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(12) Patent:

(54) METHOD AND APPARATUS FOR PRODUCING SYNTHESIS GAS

(54)

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(72) Inventor: **Unknown**

*** Note: Data on abstracts and claims is shown in the official language in which it was submitted.

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My invention relates to an improved method and apparatus for producing synthesis gas.

5 Synthesis gas is a mixture of carbon monoxide and hydrogen which is appropriate as a charge to a synthesis process for the production of hydrocarbons and the like. The synthesis gas, furthermore, is a ready source of hydrogen or carbon monoxide for use in other chemical processes. The mixture, furthermore, is an excellent reducing gas advantageously employable in the direct reduction of iron ore. The generation of synthesis gas by the partial oxidation of hydrocarbons, and particularly gaseous hydrocarbons, by oxygen of high purity at elevated pressure and at elevated temperatures is known to the art. I have found that the partial oxidation process under appropriate process conditions may be substantially completed in less than a second, and that the process requires no catalyst. I have found, further, that the shape of the reaction zone, that is, the relationship between the surface area of the reaction zone and its volume, does not substantially affect the process.

10

15

A plant employing the method of the prior art with the partial oxidation of gaseous hydrocarbons for the generation of the synthesis gas has been built by Carthage Hydrocol at Brownsville, Texas. This plant has been unable to operate continuously and has, during its periods of intermittent operation, operated at only a fraction of its designed capacity. The difficulty has been occasioned in the synthesis gas generators where partial combustion of methane with substantially pure oxygen under conditions for optimum generation of synthesis gas has resulted in repeated burnouts of the generator jets.

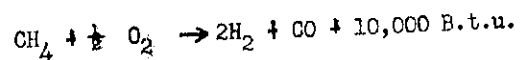
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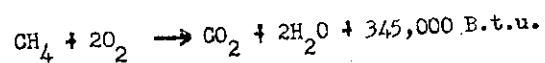
The reaction for the partial oxidation of methane may be represented as follows:

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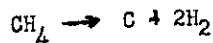
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If there is excessive oxygen present, two reactions occur. First, we have the complete oxidation of methane which may be represented as follows:



It will be noted that there is a tremendous heat generated by this highly exothermic reaction. The arrangement of the generator jets in the prior art is such that there is always present in the reaction chamber a local excess of oxygen permitting the highly exothermic reaction of complete oxidation of the hydrocarbon to occur. The heat thus generated is the cause of the difficulty being experienced at the Brownsville, Texas, Hydrocol plant. There is an additional side effect created by permitting the complete oxidation of methane to occur. The local reduction in the oxygen present by the overuse of some of it results in a local oxygen deficiency with the result that some of the methane of the charge will produce free carbon, as follows:



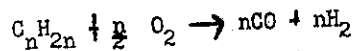
The carbon dioxide present will produce a synthesis gas mixture by the following reaction:



The deleterious effects of the local excess of oxygen and the accompanying exothermic complete oxidation of methane caused thereby will produce the excessive heat which causes the metal of the generator jets to burn out. In addition, free carbon is formed.

It will be seen that a complete, continuous and rapid commingling of the reactant gases is necessary if a sustained, continuous production of synthesis gas is to be obtained unaccompanied by the deleterious effects pointed out above. The gases cannot be premixed before entering the reaction zone since flash backs will always occur if this be attempted. The gases cannot be mixed until they reach the reaction zone and then their commingling must take place through an extended area within the reaction zone. In this manner local excesses of oxygen are prevented and the deleterious highly exothermic complete oxidation of methane will not occur to any substantial degree.

In general, my invention contemplates preheating the reactant gases to a temperature of about 1000° F. The hydrocarbon may be a mixture of hydrocarbon gases or may be a liquid hydrocarbon, if desired. In the case of liquid hydrocarbons, the average reaction may be represented by the equation:



The oxygen reactant should have a high purity, preferably of better than 80%, though the process may operate with an oxygen content of at least 40 volume per cent of free oxygen. The preheating temperature in the case of liquid hydrocarbons will be sufficient to vaporize them so they may be considered as gaseous hydrocarbons for the purpose of my process.

