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[54] **APPARATUS AND PROCESS FOR BURNING LIQUID HYDROCARBONS IN A SYNTHESIS GAS GENERATOR**

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[*] Notice: The portion of the term of this patent subsequent to July 3, 1990, has been disclaimed.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 5,444, Jan. 23, 1970, Pat. No. 3,743,606, which is a continuation-in-part of Ser. No. 787,885, Dec. 30, 1968, abandoned.

[52] **U.S. Cl.** **48/95,** 48/215, 252/373
[51] **Int. Cl.** **C07c 1/02**
[58] **Field of Search** 48/95, 215; 252/373

[56] **References Cited**

UNITED STATES PATENTS

3,743,606	7/1970	Marion et al.	48/95 X
2,809,104	10/1957	Strasser et al.	48/214 X
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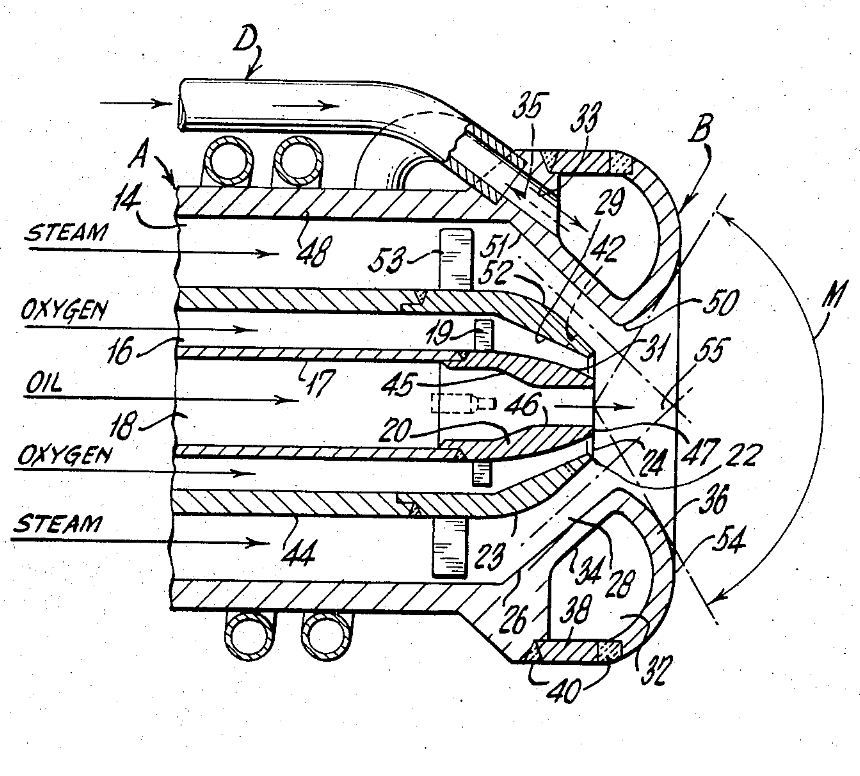
[57] **ABSTRACT**

This disclosure pertains to a triple-orifice burner and process for atomizing a stream of normally liquid hydrocarbon with a separate stream of free-oxygen-containing gas a finite distance downstream from the tip of the burner and for simultaneously enveloping the mixed streams with a separate stream of temperature-moderating gas so that none of the three streams comes into contact with any other gas with which it is combustible until it reaches a distance downstream from the tips of the burner orifices beyond that close enough to cause appreciable deterioration of the tips when reaction takes place in a free-flow partial oxidation gas generator at a temperature in the range of about 1,200° to 3500°F. and at a pressure in the range of about 1 to 275 atmospheres to produce a gaseous mixture comprising principally H_2 and CO, e.g., synthesis gas, reducing gas, or fuel gas. While the liquid hydrocarbon is passed through the burner at a velocity in the range of about 10 to 100 feet per second, both the stream of free-oxygen-containing gas and the stream of temperature-moderating gas may be passed through the burner at velocities up to sonic velocity when it is desired to offset the effects of variable back pressure in the gas generator.

The burner comprises three coaxial concentric nozzles whose tips are recessed from the downstream tip of the burner and which discharge into a single unobstructed coaxial central outwardly-diverging passage with an annular face of convex configuration at the extremity of the downstream tip of the burner. An imaginary plane tangent to said annular face at its outermost extremity is normal to the burner axis. The three nozzles provide, respectively, a central passage with a circular opening for discharging a stream of liquid hydrocarbon, an intermediate converging annular passage for discharging a stream of free-oxygen-containing gas, and an outer converging annular passage for discharging a stream of temperature-moderating gas, such as steam. An annular coolant chamber is disposed about the outside periphery of said outer discharge passage and downstream burner tip.

19 Claims, 3 Drawing Figures



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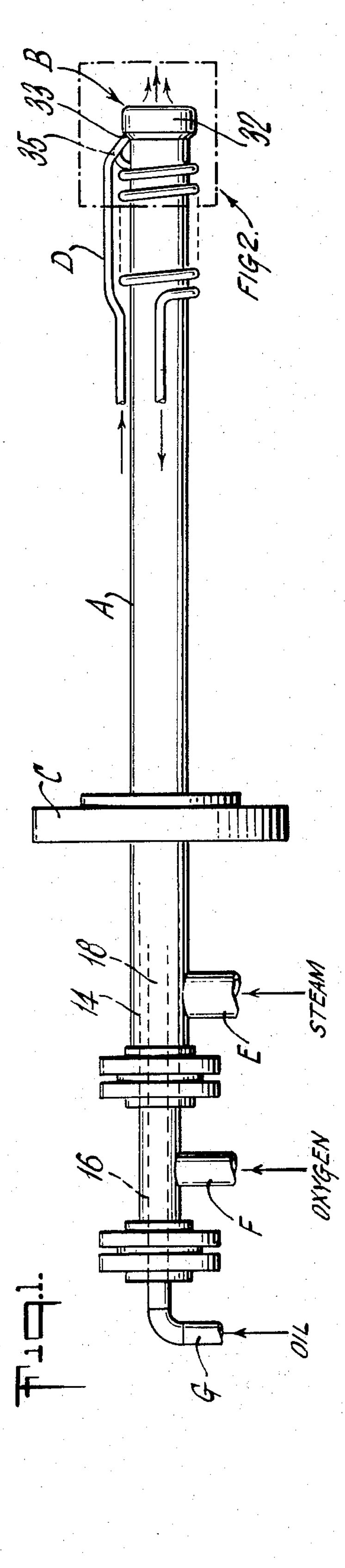

