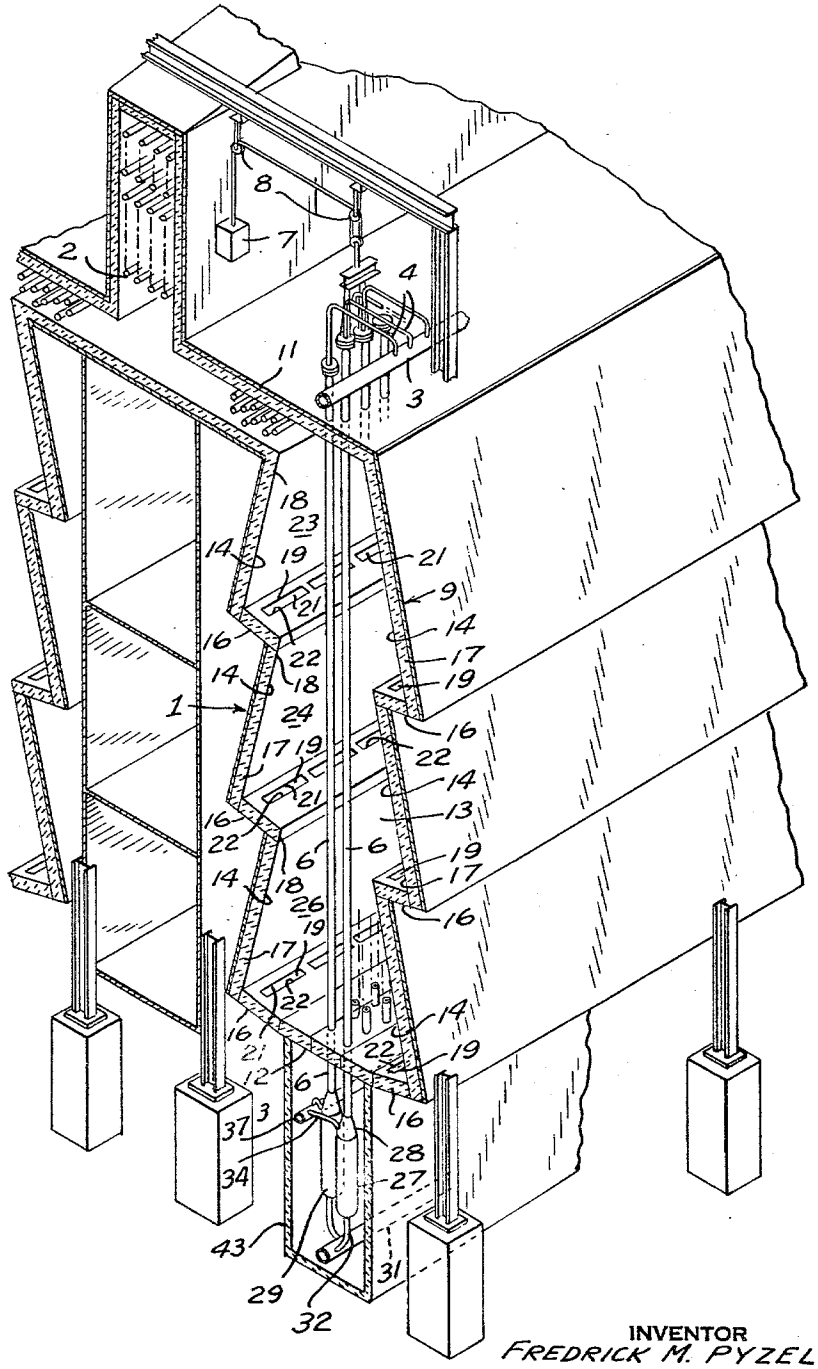
July 20, 1965 F. M. PYZEL 3,195,989

INTEGRAL TUBE FURNACE AND OXIDIZER

Filed July 9, 1962 2 Sheets-Sheet 1

FIG. I.



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FIG. II.

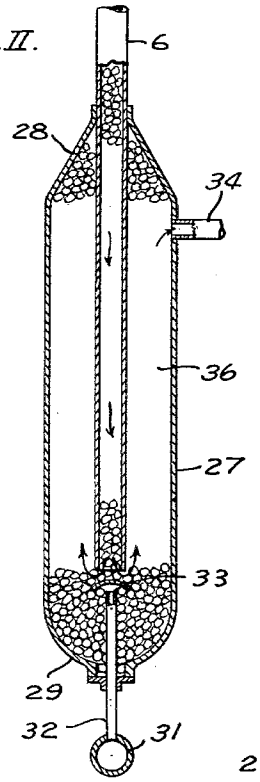


FIG. III.

