

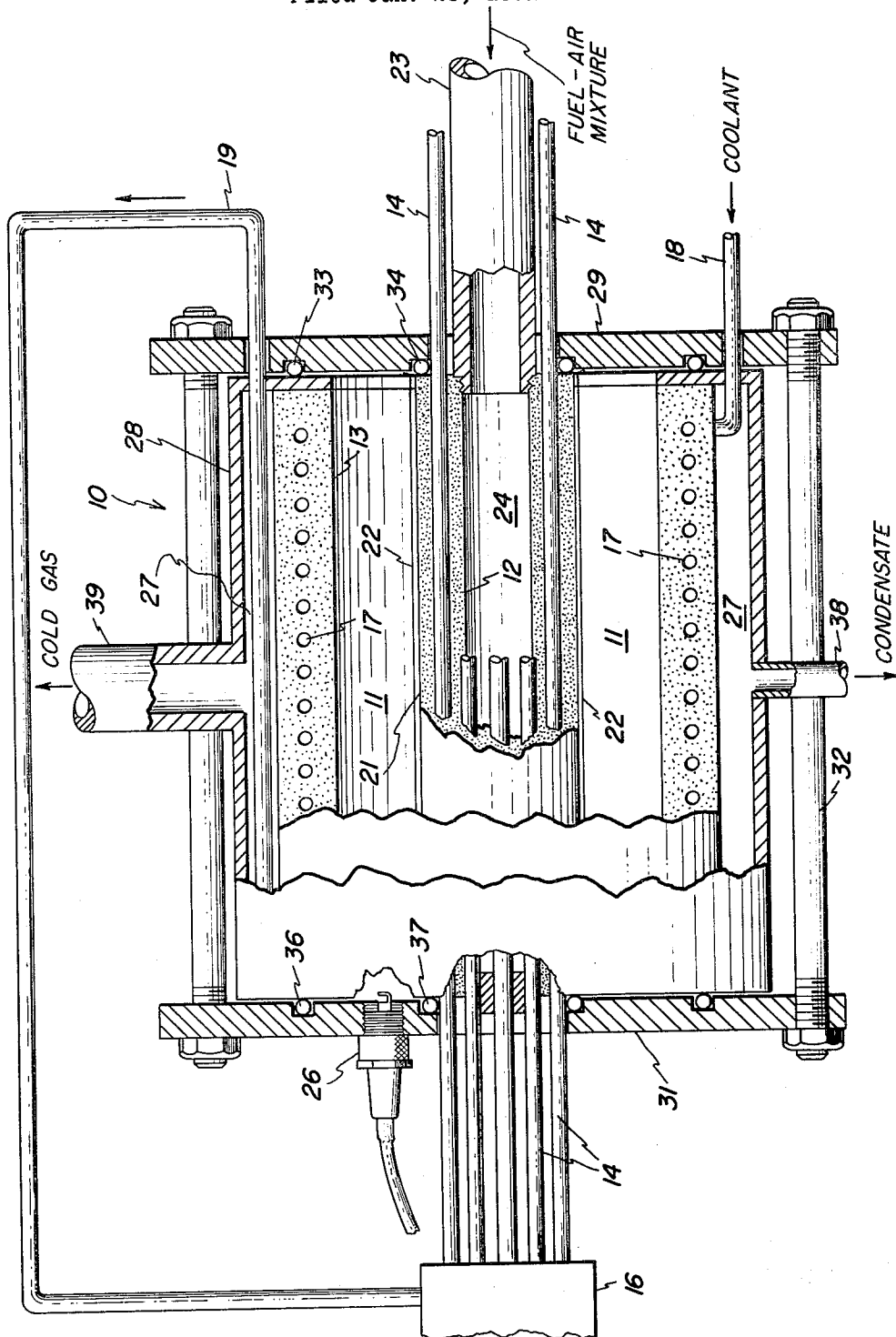
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BURNER-COOLER SYSTEM FOR GENERATING EXOTHERMIC GAS

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BURNER-COOLER SYSTEM FOR GENERATING EXOTHERMIC GAS

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6 Claims

ABSTRACT OF THE DISCLOSURE

A burner-cooler combination performing the functions of burner, flame arrester and cooler is provided in a single compact device. Both the burner and the cooler-condenser elements are of sintered metal construction and are cylindrical in configuration. In the construction described both the burner cylinder and the cooler-condenser are right circular cylinders and the cooler-condenser encircles and is spaced from the burner. Both components are enclosed in a single housing providing both for containment and dispensing of the cold product gas and for collection and removal of condensate. Ignition means are disposed in communication with the space between the burner and the cooler-condenser.