The reaction time is substantially independent of pressure, being completed in much less than one second, provided the intermixing, which will be pointed out more fully hereinafter, is practiced. Any appropriate pressure may be employed in the synthesis reactor, depending upon the pressure of the after reaction zones to which the synthesis gas is to be charged. A pressure between two hundred pounds per square inch and four hundred pounds per square

inch is appropriate, though pressures ranging from atmospheric pressure to pressures as high as seven hundred and fifty pounds per square inch may be employed. The temperature within the reaction zone should be maintained between 1800° F. and 3000° F. The best results are obtained by maintaining the temperature in the vicinity of 2300° F. This temperature is maintained by controlling the relative rate of flow of oxygen with respect to the methane and the combined rate of flow of both reactants as well as the degree of preheat. It was seen above that the desired reaction is not highly exothermic and when the proper rates of flow are achieved a temperature of 2300° F. gives optimum process results. If the temperature is much below 1800° F., the synthesis gas contains increased quantities of methane. If the temperature of 3000° F. is exceeded, burnouts are apt to take place and too large a percentage of carbon dioxide will appear in the final product as well as concomitant free carbon. With the aid of my method and apparatus proper conditions can be readily achieved by adjusting the relative flow of oxygen to the methane and a stable, continuous process condition can be readily achieved. Increasing the quantity of oxygen increases the temperature. Decreasing the quantity of oxygen reduces the temperature. The exothermic heat of the desired reaction will furnish sufficient heat to maintain the temperature at a substantially constant point.

The preheated reactant gases are introduced through a plurality of comparatively minute jets over an extended area within the reaction zone in such manner that the reactant gases are jettted against each other and commingled to permit the reaction to take place over an extended area within the reaction zone and thus avoid local excesses of oxygen which lead to the deleterious results outlined above.

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In the accompanying drawings which form part of the instant specification and which are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

5 Figure 1 is a diagrammatic sectional view of a reactor containing one embodiment of the apparatus of my invention and capable of carrying out the process of my invention.

Figure 2 is a sectional view drawn on an enlarged scale taken along the line 2-2 of Figure 1.

10 Figure 3 is a fragmentary sectional view drawn on an enlarged scale taken along the line 3-3 of Figure 2.

Figure 4 is a sectional view similar to Figure 2 showing another form of apparatus embodying my invention and capable of carrying out the process of my invention.

15 Figure 5 is a sectional view drawn on an enlarged scale viewed along the line 5-5 of Figure 4.

Figure 6 is a sectional view similar to Figure 3 showing a modified form of the apparatus of my invention.

20 Referring now to the drawings, the reactor, indicated generally by the reference numeral 10, may have any desired shape or size dictated by the volume of gases to be processed. The rate of flow of gases and the size of the reaction chamber are such that the gases will pass through the reaction zone in less than one second. The chamber 12 of the reactor is lined with a refractory lining material 14 housed by a metal casing 16. It is 25 to be understood, of course, that heat-exchange coils (not shown) may be positioned in the path of the gases emerging through the outlet port 18 to utilize some of the heat of the reaction, if desired, as is well understood in the art. Oxygen from any 30 suitable source is preheated in a preheater (not shown) and intro-

duced into a supply manifold 20 controlled by a valve 22. The hydrocarbon reactant, similarly preheated, is introduced into a supply manifold 24 controlled by a valve 26. Adjacent the bottom of the reaction zone and appropriately supported therein I provide a plurality of nozzle manifolds 28 formed with a plurality of nozzles 30, as can readily be seen by reference to Figure 3. Adjacent each of the nozzle manifold sections 28 I position a second plurality of nozzle manifolds 32 similarly provided with nozzles 34. By reference to Figure 3 it will be seen that the nozzles 30 are in apposition with the nozzles 34. It will be further observed that both the nozzles 30 and 34 are advantageously formed of converging diverging shape so that the pressure energy existing within the manifold will be converted into velocity energy in jetting through the nozzles. The jetted gases from the juxtaposed nozzles directed toward each other will intimately commingle, commencing the reaction. The intimate commingling of the gases through a plurality of comparatively small nozzles accomplishes the unexpected and desirable result in a simple, convenient manner. The number of nozzles is substantially critical. In the Brownsville operation referred to above, only eight nozzles were employed in what are known as "burners". Actually, I do not employ my nozzles as "burners". With the use of eight nozzles in Brownsville each nozzle must handle 12-1/2% of the total gas flow. I have found that no nozzle should handle more than 3% of the gas flow and that it is preferable that no one nozzle should handle more than 1% of the gas flow. Optimum results can be obtained by having a sufficient number of nozzles so that each nozzle will handle between 1/2% and 1-1/2% of the gas flow. For example, with a reactor as shown in Figure 1 having an internal diameter of 6-1/2 feet, a quantity of 86,400,000 standard cubic feet per day of natural gas can be