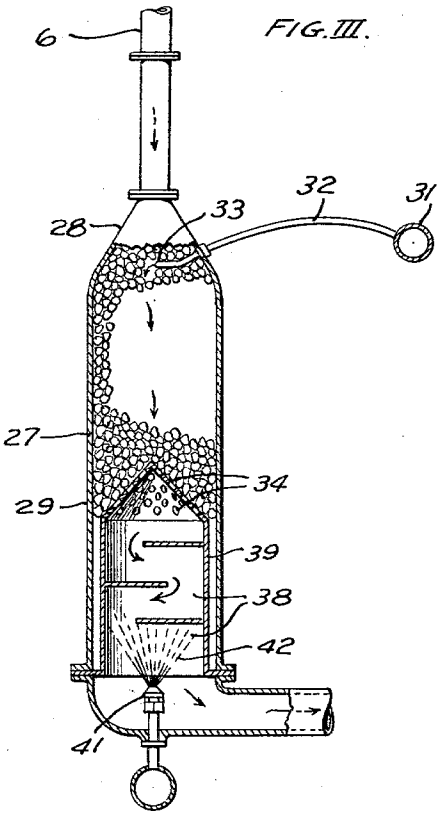
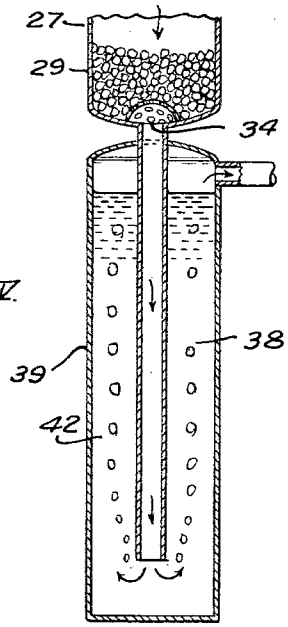


FIG. IV.



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INTEGRAL TUBE FURNACE AND OXIDIZER

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This invention relates to furnaces with catalyst filled tubes used in reforming light hydrocarbons to produce hydrogen and carbon monoxide mixtures. More particularly, the invention contemplates a reformer tube having an oxidizer integrally formed therewith.

A typical reforming process involved in this apparatus is represented by the following equation for methane:

$$CH_4+H_2O\rightarrow CO+3H_2$$

This equation merely characterizes the main reaction performed. In actual practice, CO_2 might also be added as an oxidant. Complete conversion is not obtained nor is the selectivity toward CO formation 100 percent as indicated by the idealized equation. In any event, unconverted hydrocarbon appears in the product gas.

To increase H_2 and CO yield, the furnace is followed by an oxidizing step wherein partial combustion of unconverted hydrocarbon may be represented for methane by the following equation:

$$CH_4+O_2\rightarrow CO+H_2+H_2O$$

This reaction is exothermal.

Prior reformer systems have included the oxidizer as a separate unit downstream from the tube furnace. Such an arrangement leaves a hiatus in the flow stream between the furnace and the oxidizer wherein unpredictable and sometimes undesired reactions take place. It is an object of this invention to eliminate these reactions.

Gas from the reformer furnace could be cooled in order to prevent undesired reactions, however, unless cooling is rapid there is jeopardy of excessive carbon deposition. Rapid quenching at the furnace outlet has been employed to quickly cool the gas through the critical carbon deposition temperature range. But cooling has imposed thermal shock problems and has penalized oxidizer performance by necessitating operation at reduced temperatures.

The present invention contemplates an apparatus capable of combining primary reformation and subsequent oxidation in a single unit.

Basically, this teaching offers the direct availability of reformer furnace product gas for oxidation at a high temperature. Intermediate piping has been eliminated. Geometries in the lower regions of tube furnaces are well suited to accommodating oxidizers. Additionally, the present advance gives rise to more compact systems occupying little ground area. Maintenance opportunities arise from the possibility of repairing or removing some of the oxidizers while others are on stream.

