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(12) **Patent:**

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(54) STEAM REFORMING OF A HYDROCARBON HEAVIER THAN METHANE TO PRODUCE A HYDROGEN AND CARBON MONOXIDE MIXTURE

(54)

(72)	(Country):	**ROBERT A. MCCALLISTER** (Not Available)
(73)	(Country):	**FOSTER WHEELER CORPORATION**
(71)	(Country):	
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This invention relates to steam reforming of a light hydrocarbon yielding a mixture of hydrogen and carbon monoxide. More particularly, the invention contemplates a process and system by which hydrocarbons heavier than methane can be reformed without prohibitive steam requirements.

In the steam reforming process it is well known to pass steam and a hydrocarbon through a reformer furnace via catalyst filled tubes. A plurality of catalyst tubes are generally arranged in parallel flow through the combustion chamber of the furnace. This system is acceptable in reforming methane. But heavier hydrocarbons require very high steam flow to minimize coking. The quantity of steam to prevent excessive coking when hydrocarbons heavier than methane is used becomes vastly greater than the steam consumed in reforming the hydrocarbon. A relatively predictable flow of steam is known to be required for coke prevention in each tube. With tubes arranged in parallel, coke prevention steam must be provided for each of the parallel paths. Total steam input is approximately the steam requirement for coke-free reforming in one tube times the number of parallel tubes. Thus in conventional systems, the steam requirement becomes inordinate.

The foregoing problem is here solved in a novel and facile manner. Reduction of steam requirement is necessary for commercial acceptability. Toward this objective, a plurality of tubes are arranged in flow series. Sufficient steam to prevent excessive coking

in one tube is passed serially through the tubes. By this expedient the same steam flow is employed to prevent coking in all of the tubes. Enough steam is also provided to reform the hydrocarbon feed introduced into each tube. But the hydrocarbon, reaction steam and product flows are small in comparison with the coke prevention steam.

Basically this teaching offers commercial acceptability to reforming hydrocarbons heavier than methane. Thermal balance is improved because steam requirements are reduced to quantities attainable by waste heat recovery from reformer furnaces.

These and other advantages will appear more fully from the accompanying drawing which schematically illustrates a system embodying this invention.

In the drawing a flow path includes a plurality of heated catalyst filled zones shown as first tube 1 and second tube 2 disposed in combustion chamber 3 of a reformer furnace generally designated 4. Burners heat tubes 1 and 2. Of course tube banks may be regarded as the equivalent of these tubes within the context of this disclosure.

Catalysts contemplated for service in these tubes may be any commercially available variety selected from the group consisting of 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 crux of this invention is to use the same steam flow to prevent coking in more than one tube. Toward this objective, series means shown as U-bend coupling 6 is connected between tubes 1 and 2 to arrange the tubes in flow series. Flow through first tube 1 is downward while flow through second tube 2 is upward. First tube 1 has upstream end 7 and downstream end 8. Second tube 2 has upstream end 9 and downstream end 11. The tubes are maintained at superatmospheric pressure.

Steam is communicated via line 12 to upstream end 7 of first tube 1 for passage through the first tube 1, coupling 6 and second tube 2. Means for exhausting gases from downstream end 11 of second tube 2 are shown as exhaust line 13.

A supply of gaseous hydrocarbon feed is communicated to line 14. With sufficient steam, it is known that hydrocarbons of the paraffin series with from two to ten carbon atoms in their molecules are reformable to yield carbon monoxide and hydrogen. These hydrocarbons are ethane, propane, butane, pentane, hexane, septane, octane, nonane and decane. Petroleum naphtha, gasoline, diesel oil and mixtures of the foregoing may also serve as the feed. If a particular relationship of carbon monoxide and steam is desired, carbon dioxide may be added to the feed.

A portion of the hydrocarbon feed is reformed in each of the tubes. The hydrocarbon is divided into first portion 16 and second portion 17 at juncture 18. Line 16 communicates the first portion of the feed to upstream end 7 of first tube 1. Line 17 communicates

the second portion of the feed to upstream end 9 of second tube 2 via coupling 6. The carbon monoxide and hydrogen product from first tube 1 constitute a small portion of the total flow in tube 2 so tubes 1 and 2 are usually the same size.

It will be apparent that wide changes may be made in the details of the shown embodiment without departing from the spirit of invention defined by the claims.