charged. This gas will be preheated to a temperature of 1000° F.
 and the pressure within the reaction zone is to be maintained at
 three hundred pounds to the square inch. Employing nozzles having
 an outlet diameter of three-quarters of an inch disposed along a
 5 circle having a diameter of approximately five feet, with the
 nozzle centers spaced one inch apart, one hundred and fifty-three
 nozzles for the natural gas are provided in the nozzle manifolds
 28 adapted to jet the natural gas into the reaction zone. Thus,
 each nozzle will handle .65% of the total quantity of the natural
 10 gas charged. The manifolds may be made of stainless steel, the
 diameter of the nozzle manifolds being approximately six inches.
 Gas from the supply manifold is led to the nozzle manifolds through
 pipes 40, 42, 44, 46, 48, 50, 52 and 54. It is to be understood,
 of course, that the transfer pipes 40 to 54, inclusive, may enter the
 15 nozzle manifolds at any appropriate position. The pressure existing
 in the manifold is such that a substantially equal flow is achieved
 through each of the respective nozzles 30 and 34. If desired, a plur-
 ality of transfer pipes may be provided between the supply manifolds
 and the nozzle manifolds, as will be understood by those skilled
 20 in the art.

By the arrangement just described, the plurality of
 nozzles in apposition ^{ENSURE} insure an intimate commingling of the reactant
 gases within the reaction zone, permitting the reaction to take
 place over an extended area under proper process conditions. In
 25 this manner, local excesses of oxygen are avoided and the highly
 exothermic complete oxidation of the methane is minimized. As a
 result of my method and apparatus the partial oxidation reaction
 of methane to produce synthesis gas may proceed continuously
 over long periods of time without danger of burning out the nozzles.
 30 The arrangement and method are such as to ^{ENSURE} insure direct and sub-
 stantially instantaneous commingling of the reactants. This estab-
 lishes process conditions so that the reaction will take place

stoichiometrically to produce the desired primary reaction, that
is, the direct partial oxidation of the hydrocarbon to carbon
monoxide and hydrogen in a manner to minimize the undesirable
secondary reaction. Thus, excessive amounts of carbon dioxide,
5 with the accompanying inordinate heat concomitant to complete
oxidation, are avoided to a large extent. Similarly, the
cracking of portions of the hydrocarbon feed to form solid carbon
is likewise minimized.

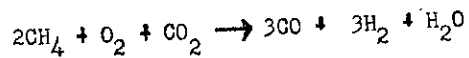
Referring now to Figure 4, another form of apparatus
10 capable of carrying out my process is there shown. It will be
observed that the oxygen supply manifold 60 supplies oxygen through
feeder manifold 62 through pipes 64, 65, 66 and 67 to the nozzle
manifolds 70, 72, 74 and 76. The manifolds 70 and 72 are disposed
on opposite sides of a methane nozzle manifold 78. Similarly,
15 the manifolds 74 and 76 are disposed on opposite sides of a nozzle
manifold 80. Methane from the supply manifold 81 passes through
feeder pipe 83 and thence through pipes 85 and 87 to the nozzle
manifolds 78 and 80. It is to be understood that the pipes 85
and 87 may enter the nozzle manifolds at any appropriate point.
20 The nozzle manifolds 70, 72, 74 and 76 are provided with single
rows of nozzles 30 which are angularly directed toward the nozzle
manifolds 78 and 80. These manifolds are provided with double rows
of nozzles 34 in apposition with their companion nozzles. The
arrangement can readily be seen by reference to Figure 5. Each
25 pair of nozzles 30 and 34 is placed in apposition so that the
jets of the reactant gases will provide a multiplicity of un-
confined streams jetting against each other to produce direct and
substantially instantaneous mixing of the reactants thus to
insure a stoichiometric relation to produce the desired primary
30 reaction in a manner similar to that described in relation to the
apparatus shown in Figures 2 and 3.