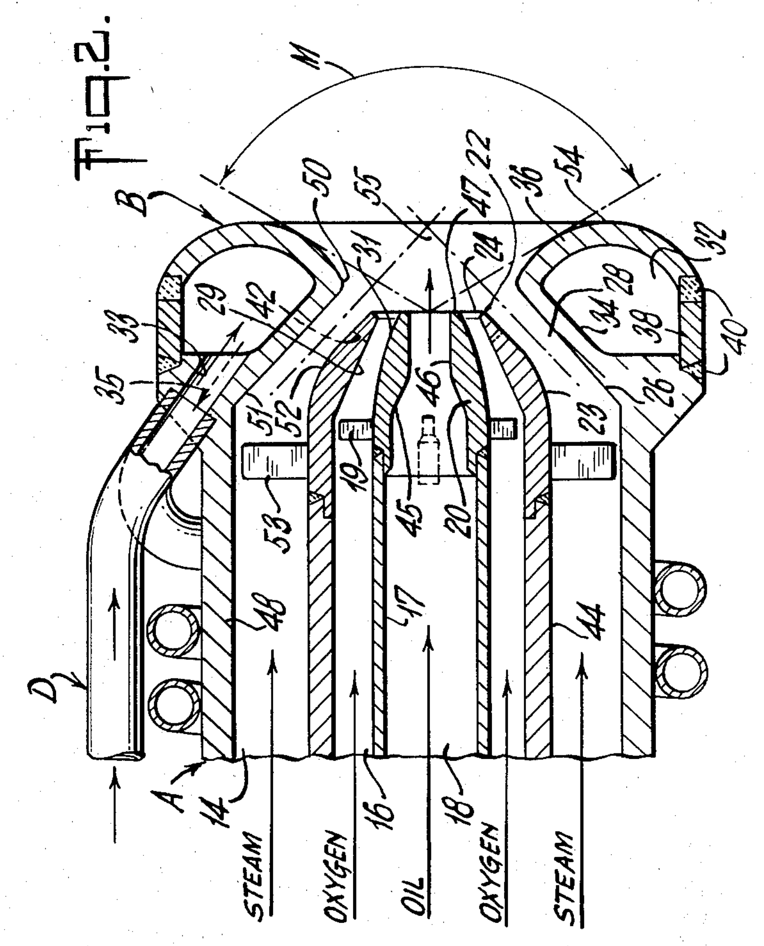

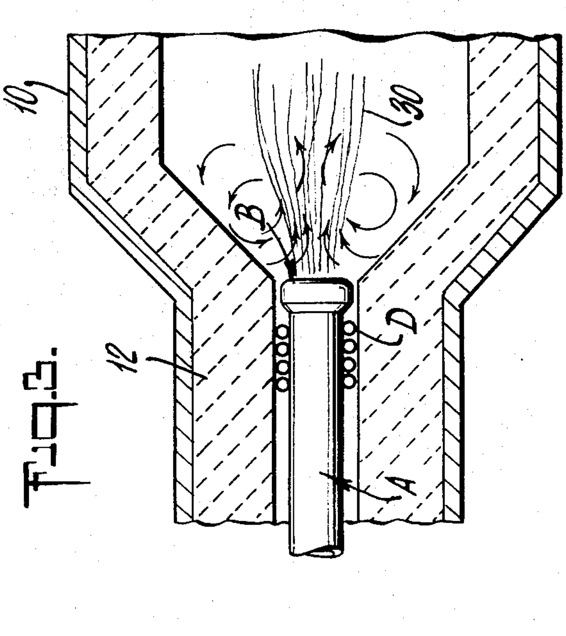

APPARATUS AND PROCESS FOR BURNING LIQUID HYDROCARBONS IN A SYNTHESIS GAS GENERATOR

This application is a continuation-in-part of copending coassigned application entitled SYNTHESIS GAS GENERATION, Ser. No. 5,444 filed Jan. 23, and which issued as U.S. Pat. No. 3,743,606 on July 3, 1973, which is a continuation-in-part of coassigned application Ser. No. 787,885 filed Dec. 30, 1968 now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This specification relates to a triple-orifice burner and process for introducing a liquid hydrocarbon, a free-oxygen-containing gas and a temperature-moderating gas into a noncatalytic free-flow partial oxidation gas generator to effect reaction therein and to produce gaseous mixtures comprising H_2 and CO, e.g., synthesis gas, reducing gas, and fuel gas.

2. Description of the Prior Art

In the generation of synthesis gas, i.e., gaseous mixtures principally comprising H_2 and CO, by the partial oxidation of a hydrocarbon fuel with a free-oxygen-containing gas, extremely high temperatures are reached, i.e., 1,200°F. and higher. While it is necessary for the synthesis gas burner to effect very rapid and complete mixing of the reactants, it is imperative that the burner or mixer be protected from overheating and/or chemical attack which may lead to subsequent failure.

Inadequate mixing of the reactants causes high oxygen concentrations to accumulate in localized areas. Complete combustion of a portion of the fuel then takes place in these areas with the release of large quantities of heat. Also, because of the reactivity of oxygen and sulfur with the metal from which the burner is fabricated, rapid oxidation, sulfidation, and deterioration of the burner metal takes place. Another problem is due to recirculating combustible gases at the tip of the burner with ensuing combustion near the burner surfaces that causes over heating and failure of the burner tips. Further, the burner elements may be subjected to heating by radiation and to the formation of carbon on the burner surfaces. This radiation also causes overheating and burner failure. When the reactants are introduced in a highly preheated state, to reduce the oxygen requirements and to increase the yield of product gas, the problem is further aggravated.

The structural design of conventional burners requires improvement to increase their life. For example, conventional annular type burners are usually equipped with a flat-faced coolant chamber at the tip of the burner. Such designs present wide flat bands of metal to the high temperatures prevailing at the burner tip. Further, in such prior-art designs, the wall thickness of the burner face must be heavy to withstand large pressure differentials. In such cases, heat conduction is impaired, and such burners fail due to overheating.

Some burners contain a plurality of small-diameter holes arranged in a circular pattern at the tip of the burner. Such holes tend to cause uneven mixing of the reactants at the burner face, localized overheating, dead flow spaces, and uneven cooling of both sides of

the metal elements of the burner tip. Further, there is danger of holes clogging.

