July 5, 1960 H. A. BIRKNESS ET AL 2,943,674

BURNER STRUCTURE FOR HIGH TEMPERATURE GAS GENERATORS

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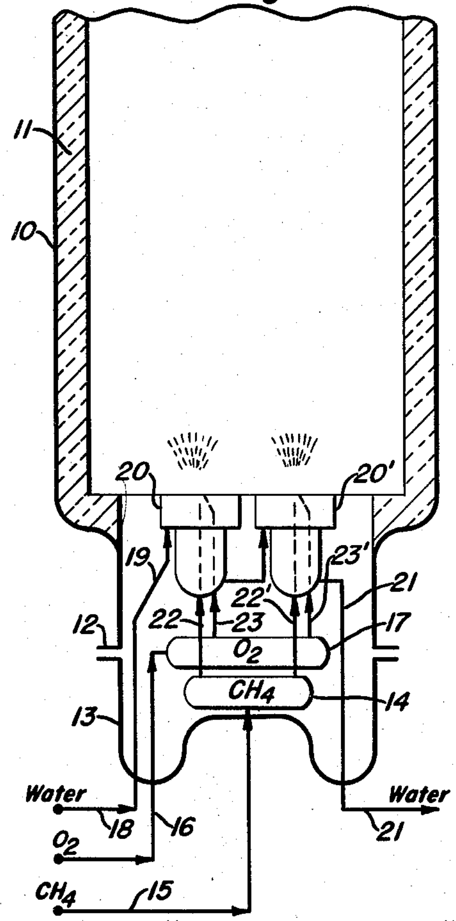
Fig. 1



