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(54) BURNER FOR THE PARTIAL OXIDATION OF HYDROCARBONS TO SYNTHESIS GAS

(54)

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BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION:

This invention relates to a burner for introducing a hydrocarbon fuel, free-oxygen containing gas, and a temperature moderating gas into a free-flow partial oxidation synthesis gas generator.

DESCRIPTION OF THE PRIOR ART

In the partial combustion of hydrocarbons with oxygen or air enriched with oxygen in the presence of steam and/or carbon dioxide temperatures between 1100 and 1500°C. are reached. Special requirements are therefore placed on the design and the material of construction of the burner. It is essential to prevent high temperatures from occuring in the immediate vicinity of the burner nozzle. This can be achieved for example by reacting the hydrocarbons with the oxygen outside the burner throat. This can be done for example with a burner consisting of two concentric tubes, the hydrocarbons together with steam and/or carbon dioxide being supplied to the combustion zone through the outer tube and the oxygen through the inner tube.

Burners such as used for the partial oxidation of hydrocarbons consist of two concentrically arranged tubes both of which are tapered towards the nozzle end, as shown in Figs. 1 and 2 of the accompanying drawing. Around the tapered portion of the outer tube in Fig. 1, there is arranged a cooling chamber. The cooling chamber may be formed by machining an annular recess in the solid material of the outer nozzle 1, thereby forming flanges 2 and 3 which are spaced a short distance apart. Plane wall 4 of the cooling chamber is located at the outermost extremity of the downstream tip of the burner. It is normal to the longitudinal axis of the burner and faces the reaction zone. Lateral closure of the cooling chamber is effected by means of a ring 5 which is slid over the cooling chamber and welded to the outer edges of the flanges by welds 6.

This type of burner design has a number of disadvantages which are outlined below:

1) the design of the cooling chamber necessitates the use of a plane front plate 4 which must be very thick if high pressures are used in the reactor. As a result, heat removal is poor; and consequently, the surface of the plate facing the reaction zone reaches a high temperature. High termal stresses are set up therefore, between the hot external surface and the cooled internal surface.

2) the welds 6 of the cooling chamber are directly exposed to the radiant heat from the reaction zone and from the reactor lining.

3) the connections for supply conduit 7 and withdrawal conduit 8 used to circulate cooling water through the cooling chamber are in close proximity to each other. They are separated in the cooling chamber by a welded-in metal sheet 9 to avoid backmixing. Thus, this design necessitates a large number of welds over a small area in the cooling chamber. Considerable stresses are therefore set up in the material. As a result, the material in these exposed areas can only withstand the thermal attack by the high temperatures in the reaction zone for a short time. Scaling phenomena and cracks formed in the material make it necessary to frequently shut down the plant and replace the

burners.

4) expensive nickel-containing alloys having high strength at elevated temperatures, such as Incoloy and Inconel, have been used for the burner portion in the region of the burner throat. Many of the hydrocarbons to be processed, e.g. crude oils and heavy fuel oils, contain sulfur. With such fuels, hydrogen sulfide is formed in the reaction zone and the materials of construction are subjected to corrosion by hydrogen sulfide in addition to the extremely severe thermal stress.

SUMMARY

The subject invention pertains to a burner for use in introducing raw materials into the reaction zone of a gas generator where at an autogenous temperature in the range of about 700° to 1900°C and a pressure in the range of about 1 to 250 atmospheres by the partial oxidation of a hydrocarbon fuel with a free-oxygen containing gas optionally in the presence of a temperature moderating gas a gaseous mixture comprising hydrogen and carbon monoxide is produced, said burner comprising a central tubular conduit and central nozzle extending therefrom disposed along the longitudinal axis of said burner through which a first stream is passed said central nozzle terminating in a single unobstructed circular orifice; and outer coaxial concentric conduit and outer converging frusto-conically shaped nozzle extending therefrom radially disposed from said central conduit and central nozzle along their length for simultaneously introducing a second stream into said reaction zone, said outer nozzle terminating in a single unobstructed circular orifice located at the outermost face of the burner; an annular cooling chamber encircling the downstream tip of

said burner and having an inside wall in common with said outer nozzle and an outside wall comprising a tubular ring of approximately hemispherical cross section; and inlet and outlet means for circulating coolant through said coolant chamber. The life of the subject burner has been extended to more than 100 days in comparison with an average life of 20 to 30 days for conventional burners by providing small wall thicknesses at the burner throat, shielding from direct radiation from the reaction zone the welds required for constructing the cooling chamber, spacing the inlet and outlet connections to the cooling chamber 180° apart, and using austenitic chromium-nickel steel as the material of construction for the cooling chamber in the region of the burner throat.

