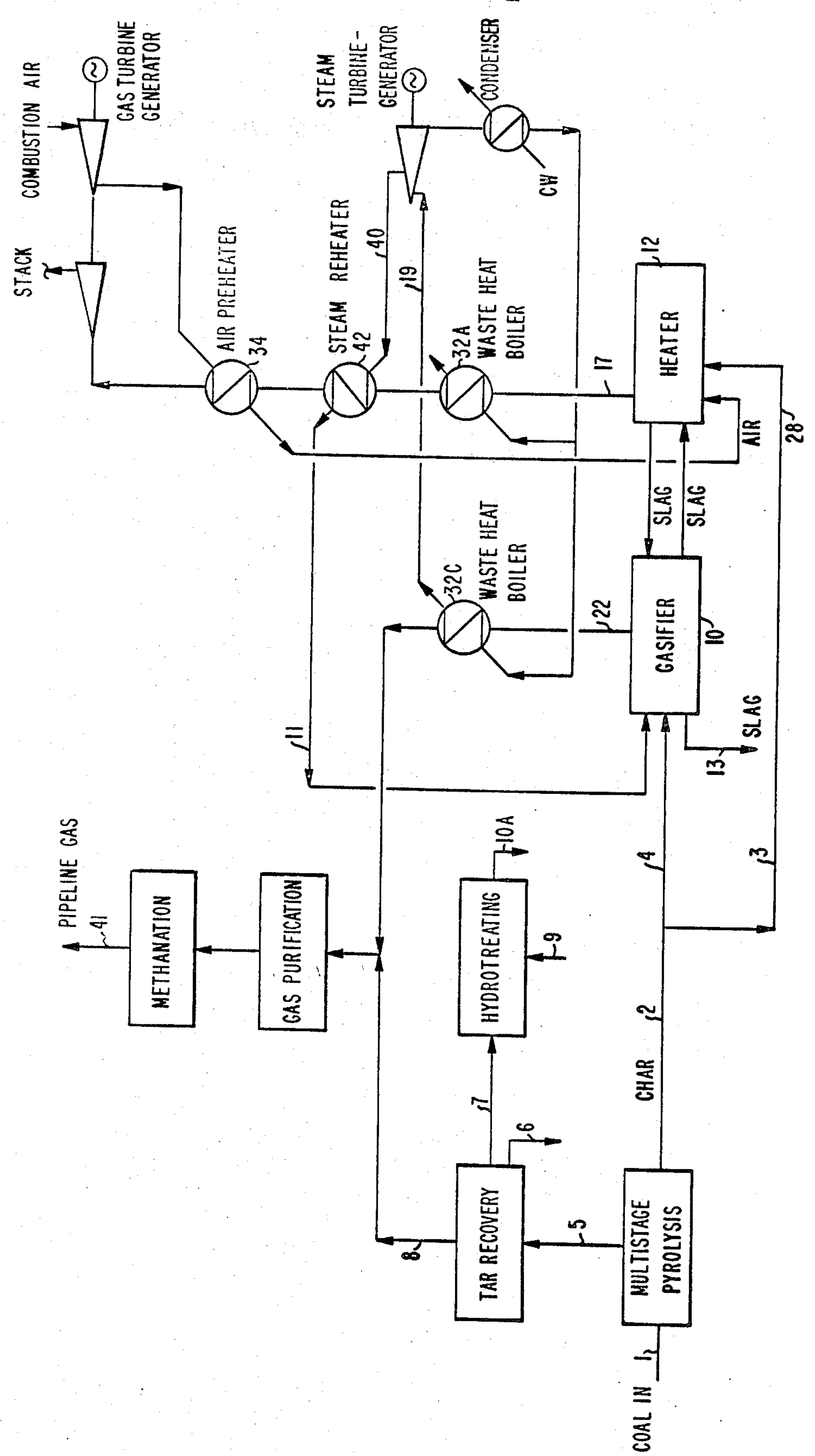

GAS TURBINE GENERATOR
COMBUSTION AIR
STACK
AIR PREHEATER
34
STEAM TURBINE-GENERATOR
CONDENSER
CW
STEAM REHEATER
40
STEAM 42
19
32A WASTE HEAT BOILER
17
12
HEATER
AIR
28
SLAG
SLAG
32C WASTE HEAT BOILER
22
GASIFIER
10
SLAG
13
11
PIPELINE GAS
41
METHANATION
GAS PURIFICATION
HYDROTREATING
10A
9
4
3
2
CHAR
7
6
TAR RECOVERY
8
5
MULTISTAGE PYROLYSIS
1
COAL IN

FIG. 2

PRODUCTION OF WATER GAS

BACKGROUND OF THE INVENTION

A. Field of the Invention

This invention is concerned with improvements in the process of making synthesis gas by the endothermic reaction of carbon and steam at elevated temperatures.

B. Prior Art

The gasification of carbonaceous solids with steam to produce a synthesis gas containing high concentrations of hydrogen and carbon monoxide has been practiced for many years; this "water gas" reaction is one of the classic processes of the fuel industry.

The principal difficulty with the process is that the reaction is endothermic, so that it is necessary to provide heat to the process. In older processes, a bed of carbon was arranged so that the lower portion of the bed was an oxidizing zone in which heat was developed; the water gas reaction was carried out in the upper portion of the bed. This meant that the CO_2, in providing heat, was mixed with the steam, so that the synthesis gas produced contained substantially more carbon monoxide by volume than hydrogen, as distinguished from pure water gas, which contains one volume of hydrogen per volume of carbon monoxide.

One suggestion for overcoming this difficulty is the use of fluidized beds of carbon, utilizing a recycle stream of carbon which is superheated by partial combustion and separated from the carbon dioxide produced before being returned to the gasification section — see, for example, Patton et al, U.S. Pat. No. 3,440,117. Such schemes involve elaborate cyclone systems to prevent excessive dusting, and rather high capital outlays.