SUMMARY

This specification discloses a novel triple-orifice burner and process for introducing a liquid hydrocarbon, free-oxygen-containing gas and a temperature-moderating gas into a gas generator in which reaction takes place at a minimum temperature of about 1,200°F. The liquid hydrocarbon is passed through the central or intermediate orifice of the burner. Alternately, the free-oxygen-containing gas is simultaneously passed through the central or intermediate orifice not being used by the liquid hydrocarbon. Simultaneously, the temperature-moderating gas is passed through the outer orifice. While the velocity of the liquid hydrocarbon stream is comparatively low, e.g., 10 to 100 feet per second, the velocities of the stream of free-oxygen-containing gas and the stream of temperature-moderating gas may be 600 feet per second, and even up to sonic velocity when it is desired to offset the effects of variable back pressure in the gas generator. By this means, gaseous mixtures comprising hydrogen and carbon monoxide are produced, e.g., synthesis gas, reducing gas, or fuel gas. The triple-orifice burner comprises:

1. a central axial tubular conduit, inlet means at the upstream end of said central conduit, a central discharge nozzle at the downstream end of said central conduit having an inwardly-converging tapered outer surface and a single unobstructed circular discharge passage;

2. an intermediate coaxial concentric tubular conduit disposed radially about the outside of said central tubular conduit along its length, inlet means at the upstream end of said intermediate concentric conduit, an intermediate coaxial concentric inwardly-converging frusto-conically shaped discharge nozzle with a circular tip at the downstream end of said intermediate concentric conduit, means for positioning said central axial conduit and central discharge nozzle with respect to said intermediate concentric conduit and intermediate discharge nozzle in spaced relationship thereby providing an intermediate annular passage having a single unobstructed inwardly-converging annular discharge passage at the downstream end;

3. an outer coaxial concentric tubular conduit radially disposed about the outside of said intermediate coaxial concentric conduit along its length, inlet means at the upstream end of said outer concentric conduit, an outer coaxial concentric inwardly-converging frusto-conically shaped discharge nozzle at the downstream end of said outer concentric conduit, means for positioning said outer concentric conduit and outer discharge nozzle with respect to said intermediate concentric conduit and intermediate discharge nozzle in spaced relationship thereby providing an outer annular passage having an unobstructed inwardly-converging annular passage that discharges into a single unobstructed concentric coaxial outwardly-diverging central passage at the downstream tip of said burner;

4. a coolant chamber at the downstream tip of said burner comprising an inside section that comprises said outer inwardly-converging frusto-conically shaped discharge nozzle of (3), an outside section that extends from and flares out from said inside section and which comprises an outwardly-diverging section with an an-

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nular face of convex configuration at the outer extremity of the downstream tip of the burner, said outside section being in part the peripheral surface of said outwardly-diverging tapered central passage of (3), a collar section joining said inside and outside sections and closing said coolant chamber, and inlet and outlet means for circulating coolant through said coolant chamber; and

5. conduit means in contact with said burner and connected to said inlet and outlet means for passing coolant fluid in direct heat exchange with said burner.

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. **1** to **3** of the drawing wherein:

FIG. **1** is a general illustration of the burner assembly.

FIG. **2** is an enlarged sectional view of the downstream end of the burner assembly, as indicated by the dot-and-dash box on FIG. **1.**

FIG. **3** is a diagrammatic representation of a burner shown in position within the reaction chamber and exemplifying in general the flow of reactants from the burner tip and recirculating synthesis gas at the periphery.

DESCRIPTION OF THE INVENTION

The present invention relates to a burner and process for producing gaseous mixtures comprising a mixture of hydrogen and carbon monoxide, e.g., synthesis gas, reducing gas, or fuel gas. More particularly, it involves a burner for the manufacture of this product at an elevated pressure and temperature by the partial combustion of a liquid hydrocarbon by a free-oxygen-containing gas in the presence of a gaseous moderator such as H_2O, CO_2, nitrogen, flue gas, and mixtures thereof.

As is known, hydrocarbons can be converted substantially into carbon monoxide and hydrogen by controlled reaction with oxidizing agents of the class consisting of molecular oxygen, water vapor and CO_2. The reaction with oxygen is an exothermic one, while the two latter agents react endothermically. Therefore, to conduct a self-supporting reaction calls for the use of a free-oxygen-containing gas. This free-oxygen-containing stream comprises preferably air, substantially pure oxygen (95 mole percent O_2 or higher) or oxygen-enriched air, as, for example, an air-oxygen mixture containing more than 21 percent of molecular oxygen. It is advantageous to carry out the partial combustion at an elevated pressure above 200 pounds per square inch, as, for example, in the range of 400 to 4,000 psi. On the other hand, it will operate at low pressures, such as one or two atmospheres.

The noncatalytic partial oxidation reaction preferably takes place within an unobstructed refractory-lined steel pressure vessel, under relatively turbulent conditions for a time period of from 0.5 to 8 seconds. For purposes of the present invention, neither the time nor pressure of reaction appears to be either critical or controlling. Reference is made to FIG. 1 of coassigned U.S. Pat. No. 2,838,105, DuBois Eastman et al, showing a typical free-flow synthesis gas generator with an axially aligned gas burner mounted in the upper head.

The burner for introducing the feed materials is necessarily subjected to intense heat and pressure. Furthermore, apart from the intense heat radiation to which the burner is subjected from the interior of the reactor, turbulent circulation of combustion gases sweeping the exposed nozzle surfaces subjects them to conditions of erosive and chemical attack. Even under the influence of internal cooling, the intense rate of heat flow may result, in the absence of the subject invention, in deterioration of the burner and may introduce hazards arising from mechanical failure.

In accordance with the present invention, the two reactant streams and the stream of temperature-moderating gas are introduced into the reaction chamber by means of a burner consisting of three concentric nozzles, so designed and operated as to obviate in large measure the detrimental effects previously referred to. In a preferred embodiment, the liquid hydrocarbon may be introduced through a central nozzle. Simultaneously, the free-oxygen-containing gas stream separately flows from an intermediate annular nozzle surrounding the central nozzle at a linear velocity substantially greater than that of the liquid hydrocarbon and converging at an acute conical angle to the axis of the hydrocarbon stream. As a result, this fuel is subjected to a shearing action by which it is first torn into ligaments and them atomized into fine droplets. The droplets form a mist downstream, finely dispersed in the free-oxygen-containing gas stream, and of such minuteness as to provide an intimacy of contact favorable for subsequent partial oxidation. Likewise, the two streams may be reversed, the free-oxygen-containing gas stream entering via the central nozzle and the liquid hydrocarbon via the intermediate annular nozzle, insofar as the parts are arranged to effect atomization a predetermined distance downstream of the tip. In this case the velocity of the stream of temperature-moderating gas, to be further described, should exceed the velocity of the annular hydrocarbon stream by at least 100 feet per second.

A third or outer stream of temperature-moderating gas or moderator, e.g., steam or water droplets, is simultaneously passed through an outer annular nozzle surrounding the intermediate nozzle and may flow at a linear velocity equal to or substantially less than that of the intermediate atomizing stream of molecular oxygen, e.g., one-half. For example, when the velocity of the temperature-moderating gas is lower, the turbulent flow of hot recirculating gas across the surfaces of the outermost nozzle is less, and chemical or physical deterioration of the exposed nozzle portions is reduced.