These and other features will appear more fully from the accompanying drawings wherein:

FIGURE I is an isometric view of a preferred embodiment of a reformer furnace with oxidizers mounted therein.

FIGURE II is an enlarged sectional elevation view depicting one reformer tube and its secondary oxidizer.

FIGURE III is sectional elevation view of a reformer and its corresponding secondary oxidizer according to a second embodiment with a quench apparatus mounted therein.

FIGURE IV is a broken sectional elevation view depicting the oxidizer exit with a quench boot.

Natural gas, methane or any normally gaseous hydrocarbon containing one to four carbon atoms in its molecule and which is of satisfactory low sulfur content may serve as the feed gas. In some cases it may be economical to use a narrow boiling gasoline fraction. (Then special catalysts might be necessary and high steam to carbon ratios would be used to resist coke deposition from higher boiling hydrocarbons.)

In advance of the reformer furnace 1 it is often necessary to desulfurize the hydrocarbon by contact with activated carbon. Analogously, CO_2 may be desulfurized by bubbling it through a potassium permanganate solution ($KMnO_4$).

With a methane feed tube furnaces are generally operated with from 1.8 to 9.0 moles of oxidant per mole of product H_2. Inlet pressures from atmospheric to 400 p.s.i.g., preheat temperature from 500° F. to 1000° F., heater zone outlet temperatures from 1450° F. to 2300° F. and space velocities from 500 to 5000 standard cubic feet of theoretical H_2 yield per hour per cubic foot of catalyst are usually employed.

In FIGURE I, the mixture of hydrocarbon and oxidant is passed through preheater tubes 2 wherein it is preheated by flue gases. Thereafter, the feed gas is transmitted via inlet manifold 3 and flexible inlet conduits 4 to reformer tubes 6 which are positioned by support means shown as counterweight 7 and pulleys 8.

Reformer furnace 1 includes a setting generally designated 9 which has roof 11 and floor 12 slidably penetrated by tubes 6. Setting 9 defines heater zone 13 embraced by a pair of stepped oppositely disposed side walls 14. Above steps 16 each side wall 14 slopes inwards upwardly so that the side walls define a number of coplanar surfaces faced with refractory material. Each refractory surface has a bottom 17 and an upper extremity 18. The cross section of heater zone 13, although being generally rectangular is substantially that produced by the outline of a number of regular trapezoids stacked large base on small base with a common axis of symmetry.

Along steps 16 are arranged heater means shown as sets of linear burners 19 which project their flame streams through longitudinal troughs 21 upward each to sweep on associated coplanar surface. Thus, each of these surfaces can be uniformly heated to evenly emit radiation therefrom. Inner rims 22 divert the streams of flame away from direct impingement onto tubes 6.

Control means (not shown) are associated with each burner to regulate the intensity of heat flux input. By altering the firing rate of any set of paired burners disposed at the same elevation in steps 16, different levels of reformer tubes 6 can be subjected uniformly to heat flux intensities. With temperature gradient reducing down the tubes, it is usual to add from 50 to 65 percent of the total heat influx to the tubes in upper level 23, 25 to 40 percent in middle level 24 and the balance in lower level 26.

The catalyst in the furnace tubes employed to produce synthesis gas is suitably a nickel catalyst, such as reduced nickel oxide, nickel-thoria-magnesia, nickel-alumina-magnesia, nickel-magnesia, nickel on carbon, or nickel on alumina. Other suitable catalysts may include cobalt molybdate supported on alumina, a group VIII metal on metal oxide on a suitable support, nickel and iron on a support or carrier, and the like.

The substantially reformed gas leaving catalyst tubes 6 passes into secondary shell 27. Secondary shell 27 has upper end 28 and lower end 29 and contains oxidizer catalyst which can be the same as that used for the reformer catalyst.

As best seen from FIGURES II and III, an oxygen containing gas is supplied to each oxidizer from manifold

31 via oxygen conduit 32 and oxygen port 33. The oxygen content of this gas generally depends upon the degree to which the elimination of diluent nitrogen from the hydrogen stream is required.

Throughout the figures the same numerals indicate like elements. In FIGURE II, exit port 34 communicates with annular space 36 between shell 27 and tube 6 in the vicinity of upper end 28 of the shell to conduct the gas to outlet manifold 37. Furnace tubes 6 are generally spaced at two diameters center to center. If there is fear of crowding the secondary shells alternate tubes can be kneed to opposite sides (as shown in FIGURE III) to accommodate more compact geometries.

