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ter Haar et al.
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[54] **METHOD FOR HEAT RECOVERY FROM SYNTHESIS GAS**

[75] Inventors: **Leonard W. ter Haar; Johan P. Schungel**, both of The Hague, Netherlands

[73] Assignee: **Shell Oil Co.**, New York, N.Y.

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ....**165/163**, 122/7 R
[51] **Int. Cl.** **F28d 7/10**
[58] **Field of Search** ....165/163, 159; 122/24, 7 R

[56] **References Cited**

UNITED STATES PATENTS

2,967,515 1/1961 Hofstede et al....................122/32 X

FOREIGN PATENTS OR APPLICATIONS

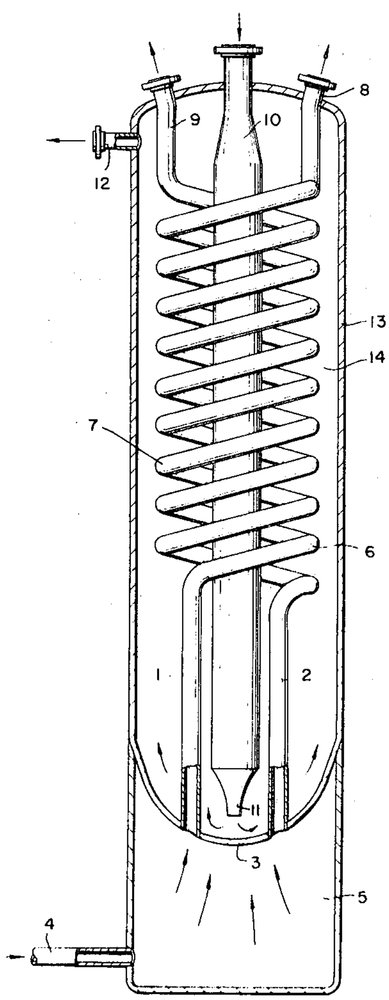
634,687 1/1962 Canada 122/7

Primary Examiner—John J. Camby
Assistant Examiner—W. C. Anderson
Attorney—Glen R. Grunewald and John H. Colvin

[57] **ABSTRACT**

An improved method and apparatus for cooling and recovering heat from soot-containing hot gases obtained by the partial combustion of hydrocarbons is disclosed. The improvement comprises partly cooling the hot gases by flowing them through one or more straight tubes of at least two meters in length at a mass velocity of at least 100 kg/m²/sec. The gases are subsequently further cooled in one or more helically coiled tubes connected to the straight tubes. The invention is particularly suitable for generating high pressure steam from hot gases obtained at moderate as well as high pressures.