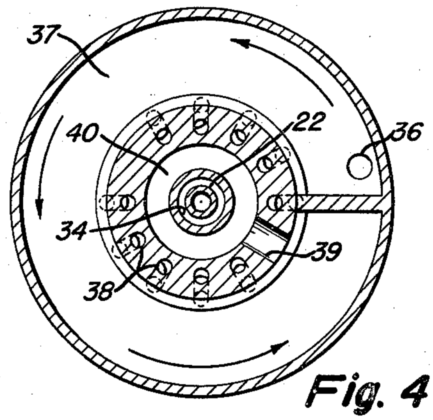


Fig. 4

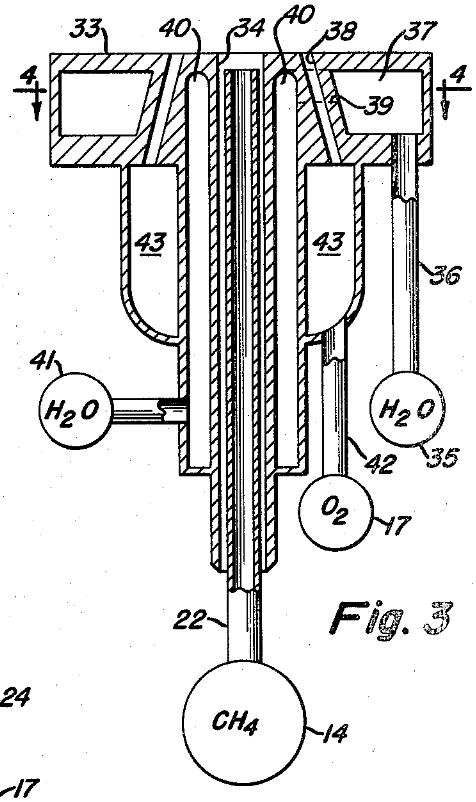


Fig. 3

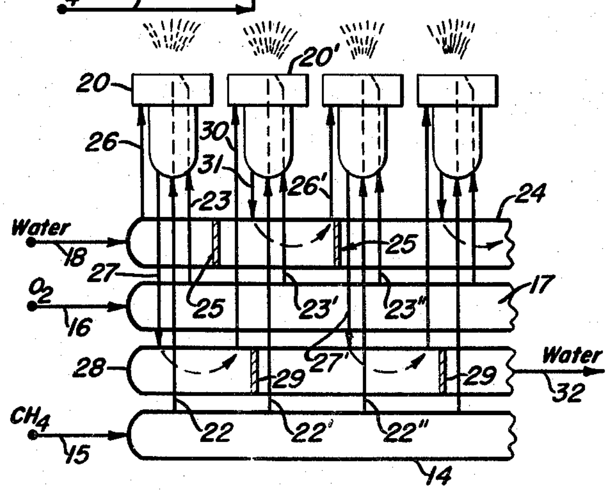


Fig. 2

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BURNER STRUCTURE FOR HIGH TEMPERATURE GAS GENERATORS

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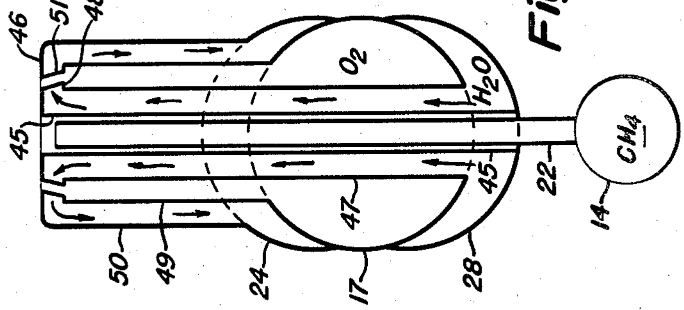

Fig. 6

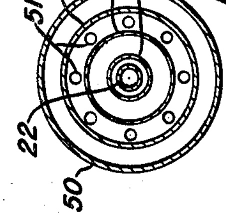

Fig. 7

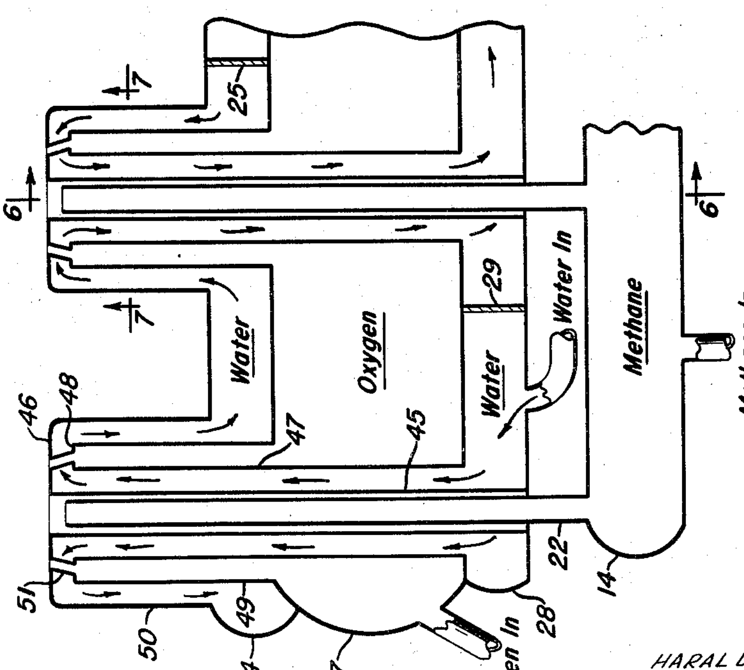

Fig. 5

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BURNER STRUCTURE FOR HIGH TEMPERATURE GAS GENERATORS

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This invention relates to an improved burner structure for high temperature gas generators and it pertains more particularly to burner assemblies for effecting partial oxidation of a hydrocarbon gas such as methane with oxygen at temperatures substantially higher than 2500° F.