The reactant streams are maintained separate from one another, and none can intermingle with any other until it leaves its respective tip and is injected into the reaction chamber to intermingle with the adjacent streams at a small, though finite, distance from the extremity of the burner tip. Accordingly, neither the liquid hydrocarbon, e.g., oil, nor the free-oxygen-containing gas, e.g., oxygen, nor the temperature-moderating gas, e.g., steam, conduit, nor the extremities thereof, is directly contacted by burning mixture. This result follows also from the fact that the oxygen and oil streams, and particularly the oxygen stream, are blanketed by the outer annular sheath of moderator, such as steam or water vapor; and thereby the oxygen is prevented from contacting and burning with recirculating synthesis gas until a substantial distance downstream from the burner tips.

As previously indicated, by decreasing the linear velocity of the outer annular flow of stream with respect to the flow of oxygen, the peripheral energy can be decreased and the turbulence or recirculation accordingly reduced. Accordingly, where high momentum of flow causes objectionably high rates of heat transfer and associated corrosive and/or erosive effects of the gases on the burner tip, a decrease in the velocity of steam flow to, for example, a velocity which is substantially less than that of the oxygen stream, correspondingly lessens the violence of the eddy induced by the burner. Since heat flow varies with gas velocity, rate of heat transfer from the reaction zone to the burner tip is also diminished, along with the corrosive or erosive effects from the recirculating hot gases.

Yet further it is to be observed that the annular sheath of moderator provides the surrounding volume in the vicinity of the outer tip of the burner with an endothermic reactant, for example, water vapor, which in its reaction with hydrocarbons is essentially a heat-absorbent as distinguished from a heat-liberating reactant, such as oxygen.

From the foregoing it will be apparent that the term "moderator" or "temperature-moderating gas" as used herein consists of steam or water droplets, as exemplified above, or any gaseous material which is either inert or substantially inert with respect to the other constituents of either the feed or the reaction zone. By "substantially inert" it is meant to include constituents which react endothermically in forming the final product or with such a small degree of exothermicity as to be negligible. Specifically, therefore, the term "moderator" as used herein, or "temperature-moderating" gas, is restricted to gaseous materials, such as steam or water droplets, carbon dioxide, inert gases (such as nitrogen), flue gas and off-gas from an ore-reduction zone which are rich in one or more of the aforesaid moderators, and mixtures thereof. It is to be particularly understood that the inerts, while broadly usable, have the disadvantage of diluting the reaction product. Where dilution is objectionable and where the diluent is not easily separable, carbon dioxide and water in the form of steam or water droplets are the preferred temperature moderators.

By way of example, the following flow velocities represent typically illustrative flow conditions prevailing at the nozzle in the system described above.

	Velocity Range (feet per second)		
	Preferred	Extended	Broad
Liquid hydrocarbon	10–50	10–100	10–100
Free-oxygen-containing gas	200–600	over 600 to sonic	at least 100 ft./sec. greater than the velocity of liquid hydrocarbon stream, e.g., 110 to sonic velocity
Temperature-moderating gas	55–300	over 300 to sonic	greater than the linear velocity of liquid hydrocarbon stream, e.g., 55 to sonic velocity

These velocities can be varied according to the size, pressure, and other operating requirements of the system; but the relative velocity of the atomizing stream, namely, the free-oxygen-containing gas, is necessarily kept substantially greater than that of the oil stream so as to enable the free-oxygen-containing gas to effect the necessary atomization of the oil and the admixture with oxygen to form a burning mist. While this can be done with a relative velocity of the free-oxygen-containing gas as low as 50 to 100 feet per second, it is preferable to effect atomization at a velocity at least 100 feet per second (and preferably more than 100–300 feet per second) greater than that at which the oil is ejected from its nozzle, for example, in the range of 200–600 feet per second and advantageously in the range of over 600 feet per second to sonic velocity. The upper limit of the velocity for the free-oxygen-containing gas may be that at which atomization and admixture are completely effective and at which further increase in velocity offers no advantage. Nevertheless, within this range the higher oxygen velocities and the resulting small size of oil drops and intimacy of admixture with oxygen ultimately lead to maximum reaction efficiency, as evidenced, for example, by low soot formation.

As intimated above, where the problems of high injection momentum and eddying in the reaction zone are not a problem, there is no upper limit of moderator velocity. Thus, in another embodiment of the invention where it is desired to eliminate the effect of gas generator pressure variations upon the free-oxygen-containing gas feedstream and the temperature-moderating gas feedstream, the velocities of both of these feedstreams passing through the burner may be increased to cover the range of above 600 feet per second to sonic velocity for the free-oxygen-containing gas and above 300 feet per second to sonic velocity for the temperature-moderating gas. Further, where pressure surges and fluctuations in the gas generator are a maximum, it is preferable to simultaneously pass both the free-oxygen-containing gas stream and the temperature-moderating gas stream through the burner at sonic velocity.

As shown above, in the type of burner disclosed, the central nozzle has been found to be relatively immune from attack in service because it is physically spaced from any combustible mixture and further because the liquid oil, although it may be and desirably is preheated, nevertheless acts as an efficient protective coolant for the metal tip. The oil cannot be burned until it is atomized, and possibly vaporized, a finite distance downstream from the burner tip. This result follows from the fact that oxygen or free-oxygen-containing gas cannot burn immediately with unvaporized and unatomized oil.

The inner annular tip is also relatively immune from attack since it is not in contact with a combustible mixture. Steam cannot burn with oxygen. This tip, therefore, is not attacked unless overheated, from which it is protected by a limited exposure as well as by the coolant effects of the oxygen and steam flows upon its inner and outer surfaces, respectively.

The outer annular tip or nozzle is also relatively immune from attack because it likewise is not in contact with a combustible mixture. This tip is contacted only by a stream of steam and by the surrounding eddy of circulating synthesis gas within the combustion chamber, as described above. Steam cannot burn with synthesis gas (in an appreciably exothermic reaction), al-

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though it can react by the water-gas shift in a very mildly exothermic reaction.

As above indicated, the rate of heat transfer from the reaction chamber to the outer tip or face of the outer annular nozzle is controllable by selecting a moderator velocity low enough so that the kinetic energy imparted to the recirculation of the hot synthesis gas across the jacket face is substantially restricted. This method, accordingly, limits the heat flux, as well as the thermal and mechanical stresses, and physical and chemical corrosion and/or erosion of the outer jacket wall. Moreover, strength can be increased by using a wall of convex shape in a relatively thin section.

It is to be understood that part of the moderator may be intermixed with the oxygen stream in the intermediate annular nozzle, preferably in an amount less than about 25 weight percent of the oxygen.

As also previously intimated, each of the three streams of reactants, being separately supplied, may be independently preheated to the desired degree.

The tip-atomizing type of equipment to which the present invention pertains, as previously indicated, normally involves impingement of one reactant stream, such as oxygen, upon another, such as a liquid hydrocarbon, to disrupt, tear and, in effect, to atomize the liquid into a finely dispersed spray of droplets. In a general way, for example, the mixing effect is based upon such variables as the relative difference in velocity between two streams where the oxygen stream has a linear velocity greater than the central stream of liquid oil. It also depends on the angle of impingement of the two streams as, for example, where the oxygen stream is inclined toward and gradually impinges on the central stream of oil.