An interesting scheme for gasifying coal with steam and CO_2 is described in the Rummel U.S. Pat. No. 2,647,045 of July 28, 1953. He suspends his coal in a molten slag, and provides heat of reaction by burning a portion of the coal in the slag. He preferably keeps the CO_2 of the exothermic reaction more or less separate from his synthesis gas by separating the reactor into two compartments, one for the heat-producing combustion, and one for the heat-consuming water gas reaction; the slag is continuously recirculated by convection, or by a combination of convection and momentum transfer from jets of his oxidizing air. The fuel for heating comprises a portion of his reduction carbon which is carried into the oxidizing compartment by the convection current.

Work with this process has shown that the process is inefficient on any scale above laboratory size. Convection circulation alone is too slow to get any substantial throughput in a reactor; momentum transfer helps, but introduces oxygen, plus nitrogen if air is used, and CO_2 into the reducing zone. In addition, the rate of circulation is proportional to surface area, not to volume; as the operation is scaled up, it becomes progressively less efficient for circulation, with no gain as to heat losses.

OBJECTS OF THE INVENTION

This invention aims to provide a circulating slag process for producing water gas which is efficient, becomes more efficient as it is scaled up, and overcomes the problem of dilution of the synthesis gas with combustion products.

STATEMENT OF THE INVENTION

In accordance with the present invention, synthesis gas is produced by reacting coal or coal char and steam in a gasification section in the presence of a body of molten coal ash or other slag containing sufficient heat to cause the reaction to take place, continuously withdrawing molten ash cooled by the reaction to an oxidizing section, introducing fuel into the molten ash after it leaves the gasification section, heating the molten ash in the oxidizing section by introducing an oxidizing gas to burn the fuel to a temperature at least about 225° F higher than the temperature of the gasification section, and continuously propelling the heated molten ash into the gasification section, the products of combustion produced while heating the molten slag being separated from the slag before it is introduced into the gasification section. Most preferably, the transfer device is a heated gas lift, the gas-transfer medium being hot products of combustion.

