

Jan. 10, 1961

M. J. HOFSTEDE ET AL

2,967,515

WASTE-HEAT BOILER

Filed Dec. 16, 1957

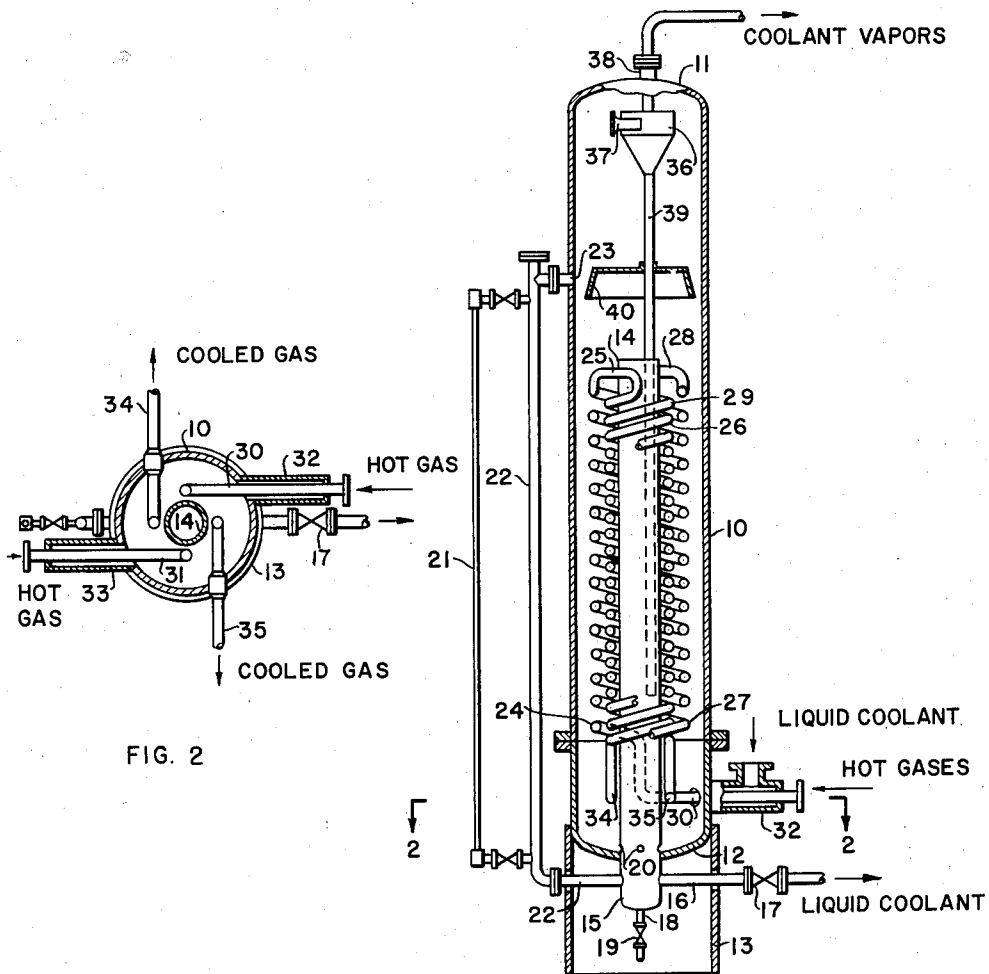


FIG. 2

FIG. 1

INVENTORS:

MARINUS J. HOFSTEDE
CHRISTIAAN DIJKSTRA

BY: *Oswald H. Milmore*
THEIR ATTORNEY

1
2,967,515

WASTE-HEAT BOILER

Marinus J. Hofstede, Delft, and Christiaan Dijkstra, The Hague, Netherlands, assignors to Shell Oil Company, New York, N.Y., a corporation of Delaware

Filed Dec. 16, 1957, Ser. No. 702,890

Claims priority, application Netherlands Dec. 21, 1956

7 Claims. (Cl. 122—7)

This invention relates to a waste-heat boiler suitable for cooling and abstracting heat from gases which have extremely high temperatures and pressures and/or contain suspended matter which is subject to deposition in heat-exchanger tubes through which the gases flow. The invention is especially applicable to generating steam under pressure from the sensible heat in the reaction gas from a plant for the preparation of hydrogen and carbon monoxide by the partial combustion of a hydrocarbon with oxygen, optionally with the supply of steam; such gas is produced in a reaction chamber in which the partial combustion of the hydrocarbon occurs at superatmospheric pressure, particularly between 5 and 35 atmospheres, the process being known as pressure oil gasification.