In the present embodiment, the converging angle between the axis of the burner and the intermediate and outer frusto-conically shaped annular discharge nozzles may, for example, vary widely.

It is clear that a more obtuse angle may bring the point of combustion to quite close to the burner face, whereas a somewhat more remote point might be more conducive to burner durability.

In the preferred embodiment of the present invention, the angles of the orifices to the axis of the burner are as follows, the central nozzle preferably being coaxial with the axis of the burner and the two annular nozzles being arranged to eject inwardly-converging conical streams, the conical surfaces of which make an angle with the longitudinal axis of the burner with the following ranges:

	Preferred Angle °	Broad Angle °
Stream ejected from the intermediate coaxial inwardly-converging discharge nozzle	20–35	10–55
Stream ejected from the outer coaxial inwardly-converging discharge nozzle	25–45	15–60

Likewise, mention is made of the desirability of avoiding any break or interruption in the annular sheath of moderator issuing from the outer annular orifice, such as would be caused by irregularities, separators, projections, etc., in the burner orifice and to assure a uniform, uninterrupted sheath of projective gas.

Moreover, where a relatively thick sheath of moderator issues from the outer orifice, the relative velocity difference between the intermediate and outer orifice streams may obviously be greater. Thus, for example, if a thin sheath of moderator is substituted in the foregoing example, a correspondingly greater linear velocity of moderator stream would be desirable in order to protect and sheath the oxygen stream between the orifice tip and the point of reaction with synthesis gas. Thus, if instead of a moderator stream having a width of 0.53 inches and a velocity of 151 feet per second, as shown in the specific example, the moderator sheath has a radial thickness of, for example, 0.25 inches or less, its velocity would preferably be in the neighborhood of 200 feet per second.

The proportions of reactants and their distribution in the various streams are such as to produce a product gas of the desired composition in the noncatalytic free-flow partial oxidation synthesis gas generator at a reaction temperature in the range of about 1,200° to 3,500°F. and at a pressure in the range of about 1 to 275 atmospheres. Reference is made to prior art literature such as:

Partial Combustion of Residual Fuels by W. L. Slater and R. M. Dille, Texaco Inc., Montebello, California. Reprinted from Chemical Engineering Progress, November 1965.

As previously stated, the present invention is concerned with the partial combustion of normally liquid hydrocarbons. This, therefore, specifically means those which are liquid at ambient conditions and temperatures therebelow. This includes, for example, butanes, pentanes, hexanes and on up through the entire liquid range including natural gasolines, kerosenes, gas oils, napthas, diesel fuels, crude oils, residua, whether atmospheric or vacuum, coal tars, tar sand oils, shale oils, as well as hydrocarbons which may contain other atoms, such as oxygen; however, in such proportions as not to interfere with self-sustaining combustion. Included by definition are slurries of solid carbonaceous fuels in the aforesaid liquid hydrocarbons.

Specifically, it may also be stated that the invention includes all hydrocarbons having a gravity in the range of from minus 15° API to 150° API.

The proportioning of the reactants, as is obvious from the references, calls for limitation of the oxidizing agents sufficient to effect only "partial oxidation" which the prior art includes and which is understood to mean the production of gaseous carbon monoxide and hydrogen to the limitation of complete oxidation products, namely H_2O and CO_2.

The selection, therefore, is a matter of design obvious to the skilled engineer, in view of the present invention and of the prior art, realizing, for example, that the lower gravity hydrocarbons tend to produce higher adiabatic flame temperatures and thus to require greater proportions of the moderating oxidants, such as CO_2 and H_2O, and thus to increase the relative production of the desired products and to alleviate and to moderate otherwise excessive temperatures within the reaction zone. Where, in a typical example, temperatures tend to run over 2,400°–2,500°F., the designer may ordinarily wish to substitute moderator in the form of CO_2 or H_2O for pure oxygen, as is fully known in the art.

Conversely, it is the same moderator requirement in the case of liquid hydrocarbons which enables the introduction of an outer protective sheath of moderator in accordance with the present invention, which would

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not otherwise be feasible in the case of those gaseous hydrocarbons wherein the available exothermal heat in the presence of oxygen may be insufficient to permit substantial use of moderators.

With respect to the question of the dimensions of the orifice openings, these obviously follow from the throughput of ingredients of feed materials and the selected nozzle velocities as determined by the requirements set forth in this disclosure.

Referring to the feature of intermixing a portion of the added steam with the stream of oxygen, this is usually preferred by the designer where there is a special tendency for an over-intensified localized combustion to occur close to the tip of the nozzle, such as may occur where a quite volatile liquid hydrocarbon is employed and which tends to vaporize and, therefore, to mix and to react rapidly with pure oxygen. This sequence, in the case of preheated volatile hydrocarbons which tend to liberate intensive heat close to the nozzle, may be overcome to a large extent by alloting a portion of moderator to the oxygen stream in order to slow down the reaction between the oxygen and liquid hydrocarbon.

Conversely, with non-volatile liquid oil, which must be either extensively vaporized or atomized before it can be involved in any extensive combustion, the introduction of steam within the oxygen stream may be unnecessary.

In general, however, steam dilution of more than 25 weight percent of the stream of oxygen is not usually necessary or advisable for the purpose of adequately moderating the activity of the oxygen stream.

Therefore, while it may be preferable in the case of ordinary heavy liquid hydrocarbon to include 100 percent of the added steam in the sheath, a proportion of this steam, determined by the design factors, may be transferable to the oxygen stream, or mixed with the liquid hydrocarbon.

DESCRIPTION OF THE DRAWING

A more complete understanding of the invention may be had by reference to the accompanying drawing which illustrates in FIGS. **1** through **3** a preferred embodiment of this invention.

The burner assembly, as shown in FIG. **1**, comprises means for introducing the several streams into the reaction zone of the synthesis gas generator. Inlet E conducts a flow of temperature-moderating gas, such as steam, to an outer annular passage **14**. A free-oxygen-containing gas, such as substantially pure oxygen, is introduced at inlet F as a feed to an intermediate annular passage **16**, whereas the liquid hydrocarbon supply, such as oil, is introduced at inlet G into central axial passage **18**.

The heat-exposed annular face of the burner assembly is of smooth convex configuration at the downstream tip B. Flange plate C is used to position the burner in the flanged inlet at the top of a synthesis gas generator (not shown). Coolant coils D are shown coiled around and in contact with the outside surface of the burner near the downstream end. The coolant tubes are shown connected to coolant chamber **32** so that coolant may enter by way of inlet **33** and depart by way of adjacent outlet **35**.