BRIEF DESCRIPTION OF THE DRAWING

In order to illustrate the invention in greater detail, reference is made to one exemplary embodiment involving a burner constructed as shown in Figs. 3 and 4 of the drawing. Figs. 1 and 2 representing a prior art burner has been previously referred to.

Fig. 1 is a sectional view of the downstream end of the prior art burner assembly.

Fig. 2 is a vertical end view of the prior art burner of Fig. 1.

Fig. 3 is a sectional view of the downstream end of the burner assembly of the subject invention.

Fig. 4 is a vertical end view of the burner of Fig. 3.

DESCRIPTION OF THE INVENTION

The present invention pertains to a burner comprising a cylindrical conduit and a concentric coaxial outer conduit radially disposed about the outside of said cylindrical conduit along its length. Near the downstream end of the burner, the outside surface of the central conduit and the inside surface of the outer conduit form a single concentric converging annular discharge passage.

We have now found that the above-mentioned disadvantages of prior art burners are overcome by the subject invention that includes the following novel features: 1) the cooling chamber is composed of machined parts and designed in the form of a tubular ring of approximately hemispherical cross section; 2) the welds made in constructing the cooling chamber from parts of the outer tube are so placed that they are not directly exposed to the radiant heat of the flames in the reaction zone and the reactor lining; 3) austenitic chromium-nickel steels are used as materials of construction for the cooling chamber in place of costly high nickel alloy; and 4) the thickness of the wall of the cooling chamber in the region of the outer lip is smaller than in conventional designs.

DESCRIPTION OF THE DRAWING AND THE INVENTION

A more complete understanding of the invention may be had by reference to the accompanying drawing which illustrates in Figs. 3 and 4 a preferred embodiment of this invention.

Referring now to Fig. 3, a sectional view of the downstream end of the burner assembly, the present invention relates to a burner for the production of synthesis gas by partial oxidation of hydrocarbons with a free-oxygen containing gas optionally in the presence of a temperature moderating gas such as steam and/or carbon dioxide at a temperature in the range of about 700 to 1900°C and a pressure in the range of about 1 to 250 atmospheres. The subject burner comprises an inner or central tube 20 disposed along the longitudinal axis of the burner and having a downstream central nozzle 35 provided with an inner unobstructed cylindrically shaped discharge orifice 36 and a converging frusto-conically shaped outside surface 37. A concentric coaxial outer tube 21 having a downstream concentric converging frusto-conically shaped outer nozzle 38 is radially disposed from said inner tube 20 and central nozzle 35 along their length so as to provide a frusto-conically shaped single unobstructed converging annular discharge passage 22 at the burner throat. Outer nozzle 38 comprises at least two sections 25 and 26, each being a substantially converging frusto-conically shaped tapered section. Outer nozzle 38 has a convergence angle in the range of about 20 to 50 degrees with the longitudinal axis of the burner. Section 25 is joined to outer tube 21 and to section 26 by welds 27. Welds 27 join said parts on the side facing the outside surfaces of inner tube 20 and central nozzle 35, and are thereby protected from radiant heat from the reaction zone of the gas generator. Austenitic chromium-nickel steels are used as materials of construction for sections 25 and 26. The thickness of the wall of cooling chamber 24 in the region of the outermost lip portion of section 26 is from 1 to 5 mm, and preferably from 2 to 4 mm.

Preferably, the free-oxygen containing gas is introduced into the reaction zone by way of the central conduit and nozzle, while simultaneously the hydrocarbon stream optionally, in admixture with temperature moderating gas is introduced into the reaction zone by way of annular discharge passage 22. However, the passage of these streams through the burner may be alternated.

