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Blaskowski

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[54] **METHOD OF OPERATING A COMBINED GASIFICATION-STEAM GENERATING PLANT**

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[52] **U.S. Cl.** **122/5,** 48/206, 110/31

[51] **Int. Cl.** **C10j 1/00**

[58] **Field of Search** 122/5; 110/31; 48/206

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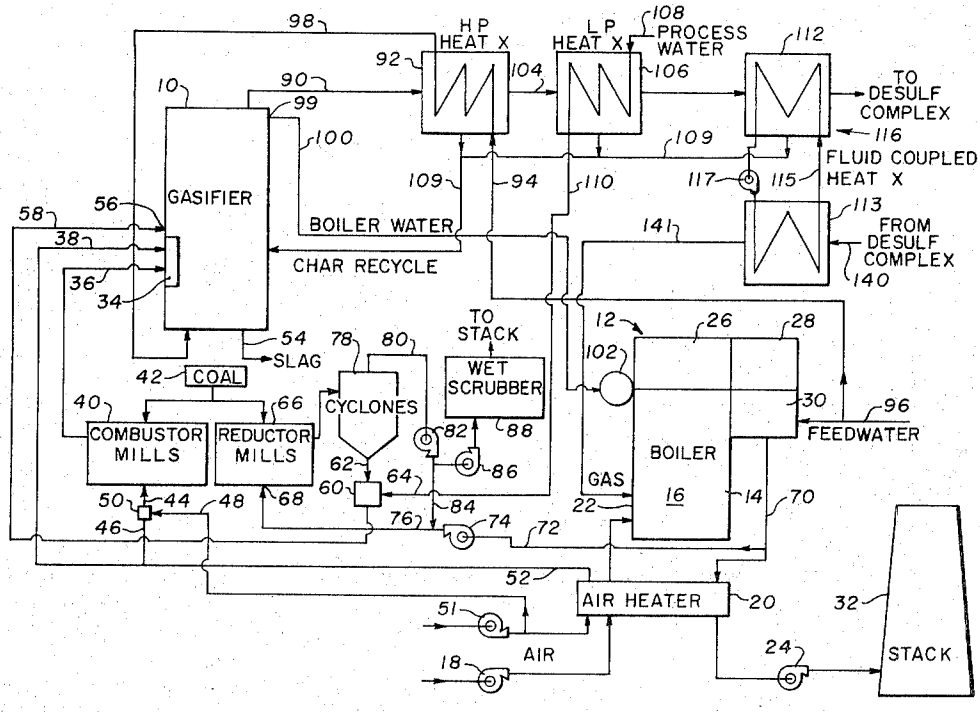
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[57] **ABSTRACT**

A steam generating plant is provided which includes an entrainment, slagging, air blown atmospheric pressure coal gasifier, a heat recovery train, atmospheric pressure desulfurization and a steam generator designed to burn the low Btu fuel gas produced in the gasifier. Heat recovered from the gas produced in the gasifier is used to raise the temperature of a portion of the steam generator feedwater, generate steam for use in the gasifier, and to reheat the fuel gas following desulfurization. Heat recovered from boiler flue gas is utilized in drying and preheating the reactants to the gasifier.

