Sept. 29, 1959 C. G. VAN DER WATEREN 2,906,509

TUBULAR WASTE-HEAT BOILER

Filed Dec. 16, 1957

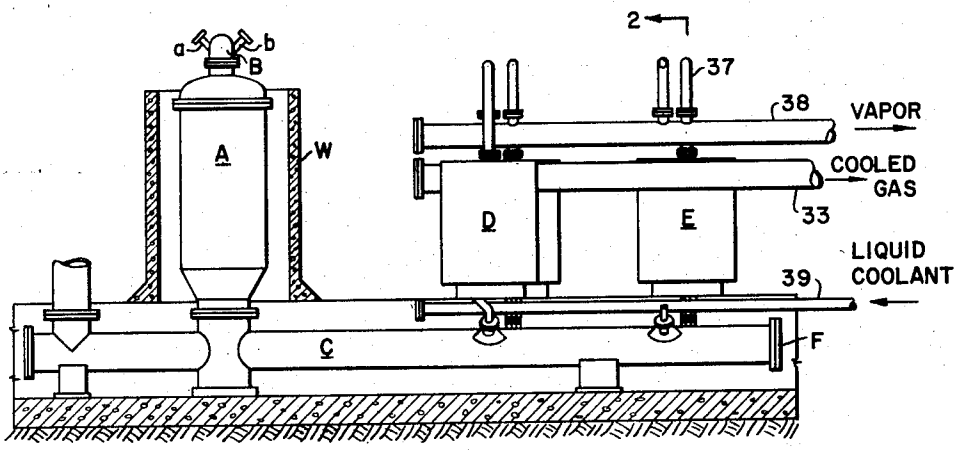


FIG. 1

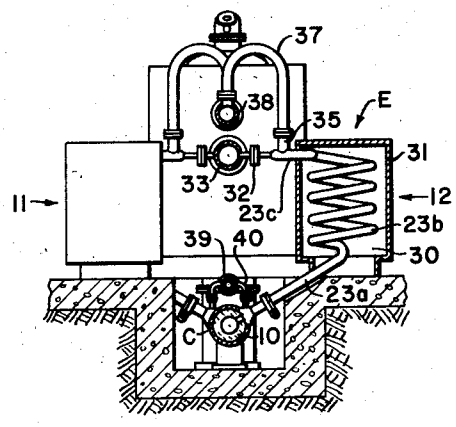


FIG. 2

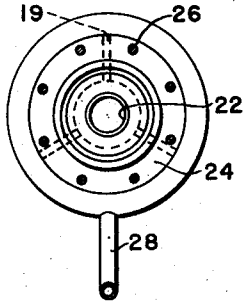


FIG. 4

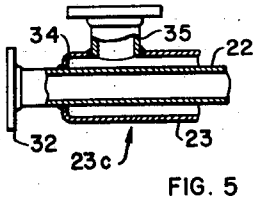


FIG. 5

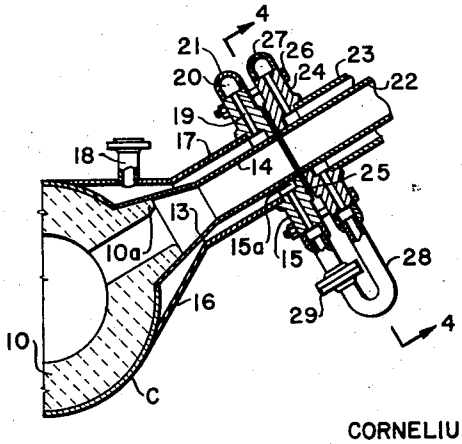


FIG. 3

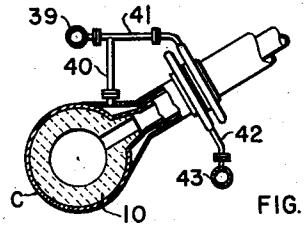


FIG. 6

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TUBULAR WASTE-HEAT BOILER

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5 Claims. (Cl. 257—246)

This invention relates to heat-exchange apparatus, particularly 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-exchange 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 hydrocarbons 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 an improved heat-exchange apparatus, viz., a boiler suitable for cooling such high-temperature gases, wherein the cooling pipe which contains the hot gases being cooled is cooled intensively throughout at least the hottest part thereof. Ancillary thereto, it is an object to protect the cooling pipe against overheating all the way to the juncture thereof with the transfer tube by which the hot gases are conducted from the reactor.

Another object is to provide heat-exchange apparatus wherein deposition of soot and the like within the cooling pipes can be minimized.

Additional objects will become apparent from the following description.