Each of the nozzle manifolds may be provided with a spaced jacket wall 80 to provide a jacket 82, as shown in Figure 6, to provide cooling of the metal. This insures that while proper process conditions are being achieved, temporary excesses of oxygen will not result in such high heat as to injure the nozzle manifolds. Similar unbalanced conditions resulting in excess CO₂ production may also result when shutting down the operation. During these periods the insurance provided by the cooling jackets is of advantage.

In the form of the invention shown in Figures 4 and 5, with the same reaction chamber as shown in Figure 1, with the same gas flow at a rate of 100 standard cubic feet per second, the total area of the nozzles is about 67 square inches. With a pressure of 20 atmospheres and a temperature of 1000° F., the nozzles of one manifold will handle a flow of 140 cubic feet per second. Each nozzle will have an outlet area of .44 square inch, thus giving one hundred fifty-three nozzle pairs, enabling each nozzle pair to handle .65% of the total reactant flow.

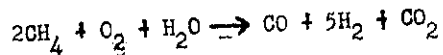
Referring now to Figure 1, I have provided a pipe 90 controlled by a valve 92 adapted to control the delivery of steam from any suitable source into the methane supply manifold 24. In a similar manner pipe 94 communicates with a source of carbon dioxide and is adapted to deliver carbon dioxide to the oxygen supply manifold 20 under the control of the valve 96. If it is desired to produce a reducing gas, say for use in the direct reduction of iron ore, it is advantageous to have an excess of carbon monoxide for the reason that in the reduction of iron ore with carbon monoxide we have an exothermic reaction while the reduction of iron oxide with hydrogen is endothermic. It is desirable to operate the reduction shaft furnace at an elevated temperature and in order to maintain this temperature the generation

of heat by the exothermic reduction is advantageous. In order to produce a mixture of carbon monoxide and hydrogen in which there is a greater proportion of carbon monoxide than hydrogen, I enrich the synthesis gas with carbon monoxide. I open the valve 96 to permit carbon dioxide to be added to the oxygen. The net reaction will be as follows:



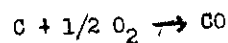
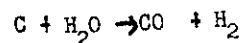
It will be seen that the partial oxidation of methane produces two volumes of hydrogen to one volume of carbon monoxide. In the reaction with carbon dioxide, however, the proportion of carbon monoxide with respect to the hydrogen is increased.

The process can also be employed when it is desired to produce a gas containing preponderantly hydrogen. This is done by introducing steam through pipe 90 into the methane manifold. The reaction is as follows:



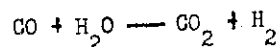
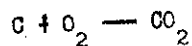
The carbon monoxide and the carbon dioxide may be readily removed and pure hydrogen thus produced.

My process and apparatus are also applicable to the producing of synthesis gas from carbonaceous fuels such as refinery bottoms and coal, including all grades from sub-lignites to anthracite. In this case the coal, for example, is pulverized by grinding in a wet mill to form a slurry of finely divided coal and water in which the coal is present in an amount of from 40% to 60% by weight. The slurry is pumped through a heater and the comminuted coal and steam enters the reaction chamber at temperatures in the vicinity of 1000° F. In this case, the following series of reactions take place:



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By the use of a multiplicity of unconfined streams
jetted against each other I avoid the undesirable complete
oxidation of carbon to carbon dioxide and minimize the secondary
reaction between steam and carbon monoxide to form carbon dioxide
and hydrogen. These reactions are as follows:



It will be found that when using coal as a carbonaceous
reactant that the output gas will have higher percentages of
carbon dioxide present than when using gaseous fuel.