Gases produced in such a partial combustion process generally are discharged from the reactor at a temperature of from 1000° C. to 1500° C. and are, therefore, a potential source of energy. Nevertheless it has not heretofore been possible to utilize this thermal energy due to the extremely high temperatures and the fact that the gases contain free carbon, since if use is made of the usual heat exchangers of the flame-tube type great difficulties are encountered. The great temperature difference and high pressure prevailing in heat exchangers dealing with such gases require the apparatus to be of special quality and strength, and it was found that the usual heat exchangers do not fulfill the mechanical requirements. Further, straight flame tubes usually cannot be used, or can be used with only very poor effects, when free carbon or the like is carried by the gas because frequent maintenance is necessary due to the deposition of soot on the inside surfaces of the tube walls, which greatly reduces the coefficient of heat transmission.

It is an object of the invention to provide a waste-heat boiler suitable for cooling such high-temperature gases wherein the cooling pipe through which the hot gases flow is intensively cooled at the entrance point, whereby mechanical difficulties are mitigated.

Another object is to provide a waste-heat boiler wherein the deposition of soot and the like can be minimized.

A further object is to provide a waste-heat boiler wherein the vapor generated from the coolant liquid is freed from entrained liquid and discharged in a substantially dry state.

According to the invention the waste-heat boiler comprises an outer upright shell containing a central liquid-tube defining and annular cooling space with the shell, a cooling pipe extending over a vertically elongated part of the said space, preferably in the form of a helical coil having an inlet end extending out of the shell at the bottom, and means for admitting a liquid coolant into the bottom of the cooling space for upward flow there-through while boiling in external contact with the cooling pipe, means being provided for discharging vaporized coolant at the top and for flow of unvaporized coolant into the liquid tube for discharge therefrom. The shell preferably contains a cyclone or the like at the top for separating entrained liquid from the vapor, the cyclone being provided with a liquid discharge pipe which forms a liquid seal within the liquid-tube.

The helical coil may be mounted so as to permit vibra-

2

tion thereof by the gases flowing therethrough and/or by the action of the boiling coolant. This may be effected, for example, by constructing the coil with thin walls and supporting it to permit vibration with respect to the liquid-tube; this feature which forms no part of the instant invention, is described in the copending application of Hofstede (one of the present applicants) and Johannes A. te Nuyl, Serial No. 671,852, filed July 15, 1957.

In the preferred construction the coolant inlet includes a supply pipe which surrounds the inlet end of the cooling pipe in spaced relation to form an annular flow passage between the two pipes for the liquid coolant. In this manner the liquid coolant is brought into contact with the cooling pipe through which the hot gases enter the boiler at the hottest part of the cooling pipe.

The very high temperatures of the parts of the boiler which first come into contact with the hot gases result in adverse effects on the mechanical strength of those parts; it is, in fact, known that the mechanical strength declines as temperature rises. By thus insuring that the hottest parts are first brought into contact with the fresh liquid coolant this difficulty is mitigated.

Moreover, by forming the cooling pipes as coils, secondary whirls are set up inside the pipe or pipes, due to the curvature therein; this prevents or minimizes soot deposits.

The invention will be described in detail in connection with the accompanying drawing which forms a part of this specification and shows one illustrative embodiment, wherein:

Figure 1 is an elevation view of the boiler, parts being broken away; and

Figure 2 is a transverse section, taken on the line 2—2 of Figure 1.