9 Claims, 2 Drawing Figures



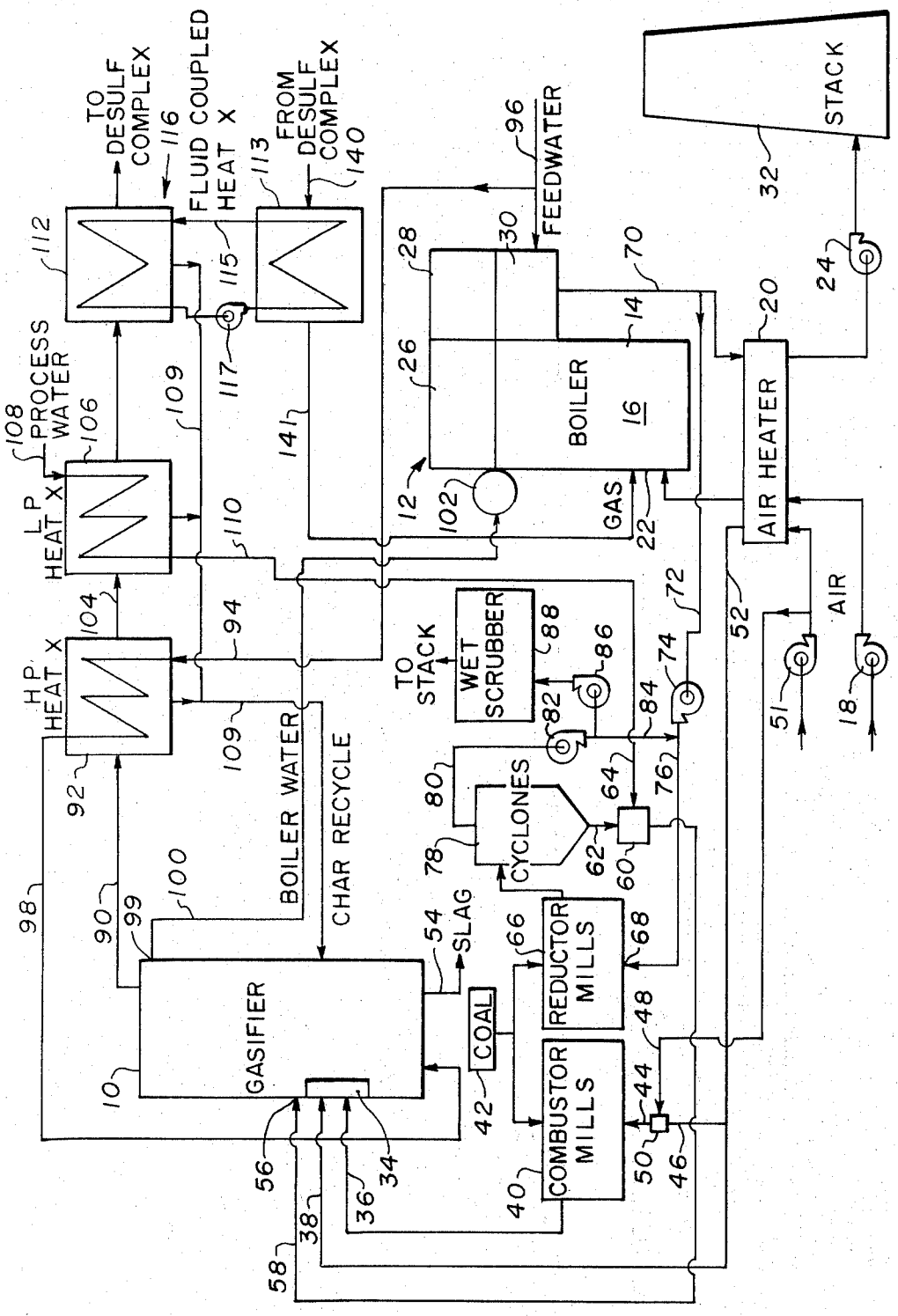

TO DESULF COMPLEX
116
FLUID COUPLED HEAT X
113
FROM DESULF COMPLEX
140
96
FEEDWATER
STACK
32
112
115
28
30
70
24
108 PROCESS WATER
106
109
117
26
14
20
LP HEAT X
141
BOILER 16
12
102
GAS
22
AIR HEATER
110
104
94
72
52
TO STACK
WET SCRUBBER
88
86
74
AIR
HP HEAT X
82
84
51
18
92
109
BOILER WATER
CHAR RECYCLE
80
64
76
98
90
99
100
CYCLONES
78
62
60
54
SLAG
66
REDUCTOR MILLS
68
GASIFIER
10
COAL
48
42
COMBUSTOR MILLS
44
56
34
36
50
46
40
38
58