An annular cooling chamber 24 encircles the downstream tip of said burner. Cooling chamber 24 has an inside wall in common with the end portion of said outer nozzle 38. A tubular ring 39 of approximately hemispherical cross section comprises the outside wall of cooling chamber 24. Tubular ring 39 is welded to the side of converging frusto-conically shaped tapered outside surface 40 of outer nozzle 38 by welding bead 41. Weld 41 is protected from radiant heat from the gas generator by cooling coils 23. Further, coolant passing through cooling chamber 24 conducts heat away from welds 27 and 41. As shown in the sectional view, tubular ring 39 is on the side of the burner and fairs into a narrow flat ring section 42. Section 42 is the outermost downstream end of outer nozzle 38 and is normal to the longitudinal axis of the burner.

Reference character 43 designates an unobstructed circular discharge orifice at the outermost face of the downstream tip of the burner. Outer discharge orifice 43 is defined by the intersection of an imaginary plane through flat surface 42 and the inside peripheral surface 44 of converging frusto-conically shaped outer nozzle 38. Also, converging outer nozzle 38 terminates at outer orifice 43. Inner discharge orifice 36 is preferably slightly recessed upstream from outer discharge orifice 43. However, in some cases both orifices may terminate in the same plane; and in some unusual circumstances inner orifice 36 may teminate downstream from outer orifice 43.

Cooling coils 23 encircle the burner near the region of the downstream tip and provide means for supplying cooling chamber 24 with a coolant. As shown in Fig. 4, a particularly advantageous additional measure consists in arranging the connections so that supply inlet 28 and withdrawal outlet 29 for the coolant are at diametrically opposite points. In this way the presence of a large number of welds over a small area of the cooling chamber is avoided and the risk of stresses occurring in the material is thereby diminished.

As previously described, cooling chamber 24 is constructed by welding machined sections to outer tube 21. In comparison with conventional flat wall construction as shown in Fig. 1, the hemispherical cross section of the tubular ring section 39 of the cooling chamber, with its curved wall, makes possible the use of thinner walls. Thus, when using austenitic chromium-nickel e.g. a V2A steel, the wall thickness may be in the range of about 1 to 5 mm, and preferably from 2.0 to 4 mm. The decrease in the thickness of the wall facing the reaction zone ensures better heat removal. This means that the material in the region of the burner throat is subjected to less thermal stress and is less susceptible to corrosion by hydrogen sulfide formed in the combustion chamber.

The special design of the cooling chamber including the use of at least two appropriately turned parts to form outer nozzle 38 enables the welds joining these parts to be so placed that they are not directly exposed to the radiant heat from the reaction chamber and its brick lining. Thus, as previously described, welds 27 are arranged in such a way that they are preferentially on that side of the tapered section of the burner throat which faces the inner tube. Further, since connections 28 and 29 for the supply and withdrawal of coolant to the cooling chamber are advantageously welded onto opposite sides of the ringshaped cooling chamber of hemispherical cross section, as shown in Fig. 4, there is no need to install the conventionally used separating plates in the cooling chamber. This arrangement has the advantage that there are fewer stresses in the material in the region of the cooling chamber than in the case of prior art designs.

Instead of the conventionally employed costly high-temperature alloys having high nickel contents (Incoloy 42% Ni, Inconel 72% Ni as described in Table I below), it was surprising and unexpectedly found that the subject burner could be made from austenitic chromium-nickel steels which have less thermal resistance but which can be worked more easily and are less expensive. For example, as shown in Table I, the high-temperature strength of V2A alloy steel at 550°C. is 12 kg/mm^2. Further, the use of austenitic chromium-nickel steels offers particular advantages with regard to corrosion resistance from hydrogen sulfide. As indicated above, hydrogen sulfide is formed during the combustion of the sulfur-containing feedstocks in the reaction zone and has a corrosive action at the high temperatures prevailing in the region of the burner throat. On the outermost surface of the front face of conventional burners, the temperatures exceed 700°C. It was not foreseeable that improved cooling in the region of the burner throat as a result of the special design of the cooling chamber of the subject invention, in conjuction with the use of chromium nickel steels having iron contents of about 60 to 70%, would result in lower susceptibility to H_2S corrosion than in the case of the alloys hitherto used which are either non-ferrous (Incoloy) or have a low iron content (Inconel).