Referring to the drawing in detail, the boiler comprises an upright shell 10 having top and bottom closures 11 and 12 and supported on a standard 13. It contains a central liquid-tube 14 which is open at the top at a level in the upper part of the shell, spaced below the top thereof, and extends downwards through the closure 12 to provide an extension 15. This tube has a liquid discharge pipe 16 and a flow-control valve 17 near the bottom and a drain pipe 18 fitted with a normally-closed valve 19 at the bottom. One or more restricted openings 20 are provided in the tube 14 at the level of the closure 12 to permit liquid to be drained via the valve 19 upon shut-down. The liquid level within the liquid tube is indicated by any suitable level gage, such as a sight gage glass 21 connected at its ends to a vertical pipe 22 the bottom of which is in communication with the tube extension 15 and the top of the shell at 23.

In the embodiment shown two separate composite cooling pipes are provided, each including two helices. Thus, the first pipe includes an outer helix 24 serially connected at the top by a pipe 25 to an inner helix 26; the second pipe includes an outer helix 27 serially connected at the top by a pipe 28 to an inner helix 29. In both instances the inner and outer helices are situated in the annular cooling space between the shell and the liquid-tube and are concentric with the central axis of the latter. The lower ends 30 and 31 of the outer helices are the inlet ends of the pipes and extend out of the shell in spaced, concentric relation to supply pipes 32 and 33, respectively, providing annular flow passages through which the liquid coolant is admitted into the shell at the bottom of the annular cooling space. The cooled gases are discharged from the lower ends 34 and 35 of the inner helices, which also extend out of the shell.

A cyclone 36 is mounted within the upper part of the shell; it has an inlet 37 for the admission of vapor from the space within the shell, a vapor discharge pipe 38 extending out of the shell, and a liquid return pipe 39 which

extends downwards into the liquid-tube beneath the liquid level therein to form a liquid seal. One or more catch plates 40 may be mounted above the liquid tube, e.g., supported on the pipe 39 below the cyclone inlet, to reduce the amount of liquid coolant entrained by the vapor, should the coolant boil excessively.

In operation the hot gases from the reactor are admitted through the inlets 30 and 31 and liquid coolant, such as water, which may be under pressure, is admitted through the supply pipes 32 and 33. Cooling of the gases commences even before the gases enter the helices because of the flow of the coolant entering the boiler through the annular flow passages within the supply pipes 32 and 33. Inside the shell the cooling pipes 24 and 27 have the form of helices so as to provide upward helical paths for the gases. At the upper ends of the helices the gases reverse their flow directions and move downward via the helical pipes 26 and 29, finally being discharged in a cooled state through the outlets 34 and 35.

The liquid coolant, entering through the supply pipes 32 and 33, is heated very rapidly within the annular cooling space and soon reaches its boiling point. It flows upwards through this space while boiling in external contact with the cooling pipes. A part of the liquid is collected directly in the liquid-tube by overflow or splashing into the open upper end thereof; another part is vaporized into steam. The latter is stripped of entrained liquid within the cyclone 36, from which dry steam is discharged through the pipe 38 and liquid into the liquid-tube through the pipe 39. The catch plate 40 insures that not too much liquid is carried into the cyclone.

Liquid is withdrawn from the liquid-tube through the valve 17 at a rate controlled to maintain a column of liquid within the tube so as to keep the bottom of the pipe 39 immersed, thereby forming a liquid seal. The gage 21 (which may be connected to control the valve 17 for automatic maintenance of the liquid column) permits the height of the liquid to be determined.

It is often desirable that the liquid coolant in the liquid-tube be not exposed to prolonged heating, e.g., to avoid excessive vapor formation which would interfere with the circulation of liquid. Such prolonged heating is reduced by extending the tube below the bottom closure, as shown at 15.

We claim as our invention:

1. A waste-heat boiler suitable for cooling high-temperature gases of the order of 1,000° to 1,500° C. comprising: an upright shell including a bottom closure; an upright liquid-tube mounted within the shell in radially spaced relation thereto and defining therewith a vertically elongated annular cooling space, said tube being in liquid-receiving communication with said cooling space at an upper part of the tube below the top of the shell; a cooling pipe for said hot gases situated within said annular cooling space over an extended vertical part thereof and having inlet and outlet ends extending out of the shell at the bottom thereof; an inlet for admitting a liquid coolant to the lower end of said annular space at the inlet end of said cooling pipe and arranged to direct the liquid coolant for immediate contact with the extremity of said inlet end and subsequent upward flow of the coolant through said space in external contact with the cooling pipe and, thereafter, into the liquid-tube; and means for discharging liquid coolant from the liquid-tube.