FIG. 1

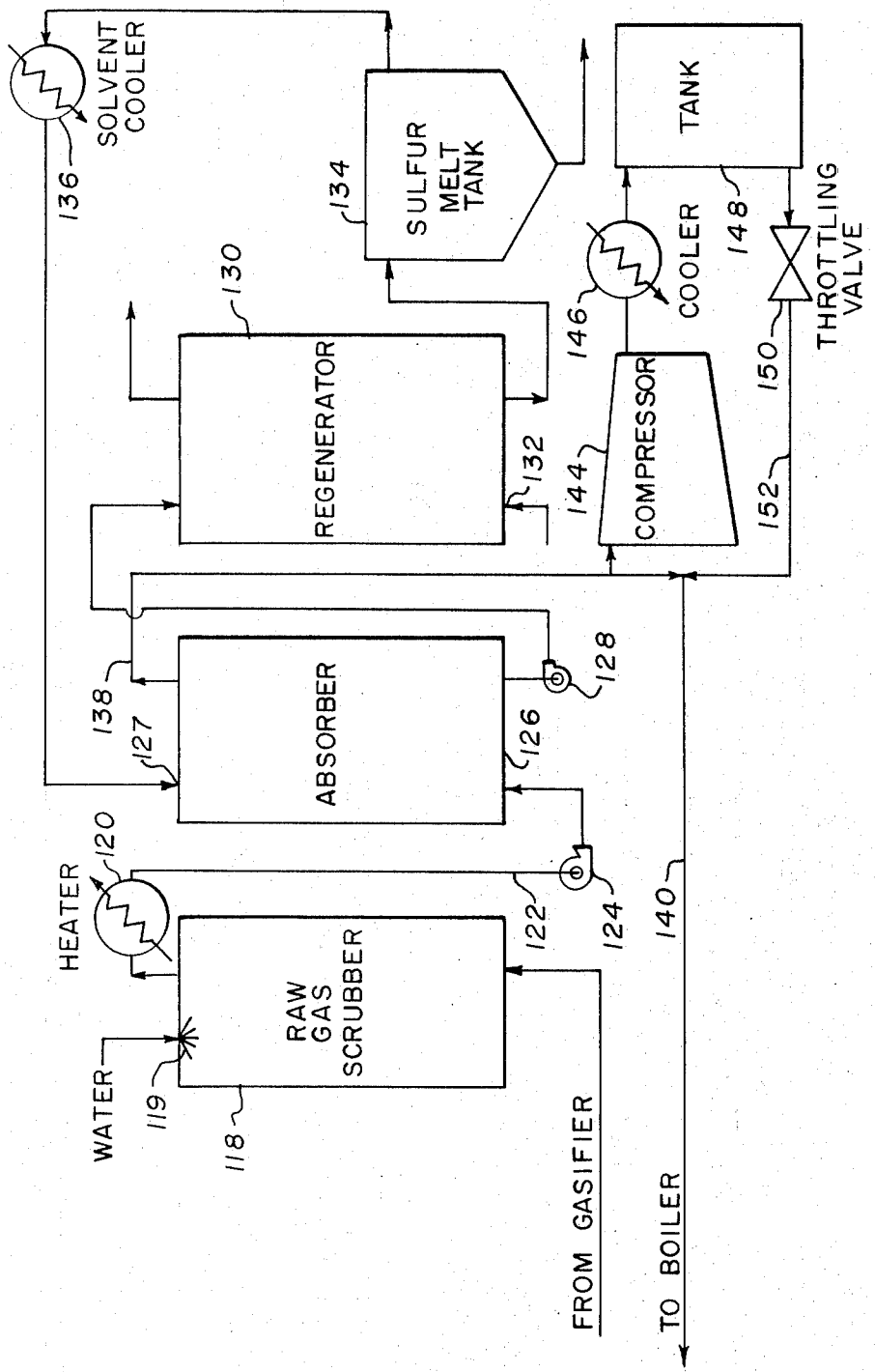

SOLVENT COOLER
136
SULFUR MELT TANK
134
TANK
148
COOLER
146
THROTTLING VALVE
150
130
REGENERATOR
132
144
COMPRESSOR
152
138
127
ABSORBER
126
128
HEATER
120
122
124
140
RAW GAS SCRUBBER
WATER
119
118
FROM GASIFIER
TO BOILER

FIG. 2

METHOD OF OPERATING A COMBINED GASIFICATION-STEAM GENERATING PLANT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to steam generating plants and more particularly to a system wherein a steam generator is integrated with an on-site coal gasification plant which provides a low Btu gaseous fuel for the steam generator.

