Nov. 17, 1931. L. C. KARRICK 1,832,219

PROCESS AND APPARATUS FOR SUPERHEATING STEAM

Filed July 5, 1928

Fig. 3

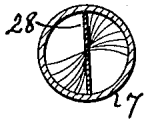

Fig. 2

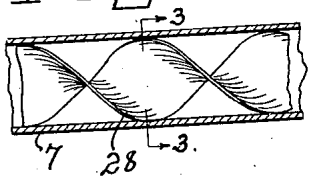

Fig. 1

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PROCESS AND APPARATUS FOR SUPERHEATING STEAM

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This invention relates to a process and apparatus for superheating steam to high temperatures in contact with certain reacting reagents which serve to protect the metals of which the superheater is constructed, and, by the chemical reactions which take place at the higher temperatures, valuable by-products are formed and as a result of these by-products the superheater delivers more heat at the desired temperatures than would be possible if no reagents were used; other advantages of my invention are also described in this application.

There are many processes in which high temperature steam could be used if suitable means were provided for heating the steam above 900° F. and particularly above 1250° F. The distillation of carbonaceous materials such as oil shale and coals or wood may be effected by internal heating with steam above 900° F. and these same materials may be completely gasified in lump or pulverized form by contacting with steam above 1250 F. Many new alloys and designs of equipment have been attempted for heating steam to temperatures above 900° F. with only limited success due to the difficulty of combining in the product the elements of strength, resistance to oxidation, permanence, and cheapness. By my invention steel, calorized steel, and alloys of iron and chromium which are readily fabricated may be used at temperatures considerably higher than has heretofore proved practicable, and the latter two materials may be used successfully above 1250° F. and as much higher as the strength of the materials and service conditions permit.

I find that if a chemically reactive coke, such as is produced by the process described in my application, Serial No. 69,300, or other similar coke is introduced in pulverized form into the superheater with the steam, a combination with the steam takes place rapidly at temperatures as low as 1250° F. and much of the coke may be rapidly reacted upon to form water gas. At the lowest temperatures of formation the water-gas reaction yields a large amount of carbon dioxide which may oxodize the iron of the superheater within certain temperature ranges unless special precautions are applied to oppose it. The rate of oxidation of iron by steam in the presence of reactive carbon is almost negligible below 1250° F. but, if desired, calorized steel or an alloy of iron and chromium may be used in the hottest portions of the tubes. Above 1250° F. the carbon dioxide formed may be largely reduced to carbon monoxide if a surplus of carbon is used and thereby oxidation from this source is eliminated. At still higher temperatures both the steam and carbon dioxide are readily reduced to hydrogen and carbon monoxide in any proportion desired by proper control of temperatures and the proportioning of the carbon and steam, and therefore no serious oxidation takes place since, in all cases, I use a sufficient quantity of coke to cause a neutral or only slightly oxidizing atmosphere in the tubes.

In a heat-exchanger, a recuperator or, as in this invention which is a steam superheater wherein heat is caused to flow from hot combustion gases through a metal wall to steam or other fluid, the temperature of the metal wall approaches nearest to that of the contacting gaseous medium which receives or delivers its heat most readily. If the heat capacities of the fluid media are equal then the metal temperature approaches that of the medium that moves the fastest along the metal surface. These conditions are applied in this invention so as to obtain the greatest rate of heat transfer, the highest temperature of the medium receiving heat and lowest metal temperature for any given temperature and velocity of movement of the combustion gases surrounding the heat exchanger.

I have found that steam superheated to various temperatures is very useful in dis-

tilling carbonaceous substance by direct contacting with the material undergoing destructive distillation. Also, hot water-gas is equally useful for the same purposes, or a mixture of the two fluids may be used satisfactorily. The carbonaceous residue produced by distilling coal and like substances with these gaseous media may have very great chemical reactivity with steam or carbon dioxide to form water-gas or producer gas, and I have shown by this invention that these reactions will take place rapidly when using such carbon residues at lower temperatures than are required in present day producers and water-gas generators using high temperature cokes. I have found that much of the carbon dioxide contained in blue gas which is formed at low temperatures may be reduced to carbon monoxide by this process.

In carrying out the features of this process, clean steam such as engine exhaust steam or steam produced from a waste heat recuperator and other economical sources, is superheated by passing it through metal tubes at high velocities counterflow to hot combustion gases which flow rapidly across the tubes. By proper regulation of steam pressure and velocity inside the tubes and using high velocities of hot gases surrounding the tubes, I have been able to heat the steam to 1950° F. while the gases surrounding the tubes were less than 2200° F. at the hottest points. When active coke was added the temperature of the fluids was less due to endothermic reactions but the heat delivered by the superheater was increased.