To supply hydrogen for the manufacture of ammonia or a hydrogen-carbon monoxide gas mixture for use in effecting hydrocarbon synthesis, gas generators are employed which effect partial combustion of a hydrocarbon gas such as methane with oxygen at temperatures which are believed to be as high as about 3500° F. The initial partial combustion products are then reformed in the upper part of the combustion zone wherein the temperature may drop to about 2500° F. after which the gases are cooled and utilized in manners known to those skilled in the art. One of the most serious problems connected wtih these gas generators is that of constructing the burners therefor. Heretofore no fully satisfactory burner has been available and all of the burners have presented one or more serious problems such as improper mixing and/or combustion leading to coke deposits, corrosion and undesired products, destruction of the generator or parts thereof by flame impingement and destruction of the burner elements caused largely by high temperatures and/or differential thermal expansion, particularly because of the thermal stresses which arise from the necessity of water cooling the burner to prevent its melting. The latter problems are aggravated because the hydrocarbon, which is usually natural gas and is herein referred to as "methane," is preferably preheated to about 800 to 1200° F. in order to attain the desired combustion temperature and during start-ups and on other occasions the temperature of the methane may be relatively cool. The object of this invention is to provide a burner structure which will avoid all of such problems and difficulties.

Our improved burner structure comprises a plurality of adjacently mounted burners, preferably in rows, each having a central opening for a methane tube which may be about ½ to ¾, e.g. ⅝ inch inside diameter, each of said tubes being supplied with preheated methane from a supply or pressure-equalizer vessel herein called a plenum chamber. Grouped around each burner's central opening for the methane tube are angularly disposed oxygen nozzles for directing oxygen against the methane stream which is discharged from the tube beyond the surface of the burner; conduits are provided for supplying oxygen to the group of nozzles which surround the central opening in each burner and each of these oxygen conduits is connected to an oxygen plenum chamber which is separated structurally from the methane plenum chamber. Each of the oxygen nozzles has a diameter of about ⅛ to 3/16 inch and we preferably employ about 6 to 12 or about 8 nozzles per burner. A cooling water circulation system is provided for cooling the surface of the burners by positive rapid flow of at least about 10 feet per second on the inner side of the burner surfaces and this cooling water system is preferably employed as a shield between

oxygen and preheated methane, i.e. the water circulates between the oxygen which is being supplied to the nozzles and the introduced hot methane as well as between the oxygen nozzles and on the inner side of the burner surface. The methane tubes terminate about ½ inch below the burner surface, i.e. a sufficient distance below the surface to be shielded against excessive heat transfer from the 3500° F. combustion zone. The methane tube is silghtly spaced from the inner opening through each burner both to avoid undue heat transfer to the circulating cooling water but, more importantly, to allow for differential thermal expansion without creating stresses in the burner structure.

The individual burner unit designs may differ to a considerable degree but it is important that a compact structural arrangement of the total burner structure be provided because so many units have to be mounted in such close proximity. For example, a commercial gas generator partially burning about a million standard cubic feet per hour of methane may have an inside diameter of about 5 feet with a 24 foot vertical open space before the hot gases are contacted with boiler tubes (the gas generator may be of the type shown in U.S. 2,660,235). The burner space at the base of this generator may be only about 38 inches in diameter but such a unit may require the use of as many as 72 individual burner units and the methane and oxygen flow rates in each unit must be critically controlled and constant. To solve the space problem, we provide superimposed plenum chambers for methane, oxygen, and water, the preferred arrangement being to have the water plenum chambers integrally associated with the oxygen plenum chamber and a separately mounted methane plenum chamber, the discharge tubes from which extend through the oxygen and water plenum chambers. The burner units may be integrated with the plenum chambers by use of a series of concentric tubes, the first tube extending from the burner surface through both water and oxygen plenum chambers (and surrounding but slightly spaced from the methane tube), a second larger diameter tube extending from a level below the burner surface through the upper water plenum chamber and the oxygen plenum chamber to the lower water plenum chamber, a third tube larger in diameter than the second and extending from the upper level of the second tube through the upper water plenum chamber to the oxygen plenum chamber and the fourth tube of largest diameter extending from the burner surface to the upper water plenum chamber; in this system the water circulates in the annular space between the first and second tubes across the burner surface around oxygen nozzles and thence through the annular space between the third and fourth tubes, the direction of circulation being reversed in adjacent burner units. The conduit for supplying oxygen to the nozzles is formed by the annular space between the second and third tubes, this space being cooled by circulating water. The space between the upper surfaces of the burner units is preferably filled in with the refractory material.