2. Description of the Prior Art

The electric utility industry in the United States is currently the target of many regulatory agencies and environmental groups whose goal is the reduction or elimination of objectionable emissions such as sulfur oxide, nitrogen oxide, and particulate matter from the stacks of power generating stations. Of the many solutions to this problem now being studied one of the most promising for near term relief is the on-site gasification and desulfurization of a high sulfur content coal to produce a clean burning low Btu fuel gas which may be burned in a steam generator. Various systems making use of this idea have been proposed; however, none have appeared particularly attractive from an economic standpoint, primarily because of the gasification losses where as much as **20** percent of the Btu content of the coal may be lost.

BRIEF SUMMARY OF THE INVENTION

In accordance with the invention there is provided a steam generating plant fully integrated with a coal gasification plant which produces a gaseous fuel to be burned in the steam generating plant. The interrelationship of the two plants is such as to take maximum advantage of the available Btu content of the coal.

The hot gas formed in the gasifier is passed through a series of three heat exchangers to effect cooling thereof before it is sent to a desulfurization complex where the hydrogen sulfide present in the gas is removed. Heat is extracted in the first of the series of heat exchangers using water as the heat exchange fluid. The hot water from this heat exchanger is then circulated through water cooling passages in the walls of the gasifier itself where additional heat is extracted. This hot water is then passed directly to the boiler of the steam generator. Heat extracted in the second heat exchanger is used to generate steam which is used as a reactant in the gasifier. The third heat exchanger is one-half of a fluid coupled heat exchanger and its function is to further cool the gas prior to desulfurization. The desulfurized gas passing from the desulfurization complex is then reheated in the second half of the fluid coupled heat exchanger, prior to being burned in the steam generator.

A gas storage capacity is included in the system in order to permit the gas supply to more promptly respond to increases in demand from the steam generator.

Other important features of the invention include; the use of the steam generator air preheater to provide hot air, which is used to dry a portion of the coal to be gasified and as a source of oxygen in the gasification reaction, and the use of spent flue gas from the steam generator to dry another portion of the coal.

Other objects and advantages of the invention will become apparent upon reading the following detailed description of an illustrative embodiment and upon reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation of a steam generating plant embodying the principles of the invention.

FIG. **2** is a schematic showing a representative desulfurization complex which may be used with the system and the gas storage system of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1** there is shown a gasifier **10** for producing a low Btu gaseous fuel, by the reaction at high temperatures of oxygen and steam with a solid carbonaceous fuel, and a steam generator **12** having a boiler **14** adapted to burn the low Btu gas produced by the gasifier **10.**

With the exception that the burners (not shown) in the boiler furnace **16** are adapted to burn a low Btu gas the steam generator **12** is of a conventional design. Air for combustion is supplied to the boiler furnace **16** by the forced-draft fan **18,** which takes atmospheric air and forces it through the air preheater **20** and into the furnace **16** to be burned with the low Btu gas which enters the furnace along with the air as shown at **22.** The product of combustion gases from the furnace **16** are removed by an induced draft fan **24** and are drawn successively through the superheater **26** where the steam temperature is raised above that existing in the boiler, the reheater **28** where superheat is added to the steam between power turbine stages, the economizer **30** where feedwater to the boiler **14** is heated, and the air preheater **20,** and discharged to the stack **32.**

Turning to the gasifier **10,** its operation and association with the steam generator **12** in such a way as to make maximum use of the heat generated in both systems will now be described. The gasifier **10** is of the entrainment, slagging, air blown atmospheric pressure type, and makes use of the so-called two stage reaction process.

The first reaction stage, which takes place in the lower end of the reactor involves the near complete combustion of a quantity of pulverized coal with preheated air in stoichiometric proportions. These reactants are injected into the gasifier through a plurality of burner nozzles, one of which is shown schematically at **34.** These burners **34,** in a typical gasifier of this type having a circular cross section, are equally spaced about the outer circumference of the gasifier and operate in the same manner as the burners conventionally utilized in pulverized coal fired steam generating boilers. Primary air and the pulverized coal are delivered to the burner **34** through a coal pipe **36** while the balance of the air, the secondary air is delivered through a separate conduit **38** and mixed with the primary air and coal as it leaves the burner nozzles.