The reaction between the coke and steam is strongly endothermic but by my process the necessary heat required to attain chemical equilibrium may be transmitted through the walls of the tubes. Much of the heating is obtained by the steam as in ordinary steam superheaters but in my invention considerable heat is absorbed by the dust particles from wall radiation and especially by the carbonaceous dust rubbing the walls of the tube at very high velocities.

The heat-consuming reaction may reduce considerably the temperature of the resulting fluids and this is most noticeable when I use excessive quantities of both coke and steam so that neither of the reacting substances are completely consumed and some of each is discharged from the device. In this case the temperature of the exit steam and water-gas approaches the minimum temperature at which the water-gas reaction takes place. However, when either the coke or steam, or both, are completely consumed the resulting products may be raised to any desired temperature before leaving the device. If there is a surplus of steam, the resulting gas will be high in carbon dioxide but if there is an excess of coke, the resulting gas will contain more carbon monoxide and be of higher fuel value and, obviously, is a highly reducing atmosphere.

By this process I am, therefore, able to superheat steam for use as a heat-carrying medium in process work to any desired temperature while preventing oxidation of the superheater tubes and simultaneously produce water-gas of variable composition from pulverized carbonaceous materials,—preferable low-temperature coke breeze or coal dust. The invention is especially useful because of the fact that the endothermic reaction that takes place can be utilized to control the temperature inside the tubes and therefore the metal temperatures which is essential in securing long life and economical operation of any device which superheats to very high temperatures. By this process of superheating, the combustion zone temperatures may be kept at high heat and the coke steam ratio varied to govern the exit temperature of the fluids and the temperature of the metal walls.

By my process of superheating steam in contact with carbonaceous materials it is possible to deliver one-third more pounds of heated fluids than the weight of the reacting steam passed into the superheater assuming all the oxygen of the steam is converted to carbon dioxide. It may be otherwise stated that the heat carried in the issuing fluids from the superheater will be approximately 50 percent greater due to the above reaction than if the converted steam were heated to the same final exit temperature. The actual quantity or gain in heat delivered depends on the portion of the steam converted to gaseous form. Now, if the conditions imposed are such that all the oxygen of the reacting steam is converted to carbon monoxide, there will be delivered two-thirds more pounds of heated fluids than the weight of the reacting steam. This is equivalent to saying that the sensible heat carried in the issuing fluids from the superheater will be about 100 per cent greater by this reaction than if the converted steam were heated to the same final temperature. It is the object, obviously, to convert as much as practicable of the steam to water gas of the latter form because of its greater fuel value, but primarily because of the greater economy in use of steam for carbonizing coal in which steam functions as the heat transferring fluid. The process is useful, therefore, as a means of conserving steam.

By this process I have superheated steam and simultaneously generated water-gas from pulverized coal and coke at pressures up to 100 pounds gage. The exit gas and hot steam under pressure was passed through a lump coal carbonizer in which the sensible heats of the fluids distilled the coal, and thence passed into a heat exchanger and condenser leaving the cold dry gas under pres-

sures amply high to transmit it long distances through pipes.

The hot steam and gases from the superheater may also be used in a heat exchanger while under pressure to generate another supply of steam at lower pressure for use in another similar superheater, or to superheat steam instead of using combustion gases as a source of heat. Any number of these units or combinations may be used in series as required to consume the coal or coke dust at a power plant, gas works, or coal-treating plant.

The invention will be understood from the description in connection with the accompanying drawings in which an illustrative embodiment of the device is shown for carrying out the invention. Fig. 1 is a vertical section through an illustrative device that may be used in carrying out the invention; Fig. 2 is a section along one of the details on an enlarged scale partly broken away; and Fig. 3 is a section along the line 3—3 of Fig. 2.

In the drawings reference character 1 indicates a heater or furnace, preferably circular in cross section that is provided with an inside cylindrical portion or core 2 to provide an annular space 3 which is of smaller cross section at the top so as to maintain high velocity of combustion gases. The lower portion of the annular space contains checkerwork 4 of refractory material and burners 5 are provided at the lower portion of the furnace 1 to project fuel into the annular space where it contacts with the checkerwork 4 and undergoes combustion. The burners may be gas burners that are fed from a gas manifold 6. I do not limit my invention to this manner of heating and in some cases I would prefer to heat electrically during off peak periods and the tube would become the electrical resister being imbedded in a heat insulating material, a power line being attached to the coil 7 as shown at 7′ and 7″. The coil 7 may be imbedded in insulating material such as low temperature coke having reducing properties, if desired, and be prevented from grounding by using insulating gaskets in the connections with the pipes leading to and from the gasifier.