A summary of prior art burner materials (1) and the improved materials (2) disclosed herein are shown in Table I:

Table I

Material	Composition in %											High-temperature strength in kg/mm² at ... °C				
	Cu	Mo	Nb	C	Si	Mn	Cr	Ni	Ti	Fe	Al	20	550	760	815	982
(1) Incoloy 825	1,5	2,5	S 0,03	max. 0,5	max. 0,5	max. 1,0	19,5-23,5	38-46	0,6-1,2	-	0,2	25,0	-	15,0	13,6	-
(1) Inconel 600	0,5	-	S 0,015	max. 0,15	max. 0,50	max. 1,0	14-17	72	-	6-10	-	25,6	-	12,0	-	2,8
(2) V2A 4541	-	-	-	max. 0,10	max. 1,0	max. 2,0	17,0-19,0	9,0-11,5	min. 5x%C	Balance, about 60-70%	-	21,0	12,0	-	-	-
(2) V2A 4550	-	-	min. 8x%C	max. 0,10	max. 1,0	max. 2,0	17,0-19,0	9,0-11,5	min. 5x%C	Balance, about 60-70%	-	19,5	12,0	-	-	-
(2) V4A 4571	-	2,0-2,5	-	max. 0,10	max. 1,0	max. 2,0	16,5-18,5	10,5-13,5	-	Balance, about 60-70%	-	21,0	13,0	-	-	-
(2) V4A 4580	-	2,0-2,5	min. 8x%C	max. 0,10	max. 1,0	max. 2,0	16,5-18,5	10,5-13,5	-	Balance, about 60-70%	-	21,0	13,0	-	-	-

(1) International Nickel Co.
(2) Krupp, Essen et al.

The abovementioned measures (namely special design of the cooling chamber in the region of the burner throat and using small wall thicknesses; placing the welds required for constructing the cooling chamber on the side facing the inner tube or protected by cooling coils; arranging the connections for the supply and withdrawal of coolant to and from the cooling chamber on opposite sides, thus avoiding the use of a welded-in separating plate; and the use of, for example, austenitic chromium-nickel steels as the material of construction for the cooling chamber in the region of the burner throat) make it possible to achieve a burner life of more than 100 days, whereas conventional burners only have an average life of 20 to 30 days. The above-mentioned life of the burner of the invention was achieved in a commercial-scale plant in which the reactor concerned had to be shut down several times because of disturbances in other sections of the plant. This shows that the burner according to the invention is perfectly capable of withstanding the additional stress (temperature shock) caused by the shutdown and renewed startup of the reactor.

Suitable feedstocks for operating the burner are gaseous and liquid hydrocarbon, e.g. methane, gasoline and particularly crude oil and heavy fuel oil. These feedstocks are mixed in suitable equipment and, if desired after being preheated to from 250° to 500°C., supplied to the outer tube of the burner. The oxygen required for heating and partial oxidation is advantageously preheated and introduced through the inner tube of the burner. Either substantially pure oxygen (95 mole % O_2 or more), air, or air enriched with oxygen (greater than 21 mole % O_2) is employed for the combustion of the hydrocarbons. To prevent scaling of the inner tube it is advantageous to add steam to the dry substantially pure oxygen or to the dry air or to dry air enriched with oxygen, generally in small amounts of from 0.5 to 5%, preferably from 1 to 3%, by wt. of free O_2. However, up to 25 weight percent of the H_2O may be introduced to the reaction zone inadmixture with the oxygen stream.

EXAMPLES

The way in which the process for reacting hydrocarbons by partial oxidation is carried out using the burner of the present invention is described in the following Examples.