With reference to FIG. **2**, a sectional view of the downstream end of the burner assembly, central feed nozzle **20** is attached to the extremity of central conduit **17** as, for example, by welding or by threading. The burner is shown substantially symmetrical and concentric about the longitudinal axis.

Central nozzle **20** is characterized by a tapered portion **45** inwardly converging towards the longitudinal axis of the burner, a cylindrical portion **46**, and a circular discharge orifice at tip **47** at the downstream end. Preferably, tapered portion **45** of central nozzle **20** is faired into cylindrical portion **46** in such a way as to produce a flat velocity profile across the cylindrical section. A plurality of fins or locking lugs **19** are located at several positions to align, to space, and to position laterally and longitudinally central conduit **17** and central nozzle **20** with respect to intermediate coaxial concentric frusto-conically shaped converging annular discharge nozzle **23**. Intermediate nozzle **23** extends from and is preferably welded to intermediate coaxial concentric conduit **44**. Intermediate conduit **44** is disposed radially about the outside of central conduit **17** along its length, thereby providing intermediate annular passage **16** and annular discharge orifice **24**.

Intermediate nozzle **23** converges inwardly towards the longitudinal axis of the burner and has a circular tip **22** on the downstream end. Inner surface **29** of intermediate nozzle **23**, together with the inwardly-converging tapered outer surface **31** of central nozzle **20**, define and intermediate inwardly-converging frusto-conical passage having unobstructed annular discharge orifice **24** at the downstream end. This passage is fed via intermediate annular passage **16** with said free-oxygen-containing stream, and it is designed to accelerate this stream to a high velocity.

Annular tip **22** of intermediate discharge nozzle **23** is advantageously advanced slightly downstream from circular tip **47** of nozzle **20**. This scheme protects tip **47** from radiation. However, the two tips may terminate in the same plane or intermediate annular tip **22** may be axially cut back a short distance, as indicated by the dotted line **42** in FIG. **2**. This latter position would allow a limited amount of intermixing of the steam and oxygen streams before they issue into the reactor. However, as a result of any such cutback, the protecting sheath of steam must not be excessively thinned to the point that the oxygen can diffuse through the blanket of steam and burn with synthesis gas too close to the burner tip or, in conjunction with other reactants, attack the outer surface of the metal tip.

A plurality of fins or locking lugs **53** are located at several positions to align, to space, and to position laterally and longitudinally intermediate coaxial concentric tubular conduit **44** and intermediate concentric converging nozzle **23** with respect to radially disposed outer coaxial concentric tubular conduit **48** and outer coaxial concentric frusto-conically shaped annular converging discharge nozzle **26**. Outer conduit **48** is radially disposed about the outside of intermediate conduit **44** along its length.

Outer frusto-conical discharge nozzle **26** is a continuation of outer tubular conduit **48**. Outer frusto-conical discharge nozzle **26** converges inwardly towards the longitudinal axis of the burner to aperture **50**. At aperture **50**, unobstructed coaxial flared diverging central passage **55** begins. An imaginary plane through aperture **50** is perpendicular to the longitudinal axis of the burner and is preferably located a little downstream from an imaginary plane across circular tip **47** of central nozzle **20**. Aperture **50** is common to outer con-

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verging nozzle **26** and diverging passage **55** where the diameter is a minimum. Aperture **50** is encircled with a cooling fluid, such as water, contained in coolant chamber **32,** to be further described. The converging frusto-conical annular passage **28** extending from the downstream end of outer annular passage **14** is bounded by the inside surface **51** of outer annular discharge nozzle **26** and the outside surface **52** of intermediate annular discharge nozzle **23.** Aperture **50** is adjacent to the discharge orifice of outer annular passage **28.**

The heat-exposed burner tip is provided with an annular coolant chamber **32.** The inside portion of annular chamber **32** is defined by a common inner wall **34** disposed concentrically about the axis of the burner. As previously mentioned, wall **34** constitutes part of outer frusto-conically shaped annular discharge nozzle **26.** The outside portion or jacket wall of coolant chamber **32** comprises the peripheral wall of outwardly-diverging passage **55** which develops into an annular face of convex configuration **36** at the outermost extremity of the downstream heat-exposed tip of the burner. The outside portion of coolant chamber **32** is preferably relatively thin-walled, e.g., 0.040 to 0.40 inches. Convex face **36** may be, for example, somewhat hemielipsoidally shapped in cross-section. To facilitate construction, coolant chamber **32** is closed on its outer circumferential side by annular wall member or collar section **38** welded at **40.**

An imaginary plane of tangency through **54** on the downstream extremity of the annular convex surface **36** on the outside face of coolant chamber **32** is perpendicular to the longitudinal axis of the burner. Thus, preferably, imaginary planes through **54, 50** and **47** are substantially parallel to each other, and are preferably spaced along the longitudinal axis in that order. The axial location of central nozzle tip **47,** and the dimensions of coaxial diverging central passage **55** are preferably such that divergence angle M in the drawing is in the range of about 70° to 140°, and preferably greater than 90° to less than 135°. Divergence angle M is the angle of intercept between two legs of an angle in a plane passing through the longitudinal axis of the burner, the apex of said angle being located at a point determined by the intersection of the longitudinal axis of the burner and a plane across the tip **47** of central nozzle **20** which is normal to the longitudinal axis of the burner, said legs being tangent respectively to the outwardly-diverging peripheral surface of passage **55** with the annular face of convex configuration **36** on the outside section of coolant chamber **32,** as shown in the drawing.

By this design, a stream of temperature-moderating gas is introduced into the reaction zone by the following route: annular passage **14,** converging outer annular passage **28** where it is accelerated upon passing through the unobstructed circular aperture **50** located near the tip of the burner, and then discharged through the concentric unobstructed flared central passageway **55** which is coaxial with the longitudinal axis of the burner. The annular sheath of temperature-moderating gas issuing from the burner prevents exothermic reaction near the burner face between H_2 and CO recirculating from the reaction zone and the oxygen stream being introduced into the reaction zone by way of the burner. Thus, the three coaxial concentric nozzles discharge simultaneously into single coaxial unobstructed otwardly-diverging central passage **55** with the two reactant streams being enveloped by the stream of temperature-moderating gas. Further, a blanket of non-burning gases is maintained immediately adjacent to the burner surface at aperture **50** so that the latter is continuously insulated from the reaction proper and thereby prevented from damage. Also, it promotes mixing of the streams in the proper proportion to hold the temperature down to the desired maximum with the reaction being initiated beyond the burner elements and the hot reaction products being immediately carried away from the burner elements.

The cooling tubes D, previously mentioned, connect to the coolant chamber **32** in any convenient way to direct continuously a stream of coolant therethrough. For example, the coolant may enter through inlet **33,** circulate around toroidal shaped coolant chamber **32,** and depart through outlet **35** which is adjacent to inlet **33.** Internal baffles may direct the flow within coolant chamber **32.** Moreover, it is to be noted that since face wall **36** is of convex configuration and relatively thin in comparison with a burner with a flat wall, it is better able to withstand the elevated pressures within the reaction chamber and to conduct away the heat.