BACKGROUND OF THE INVENTION

"Exothermic" gas is defined herein as being the combustion product of a rich but flammable (i.e. self-heating) hydrocarbon-air mixture. Very rich non-flammable mixtures produce endothermic gas, but external heating is required for this process.

Exothermic atmosphere-gas generators are employed to provide control atmospheres for various laboratory and industrial processes. Exothermic gas is usually generated by burning a rich pre-mixture of some hydrocarbon, e.g. natural gas, with air. The combustion products are cooled to about ambient temperature, the CO₂ content thereof is chemically absorbed and the gas is then dried. The product thus obtained is a dry mixture consisting of about 80 volume percent nitrogen with the balance composed of carbon monoxide and hydrogen. The exact composition can be adjusted by varying the composition of the gaseous input (with the limitation that the composition must be flammable). The product gas usually must contain very little if any oxygen, since the processes in which such atmospheres are generally employed e.g. heat treating, annealing and sintering, cannot tolerate any significant amount of oxygen.

In conventional equipment for the preparation of exothermic gas, separate units are required to carry out the several functions of burning; cooling; condensing, and providing safe operating conditions at all times.

SUMMARY OF THE INVENTION

A simple, very compact unit embodying elements for executing each of three functions in preparing exothermic gas is the subject of the instant invention. The exothermic gas generating system of this invention comprises a cylindrical sintered metal burner, a cylindrical sintered metal cooler-condenser, means for circulating coolant through the burner, means for circulating coolant through the liquid-condenser, an enclosure containing the burner disposed within and spaced from the larger cooler-condenser, outlet means connected to said enclosure for removing the cold product gas, means connected to said enclosure for collecting and removing the condensate, and ignition means disposed in communication with the space between the burner and the cooler-condenser.

BRIEF DESCRIPTION OF THE DRAWING

The exact nature of this invention as well as objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawing schematically representing the apparatus of this invention in cross-section.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Exothermic gas generator 10 employs in combination two cylindrical sintered metal walled elements in substantially concentric relationship defining an annular space 11 (the combustion chamber) therebetween. The wall construction of both burner 12 and cooler-condenser 13 is porous and made of sintered metal particles, for example, copper shot, bronze shot, nickel shot or any structurally sound metallic shot material having a thermal conductivity of at least 30 percent of the value of thermal conductivity for sintered copper shot. The sintered metal particles define interconnecting voids which permit continuous passage of gas or vapor therethrough from face to face. Preferably, the porosity should be in the range of from about 30 to 50 percent by volume to provide a desirable compromise between strength and thermal conductance while maintaining a reasonably small pressure drop. Preferably, the pressure drop through the porous sintered metal wall should be less than 1 p.s.i. through a wall thickness of about 1/2 of an inch. The particle size of the metal shot employed should be in the range of from about 1 to about 300 microns, although this is not critical.

By way of example, copper shot (Alcan Metals MD68HP) having a particle size between 180 and 250 microns has been employed to produce a porosity (after sintering) of about 38 volume percent.

In the construction shown, a number of cooling tubes 14 are provided for burner cylinder 12 embedded in the wall thereof and extending in the generally axial direction. One end of each of tubes 14 is in flow communication with burner water manifold 16 to receive cooling water therefrom and the other end of each coolant tube 14 extends out of generator 10 to a manifold (not shown) for disposition thereto of the heated cooling fluid.