It will be seen that I have accomplished the objects
of my invention. I have provided a method and apparatus for the
generation of synthesis gas which will operate continuously
at maximum capacity and high efficiency without repeated burning
out of the reactant nozzles. By providing a multiplicity of
nozzles whereby to jet the reactant streams in fractional un-
confined jets I insure direct and instantaneous mixing of the
reactants. Thus, the constituents of the feed will react in
stoichiometric relationship to produce the desired primary
reaction, that is, the direct partial oxidation of the carbon-
aceous fuel to carbon monoxide and hydrogen. My method and
apparatus minimizes the undesirable secondary reactions, thus
avoiding the formation of excessive amounts of carbon dioxide and
steam which accompany complete oxidation. At the same time the
unbalance produced by complete oxidation is avoided, thus
minimizing thermal cracking to form solid carbon. I am enabled
to produce a reducing gas rich in carbon monoxide or hydrogen,
as may be desired. My process is applicable to any carbonaceous

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fuel though for synthesis gas more uniform results are obtained when charging gaseous hydrocarbons which are preponderantly methane.

5 It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is
10 therefore to be understood that my invention is not to be limited to the specific details shown and described.

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

1. A method of producing a mixture of carbon monoxide and hydrogen including the steps of continuously jetting over an extended area in a reaction zone a preheated carboniferous reactant in a plurality of unconfined streams against a plurality of preheated unconfined streams of oxygen, maintaining the reaction zone at a temperature between 1800° F. and 3000° F. by regulating the flow of one of the reactants with respect to the other and continuously removing the mixture of carbon monoxide and hydrogen from the reaction zone, the process being such as to partially oxidize the carboniferous reactant while substantially eliminating local excesses of oxygen and the accompanying highly exothermic complete oxidation of the carboniferous reactant.

2. A method of producing a mixture of carbon monoxide and hydrogen including the steps of continuously jetting over an extended area in a reaction zone preheated hydrocarbon in a plurality of unconfined streams against a plurality of preheated unconfined streams of oxygen, maintaining the reaction zone at a temperature between 1800° F. and 3000° F. by regulating the flow of one of the reactants with respect to the other and continuously removing the mixture of carbon monoxide and hydrogen from the reaction zone, the process being such as to partially oxidize the hydrocarbon while substantially eliminating local excesses of oxygen and the accompanying highly exothermic complete oxidation of the hydrocarbon.

A method of producing a mixture of carbon monoxide and hydrogen including the steps of continuously jetting over an extended area in a reaction zone preheated methane in a plurality of unconfined streams against a plurality of preheated unconfined streams of oxygen, maintaining the reaction zone at a temperature between 1800° F. and 3000° F. by regulating the flow of one of the reactants with respect to the other and continuously removing the mixture of carbon monoxide and hydrogen from the reaction zone, the process being such as to partially oxidize the methane while substantially eliminating local excesses of oxygen and the accompanying highly exothermic complete oxidation of the methane.

4. A method of producing a mixture of carbon monoxide and hydrogen by the partial oxidation of methane, including the steps of preheating methane to a temperature about 1000° F., preheating oxygen, jetting the oxygen and methane against each other over an extended area in a plurality of unconfined streams within a reaction zone, adjusting the flow of the oxygen with respect to the methane to maintain the temperature in the reaction zone between 1800° F. and 3000° F. and continuously removing the mixture of carbon monoxide and hydrogen thus formed at a rate to maintain the reactant gases in the reaction zone for not more than one second.

5. A method of producing a mixture of carbon monoxide and hydrogen including the steps of preheating oxygen having a purity of greater than forty per cent to a temperature about 1000° F., preheating a hydrocarbon gas to a temperature about 1000° F., jetting the preheated hydrocarbon gas in a plurality of unconfined streams over an extended area against a plurality of unconfined streams of preheated oxygen within a reaction zone, adjusting the flow of oxygen with respect to the

hydrocarbon gas to maintain the temperature within the reaction zone about 2300° F. and continuously removing from the reaction zone the mixture of carbon monoxide and hydrogen thus formed, the process being such that local excesses of oxygen are minimized and the highly exothermic reaction of complete oxidation of the hydrocarbon gas is minimized.