THE DRAWINGS

In the drawings, FIG. 1 is a schematic flow sheet of the process of this invention.

FIG. 2 is a schematic flow sheet showing the process of this invention as applied to a scheme for making pipeline gas from coal.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, we provide a gasification section **10**, a heat section **12**, a pipe **14** for circulating molten coal ash from the gasification section **10** for heating section **12**, and a pumping device **16** for recirculating superheated molten ash from the heating section back to the gasification section.

In the gasification section, a stream **18** of mixed molten ash and carbon (coal or coal char) is fed onto a bed **20** of molten ash. Steam is introduced into the bed **20**, and reacts with the carbon to form synthesis gas, essentially H_2 and CO in equal volumes. This runs off through a vent **22** to purification and storage.

The ash present in the carbon joins the ash pool, except that metallic elements such as iron are reduced and form a metal pool **24** in the bottom of the section; this is tapped off as required. The accretions of ash to the pool are dealt with by taking excess ash to waste.

The molten ash is continuously withdrawn through line **14** and circulates to the heating section. Fuel is introduced into the molten ash, either in the line **14** or in the oxidizing section **12**, where a body of molten ash **26** is maintained. The fuel may be a portion of the synthesis gas, other gas, or solid fuel. In the drawing, it is shown as gas fed into the molten ash body **26** through lines **28**, along with air in lines **30**. The combustion gases are stacked (**17**) through a waste-heat boiler **32** and a heat exchanger **34**, which preheats the air going into line **30**; the waste gases are treated as necessary to remove fly ash.

The transfer device **16** is preferably a gas lift in which the gas for the lift is fuel from line **28** burned with air from line **30**. At the top of the lift, the ash is separated from the combustion products in a space **36**, and the gas is vented into the main stack of the heating section.

A screw conveyor **38** feeds the reactant carbon into the recycle superheated ash just before it enters the reducing section, so that the two form the single stream **18** previously described.

The gasifier may be operated at any temperature from 1,600° F upward, but since the coal ash must be kept liquid, operations are conducted above the melting point of the ash, so as to make it unnecessary to add fluxes to the ash to lower the melting point. Temperatures of the order of about 2,100° to 2,500° F are preferred.

The endothermic heat of reaction is sufficiently great so that, in order to get economic recycle rates, the heating section should be operated at a temperature at least about 225° F above the gasifier temperature. Typically, the molten ash enters the gasifier in a ratio of about 20 to 60 parts by weight of molten ash to one part by weight of added carbon.

The carbon used may be coal or any rank from peat to anthracite, or any char prepared from coal. With coal or coal char, the molten coal ash becomes the heat-transfer medium.

The process is also applicable to low-ash carbons such as petroleum coke. With such feeds, a synthetic molten ash can be prepared, and the process can be operated at a lower temperature by choosing a melt which is lower-melting. However, the use of molten coal ash as the heat-transfer medium offers marked economic advantages over the use of other heat-transfer media, particularly when combined with the fact that very-low-cost coals may be used.

The superheater section, gasification section and air lifts are preferably water-jacketed, so as to freeze a layer of slag adjacent the refractory walls, in known fashion, to minimize attack on the refractories.

The process may be used in an over-all scheme to produce a synthetic pipeline gas to be used as a substitute for natural gas, as shown schematically in FIG. **2.**

Coal **1** is subjected to multistage pyrolysis to produce char **2** and a tar-forming vapor stream **5.** This stream is divided into a noncondensible gas stream **8,** a liquid tar stream **7** and an aqueous liquor stream **6** which is treated and discharged. The tar is treated with hydrogen **9** to form a synthetic crude oil **10A.**

The char stream **2** is divided, part **4** going to the gasifier **10** and part **3** going to the heater **12** in line **28.** In the gasifier **10,** the char is converted into water gas, whence it passes through line **22** through a waste-heat boiler **32C** to join the gas in line **8**; the gas is purified, methanated and discharges as pipeline gas (line **4**).