The mixture of primary air and pulverized coal is prepared in the combustor mills **40,** which may be of any well known design such as a bowl mill or a ball mill. Coal is supplied to the combustor mills **40** from a suitable source, as represented at **42,** while the primary air is supplied through conduit **44.** The air entering the mill through conduit **44** is preferably maintained at a temperature between about 550°–600° F. This temperature is maintained by mixing, as shown at **50,** a stream

of hot air **46**, which has passed through the air preheater **20** of the steam generator **12**, with a stream of cooler atmospheric air **48**. Both streams of air are provided by a fan **51**, the cool air being bled off from the main stream **52** before it passes through the air preheater **20**. The stream of hot air **46** to the combustor mills is taken from the main stream of hot air **52** as required while the balance of this air passes to the burner **34** through the secondary air conduit **38**. Such an arrangement is typical of pulverized coal burning equipment and is designed to reduce the moisture content of the coal to an acceptable level and to preheat it to a temperature generally not exceeding 180° F.

The complete combustion of these reactants which occurs upon their injection into the gasifier **10** results in the production of a very high temperature product of combustion gas. This high temperature, preferably **3100°F** or above is required for two reasons: it is above the fusion temperature of the ash in the coal, thus resulting in the formation of molten slag which is removed from the lower end of the reactor by a suitable slag disposal system **54**; and it provides, in the form of the hot rising gases, a high temperature heat source which is necessary to sustain the primarily endothermic reduction reaction, the second stage of gasification, which occurs in the region overlying the combustion zone.

The second reaction stage involves the reaction of a second stream of reactants, containing pulverized coal and steam, with the hot gases rising from the oxidation or combustion zone. As indicated the reactions occurring here are primarily endothermic and result in the formation of a low Btu fuel gas containing mostly carbon monoxide and hydrogen with some methane. Hydrogen sulfide in quantities proportionate to the initial sulfur content of the coal is also present in the gas.

The stream of steam and coal for the second reaction stage is injected into the gasifier at **56** and is supplied thereto by means of a suitable conduit **58** which communicates with a mixing chamber **60**. The mixing chamber **60** is in turn supplied with separate streams of dried pulverized coal **62** and steam **64**. The coal is pulverized and dried in the reductor mills **66** which are, as were the combustor mills **40**, of conventional design. The drying of the coal in the reductor mills **66**, which is supplied from the same coal source **42** as the combustor mills, is accomplished by passing through the mills a stream of hot flue gas **68**, passing from the steam generator economizer **30**. This gas is drawn from the passage **70**, through duct **72**, by a suitable fan **74** and delivered to the mills **66** through duct **76**. Hot flue gas, instead of hot air, is used to dry this coal in order to insure a minimum oxygen level in the coal when it enters the gasifier.

The dry coal/flue gas mixture from the reductor mills **66** is then passed through a cyclone separator **78**, where the coal and flue gas are separated, and the coal is passed from the bottom of the separator as at **62** to the mixing chamber **60**. The flue gas from the separator **78** is drawn out through conduit **80** by means of a fan **82**. This gas is at a substantially reduced temperature and a portion of it is recirculated through duct **84** to the duct **76** which carries flue gas to the reductor mills **66** thereby maintaining the temperature of this gas in the range needed to accomplish sufficient drying of the coal in the mills. The balance of the flue gas passing from fan **82** is drawn by a second fan **86** and directed to a wet scrubber **88** which removes any particles of pulverized coal which may have passed with the gas through the cyclone separator **78** before directing it to the stack **32** and thence to the atmosphere.

The gaseous fuel exiting from the gasifier is preferably at a temperature ranging up to about 1,700° F. This is considerably cooler than the 3,100° F existing in the combustion zone, due to the endothermic nature of the reactions in the reduction zone, however, the gas still contains a large quantity of sensible heat which should be utilized in order to increase the overall efficiency of the entire system. Accordingly, the hot fuel from the gasifier **10** is passed directly, through conduit **90**, to a high pressure heat exchanger **92** where it gives up heat to water bled through pipe **94** from the boiler feedwater supply line **96**. In a typical installation the water passing through the high pressure heat exchanger **92** would enter at a pressure of 3,050 psia and a temperature of 487° F and leave at 3,000 psia and 630° F. The hot water from this heat exchanger **92** is then passed via conduit **98** to the inlet manifold (not shown) of a water wall cooling system in the gasifier **10**. The water is circulated through the wall cooling system where it is further heated so that the water exiting from the system, at **99**, is at a temperature and pressure of 690° F and 2,900 psia respectively. This water is then directed through conduit **100** to the steam generator **12** where it is admitted directly to the boiler steam drum **102**.