5
6. A method of producing a mixture of carbon monoxide and hydrogen including the steps of preheating oxygen of a purity of greater than forty per cent to a temperature about 1000° F.,
10 preheating methane to a temperature about 1000° F.,

dividing the oxygen into a plurality of unconfined streams each of which is no greater than three per cent of the total oxygen flow, dividing the preheated methane into a plurality of unconfined streams each of which is no greater than three per
15 cent of the total methane flow, jetting the divided unconfined streams against each other over an extended area within a reaction zone, adjusting the flow of oxygen with respect to the flow of methane to maintain the temperature within the reaction zone between 1800° F. and 3000° F. and continuously removing the mixture of carbon monoxide and hydrogen from
20 the reaction zone, the process being such that a continuous complete and rapid commingling of the reactant gases is achieved to avoid local excesses of oxygen or local deficiencies thereof whereby to avoid excessive production of carbon dioxide and free carbon.

25 7. A method of producing a mixture of carbon monoxide and hydrogen including the steps of preheating oxygen of a purity of greater than forty per cent to a temperature about 1000° F., preheating methane to a temperature about 1000° F., dividing the oxygen into a plurality of unconfined streams each of which is between one-half per cent and one and one-half per
30 cent of the total oxygen flow, dividing the preheated methane into a plurality of unconfined streams each of which is between

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one-half per cent and one and one-half per cent of the total methane flow, jetting the divided unconfined streams against each other over an extended area within a reaction zone, adjusting the flow of oxygen with respect to the flow of methane to maintain the temperature within the reaction zone between 1800° F. and 3000° F. and continuously removing the mixture of carbon monoxide and hydrogen from the reaction zone, the process being such that a continuous, complete and rapid commingling of the reactant gases is achieved to avoid local excesses of oxygen or local deficiencies thereof whereby to avoid excessive production of carbon dioxide and free carbon.

8. Apparatus for producing synthesis gas including in combination a reaction vessel, a refractory lining for said vessel, a plurality of nozzle manifolds positioned within the reaction vessel, said nozzle manifolds occupying an extended area within the reaction vessel, said nozzle manifolds being formed with a plurality of nozzles, the respective nozzles in one manifold being directed toward the respective apposite nozzles of an adjacent manifold, means for supplying a reactant to one nozzle manifold and means for supplying another reactant to an adjacent nozzle manifold, the construction being such that the reactants will be jetted against one another within the reaction vessel.

9. Apparatus for producing synthesis gas including in combination a reaction vessel, a refractory lining for said vessel, a plurality of nozzle manifolds positioned within the reaction vessel, said nozzle manifolds occupying an extended area within the reaction vessel, said nozzle manifolds being formed with at least thirty-four pairs of nozzles, the respective nozzles in one manifold being directed toward the respective apposite nozzles of an adjacent manifold, means for supplying a reactant to one nozzle

manifold, means for supplying another reactant to an adjacent nozzle manifold and separate means for controlling the flow of the reactants through said supply means, the construction being such that the reactants will be jetted against one another within the reaction vessel.

10. Apparatus as in Claim 9 in which said nozzle manifolds are provided with cooling jackets.

11. Apparatus as in Claim 9 in which said nozzle manifolds are arranged in a plurality of pairs.

12. Apparatus as in Claim 9 in which one of said nozzle manifolds is provided with a pair of rows of outwardly directed nozzles adapted to jet one of the reactants, there being a pair of nozzle manifolds disposed on opposite sides of said first manifold, flanking the same, each of said flanking manifolds being provided with a single row of nozzles direction toward the nozzles in the first manifold and being adapted to receive the other reactant.

13. Apparatus as in Claim 9 in which said nozzles are formed with a converging-diverging cross section whereby to convert pressure energy within the manifolds to velocity energy.

14. Method of producing a mixture of carbon monoxide and hydrogen including the steps of continuously jetting methane in a plurality of unconfined streams against a plurality of unconfined streams of oxygen over an extended area in a reaction zone, maintaining the reaction zone at a temperature to sustain the reaction by regulating the flow of one of the reactants with respect to the other, continuously introducing steam into the methane reactant and continuously removing the mixture of carbon monoxide and hydrogen which is preponderantly hydrogen, the process being such as to partially oxidize the methane while substantially minimizing local excesses of oxygen and the accompanying highly exothermic complete oxidation of methane.