A tube coil 7 of large radius and with no sharp turns is installed in the annular space 3 and the convolutions thereof are spaced and supported by means of the vertically extending supports 8. A chimney or outlet 9 is provided at the top of the furnace.

A coal hopper 10 for pulverized coal or coke or other carbonaceous material leads through the valved outlet 11 to a magazine 12 from which a valved outlet 13 leads to the bin 14. A stirrer shaft 15 extends through the magazine 12 and bin 14 and is provided with blades or arms 16 for stirring the material. The shaft is driven by means of the gears 17 from any convenient source of power. A screw 18 is provided at the lower end of the shaft 15 to assist in preventing flooding or irregular flow of the aerated or pulverized material from the bin 14 into the coal feeder.

A steam jacket 19 surrounds the magazine 12 and a steam pipe 20 leads steam to this jacket. A pipe 21 leads from the jacket 19 to a similar jacket 22 that surrounds the bin 14 and this jacket is connected to the jacket 23 that surrounds the housing 24 of a coal feeder. A valved pipe 25 leads from the jacket 23 into the housing 24 and serves to maintain a jacket pressure above that used in the superheater and insures a temperature inside the magazine and bin higher than the condensing temperature of the steam at the superheater pressure, thus obviating any possibility of steam condensing in the two chambers. The mechanical screw feeder 26 is located inside of the conveyor housing 24 and is driven from any convenient source of power by means of the gears 27. The housing 24 of the coal feeder leads to the inlet end of the coil 7 and this coil is provided with a twisted ribbon 28, of heat resisting alloy metal, so as to cause a large portion of the solid particles to be thrown out against the inside walls of the pipe 7 and be carried along in contact with the same to absorb heat therefrom.

The operation is as follows: The hot products of combustion from the fuel introduced through the burners 5 rise in the annular space 3 and heat the coil 7 and then pass out through the outlet 9. A batch of pulverized carbonaceous material is passed from the hopper 10 into the magazine 12 while the valve 13 is closed. The valve 11 is then closed and the valve 13 opened, whereupon the pulverized carbonaceous material passes into the bin 14 as the contents of bin 14 enter the coil 7. After magazine 12 is empty the valve 13 is closed and a new charge is introduced into the magazine and the operations repeated as described. The stirrer arms 16 keep the material agitated so that it will become quickly heated from contacting with the hot walls and will maintain a fluidized condition. The screw conveyor 26 feeds the material into the tube 7 at the desired rate and at the same time steam that has entered through the pipe 20 and passed through the jackets 19, 22 and 23 passes together with the powdered carbonaceous material and any water from condensation of steam into the coil 7 where the water is evaporated and the mixture is heated during which the desired reactions are caused to take place. The superheated steam and other products pass out through the exit end 29 of the coil 7 and may be cleaned and separated into its constituents in any of the convenient and well known ways, or the sensible heat of the products can be used for the different purposes described herein. I have used steam velocities above 600 feet per second. The

desired pressure may be maintained in the coil 7 because either the valve 13 or the valve 11 is always closed. When this valve 13 is closed for feeding another supply of material from the magazine 12 into the bin 14, the pressure is not released as the valve 11 will be closed at this time. The carbonaceous material will become heated while passing through the magazine 12 and bin 14 and the temperature of this material in the conveyor housing 24 will be sufficiently high to prevent steam from condensing. Some condensation of steam will take place in the jackets 19, 22 and 23 by heat given up in heating the carbonaceous materials and by radiation losses, but any water derived from these sources or from the steam lines will be evaporated in the upper part of the superheater. I may use any other reacting ingredient besides coke.

I claim:

1. The process of superheating steam within metal tubes to high temperatures in contact with solid carbonaceous material which comprises mixing solid carbonaceous materials in finely divided form together with steam under pressure and at a high velocity and applying sufficient heat so that the steam and carbonaceous materials react chemically substantially instantaneously to form water gas, the velocity being such that a scouring action by said solid carbonaceous materials maintains clean inner surfaces of said tubes.

2. The process of superheating steam within metal tubes to high temperatures in contact with solid carbonaceous materials which comprises introducing the solid carbonaceous materials in finely divided form together with steam under pressure and at high velocity and heating the mixture above 1250° F., and effecting a chemical combination of said solid carbonaceous material with the steam.

3. The process of superheating steam to high temperatures in contact with solid carbonaceous material which comprises introducing the solid carbonaceous materials in finely divided form together with steam under pressure into a tube, and heating the tube from the outside with hot products of combustion passing in countercurrent direction to the steam and carbonaceous material and passing the contents of said tubes at increasing velocity through increasing temperature zones and removing the resulting products at the point of highest velocity of flow.