The cooling means shown for cooler condenser 13 is a continuous conduit 17 in a spiral configuration embedded in the wall thereof and connected in inlet tube 18 with the opposite end thereof connected to outlet tube 19. Inlet tube 18 is in flow communication with a source of cold water (not shown) and outlet tube 19 is in flow communication with burner water manifold 16 in order to provide manifold 16 with a supply of heated water (about 35–60° C.) in order to minimize or prevent the condensation of water from the combustion gases on the surface 21 of burner 12. The accumulation of such condensate water on combustion surface 21 is undesirable and could interfere with the stability of flame 22, especially when burning mixtures have a very low burning velocity.

A fuel-air mixture is supplied to pipe 23 (source is not shown) connected to the hollow interior 24 of burner 12. This fuel-air mixture is, of course, combustible and as the mixture passes radially outward through the porous wall of burner 12 and exits from surface 21 thereof it is ignited. Initially this ignition is accomplished by igniting means 26 and, once in operation, ignition is accomplished by the existing stabilized flame 22 spread over surface 21. If the flow of fuel-air mixture is intermittent in nature, it will be beneficial to provide for continuous operation of the igniter. When the fuel-air mixture is ignited, the resulting stabilized flame 22 spreads over cylindrical surface 21 and it continues to receive and burn the uniform gas flow issuing from the porous wall of burner 12.

In operation a given temperature gradient becomes established in the porous wall of burner 12 depending upon the unburned gas flow velocity so that heat generated from the fuel combustion is at least in part rejected to the interior of the wall of burner 12, where it is efficiently removed by the coolant, e.g. water, circulating through cooling tubes 14.

The products of combustion leave the hot gas annulus 11 and pass radially outward through the wall of the cooler-condenser 13 where additional heat is removed therefrom. The cold product gas is released into space 27 between cooler-condenser 13 and housing 28. Hot gas annulus 11 is closed off at each end by copper end plates 29, 31 held in place by tie bolts 32 to insure the sealing of rubber O-rings 33, 34, 36, 37. The porous ends of burner cylinder 12 are sealed off by filling the voids of the end surfaces with a heat stable material, e.g. by painting with an epoxy resin. End plates 29, 31 are adapted to permit the passage of the bundle of coolant tubes 14, pipe 23, inlet tube 18, outlet tube 19 and ignition means 26 there-through.

The generator 10 was mounted with the central axis in the substantially horizontal position and condensate outlet 38 is located at the underside thereof while the cold gas outlet 39 is preferably located at the top thereof. The emerging cold gas is saturated with water vapor and with an input of 13.8 percent by volume methane (the balance being air) and a methane/air ratio of .159 the product composition was as follows:

TABLE I

Gaseous components:	Volume percent
Carbon dioxide -----	4.8
Carbon monoxide -----	9.0
Methane -----	0.3
Hydrogen -----	9.8
Oxygen -----	0.0
Nitrogen -----	76.1

All percentages set forth herein are to be considered as expressed in "percent by volume" unless otherwise stated.

Burner 12 will operate maintaining a steady flame 22 indefinitely even with the temperature of surface 21 being only a few degrees above ambient. The effective pore size of the voids in the sintered wall of burner 12 should be less than 0.2 mm., a distance smaller than the quenching distance for even the most energetic explosive mixture of hydrocarbon gas-air and for this reason the construction of burner 12 insures the absence of flashback.

The amount of the total absorbed heat, that is absorbed by the burner relative to the cooler-condenser will vary depending upon the composition of the fuel-air mixture, the flow velocity and the pressure. For example at lower pressures little heat is absorbed at the burner and most of the heat is absorbed by the cooler-condenser. At higher pressures the reverse conditions apply.

Since a significant fraction of the heat of combustion may be continuously absorbed by the cooling system passing through burner 12, this unit may, if so operated, be continuously subjected to a very large heat flux, e.g. in excess of 25 cal./cm.²-sec. However, in practice at atmospheric pressure the burner heat flux will be about 1 cal./cm.²-sec. while the cooler-condenser heat flux will be about 2 cal./cm.²-sec. At higher pressures the burner heat flux will run about 10 cal./cm.²-sec.