In summary, the apparatus of the instant invention includes a cooling pipe for the flow of the hot gases, which pipe is surrounded by a larger tube which forms an annular flow passage for the coolant, which is admitted as a liquid, both tubes being preferably curved, e.g., in the form of helices to minimize the deposition of soot.

When the hot gases and the coolant flow respectively through the cooling pipe and the annular passage surrounding the pipe the outer surface of the cooling pipe wall is intensively cooled all along its length and it becomes possible to achieve a sufficiently high flow velocity of the coolant to insure good heat transfer between the coolant and the said surface and to avoid the formation of dead spots or stagnant regions on that surface, whereby no parts of the wall become heated excessively. By flowing the hot gases and coolant concurrently the fresh coolant comes into contact first with the hottest part of the cooling tube, thereby insuring effective cooling at this critical region.

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 being known that the mechanical strength of metal declines as the 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 pipe as a coil whirls are set up inside the pipe, due to the curvature therein; this prevents or minimizes soot deposition.

The invention further comprises a jacketed, detachable connection between the cooling pipe and a transfer tube, which may be lagged with temperature-resistant material, whereby the coolant can be admitted at the point at which the hot gases first leave the transfer tube.

The invention will be described in detail with reference to the accompanying drawing forming a part of this specification and showing two preferred embodiments by way of illustration, wherein:

Figure 1 is an elevation view of a part of a pressure oil gasification plant including the reactor and several waste-heat boilers;

Figure 2 is a vertical sectional view taken on the line 2—2 of Figure 1, parts being shown in elevation;

Figure 3 is an enlarged longitudinal sectional view of the inlet end of the boiler pipe;

Figure 4 is a transverse sectional view taken on the line 4—4 of Figure 3;

Figure 5 is an enlarged longitudinal sectional view of the outlet end of the boiler pipes; and

Figure 6 is a fragmentary view of a part of Figure 2, showing a modification.

Referring to Figures 1 and 2, the reactor is represented at A; it is mounted within a protective wall W and provided with a supply pipe *a* for the hydrocarbon fuel to a burner B and a supply pipe *b* for the oxygen and steam, if used. A transfer or distributing duct C receives the hot reaction gases from the bottom of the reactor; it has an ample internal cross sectional area to distribute the gases without substantial pressure loss to a plurality of waste-heat boilers of which two pairs D and E are shown. The duct C may be laid underground, as shown, and lagged internally with temperature-resistant material **10** which provides some thermal insulation and thereby protects the enclosing metal sheath against excessively high temperatures. The end of the transfer duct is closed by a blind flange F, which facilitates inspection and the facile connection of additional boilers.

As is shown in Figure 2 the pair of boilers E, indicated at **11** and **12**, are identical in construction and only the latter will, therefore, be described herein. (The boiler **11** is omitted in Figure 1 for clarity.) The transfer duct C has, for each boiler, a lateral outlet pipe **13** which forms the inlet end of the cooling pipe of the boiler. The pipe **13** is advantageously outwardly convergent so that the lagging can extend partly into it, as indicated at **10***a*. The pipe **13** is permanently connected to a cylindrical pipe section **14** which is, in turn, fixed to a bolting flange **15** of special construction. The flange is counter-bored to provide an annular channel **15***a* surrounding the pipe **14**. A jacket, including a frusto-conical tube section **16** and a cylindrical tube section **17** is mounted between the

sheath of the duct C and the flange **15** in radially spaced relation to the sections **13** and **14** and a flanged nozzle **18** is connected to the section **16** near the duct C for admission of a liquid coolant, as described hereinafter. The flange **15** has a plurality of radial bores **19** by which the channel **15***a* is placed in communication with a peripheral channel **20** defined by the outer edge of the flange and a toroidal wall **21**.

The pipe and tube sections up to the flange **15** constitute the inlet section of the boiler. The downstream and major part of the boiler, beyond the flange **15** includes an inner cooling pipe **22** and a concentric, outer tube **23** which is radially spaced therefrom throughout the lengths of the pipes. These are fixed to a bolting flange **24** which is constructed identically to the flange **15** and is sealed to the latter by means of an O ring **25** of suitable heat-resistant gasketing material which is compressed by bolts **26** which extend through bolt holes situated between the radial bores. The annular channel **20** is connected to the corresponding channel **27** of the flange **24** by a connecting pipe **28** having a coupling unit **29**.

The concentric pipe **22** and tube **23** include a straight, inclined riser section **23***a* (Fig. 2), a helically coiled section **23***b*, and a straight outlet section **23***c*. The coiled section is supported within a space **30** which may be enclosed in a protective, cylindrical sheath **31**. As shown in Figure 5, the outlet section of the cooling pipe **23** is connected to a bolting flange **32** which is coupled to a gas collecting duct **33**, which receives the cooled gas from the several boilers. The outer tube **23** terminates in a wall **34** which is sealed to the cooling tube and has a flanged nozzle **35**; this is coupled to a steam outlet pipe **37** leading to a vapor collecting pipe **38** which receives the coolant from the several boilers.