4. The process of superheating steam in contact with carbonaceous material which comprises introducing solid carbonaceous materials in finely divided form together with steam under pressure into a tube, heating the tube to increase the temperature of the contents above 1250° F., and withdrawing the contents of said tube at substantially their highest attained temperature.

5. The process of superheating steam in contact with solid carbonaceous material which comprises introducing the solid carbonaceous materials in finely divided form together with steam under pressure into a tube, heating the contents from the outside, regulating the amount of steam and carbonaceous material introduced per unit of time, and causing the tube contents to rotate at increasing velocity while passing through said tube and with gradual changes of direction.

6. The process of superheating steam to high temperatures in contact with carbonaceous material which comprises heating said material by means of the latent heat of steam and introducing the carbonaceous materials in finely divided form together with steam under pressure into a tube, heating the tube from the outside, and regulating the amount of steam and carbonaceous material introduced per unit of time.

7. The process of superheating steam in contact with a reactive low-temperature coke which comprises heating and introducing coke continuously in finely divided form together with steam under pressure and high velocity into the superheater, heating the contents of the superheater to a temperature of at least 1250° F which will cause the steam and carbonaceous material to react chemically, exhausting the contents of the superheater under high pressure.

8. In a device for superheating steam in contact with carbonaceous material, tube in the form of a coil, means for introducing steam and finely divided solid carbonaceous material into said tube under pressure and means applying sufficient heat to said tube contents, so that the steam and carbonaceous material react substantially instantaneously to form water gas.

9. In a device for superheating steam in contact with solid carbonaceous material, a large radius tube in the form of a coil with straight tangentially disposed inlet and outlet extensions, means for introducing steam and finely divided solid carbonaceous material into said tube under pressure and means such as a fuel gas supply and a furnace to heat said tube by contacting the convolutions thereof with hot products of combustion, said straight inlet and outlet extensions of the tube passing directly out of the furnace.

10. In a device for superheating steam in contact with solid carbonaceous material, a large radius tube in the form of a coil with straight tangentially disposed inlet and outlet extensions, means for introducing steam and finely divided carbonaceous material into said tube under pressure and means to heat said tube, said tube being located in an annular chamber through which hot gases are

passed countercurrent to the flow of the contents of the superheater, said straight inlet and outlet extensions of the coil passing directly out of the hot gas chamber.

11. In a device for superheating steam in contact with solid carbonaceous material, a large radius tube in the form of a coil, means for introducing steam and finely divided solid carbonaceous material into said tube under pressure and means to heat said tube, said tube being located in an annular chamber through which hot gases are passed countercurrent to the flow of the contents of the superheater, and said annular chamber decreases in area in the direction of the flow of the combustion gases.

12. In a device for superheating steam in contact with solid carbonaceous material, a large radius tube in the form of a coil with straight tangentially disposed inlet and outlet extensions, means for introducing steam and finely divided solid carbonaceous material into said tube under pressure and means to heat said tube progressively to higher temperatures from inlet to outlet of said tube, said tube being provided with a twisted alloy metal ribbon along the inside of the same, and with its tangential extensions passing directly out of said heating means.

13. In a device for superheating steam in contact with solid carbonaceous material, a tube, means comprising a steam jacketed feeder for introducing steam and finely divided solid carbonaceous material into said tube under pressure and means to heat said tube.

14. In a device for superheating steam in contact with solid carbonaceous material, a tube, means for introducing steam and finely divided solid carbonaceous material into said tube under pressure, means to heat said tube, and a heated bin for supplying carbonaceous material at variable rates to said first named means.

15. In a device for superheating steam in contact with solid carbonaceous material, a large radius coiled tube, means for introducing steam and finely divided solid carbonaceous material into said tube under pressure and means to pass electricity through said tube to heat the same the application of heat being such that the velocity of the material in the coil is increased in the direction of the outlet.

16. The process of superheating steam at high temperatures in contact with carbonaceous material which comprises introducing the carbonaceous materials in finely divided form into a feeding and preheating device under pressure to receive treatment therein, agitating the material in the presence of steam to produce fluidity and passing said treated material into a stream of steam under pressure into a tube superheater, heating the superheater from the outside to high temperature and causing the solid particles to move in continuous contact with the inside walls of the tube.

17. The process of generating and superheating steam in contact with solid carbonaceous material which comprises mixing solid carbonaceous materials in finely divided form together with steam and water under pressure and causing them to flow together at high velocity while applying sufficient heat to effect superheat of the steam, and effecting the substantially instantaneous formation of water gas.

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