4 Claims, 3 Drawing Figures



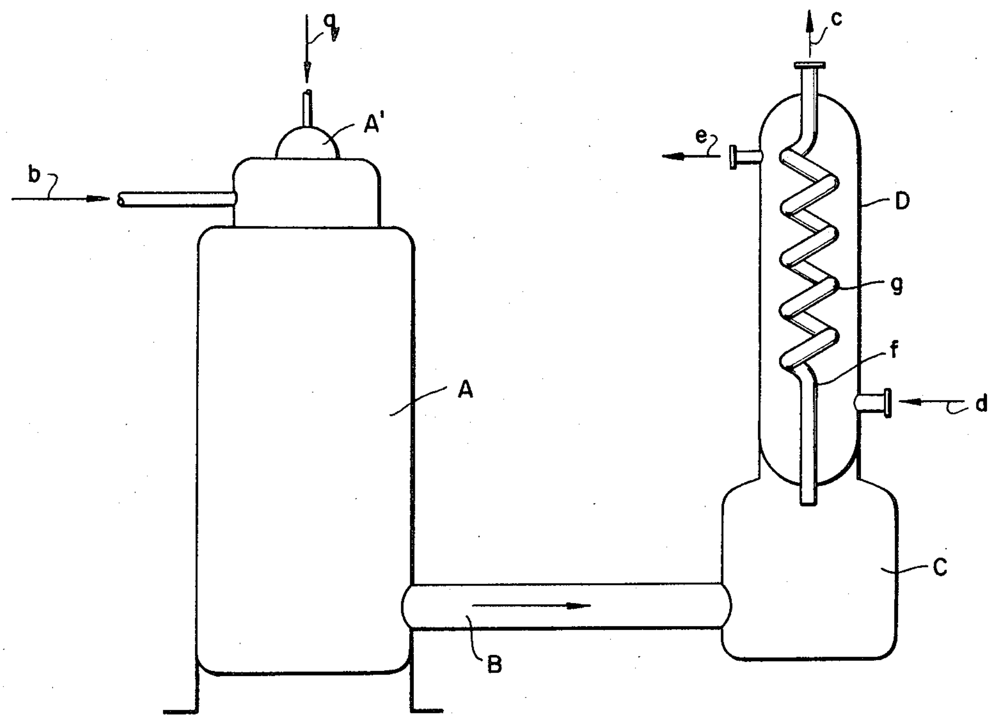


FIG. 1

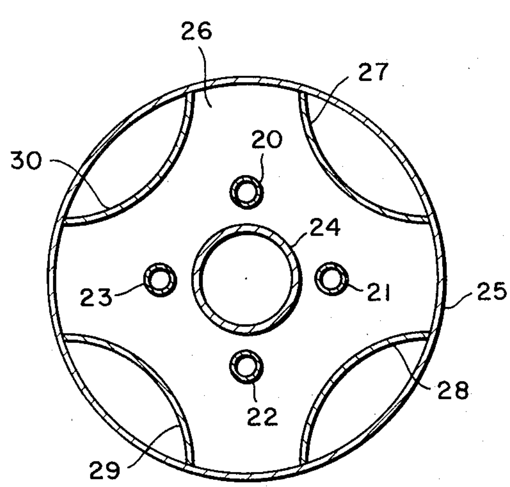


FIG. 3

INVENTORS:
LEONARD W. TER HAAR
JOHAN P. SCHUNGEL
BY: Glen R. Grunewald
THEIR ATTORNEY

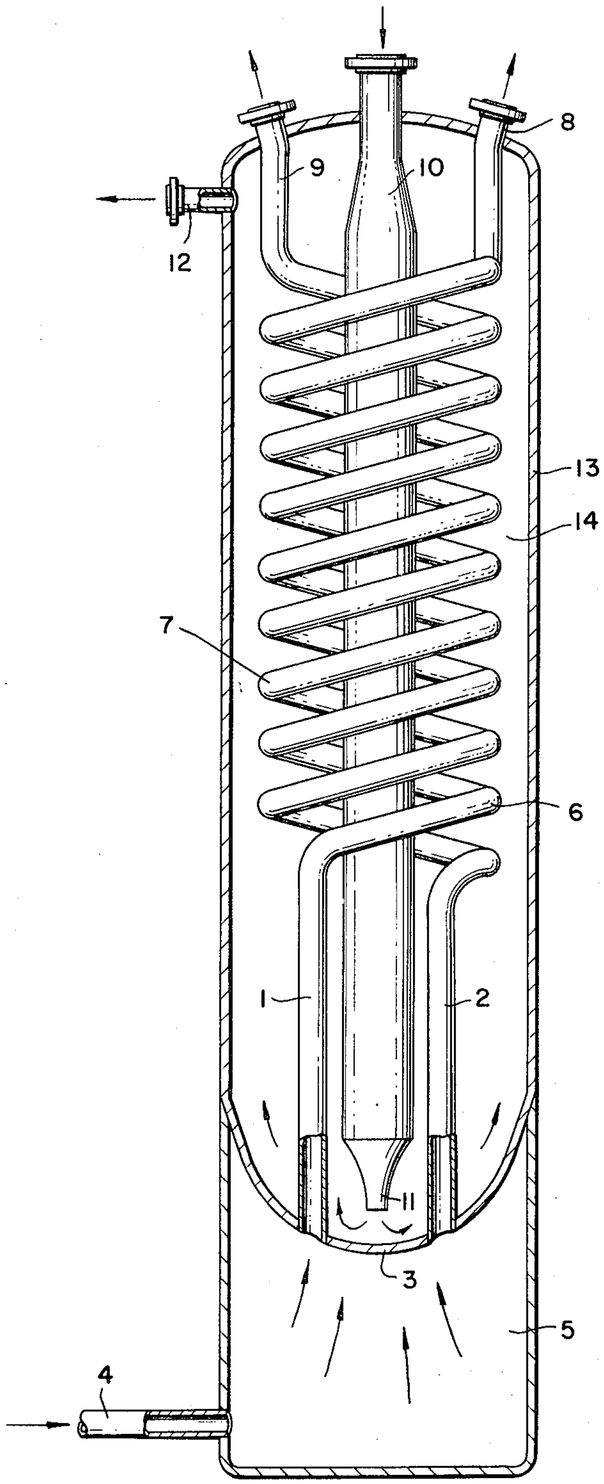


FIG. 2

INVENTORS:
LEONARD W. TER HAAR
JOHAN P. SCHUNGEL
BY: Glen R Grunewald
THEIR ATTORNEY

METHOD FOR HEAT RECOVERY FROM SYNTHESIS GAS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an improved method and apparatus for cooling and abstracting heat from gases which have extremely high temperatures and which contain matter subject to deposition in heat exchanger tubes through which the gases flow. This invention is particularly applicable to the generation of high pressure steam, e.g., steam having a pressure of 50–150 atmospheres, using the sensible heat from gases obtained by the partial combustion of hydrocarbons with oxygen or oxygen-enriched air, e.g., synthesis gas obtained from a pressure oil gasification process.

2. Description of the Prior Art

Crude synthesis gas produced by the partial combustion of hydrocarbons generally is discharged from the reactor at a temperature of from 1,300° to 1,400°C or higher, thus making it an obvious source of potential energy. The thermal energy in synthesis gas, however, can be recovered only with great difficulty utilizing conventional heat exchangers, because of the presence in such gases of large amounts of soot (i.e., free carbon), often up to 5 percent or more, which tends to deposit on the inside of heat exchanger tubes. U.S. Pat. No. 2,967,515 to Hofstede et al. describes a means of substantially overcoming the problem of soot deposition by the use of helically coiled cooling tubes which are disclosed as being considerably less subject to deposit formation than straight cooling tubes.

While effective in overcoming the soot deposition problem, the use of helically coiled tubes places certain other limitations on the process, particularly in respect to permissible pipewall temperatures and the pressure differential between the cooling medium and the gases to be cooled. These limitations result from the lower mechanical strength of helically coiled tubes due to their method of manufacture. (Generally coiled tubes are formed by winding straight tubes which results in unroundness which in turn appreciably reduces the mechanical strength of the coiled