EXAMPLE 1

A free-flow non-catlytic synthesis-gas generator such as previously described is used in combination with a burner such as shown in the accompanying drawing (Fig. 3). On an hourly basis, 15,100 kg per hr. of heavy fuel oil is mixed with 6,060 kg per hr. of steam at a pressure of 85 atm., heated to 320°C. in a preheating coil, and introduced through the cooled outer tube of the burner into the reaction zone of said gas generator. Cooling of the burner is effected with 16 m^3 per hr. of water at a pressure of 10 atm. At the same time 12,200 m^3 per hr. standard temperature and pressure (STP)/hr of substantially pure oxygen preheated to 110°C and mixed with 440 kg per hr. of steam is introduced into the reaction zone through the inner tube of the burner. Thus, 2.5% by weight of steam is introduced in admixture with the oxygen. The reaction takes place in the reaction chamber at 1350°C.

The burner, which is made of V2A steel, is trouble-free in operation during more than 100 days, producing 47,000

m^3 per hr. (STP)/hr. of synthesis gas having the following composition (volume %- dry basis): CO 46.2%, H_2 47.0%, CO_2 5.6%, N_2 0.7%, and CH_4 0.5%. The gas also contains 3.0 g of H_2S and 100 mg of COS per m^3 (STP).

EXAMPLE 2

In the industrial synthesis-gas plant mentioned in Example 1 another experiment is carried out using a different feedstock and throughput but with the same burner. On an hourly basis, 8200 kg per hr of Landau crude oil is mixed with 5000 kg per hr. of steam at a pressure of 82 atm., preheated in a heating coil to 320°C and introduced through the cooled outer tube into the burner chamber. Cooling of the burner is effected with 17 m^3 per hr. of water at a pressure of 10 atm. At the same time 7000 m^3 per hr. of substantially pure oxygen preheated to 110°C and mixed with 300 kg per hr. of steam is introduced through the inner tube; this means that 3.0% by weight of steam is used with reference to oxygen. The reaction takes place in the reaction chamber at 1280°C.

In this experiment, too, operation of the burner is trouble-free for more than 100 days although, owing to the fact that the burner is operated at less than capacity, the flame is closer to the burner throat and heats it to a higher temperature. 26,000 m^3 per hr. (STP) of synthesis gas having the following composition (volume % - dry basis) CO 45%, H_2 48.4%, CO_2 5.0%, N_2 0.6%, CH_4 1.0%. The gas also contains 4 g of H_2S and 150 mg of COS per m^3 (STP).

Although modifications and variations of the invention may be made without departing from the spirit and scope thereof, only such limitations should be imposed as are indicated in the appended claims.

The embodiments of the invention on which an exclusive property or privilege is claimed are defined as follows:

1. A burner for use in introducing raw materials into the reaction zone of a gas generator where at an autogenous temperature in the range of about 700 to 1900°C. and a pressure in the range of about 1 to 250 atmospheres by the partial oxidation of a hydrocarbon fuel with a free-oxygen containing gas optionally in the presence of a temperature moderating gas a gaseous mixture comprising hydrogen and carbon monoxide is produced said burner comprising a central tubular conduit and central nozzle extending therefrom disposed along the longitudinal axis of said burner through which a first stream is passed, said central nozzle terminating in a single unobstructed circular orifice; an outer coaxial concentric conduit and outer converging frusto-conically shaped nozzle extending therefrom radially disposed from said central conduit and central nozzle along their length for simultaneously introducing a second stream into said reaction zone, said outer nozzle terminating in a single unobstructed circular orifice located at the outermost face of the burner; an annular cooling chamber encircling the downstream tip of said burner and having an inside wall in common with said outer nozzle and an outside wall comprising a tubular ring of approximately hemispherical cross section; and inlet and outlet means for circulating coolant through said cooling chamber.

2. The burner of Claim 1 wherein said annular cooling chamber is formed by welding and the welds are shielded from direct radiation from said reaction zone.

3. The burner of Claim 1 wherein austentitic chromium-nickel steel is used as the material of construction for said annular cooling chamber, and said central

and outer nozzles.

4. The burner of Claim 1 wherein the thickness of the wall of said cooling chamber in the region of the outer tip is from 1 to 5 mm.