Each boiler has the nozzle **18** coupled to a supply pipe **39** for liquid coolant by a pipe **40**. In this way the liquid coolant flows first through the space within the jacket sections **16** and **17**, and flows thence through the recess **15***a*, the radial bores **19**, the channel **20**, pipe **28**, channel **27**, the radial bores of the flange **24**, and through the annular space inside the tube **23**.

It is evident that it is possible, as shown in Figure 6, to connect the supply pipe **39** directly to the channel **27** by a pipe **41** and to discharge coolant from the channel **20** by a pipe **42** to a collecting pipe **43**.

In operation hot gases are discharged from the reactor A, e.g., at a temperature of 1000° C. to 1500° C. and a pressure from 20 to 30 atmospheres, and flow through the transfer duct C to the several boilers. They leave the duct C through the pipes **13**, **14** and **22**, which are externally cooled by liquid coolant, such as water, admitted from the supply pipe **39** via the pipe **40** and nozzle **18**. In this manner the inner pipe is cooled even at the point whereat the hot gases first leave the transfer duct C, while the lagging **10***a* protects the part of the section **13** immediately adjacent the transfer tube. The coolant enters the channel **27** either from the channel **20** of the flange **15** (Figures 1–3) or directly from the supply via a pipe **41** (Figure 6) and flows thence through the annular flow channel within the tube **23**.

The liquid coolant is heated rapidly within the annular flow passages within the tubes **16**, **17** and **23** and soon reaches its boiling point. It flows in a boiling state through the tube **23** and is discharged through the nozzle **35** to the vapor collecting pipe **38**. (In the case of Figure 6 coolant is also discharged via the pipe **42** to the collecting pipe **43**.) The rate of liquid supply may be such that all of it is vaporized, or it may be supplied at a rate sufficient to cause a mixture of liquid and vapor to be discharged.

Cooling of the gas commences immediately upon leaving the transfer tube C. The gas follows a curved, helical path in the section **23***b*, i.e., throughout most of the distance between the transfer tube and the outlet, whereby deposition of soot is minimized. The cooled gas is discharged into the gas collecting duct **33**.

I claim as my invention:

1. A waste-heat boiler for cooling high-temperature gas comprising: a distributor duct through which said hot gas is supplied, said duct having a lateral opening, an elongated cooling pipe connected to said opening to receive gas from said duct, a tube of larger diameter surrounding the cooling pipe in spaced relation and defining therewith an annular flow passage, said tube extending to the duct, an inlet situated near said duct for the admission of a coolant fluid into said annular flow passage, an outlet for discharging cooled gas from the end of said cooling pipe remote from the duct, and an outlet for discharging coolant fluid from said flow passage at a point remote from said duct.

2. A waste-heat boiler for cooling high-temperature gas comprising: a distributor duct through which said hot gas is supplied, said duct having a lateral opening, an elongated cooling pipe having an enlarged inlet end connected to said opening to receive gas from said duct, said duct being internally lagged with temperature-resistant material which extends into said enlarged inlet end of the cooling pipe, an outlet for discharging cooled gases from the end of said cooling pipe remote from the duct, a tube of larger diameter surrounding the cooling pipe in spaced relation and defining therewith an annular flow passage, said tube extending toward said duct at least as far as the lagging within the cooling pipe inlet end, an inlet situated near the end of the tube adjoining the duct for admitting a coolant fluid into said annular flow passage, and an outlet for discharging coolant from said flow passage at a point remote from the duct.

3. Heat exchange apparatus comprising: a distributing duct for hot gases, a collecting duct for cooled gases, a coolant supply pipe, a vapor collecting pipe, a plurality of cooling pipes interconnecting the said ducts for the flow of gas from the distributor duct into the collecting duct, a separate tube surrounding each of said cooling pipes in closely spaced relation thereto and defining with the respective cooling pipes annular flow passages for a coolant, flow means connecting the said coolant supply pipe to each of said flow passages at the ends thereof near said distributing duct, and flow means connecting the other ends of said flow passages to the vapor collecting pipe.

4. Heat exchange apparatus according to claim 3 wherein each of said cooling pipes and each of said tubes includes a short inlet section immediately adjacent the distributing duct and a downstream second section, the said sections of the cooling pipe being in direct communication and the annular flow passages within the sections of the tubes being separated by partition means, each of said flow passages having an individual inlet and an individual outlet for coolant.

5. Heat exchange apparatus according to claim 3 wherein said cooling pipes and tubes are coiled throughout the major parts thereof.

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