FIG. **3** shows the portions of the reaction chamber of the synthesis gas generator located about the burner as an outer shell **10** and an inner refractory lining **12.** Burner A with a tip or nozzle portion B passes through an elongated passageway formed in the reaction vessel and refractory lining, so that its axial extremity or tip B faces the heated interior of the reaction chamber. A mounting flange C, illustrated in FIG. **1** but not shown in FIG. **3,** is provided to attach the burner to the reaction vessel. Coolant tubes D can be used to conduct a continual flow of coolant through the burner tip, as previously mentioned. FIG. **3** shows how turbulent eddies or currents may be set up by the kinetic energy of the high-velocity injection of the reactant streams into the reaction chamber. As indicated, the kinetic energy of a high-velocity stream, as at **30,** sets up swirls which may sweep the exposed surfaces of the burner tip with chemically-active, high-velocity flow of hot gases which can lead to excessively high metal-surface temperatures. This action is avoided by the subject invention, and burner life is thereby extended.

SPECIFIC EXAMPLE

The following is an example of a commercial design process using a 5-inch triple-orifice tip-atomizing burner, such as shown in the drawing.

Liquid oil, specifically a petroleum fraction with gravity of 5° API, enters at the rate of 55,000 pounds per hour and a temperature of 300°F. through the central orifice of the burner disclosed in the drawing.

The innermost orifice has a diameter of 1.215 inches, and the velocity of the liquid at the tip is 30 feet per second.

The oxygen enters through the intermediate annular orifice, as shown in the drawing, converging at a conical angle of approximately 25° to the axis of the central orifice.

The oxygen feed amounts to 683 short tons per day at a temperature of 300°F.

The burner is constructed of heat- and oxidation-resistant alloys.

The inside diameter of the intermediate annular orifice for the oxygen is 1.250 inches; and the outer diam-

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eter is 1.719 inches, with all diameters measured in planes normal to the axis of the central nozzle. Therefore, the stream of oxygen issuing from the intermediate annular orifice flows at the velocity rate of 415 feet per second.

The outer annular orifice conducts a moderator comprising 27,000 pounds per hour of steam at a temperature of 750°F. The inside diameter of the outer orifice is 1.827 inches, measured as above; and the outer diameter is 2.750 inches. Therefore, the nozzle velocity of the steam is 151 feet per second.

The outer annular nozzle converges at a conical angle of 30° with respect to the longitudinal axis of the central nozzle, so that the outer wall remains substantially equidistant from the inner wall.

The width of the outer annular orifice is 0.53 inches, while the width of the inner annular orifice is 0.27 inches, or approximately one-half of the former width. This therefore, in practice, permits some greater variation between the relative velocities of the steam and oxygen than would be the case of an outer moderator sheath which might be of substantially decreased thickness and therefore susceptible to disruption.

The burner injects the reactant streams directly into a combustion chamber which operates at a pressure of 1,200 psig and a temperature of approximately 2,500°F. Inasmuch as the diameter of the outermost burner pipe is approximately 5 inches, there is considerable of the burner extremity projecting radially outward beyond the periphery of the outer annular orifice and exposed to the interior of the reaction zone. The wall thickness of the convex heat-exposed face of the coolant chamber at the tip of the burner assembly is about 0.125 inches. If the burner had a flat face, it would be necessary to increase the wall thickness about 25 percent or more in order to withstand the 1,100 psig pressure difference that exists between inside and outside of the coolant chamber. In spite of this reduced wall thickness, the burner operates in the process over extended periods of time without damage to the exposed surfaces of the burner. Further, the life of the subject burner is increased at least 25 percent in comparison with a burner having a flat heat-exposed face.

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.

We claim:

1. A burner, for introducing a liquid hydrocarbon, a free-oxygen-containing gas, and a temperature moderator into a gas generator in which reaction takes place at a minimum temperature of about 1,200°F. comprising:

1. a central axial tubular conduit, inlet means at the upstream end of said central conduit, a central discharge nozzle at the downstream end of said central conduit having an inwardly converging tapered outer surface and a single unobstructed circular discharge passage;
2. an intermediate coaxial concentric tubular conduit disposed radially about the outside of said central tubular conduit along its length, inlet means at the upstream end of said intermediate concentric conduit, an intermediate coaxial concentric inwardly converging frusto-conically shaped discharge nozzle with a circular tip at the downstream end of said intermediate concentric conduit, means for positioning said central axial conduit and central discharge nozzle with respect to said intermediate concentric conduit and intermediate discharge nozzle in spaced relationship thereby providing an intermediate annular passage having a single unobstructed inwardly converging intermediate annular discharge passage at the downstream end;
3. an outer coaxial concentric tubular conduit radially disposed about the outside of said intermediate coaxial concentric conduit along its length, inlet means at the upstream end of said outer concentric conduit, an outer coaxial concentric inwardly converging frusto-conically shaped discharge nozzle at the downstream end of said outer concentric conduit, means for positioning said outer concentric conduit and outer discharge nozzle with respect to said intermediate concentric conduit and intermediate discharge nozzle in spaced relationship thereby providing an outer annular passage having an unobstructed inwardly converging annular passage that discharges into a single unobstructed concentric coaxial outwardly diverging central passage at the downstream tip of said burner;
4. a coolant chamber at the downstream tip of said burner comprising an inside section that comprises said outer inwardly converging frusto-conically shaped discharge nozzle of (3), an outside section that extends from and flares out from said inside section and which comprises an outwardly diverging section with an annular face of convex configuration at the outer extremity of the downstream tip of the burner, said outside section being in part the peripheral surface of said outwardly diverging tapered central passage of (3), a collar section joining said inside and outside sections and closing said coolant chamber, and inlet and outlet means for circulating coolant through said coolant chamber; and
5. conduit means in contact with said burner and connected to said inlet and outlet means for passing coolant in direct heat exchange with said burner.

2. The burner of claim **1** wherein the central discharge nozzle in (1) is further provided with a longitudinal axial passage having an inwardly converging tapered portion which fairs into a cylindrical section having a single unobstructed circular discharge orifice.

3. The burner of claim **1** further provided with means for simultaneously passing liquid hydrocarbon fuel at a velocity in the range of about 10 to 100 feet per second through said central discharge nozzle, free-oxygen-containing gas at a velocity in the range of about 110 feet per second to sonic velocity through said intermediate discharge nozzle, and a temperature-moderating gas at a velocity in the range of about 55 feet per second to sonic velocity through said outer discharge nozzle.