tube.) Because of this decreased strength, helically coiled tubes are not well-suited for the generation steam at high pressures, e.g., 50 to 150 atmospheres or higher, from hot gases obtained at moderate pressures. Under such conditions, the pressure of the coolant on the outside of the coiled tube considerably exceeds that of the hot gases flowing through the tube. Moreover, high tubewall temperatures are often experienced which also contribute to tube failures.

This problem cannot be overcome merely by reducing the velocity of the gases flowing in the helical tube. Such a reduction in velocity, while possibly decreasing tubewall temperatures because of reduced heat transmission, will also result in correspondingly lower steam pressures and in an increased risk of soot deposition on the inside wall of the tubes. Once a thin layer of soot has deposited on the wall of the cooling tube, a further decrease in heat transmission is experienced resulting in still lower steam pressures and an undesirable increase in the discharge temperature of the gas. The method and apparatus herein provided substantially overcomes the aforementioned problems.

SUMMARY OF THE INVENTION

It has now been found that helically coiled tubes can be safely and effectively used for the cooling of high temperature soot-containing gases with the concomitant generation of high pressure steam, if the gases prior to being passed through the coiled tubes are first partly cooled by flowing them through one or more straight tubes under the critical conditions hereinafter described. Thus, in accordance with the invention, high temperature soot-containing gases obtained by the partial combustion of hydrocarbons are flowed through one or more straight tubes, the outsides of which are in contact with a coolant, preferably water, at a mass velocity of at least 100 kilograms/meter^2/second (kg/m^2/sec.). The length of the tube and velocity are selected so the gases passing through the straight tube are cooled to a temperature not exceeding 1,200°C. Preferably, the temperature of the gases discharging from the straight tube will be between 1,200° and 1,000°C. The gases are subsequently further cooled, e.g., to a final temperature of about 200°–400°C, by flowing them through one or more helically coiled tubes which are also in contact with the coolant and which are connected to the straight tubes.