15. A method of producing a mixture of carbon monoxide and hydrogen containing more than thirty-five per cent of carbon monoxide by volume, including the steps of continuously jetting methane in a plurality of unconfined streams against a plurality of unconfined streams of oxygen over an extended area in a reaction zone, maintaining the reaction zone at the desired reaction temperature by regulating the flow of one of the reactants with respect to the other, continuously adding carbon dioxide to the oxygen reactant and continuously removing the desired mixture of carbon monoxide and hydrogen from the reaction zone, the process being such as to partially oxidize the methane while substantially eliminating local excesses of oxygen and the accompanying highly exothermic complete oxidation of methane.

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16. A method of producing a mixture of carbon monoxide and hydrogen including the steps of continuously jetting over an extended area in a reaction zone a hydrocarbon in a plurality of unconfined streams against a plurality of unconfined streams of oxygen, maintaining the reaction zone at a temperature between 1800° F. and 3000° F. by regulating the flow of one of the reactants with respect to the other of the reactants and continuously removing the mixture of carbon monoxide and hydrogen from the reaction zone, the process being such as to partially oxidize the hydrocarbon while substantially eliminating local excesses of oxygen and the accompanying highly exothermic complete oxidation of the hydrocarbon.

17. Apparatus for producing synthesis gas including in combination a reaction vessel, a plurality of nozzle manifolds, nozzles communicating with said nozzle manifolds and occupying an extended area within the reaction vessel, the respective nozzles communicating with one manifold being directed toward the opposite nozzles communicating with the other manifold, means for supplying a reactant to one nozzle manifold and means for supplying another reactant to the other nozzle manifold, the construction being such that the reactants will be jetted against one another over an extended surface within the reaction vessel.

18. A method of producing a mixture of carbon monoxide and hydrogen including the steps of continuously jetting over an extended area in a reaction zone a hydrocarbon in a plurality of unconfined streams against a plurality of unconfined streams of oxygen, maintaining the reaction zone at a temperature substantially above the ignition temperature of methane but below its thermal cracking range by regulating the flow of one of the reactants with respect to the flow of the other of the reactants and continuously removing the mixture of carbon monoxide and hydrogen from the reaction zone, the process being such as to partially oxidize the hydrocarbon while substantially eliminating local excesses of oxygen and the accompanying highly exothermic complete oxidation of the hydrocarbon.