WHAT IS CLAIMED IS:

1. A process for manufacturing a mixture of carbon monoxide and hydrogen from a hydrocarbon feed selected from a group consisting of a hydrocarbon of the paraffin series having from one to ten carbon atoms in its molecule, petroleum naphtha, gasoline, diesel oil and mixtures thereof; the process comprising the steps of passing steam through a flow path including a plurality of heated catalyst filled zones arranged in flow series, maintaining the zones at superstmospheric pressure, dividing the hydrocarbon feed into at least two portions, introducing each of the portions upstream of a different zone of the zones.

2. The process of Claim 1 with butane as the hydrocarbon feed.

3. A system comprising a reforming furnace which defines a combustion chamber, a first tube and a second tube each filled with a suitable catalyst and disposed in the combustion chamber, means for maintaining the tubes at superatmospheric pressure, series means connecting the tubes in flow series relationship, each of the tubes having an upstream end and a downstream end, means for delivering steam to the upstream end of the first tube so that it passes serially through the first and second tube, a supply of hydrocarbon feed,

means for dividing the hydrocarbon feed into a first portion and a second portion, means for communicating the first portion of the feed to the upstream end of the first tube, means for communicating the second portion of the feed to the upstream end of the second tube, means for exhausting gases from the downstream end of the second tube.

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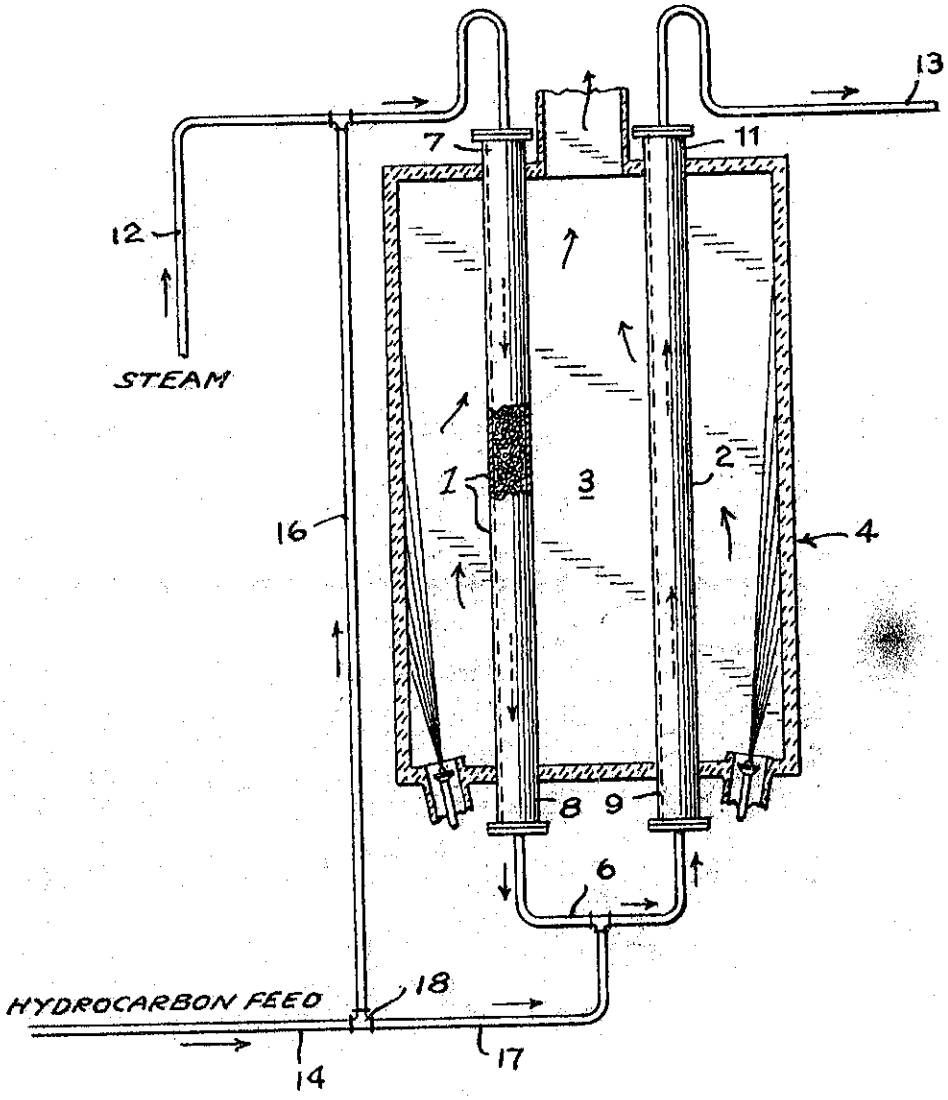

R. A. McCallister
INVENTOR

Marks & Clerk
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