4. The burner of claim **1** further provided with means for simultaneously passing free-oxygen-containing gas through said central discharge nozzle, liquid hydrocarbon fuel through said intermediate discharge nozzle, and a temperature-moderating gas through said outer discharge nozzle.

5. The burner of claim **3** having means to admix said liquid hydrocarbon fuel with a portion of said temperature-moderating gas.

6. The burner of claim 3 wherein said temperature moderating gas is steam or water droplets and further provided with means for introducing up to 25 weight percent of said temperature-moderating gas into said gas generator in admixture with said free-oxygen-containing gas.

7. The burner of claim 1 wherein the conical surface of the stream ejected from the intermediate coaxial inwardly converging discharge nozzle makes an angle with the longitudinal axis of the burner in the range of about 10° to 55°, and the conical surface of the stream ejected from the outer coaxial inwardly converging discharge nozzle makes an angle with the longitudinal axis of the burner in the range of about 15° to 60°.

8. A burner for atomizing a stream of liquid hydrocarbon fuel with a stream of free-oxygen-containing gas so as to react in a gas generator at a temperature in the range of about 1,200° to 3,500°F. and at a pressure in the range of about 1 to 275 atmospheres and for enveloping the mixed streams with a stream of temperature-moderating gas comprising:

1. a central discharge nozzle with a circular discharge orifice and an upstream coaxial tubular conduit attached thereto through which preferably a stream of liquid hydrocarbon in liquid phase is passed;
2. an intermediate coaxial concentric inwardly converging frusto-conically shaped discharge nozzle with a circular discharge orifice and an upstream coaxial concentric tubular conduit attached thereto radially disposed about the structure of (1) along its length thereby providing an intermediate annular passage having a single unobstructed inwardly converging annular discharge passage at the downstream end through which preferably a stream of free-oxygen-containing gas, optionally in admixture with H_2O is passed;
3. an outer coaxial concentric discharge nozzle extending from an outer coaxial concentric tubular conduit, said outer discharge nozzle comprising an inwardly converging frusto-conically shaped inside section that flares out into an outwardly diverging outside section with an annular face of convex configuration at the outer extremity of the downstream tip of the burner, said outer discharge nozzle and outer tubular conduit being radially disposed about the structure of (2) along its length so as to provide an outer converging annular passage that discharges into an unobstructed outwardly diverging central passage through which a stream of temperature-moderating gas is passed;
4. a coolant chamber disposed about the periphery of the outer nozzle of (3) with which it has walls in common; and
5. conduit means for circulating coolant through the coolant chamber of (4).

9. The burner of claim 8 further provided with the tip of the central discharge nozzle in (1) being recessed upstream from the tip of the intermediate discharge nozzle in (2).

10. The burner of claim 8 further provided with the tip of the intermediate discharge nozzle in (2) being recessed upstream from the tip of the central discharge nozzle in (1).

11. The burner of claim 8 wherein the outwardly diverging outside section of said outer discharge nozzle has a divergence angle M in the range of about 70° to 150°, saie angle M being the angle of intercept between two legs of an angle in a plane passing through the longitudinal axis of the burner, the apex of said angle being located at a point determined by the intersection of the longitudinal axis of the burner, and a plane across the tip of the central nozzle which is normal to the longitudinal axis of the burner, said legs being tangent respectively to the peripheral surface of said outwardly diverging central passage with said annular face of convex configuration.

12. The burner of claim 8 which includes means for passing said stream of liquid hydrocarbon through said intermediate annular passage in (2) in place of said stream of free-oxygen-containing gas and which includes means for simultaneously passing said stream of free-oxygen-containing gas through said central discharge nozzle in (1) in place of said stream of liquid hydrocarbon.

13. In the manufacture of synthesis gas reducing gas or fuel gas by reacting a stream of free-Oxygen-containing gas and a stream of normally liquid hydrocarbon in the presence of a stream of temperature moderating gas in a reaction zone of a noncatalytic free-flow gas generator at a pressure in the range of about 1 to 275 atmospheres and a temperature in the range of about 1,200 to 3,500°F. and in proportions effective to produce a product comprising hydrogen and carbon monoxide by the partial oxidation process, the improvement which comprises simultaneously injecting said reactants into the reaction zone from a burner having a plurality of separate concentric passages coaxial with the longitudinal axis of said burner and comprising a central cylindrical discharge passage, a single intermediate inwardly converging annular discharge passage coaxial with the central passage, and an outer discharge passage comprising an inwardly converging annular passage surrounding and coaxial with the first named passages and which flares out at its downstream end into an outwardly diverging unobstructed central passageway near the downstream tip of the burner, and a coolant chamber disposed about the outer periphery of said downstream burner tip, said liquid hydrocarbon stream and said stream of free-oxygen-containing gas being separately injected from said central passage and said intermediate passage respectively into said reaction zone at sharply disparate linear velocities and at an acute angle relative to each other so as to effect atomization of the liquid hydrocarbon and intimate association of the reactants at a finite distance downstream from the extremity of the burner tip so that burning can take place without damaging the orifices at the downstream ends of said passages, the velocity of the liquid hydrocarbon being in the range of about 10 to 100 feet per second and the velocity of the free-oxygen-containing gas being in the range of over 600 feet per second to sonic velocity and simultaneously injecting the stream of temperature moderating gas through the outer discharge passage at a velocity of over 300 feet per second to sonic velocity.

14. The process of claim 13 wherein said stream of liquid hydrocarbon is passed through said intermediate annular passage in place of said stream of free-oxygen-containing gas, and simultaneously said stream of free-oxygen-containing gas is passed through said central discharge nozzle in place of said stream of liquid hydrocarbon.

15. The process of claim 13 wherein the surface of the stream ejected from the intermediate inwardly con-

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verging annular discharge passage makes an angle with the longitudinal axis of the burner in the range of about 10° to 55° and the surface of the stream ejected from said outer inwardly converging annular passage makes an angle with the longitudinal axis of the burner in the range of about 15° to 60°.

16. The process of claim **13** wherein said liquid hydrocarbon is selected from the group consisting of butane, pentane, hexane, gasoline, kerosene, gas oil, naphtha, diesel fuel, crude oil, residua, coal tar, tar sand oil, shale oil, oxygen-containing hydrocarbons, slurries of solid carbonaceous fuels, and mixtures thereof.

17. The process of claim **13** wherein said free-oxygen-containing gas is selected from the group consisting of air, oxygen-enriched air (greater than 21 mole percent oxygen), and substantially pure oxygen (greater than 95 mole percent oxygen).

18. The process of claim **13** wherein said temperature moderating gas is selected from the group consisting of steam, water droplets, CO_2, nitrogen and other inert gases, flue gas, and off-gas from an ore-reduction zone.

19. The process of claim **18** wherein said temperature moderating gas is steam or water droplets and up to 25 weight percent of said temperature moderating gas is introduced into said gas generator in admixture with said free-oxygen-containing gas.

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