The stack gases from the heater (line **17**) pass through waste-heat boiler **32A** and an air preheater **34,** preferably also through a steam-reheater **42** used to superheat feed steam into line **11** for feeding to the gasifier; this steam comes from line **40,** being the steam discharged from a generator operated by steam (line **19**) coming from the waste-heat boilers **32A** and **32C.**

EXAMPLE OF THE INVENTION

A plant for making 250 million standard cubic feet of synthesis gas per day has been designed on the basis of laboratory and pilot plant work. Using Illinois No. 6 coal (a bituminous A coal), the table below shows the amounts of material, and their composition, being fed through the various streams shown in FIG. **2** of the drawing, in pounds per hour:

TABLE

Stream No.	Identification	Flow (lb./hr.)	Temperature (°F)	Pressure (psi)
1	Coal feed	2,158,000	Room	60
2	Char from pyrolysis	1,317,000	1000	60
3	Char to heater	715,000	1000	60
4	Char to gasifier	602,000	1000	60
5	Vapors from coal pyrolysis	841,000	700	60
6	Liquor from tar recovery	50,000	140	60
7	Tar from tar recovery	562,000	140	60
8	Pyrolysis gases from tar recovery	229,000	140	60
9	Hydrogen to hydrotreating	45,000	Room	3000
10A	Syncrude (42,000 bbl./day)	583,000	Room	atm.
11	Steam to gasifier	752,000	1000	60
22	Gases from gasifier	1,253,000	2500	60
13	Slag tapped from gasifier	205,000	2500	60
14	Slag from gasifier to heater	28,620,000	2500	60
16	Slag from heater to gasifier	28,732,000	3000	60
30	Preheated air to heater	7,533,000	1000	60
17	Combustion gases from heater	8,137,000	3000	60
38	Feed water to waste-heat boiler	2,457,000	100	900
19	Steam from waste-heat boiler to power turbine	2,457,000	1000	900
40	Steam extraction from power turbine	752,000	320	60
41	Pipeline gas from methanation (250,000,000 cu. ft./day)	454,514	100	1000

CHEMICAL ANALYSIS OF STREAM PRODUCTS

Stream No.	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
1	1,736,000	74,400	89,000	23,000	30,000	205,400
2	1,096,000	–	–	–	15,900	205,400
3	595,000	–	–	–	8,600	111,600
4	501,000	–	–	–	7,300	93,800
5	646,000	–	–	–	–	–
6	5,500	–	44,400	–	–	–
7	518,000	22,500	13,500	3,100	4,800	–
8	122,500	46,400	30,700	19,700	9,500	–
9	–	45,000	–	–	–	–

Obviously examples can be multiplied without departing from the scope of the invention as defined in the claims.

We claim:

1. Method of producing synthesis gas from carbon and steam in a gasifier consisting of gasification and heating zones physically separated from each other which comprises (1) introducing carbon and steam into the gasification zone in the presence of a body of molten slag heated to a temperature sufficient to cause the carbon to react with the steam to produce carbon monoxide and hydrogen; (2) continuously withdrawing molten slag cooled by the reaction from the gasification zone to the heating zone; (3) introducing fuel into the molten slag after it leaves the gasification zone; (4) burning the fuel with oxygen in the heating zone to heat the slag to a temperature at least 225° F higher than its temperature when withdrawn from the gasification zone; and (5) continuously propelling the molten slag into the gasification section after separation of the products of combustion used to heat the slag.

2. The method of claim 1, in which the heated slag is propelled into the gasification zone by an air lift operated by hot products of combustion.

3. The method of claim 1, in which the carbon is coal or coal char, and the slag is ash derived from the coal or coal char.

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