The invention will be more clearly understood from the following description of preferred embodiments thereof read in conjunction with the accompanying drawings which form a part of this specification and in which:

Figure 1 is a diagrammatic section through the lower part of a gas generator showing how our burner assembly is associated therewith,

Figure 2 is a diagrammatic representation of a burner unit assembly showing the integration of closely spaced burner units with the various plenum chambers and indicating directions of flow,

Figure 3 is a sectional view through one type of burner assembly unit,

Figure 4 is a cross section taken along the lines 4—4 of Figure 3,

Figure 5 is a vertical section through another type of burner assembly unit,

Figure 6 is a section taken along lines 6—6 of Figure 5, and

Figure 7 is a section through a burner unit taken along the line 7—7 of Figure 5.

Referring to Figure 1, the gas generator **10** is a steel vessel about 8 feet in diameter and upwards of 25 feet in height and it is lined with refractory **11** to give an inside diameter of approximately 5 feet. The bottom of the vessel is narrowed down to provide a flanged opening about 38 inches in diameter and the burner assembly is introduced through this opening and secured to flange **12**. The burner assembly comprises a double U-shaped closure member **13** carrying a plurality of methane plenum chambers diagrammatically illustrated by vessel **14** into which preheated methane usually at about 950° F. is introduced through lines **15**. Oxygen is introduced by line **16** to separately supported oxygen plenum chambers **17**. Cooling water is introduced through line **18**, preferably in a jacket around line **16**, and is thence introduced by line **19** to one or more of the individual burner units **20**, the cooling water preferably passing through water plenum chambers as will be hereinafter described. In the simplified drawing, Figure 1, cooling water is removed from the system through line **21**. Tubes **22** and **22'** from the methane plenum chambers **14** may pass around or through oxygen plenum chambers **17** and they extend upwardly through a central opening in the burner unit to a level just below the upper surface of burners **20**. Separate oxygen conduits **23** and **23'** extend from plenum chambers **17** to distribute oxygen in nozzles which discharge from the burner surface in an angular direction so that the base of the combustion flame will be about an inch or so above the surface of the burner units, these oxygen conduits preferably being surrounded by cooling water. The structure in Figure 1 is over-simplified and the actual structural arrangement of the burner assembly will be more clearly set forth in connection with Figures 3 to 7. In the actual gas burner for handling 2,678 mols per hour of methane and 1,840 mols per hour of oxygen, 72 burner units are employed and the combustion is effected at a pressure of about 300 p.s.i. to maintain an initial combustion zone temperature of approximately 3500° F., the temperature dropping to about 2500° F. by endothermic water gas shift reactions which take place in the upper part of the gas generator. The pressures in the oxygen and methane plenum chambers are, of course, carefully controlled and balanced and in this example are maintained in the range of about 305 to 310 p.s.i.g.

In Figure 2 the general arrangement of plenum chambers in conjunction with burner units is diagrammatically shown although it should be understood that each burner assembly may comprise 8 to 16 or more individual burner units instead of the 4 illustrated. Water from line **18** enters upper water plenum chamber **24** which is provided with dams or closure blinds **25**. The water flows from plenum chamber **24** through line **26** through the cooling channels in burner **20**, thence through line **27** to lower water plenum chamber **28** which is provided with dams **29**. Thence the water from plenum chamber **28** flows through line **30** to burner unit **20'** and then back by line **31** to the upper plenum chamber **24**. Water from the upper plenum chamber then flows upwardly through line **26'** to the next burner unit, etc. It will thus be seen that there is a series water flow in a closed channel through the whole series of burner units and it is important that the flow velocity be relatively high across the burner surface, i.e. at least about 10 feet per second, in order to obtain effective heat transfer by film boiling at extremely hot surfaces while maintaining water at a temperature of the order of 80 to 160° F. Methane is introduced by line **15** into methane plenum chamber **14** and tubes **22**, **22'**, **22''**, etc. extend upwardly through an opening in each burner unit as will be hereinafter described in more detail. Oxygen is introduced by line **16** into separately mounted oxygen plenum chamber **17** and separate conduits **23**, **23'**, **23''**, etc. conduct the oxygen to the nozzles in the burner units as will likewise be hereinafter described. The water is removed from lower water plenum chamber through line **32**.