The gaseous fuel passes from the high pressure heat exchanger at a reduced temperature of about 1,040° F, and is conducted directly through conduit **104** to a low pressure heat exchanger **106**. The heat exchange fluid in the low pressure heat exchanger is a suitable supply of process water **108** at atmospheric pressure which is converted to steam by the passage therethrough. The steam generated therein typically will be at 700° F and 165 psia, and passes from the heat exchanger **106** through a suitable steam line **110** to the mixing chamber **60**, thus providing the steam supply required to carry out the gasification reaction.

The gas passing from the low pressure heat exchanger **106** is reduced in temperature to about 640° F. It is then further cooled to about 300° F before entering the desulfurization complex **114** by passing through the first section **112** of a fluid coupled heat exchanger **115**. The fluid coupled heat exchanger **115** comprises two heat exchange sections **112**, **113** remotely located from one another and interconnected by a flow of heat exchange fluid through closed circuit flow path **116**. Fluid flow through this circuit is maintained by a suitable pump **117**. The second section **113** of the fluid coupled heat exchanger **115** returns to the gas the heat removed from it in the first section **112**, after the gas has been desulfurized as will be described hereinbelow. Each of the three heat exchangers **92**, **106**, **112** through which the gas passes prior to desulfurization is provided at the bottom of the gas passage with a hopper to collect char which may accumulate. This char is periodically recycled back to the gasifier through recycling lines **109**.

As indicated above the gas passes from the first section **112** of the fluid coupled heat exchanger **115** to the desulfurization complex **114** where the hydrogen sulfide present in the gas is removed. Desulfurization may be carried out by one of several known processes such as for example solvent extraction, or dry techniques. A typical desulfurization system is shown in FIG. **2** and

will be described in connection with a fuel storage arrangement also illustrated therein.

Referring to FIG. 2 the gas from the first section of the fluid coupled heat exchanger **112** passes first to a raw gas scrubber **118** where any remaining particulates are removed from the gas and it is further cooled by adiabatic humidification. The water spray **119** to the gas scrubber **118** saturates the gas and cools it to the dew point. In order to preclude formation of hydrogen sulfide and the resulting acid corrosion which would occur, a heater **120** positioned at the top of the scrubber **118** raises the temperature of the exiting gas to about 10° F above the dew point. The gas then flows via conduit **122**, through a booster fan **124** to the absorber **126** where the H_2S is removed as a result of chemical reactions occurring upon exposure of the H_2S in the gas with a suitable absorption solution, which is admitted at **127**.

The used solution from the absorber is pumped, by pump **128**, to the regenerator **130** where air is blown through the solution as at **132**. The air regenerates the absorbant to an oxidizing from so that it may be returned through sulfur melt tank **134**, and cooler **136** to the absorber **126** where it is reused. Elemental sulfur is separated from the absorbant upon passage through the sulfur melt tank **134** and the sulfur is heated therein so that it may be conveniently removed in a liquid form for disposal.

The desulfurized gas passing from the absorber is then conducted, as needed, through conduits **138** and **140** (FIGS. **1** and **2**) to the second section **142** of the fluid coupled heat exchanger **116** where it is reheated, and from there through conduit **141** to the steam generator **12** to be burned.

In order to provide for occasional imbalance which may exist between the gasifier output and steam generator demand a gas compression and storage capability is provided in the system. Referring to FIG. **2**, during periods when steam generator demand is less than gasifier output, quantities of clean gas passing from the absorber **126** are compressed by compressor **144**, further reduced in volume by cooler **146**, and then passed to storage tank **148** where it is stored at about **150** psia. When steam generator demand temporarily exceeds gasifier output the quantity of gas necessary to supplement the gasifier output in order to meet the demand is supplied from the storage tank **148**. The flow of gas from the tank **148** is controlled by a throttling valve **150** which is located in the tank storage supply conduit **152** which ties into the conduit **140** which feeds the gas to the steam generator. The throttling valve **150** also serves to let down the pressure of the gas coming from the storage tank **148** to atmospheric pressure.