It has been found that by maintaining the mass velocity of the gases at least 100 kg/m^2/sec, soot deposits which normally form more rapidly in straight cooling tubes than in helical tubes, occur to a surprisingly small extent and do not interfer with the operation of the process as would be expected. The upper limit of the mass velocity of the gases is governed primarily by permissible tubewall temperatures. Preferably, mass velocities of above 500 kg/m^2/sec are avoided since at these high velocities the temperature of the tubewalls become so high that resistance to the erosive effect of soot particles rapidly diminishes. Hence the mass velocity of the gases in the straight tube should be from 100 to about 500 kg/m^2/sec, and more preferably from 200–350 kg/m^2/sec.

For cooling to a temperature not exceeding 1,200°C it is as a rule sufficient for the straight tube to have a length of about 2 meters. If it is desirable for the heat transmission to be increased, the gas velocity may be increased and the tube length may be chosen longer than two meters to obtain a sufficiently long residence time. It is also possible to use several straight tubes arranged in parallel, each connected to a helical coil as defined.

If desired, the length of the straight tube may be chosen up to ten meters. As a rule, however, this length will not be adopted on account of the consequent height of the heat exchanger. For this reason, the tube length will preferably be kept smaller by using several straight tubes arranged in parallel, each connected to a helical coil.

It is preferred that at least some of the successive coils of the helically coiled tube extend, at least substantially, in the direction of the straight tube. In connection with the space available, the longitudinal axis of the coils may form a small angle with the extension of the longitudinal axis of the straight tube. The connection of the straight tube to the helically coiled tube may be such that the longitudinal axis of the said coils is, at least substantially, in the extension of the longitudinal axis of the straight tube, or such that the longitudinal axis of the said coils is, at least substantially, parallel with the extension of the longitudinal axis of the straight tube. If desired, the helically coiled tube may consist of two parts, the arrangement being such that the first part extends in the direction of the straight tube and connects to a second part, the coils of which have the same longitudinal axis but have a different radius relative to the longitudinal axis. This second part can be situated inside or outside the first part, preferably on the inside. In this way "concentric" helically coiled tubes are formed.

At high steam pressures, for example of 80 atm. and higher, the length of the straight tube is preferably chosen larger than 2 meters, for example 4–6 meters. The mass velocity in this case is preferably 200–350 kg/m²/sec.

The cooling liquid is preferably introduced in such a way that the straight tube (tubes) is (are) cooled in parallel flow with the gases flowing in this tube (these tubes). During the cooling, at least part of the cooling liquid is evaporated and a mixture of coolant liquid and generated vapors formed. The same coolant also cools the helical coils where additional quantities of vapor (steam) are formed. It is generally advantageous (in view of the rate of flow and turbulence of the cooling medium) to ensure that the free cross sectional area of the space accommodating the straight tubes is not more than 30 percent of the cross sectional area of the space accommodating the helical coil (coils). In those cases where the abovementioned free cross sectional area is larger than 30 percent, use may be made of baffle plates provided in the space accommodating the straight tube (tubes). For example, if four straight tubes are used, baffle plates having the shape of a curved shield arranged symmetrically along the wall of the space, the concave side being turned towards the wall, are very suitable.

DESCRIPTION OF DRAWINGS AND PREFERRED EMBODIMENTS

The invention will now be further explained with reference to the drawings in which different embodiments of the invention are shown by way of example.

FIG. I is a diagrammatic representation of an apparatus for the partial combustion of hydrocarbons and the cooling thereof.

FIG. II is a diagrammatic representation of an embodiment of the heat exchanger.

FIG. III shows a cross-section of an embodiment of the heat exchanger, through the space accommodating the straight tubes, and in which the heat exchanger is provided with four straight tubes, four helical coils and with baffle plates which are arranged in the space accommodating the straight tubes.