Referring to Figures 3 and 4, each burner unit has an upper burner surfaces **33** and a central opening **34** through which extends the methane tube **22**. Water from plenum chamber **35** is introduced through conduit **36** to channel **37** which surrounds oxygen nozzles **38** so that there is positive rapid flow of water across the burner surface and around the oxygen nozzles. The cooling water then flows inwardly through channel **39** through annular channel **40** to exit water plenum chamber **41**. It will be observed that channel **40** constitutes an annular column of water surrounding the hot methane inlet tube. Oxygen plenum chamber **17** is structurally mounted separate from methane plenum chamber **14** and conduit **42** conducts oxygen from plenum chamber **17** to annular distributor space **43** which surrounds the column of water in channel **40**. Nozzles **38** in this case are formed by holes drilled through the burner structure and they are angularly disposed around the central opening so that the oxygen streams will intersect the methane stream about ½ to 6 inches, preferably about 1 or 2 inches, above the upper surface of the burner. The upper end of methane tube **22** must be near enough to the burner surface so that the walls of central opening **34** will not interfere with the jet flow of methane from tube **22**, but since tube **22** is not water cooled its upper level must be below the burner surface a sufficient distance, usually of the order of about ½ inch, to shield it from the intense combustion zone heat and thereby avoid melting or disintegration of the upper part of tube **22**. It will be observed that rows of closely spaced burner units may thus be closely mounted in a relatively small space, that the burner surfaces and all portions of the oxygen system are protected by water cooling and that any difference in temperatures of introduced methane from ordinary temperatures up to 1200° F. does not cause thermal stresses in the burner structure.

In the burner assembly of Figures 5, 6 and 7 the upper water plenum chamber **24** is integrally welded on top of oxygen plenum chamber **17** and lower water plenum chamber **28** is integrally welded to the bottom of the oxygen plenum chamber. A first tube **45** extends through oxygen plenum chamber and both water plenum chambers and is welded to the base of water plenum chamber **28** and the upper burner surface **46**. A second tube **47** is welded to the base of oxygen plenum chamber **17** and extends upwardly through the oxygen and upper plenum chambers to closure member **48**. A third tube **49** is welded to the top of oxygen plenum chamber **17** and extends upwardly to closure **48**. A fourth tube **50** is welded to the top of upper water plenum chamber **24** and extends upwardly to burner surface **46**. A group of angularly disposed oxygen nozzles **51** extend from upper closure **48** through upper burner surface **46**. Cooling water flows from lower water plenum chamber **28** upwardly through the annular space between tubes **45** and **47**, thence laterally across the burner surface around oxygen nozzles **51** between closure **48** and burner surface **46** and thence downwardly through the annular space between tubes **49** and **50** to upper water plenum chamber **24**. Oxygen flows upwardly through the annular space between tubes **47** and **49** for distributing oxygen to nozzles **51**. The methane tube **22** has an outside diameter which is slightly less than the inside diameter of tube **45** and it terminates about ½ inch below the upper burner surface. From Figure 5 it will be observed that the water flow through the first burner is from lower plenum chamber through the central annular column across the burner surface and thence through the outer annular column to the upper water plenum chamber while in the next unit it is from the upper water plenum chamber through the outer annular column across the burner surface and thence through the inner annular column to the lower water plenum chamber. The oxygen nozzles may be about ⅛ to $\frac{3}{16}$ inch inside diameter, the methane tube may be about ⅝ inch inside diameter and the total diameter of each burner unit may be only about 2½ to 3 inches. By carefully controlling the pressure in the respective plenum chambers, i.e. by holding the pressure in the methane and oxygen plenum chambers at about 8 p.s.i. higher than the pressure in the gas generator, remarkably efficient partial combustion is obtained. The burner herein described has been found to be remarkably successful and to avoid the problems which have been encountered with all previous types of burners.