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FIG 1

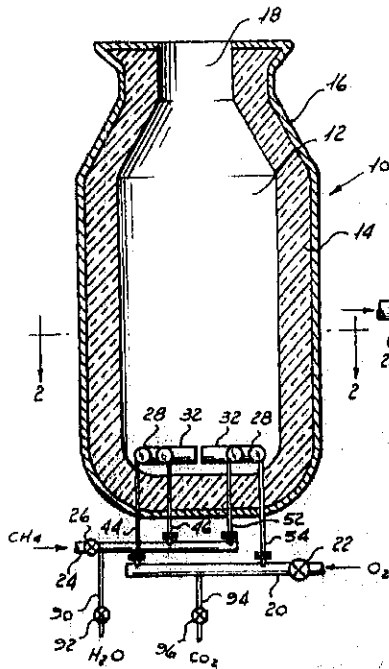


FIG 2

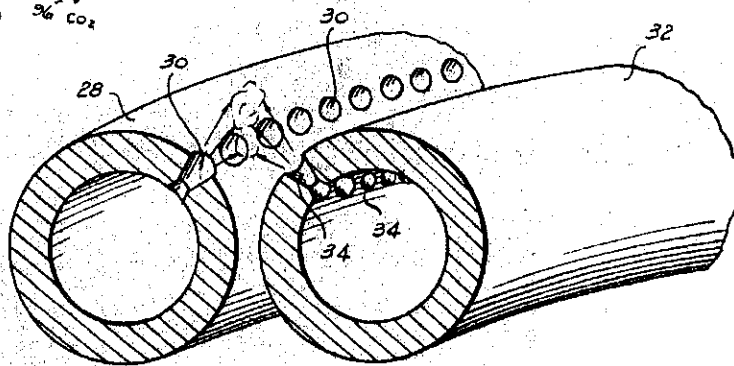
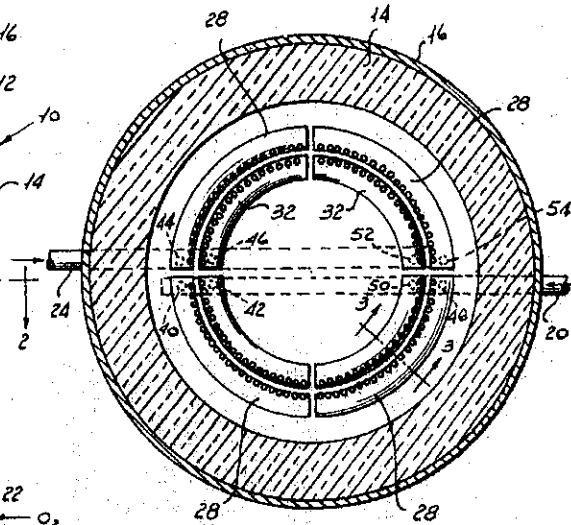


FIG 3

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Fig 4

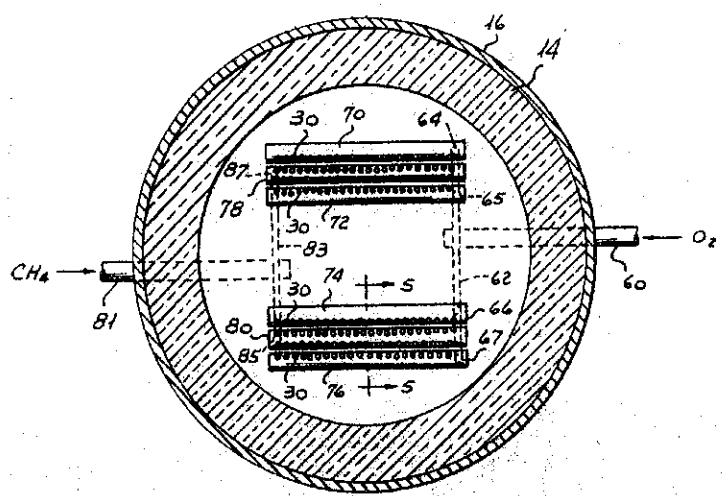
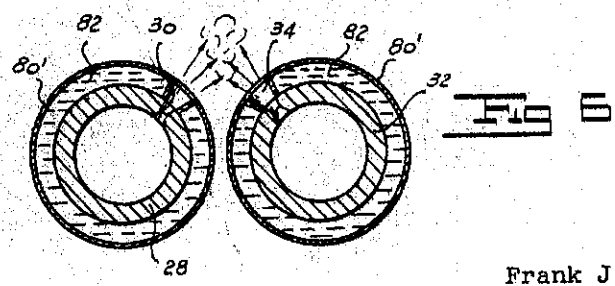
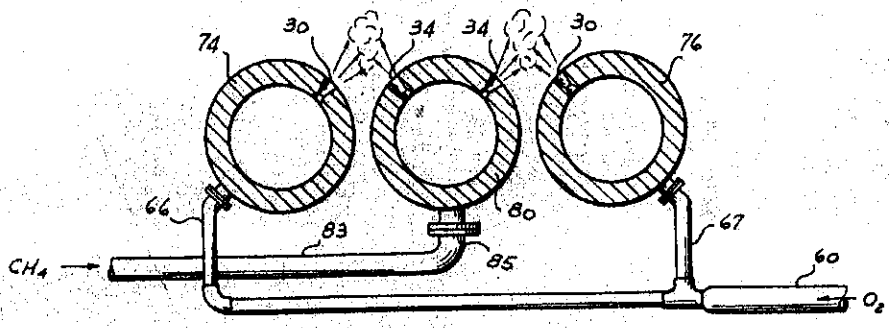


Fig 5



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