2. A boiler according to claim 1 wherein said cooling pipe is in the form of a pair of helical coils concentric to the central axis of the shell, said coils being serially connected at the top and having their lower ends extending out of the shell to constitute the said inlet and outlet ends.

3. A waste-heat boiler suitable for cooling high-temperature gases of the order of 1,000° to 1,500° C. comprising: an upright shell including a bottom closure; an upright liquid-tube mounted within the shell in radially spaced relation thereto and defining therewith a vertically

elongated annular cooling space, said tube being in liquid-receiving communication with said cooling space at an upper part of the tube below the top of the shell; a cooling pipe in the form of a vertically extended coil concentric with the central axis of the liquid-tube situated within said annular cooling space and having inlet and outlet ends extending out of the shell, at least the inlet end being situated near the bottom of said annular cooling space; an inlet for admitting a liquid coolant to the lower end of said annular space at said inlet end of the cooling pipe and arranged to direct the liquid coolant for immediate contact with the extremity of said inlet end and subsequent upward flow of the coolant through the said annular space in external contact with the coiled pipe and, thereafter, into the liquid-tube; means for discharging liquid coolant from the bottom of the liquid-tube at a controlled rate to maintain a column of liquid therein; and means for discharging vaporized coolant from the top of the shell.

4. A waste-heat boiler according to claim 3 wherein the said coolant inlet comprises a supply pipe surrounding the said inlet end of the cooling pipe in spaced relation to form an annular flow passage between the two pipes, said flow passage opening into the said cooling space.

5. A boiler according to claim 3 wherein said liquid-tube is provided with at least one restricted passage providing liquid-flow communication between the bottom of said annular cooling space and the interior of said tube.

6. A waste-heat boiler suitable for cooling high-temperature gases of the order of 1,000° to 1,500° C. comprising: an upright shell including a top closure and a bottom closure; an upright liquid-tube within the shell in radially spaced relation thereto and defining therewith a vertically elongated annular cooling space, said tube being in liquid inlet communication with said cooling space at an upper part of the tube below the top of the shell; a cooling pipe for said hot gases situated within said annular cooling space over an extended vertical part thereof and having inlet and outlet ends extending out of the shell, at least the inlet end being at the bottom of the shell; an inlet at the inlet end of said cooling pipe for admitting a liquid coolant to the lower end of said annular space, said inlet being arranged to direct the liquid coolant for immediate contact with the extremity of said inlet end and subsequent upward flow of the coolant therethrough in external contact with the cooling pipe and, thereafter, into the liquid-tube; means for discharging liquid from the liquid-tube; and separating means mounted within the upper part of the shell for separating liquid from vapor, said separating means having an inlet in communication with the space within the shell above the said liquid inlet to the tube for the admission of vaporized coolant and entrained liquid coolant, a vapor outlet for discharging dry vaporized coolant to the outside of the shell, and a liquid outlet disposed to discharge separated liquid coolant into the liquid-tube.

7. A boiler according to claim 6 wherein said separating means is a cyclone situated above the top of the liquid-tube and said liquid outlet of the separating means includes a pipe which extends downwards from the cyclone into the liquid-tube below the said liquid inlet thereof to form a liquid seal.

References Cited in the file of this patent

UNITED STATES PATENTS

388,772	Gold	Aug. 28, 1888
591,505	Shepard et al.	Oct. 12, 1897
747,943	Condict	Dec. 29, 1903
1,944,817	Thomas	Jan. 23, 1934
2,535,996	Worn et al.	Dec. 26, 1950
2,808,034	Cerny	Oct. 1, 1957

FOREIGN PATENTS

690,993	Great Britain	May 6, 1953
748,047	Great Britain	Apr. 18, 1956