While particular embodiments of our invention have been described in considerable detail, it should be understood that alternative structures and relationships will be apparent from the above description to those skilled in the art. In all cases the burner units of each assembly must be mounted close together and the spaces between the adjacent upper surfaces of the burner units are filled in with refractory material in order to prevent overheating of the cooling water and to protect the plenum chambers and structural elements of the burner assembly from the intense heat in the lower part of the gas generator. The methane tube may move freely in a vertical direction to take care of thermal expansion, and also laterally (due to space around such tubes) to take care of longitudinal expansion of the methane plenum chamber.

We claim:

1. A gas generator burner assembly for effecting partial combustion of a hydrocarbon gas such as methane with oxygen at temperatures above 2500° F. for the production of a carbon monoxide-hydrogen gas mixture, which burner assembly comprises a methane plenum chamber, a plurality of methane discharge tubes communicating with said plenum chamber and extending upwardly therefrom at spaced intervals, a separately mounted oxygen plenum chamber, an upper water plenum chamber, a lower water plenum chamber, a plurality of burner units each surrounding a methane tube and each unit comprising a first tube extending from the burner surface through the upper water plenum chamber, the oxygen plenum chamber, and the lower water plenum chamber and surrounding but slightly spaced from the methane tube, a second larger diameter tube surrounding the first tube and extending from a level below the burner surface through the upper water plenum chamber and the oxygen plenum chamber to the lower water plenum chamber, the annular space between the first and second tubes forming a cooling water passage communicating with the lower water plenum chamber and surrounding the second and extending from the upper level of the second tube through the upper water plenum chamber to the oxygen plenum chamber, the space between the second and third tubes forming an oxygen conduit which is closed by an annular upper top member and which communicates with the oxygen plenum chamber, a group of oxygen nozzles extending from said top member to the burner surface for directing oxygen streams against the methane stream beyond said surface, a fourth tube of larger diameter than and surrounding the third and extending from the burner surface to the upper water plenum chamber, the annular space between the third and fourth tubes forming a cooling water passage communicating with the upper water plenum chamber, an annular closure between the first and fourth tubes forming the burner surface through which the oxygen nozzles extend, connections for introducing cooling water in the lower water plenum chamber whereby cooling water may be rapidly circulated through the cooling water passageways and in contact with the burner surface around oxygen nozzles, the upper end of the methane tube being at a lower level than the burner surface in order to shield it from the intense heat of the combustion zone above said surface.

2. A gas generator burner assembly for effecting partial combustion of a hydrocarbon gas such as methane with oxygen at temperatures above 2500° F. for the production of a carbon monoxide-hydrogen gas mixture, which burner assembly comprises a methane plenum chamber, a plurality of methane discharge tubes communicating with said plenum chamber and extending upwardly therefrom at spaced intervals, a vertical tubular water jacket surrounding and slightly spaced from each methane tube and extending slightly beyond the discharge end thereof without being in physical contact with any part thereof, a horizontal water jacket communicating with the upper end of the vertical tubular water jacket, a first water plenum chamber, a second water plenum chamber, connections for flowing a stream of water rapidly in series from one water plenum chamber to the other through the horizontal and vertical water jackets, an oxygen plenum chamber, an annular oxygen distributor surrounding each tubular water jacket and below the corresponding horizontal water jacket conduits extending from said oxygen plenum chamber to said annular oxygen distributor, and a group of oxygen nozzles extending from each oxygen distributor in heat exchange relationship with water in the horizontal water jacket for directing oxygen streams against the methane stream discharged from each methane discharge tube.

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