5. The burner of Claim 1 wherein the inlet and outlet connections for the supply and withdrawal of coolant are arranged on opposite sides of the cooling chamber.

6. The burner of Claim 1 wherein said temperature moderating gas is steam and up to 25 weight percent of said steam in introduced into the reaction zone in admixture with the free-oxygen containing gas.

7. The burner of Claim 1 wherein said free-oxygen containing gas in introduced into the reaction zone by way of said central nozzle and said hydrocarbon fuel, optionally in admixture with at least a portion of said temperature moderating gas, is introduced into the reaction zone by way of said outer nozzle.

8. The burner of Claim 1 wherein said free-oxygen containing gas is introduced into the reaction zone by way of said outer nozzle and said hydrocarbon fuel, optionally in admixture with at least a portion of said temperature moderating gas, is introduced into said reaction zone by way of said central nozzle.

Fig.1.

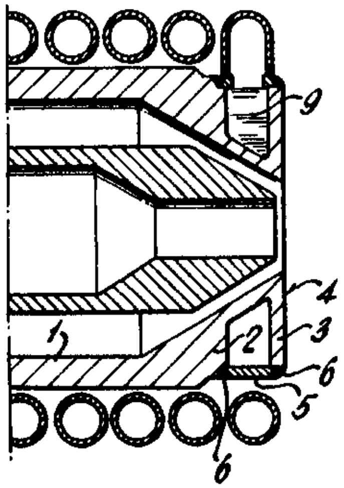


Fig.2.

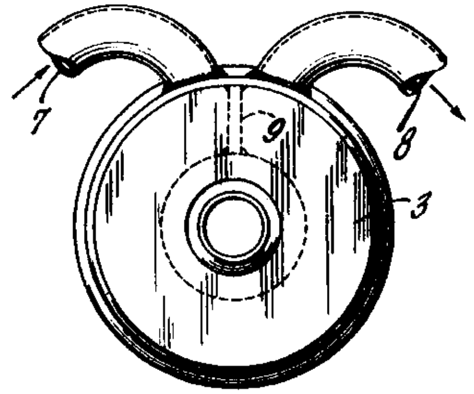


Fig.3.

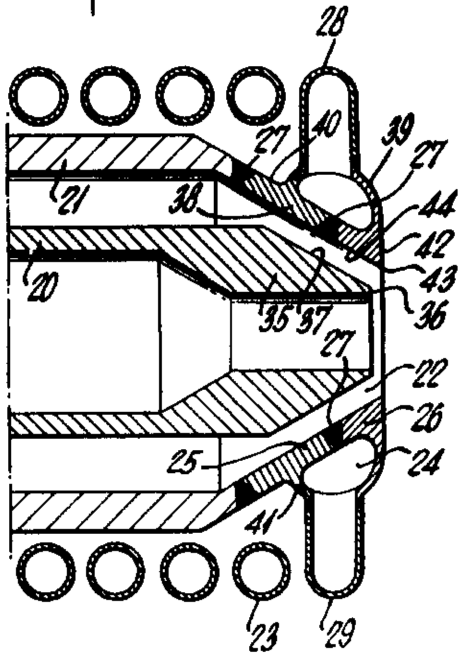
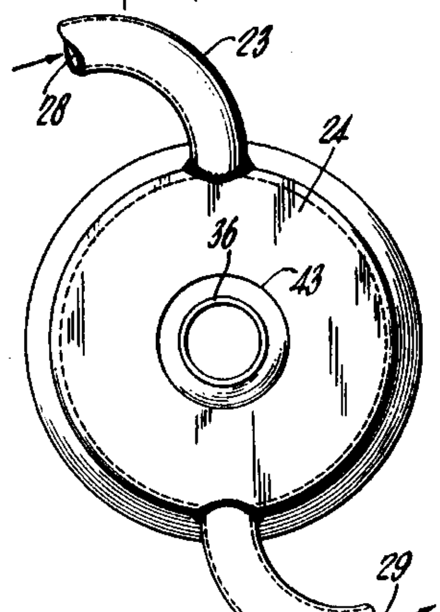


Fig.4.



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