The diversion of gas to the storage tank **148** of course can only be carried out when the tank is at less than full capacity. Accordingly, when the tank is full and the steam generator demand is less than maximum, the output of the gasifier must be reduced to match the steam generator demand.

While this preferred embodiment of the invention has been shown and described, it will be understood that it is merely illustrative and that changes may be made without departing from the scope of the invention as claimed.

What is claimed is:

1. A method of operating a steam generating plant in conjunction with a coal gasification plant which produces gaseous fuel to be burned in the steam generating plant, comprising the steps of:

producing a low Btu gaseous fuel in said gasifier by the reaction at high temperatures of oxygen and steam with a solid carbonaceous fuel;

flowing the gaseous fuel from the gasifier in heat exchange relation with a flow of water;

passing said flow of water through the walls of said gasifier to effect the cooling thereof;

burning said gaseous fuel in said steam generating plant to produce heat for the generation of steam therein; and

conducting the hot water exiting from said gasifier walls to the boiler of said steam generating plant.

2. A method of operating a steam generating plant in conjunction with a coal gasification plant which produces gaseous fuel to be burned in the steam generating plant, comprising the steps of:

burning a first reactant stream of pulverized coal and preheated stoichiometric air in said gasifier to produce hot product of combustion gases;

reacting a second reactant stream of pulverized coal and steam with said hot product of combustion gases in said gasifier to produce a low Btu gaseous fuel therein;

flowing water through the walls of said gasifier to effect the cooling thereof;

burning said gaseous fuel in said steam generating plant to produce heat for the generation of steam therein; and

conducting the hot water exiting from said gasifier walls to the boiler of said steam generating plant.

3. The method of claim **2** including the steps of flowing the hot gaseous fuel from the gasifier in heat exchange relation with process water to form steam; and

mixing the steam formed in the preceeding step with pulverized coal to form said second reactant stream.

4. The method of claim **2** including the steps of: flowing the hot flue gases from the steam generating plant in heat exchange relation with atmospheric air to raise the temperature of said air;

mixing a first portion of said air with pulverized coal to dry the coal; and

mixing a second portion of said air along with said previously mixed air and pulverized coal, to form said first reactant stream.

5. The method of claim **2** including the steps of:

mixing a quantity of hot flue gases from the steam generating plant with pulverized coal to lower the moisture content of the coal;

separating the dry pulverized coal from the hot flue gases; and;

mixing the dry puvlerized coal with steam to form said second reactant stream.

6. A method of operating a steam generating plant in conjunction with a coal gasification plant which produces gaseous fuel to be burned in the steam generating plant, comprising the steps of:

producing a low Btu gaseous fuel in said gasifier by the reaction at high temperatures of oxygen and steam with a solid carbonaceous fuel;

flowing water through the walls of said gasifier to effect the cooling thereof;

cooling the gaseous fuel from the gasifier by passing it in heat exchange relation with the fluid in one half of a fluid coupled heat exchanger;

removing the H_2S from the gaseous fuel;

reheating the cleaned gas by passing it in heat exchange relation with the fluid in the second half of said fluid coupled heat exchanger;

burning said gaseous fuel in said steam generating plant to produce heat for the generation of steam therein; and

conducting the hot water exiting from said gasifier walls to the boiler of said steam generating plant.

7. The method of claim **1** wherein the step of producing a low Btu gaseous fuel comprises the steps of:

burning a first reactant stream of pulverized coal and preheated stoichiometric air in said gasifier to produce hot product of combustion gases; and

reacting a second stream of pulverized coal and steam with said hot product of combustion gases.

8. The method of claim **7** including the steps of:

flowing the hot gaseous fuel from the gasifier in heat exchange relation with process water to form steam; and

mixing the steam formed in the preceeding step with pulverized coal to form said second reactant stream.

9. The method of claim **8** including the steps of:

flowing the hot flue gas from the steam generating plant in heat exchange relation with atmospheric air to raise the temperature of the air;

mixing a first portion of said heated air with pulverized coal to dry the coal;

mixing a second portion of said air along with said previously mixed air and pulverized coal, to form said first reactant stream;

mixing a quantity of hot flue gases from the steam generating plant with pulverized coal to dry the coal;

separating the dry pulverized coal from the hot flue gases; and

using said dry pulverized coal as the coal which is mixed with steam to form said second reactant stream.

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