In the embodiment of FIGURES III and IV the product gas exits via quench chamber 38 formed by quench housing 39. Cooling means are shown in FIGURE III as spray 41 and in FIGURE IV as bath 42.

As shown in FIGURE I, oxidizer shells 27 are embraced by refractory enclosure 43.

It will be understood by those skilled in steam reforming and related equipment that wide changes may be made in the details of this system without departing from the main theme of invention defined by the claims.

What is claimed is:

1. A reformer system which includes a primary reformer and oxidizer for use in the production of hydrogen and hydrogen and carbon monoxide mixtures from a hydrocarbon comprising in combination

wall means defining an enclosed heating chamber;

at least one tube positioned to extend through said chamber defining a primary reformer reaction zone;

support means for positioning the tube;

inlet means for introducing a feed comprising hydrocarbon and an oxidant into said tube, said tube containing a suitable catalyst;

heater means heating said chamber to heat said tube;

vessel means connected in flow series with said tube to receive substantially reformed gas from the tube, said vessel means containing a catalyst and defining an oxidizer reaction zone;

a refractory enclosure entirely encompassing said vessel means and separating said vessel means from said heating chamber and from ambient conditions, said enclosure including a refractory wall common with said heating chamber wall means penetrated by said tube;

means for introducing an oxygen containing gas into said vessel means near the upstream end thereof to react with unconverted hydrocarbon therein;

and outlet means for exhausting product gas from said vessel means.

2. A reformer system which includes a primary reformer and oxidizer for use in the production of hydrogen and hydrogen and carbon monoxide mixtures from a hydrocarbon comprising in combination

wall means having end and side walls defining an enclosed first chamber;

enclosure means having refractory end and side walls adjacent said first chamber defining an enclosed second chamber, the second chamber being separated from the first chamber by a refractory wall common to both said chambers and from ambient conditions by said end and side walls;

a plurality of tubes defining heated primary reformer reaction zones positioned to extend through the first chamber and into the second chamber;

support means for positioning said tubes;

heater means heating the first chamber to heat the tubes in the chamber;

inlet means for introducing a feed comprising a hydocarbon and an oxidant into said tubes, said tubes containing a suitable catalyst;

vessel means connected in flow series with said tubes to receive substantially reformed gas from the tubes, said vessel means containing a catalyst and defining an oxidizer reaction zone; said vessel means being disposed within said second chamber the enclosure means thereof encompassing said vessel means and separating the vessel means for the first chamber and from ambient conditions;

means for introducing an oxygen containing gas into said vessel means near the upstream ends thereof to react with unconverted hydrocarbon therein;

and outlet means for exhausting product gas from said vessel means.

3. A reformer system which includes a primary reformer and oxidizer for use in the production of hydrogen and hydrogen and carbon monoxide mixtures from a hydrocarbon comprising in combination

wall means including side walls and roof and floor walls defining an elongated enclosed upright first chamber;

enclosure means having refractory end and side walls adjacent and below said first chamber defining an enclosed second chamber, the second chamber being separated from said first chamber by a refractory wall which is common with the floor of the first chamber;

at least one straight tube defining a heated primary reformer reaction zone having an upstream end and a downstream end;

means supporting said tube vertically to extend lengthwise through the first chamber with the upstream end slidably penetrating through the roof of the chamber and the downstream end slidably penetrating through the floor of the chamber into the second chamber;

conduit means communicating with a source of feed comprising a hydrocarbon and an oxidant connected to the upstream end of the tube to deliver the feed thereto, the tube containing a suitable primary reformer catalyst;

refractory surfaces in said first chamber on opposite sides of said tube;

a plurality of burners penetrating said refractory surfaces to introduce streams of flames which sweep said refractory surfaces heating the surfaces to radiate energy to said tube;

a vessel connected in flow series with said tube to receive substantially reformed gas from the tube, said vessel containing a catalyst and defining an oxidizer reaction zone, said vessel being disposed within the second chamber, the enclosure means thereof encompassing the vessel and separating the vessel from the first chamber and from ambient conditions;

means for introducing an oxygen containing gas into said vessel near the upstream end of the vessel for oxidizing unconverted hydrocarbon therein;

and outlet means for exhausting product gas from the vessel.

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