Referring to FIG. I, part A represents the actual reactor which is provided with fuel supply line *q* leading to burner A′ of the reactor, and with oxygen supply line *b*. If steam is used, it may be supplied through either line *q* or line *b*. Part B is a connection between the reactor and connecting piece C. The hot gases are passed through connection B and connecting piece C into heat exchanger D comprising a vertical outer shell including top and bottom closures which is provided with a straight tube and a helical coil, and further with discharge *c* for the cooled gases and an inlet and outlet for the coolant, *d* and *e*, respectively. The straight tube which has a length of at least **2** meters is designated by *f*, and the helical coil by *g*.

FIG. II is a partial longitudinal cross-section of an embodiment of the heat exchanger. The heat exchanger comprises a cylindrical vessel **13** having a bottom plate **3**, placed on a connecting piece **5**, which is provided with a gas supply line **4**. The heat exchanger further comprises discharges **8** and **9** for the cooled gas, a coolant supply line **10**, the bottom end of which is provided with a spray nozzle **11**, helical coils **6** and **7** connected to straight tubes **1** and **2**, respectively, the length of which is at least **2** meters. The coolant, preferably water, is supplied through the line **10** and is sprayed against the bottom plate subsequently flowing upwards, thereby cooling straight tubes **1** and **2** and helical coils **6** and **7**. The helical coils are arranged in annular space **14** formed by the wall of the supply line and the shell of the cylindrical vessel. The helical coils have a common longitudinal axis which coincides with the longitudinal axis of the supply line. The heat exchanger further has two baffle plates for the cooling water which extend from the bottom plate to substantially the place where the helical coils connect to the straight tubes. The location of these baffle plates is not shown.

In operation, a hot-soot containing gas at a temperature of 1,300° to 1,400°C or higher, e.g., crude synthesis gas, is introduced into connecting piece **5** via gas supply line **4**. The hot gas is flowed through straight tubes **1** and **2** at a mass velocity of at least 100 kg/m²/sec. The gas in the straight tubes is cooled to a temperature between 1,000–1,200°CC by means of a coolant liquid, in this case water, supplied through line **10** and sprayed against bottom plate **3** by means of spray nozzle **11**. Upon striking the bottom plate, the water flows upward in a substantially parallel direction to the flow of gas in tubes **1** and **2**, cooling both the straight and helically coiled tubes. Steam generated by the partial vaporization of the water in contact with the outside walls of the tubes, ascends with the remaining liquid coolant and is discharged through line **12**. The cooled gas, e.g., at a final temperature of about 200°C to 400°C is discharged through lines **8** and **9**. By operating in this manner it is possible to generate steam at pressures of from 50 to 150 atmospheres or higher without subjecting the helically coiled tubes to excessive pressure differentials and without experiencing any substantial soot deposition problems.

FIG. III is a cross-section through the space accommodating the straight tubes of an embodiment of a heat exchanger having the configuration shown in FIG. II, but which has four helical coils connected to four straight tubes. The cross-section shows the baffle plates for the coolant, the four straight tubes and the coolant supply line. In the drawing the reference numerals **20**, **21**, **22** and **23** designate the straight tubes, **24** is the coolant supply line, **25** is the shell of the heat exchanger, **26** is the space accommodating the tubes **20-23**, and **27**, **28**, **29** and **30** are shield-shaped baffle plates for the coolant, which are secured to the shell **25**.

WE CLAIM AS OUR INVENTION:

1. In a process for the preparation of synthesis gas by the partial combustion of hydrocarbons using oxygen or oxygeneenriched air wherein said synthesis gas is cooled in a helical coil waste heat boiler, the improvement which comprises generating steam in said waste heat boiler at a pressure of 50 to 150 atmospheres from the sensible heat contained in said gas, by flowing said gas at a mass velocity of from 100–500 kg/m^2/sec through a straight tube of 2–10 meters in length which is in external contact with water thereby cooling the gas to a temperature between 1,000 and 1,200°C, and subsequently passing said gas through a helically coiled tube which is also in contact with water, said helically coiled tube being connected to said straight tube.

2. The process of claim 1 wherein the water is in substantially parallel flow with the hot gases flowing in the straight tube.

3. The process of claim 1 wherein the straight tube has a length of from 4–6 meters.

4. The process of claim 3 wherein the gas is flowed through the straight tube at a mass velocity of from 200–350 kg/m^2/sec.

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