The exothermic gas generator construction of this invention permits the burning in a stable uniform flame of stoichiometric gas mixtures entering the system at a velocity in the range of from about 5 to 30 centimeters/second or more. As the mixture is made richer than stoichiometric, the range of useable velocities yielding stable flames decreases until only a single velocity may be used at the rich limit for the mixture. For example, the rich limit for methane/air mixtures is about 15 percent methane. However, methane/air mixtures containing about 14

percent methane are commonly used and the useable gas velocities for the latter mixture would be between about 6 centimeters/second and 13 centimeters/second.

Starting the generator is straightforward and simple; with the cooling water on, the air flow is set at some value to provide the desired gas mixture velocity together with some pre-selected value of fuel flow; the igniter spark is energized and the fuel regulator is advanced to bring the fuel percentage from zero continuously through the whole range of compositions up to the desired pre-selected value. The whole starting procedure may easily be accomplished in about 15 seconds.

Ignition occurs dependably and with no difficulty shortly after the composition goes above the lower limit. Because ignition occurs at one end of the annular chamber which is then filled with explosive mixture, it may be accompanied by a mild, but audible, sound at which time a pulse is observable on the back-pressure gauge (not shown). Though this pressure pulse must decrease the mixture flow (and perhaps even stop it) momentarily, establishment of the steady flame always follows immediately thereafter as is indicated by a rise in the water temperature.

In practice the product gas, which is at a temperature of about 30-40° C., is treated by auxiliary equipment to remove the carbon dioxide and to dry the gas to render the gas useable, e.g. as a furnace atmosphere. The gas analysis set forth hereinabove (Table I) was given on a dry basis.

Cooler condenser 13 may conveniently be made sturdy enough to function as a reliable pressure vessel and, therefore, generator 10 may be operated at elevated pressures, e.g. up to about 100 p.s.i. Raising the operating pressure has the effect of increasing the throughput of the unit and, as well, increasing the heat flux to both burner 12 and cooler-condenser 13. The quenching distance for the particular mixture employed becomes smaller at higher operating pressures, so that as the pressure is increased, more stringent demands are placed, upon the flame arresting properties of the burner.

It has been found that there is a distinct advantage to covering the end plates 31, 29 with insulation but use thereof is not critical.

Relatively small gas generator units 10 e.g. about 5 inches in diameter and about 5 inches long will provide outputs considerably in excess of 770°/cc./sec. of product gas on a dry, CO₂-free basis (about 100 cubic feet per hour). Larger generators may be conveniently assembled by interconnecting such small units as modules.

The sintered cylinder for burner 12 was prepared utilizing a cut-wire copper shot of particle size ranging between about 180 microns and 250 microns. The copper shot with six protruding copper tubes 14 in place therein was confined between an outer cylindrical graphite mold and a centrally-located graphite rod. A compacting load was applied to the copper shot in the mold to produce (after sintering) a porosity of about 38 volume percent. The assembly was clamped together and was then placed in a retort in a hydrogen atmosphere and transferred to a furnace, where it was kept at 870° C. in dry hydrogen for about 2-hours to achieve sintering.

Initially, it was found that the apparent porosity of the resulting sintered burner cylinder (1¼" outside diameter; ½" inside diameter) was unsatisfactory. It was suspected that the difficulty was caused by shrinkage or compression about the solid core mandrel either during the sintering operation or in the early stages of cooling producing overly dense material near the inside surface of the cylinder. Accordingly, the center hole was reamed out from each end with a burnishing tool thereby removing a thin layer (about ¼ inch thick) from the wall of the center hole. Unexpectedly, the metal particles, instead of being cut and pushed into the surface voids, crumbled away under the action of the burnishing tool. As a result the new wall surface instead of sealing the

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surface, gained an acceptable degree of porosity. When tested, it was found that the burner cylinder so prepared developed a nicely cylindrical, uniform flame with a pressure drop of less than 1 p.s.i. for a gas velocity of 10 cm./sec. The larger diameter cooler-condenser (about 2½" inside diameter) did not present this problem, however.

The configuration of burner described herein offers several capabilities for reducing oxygen content in the product gas. Each of these capabilities relates to decreasing the quenching distance for the fuel-air mixture, which effect may be brought about by (a) raising the operating pressure, (b) increasing the length of the burner (same diameter), (c) insulating the "cold" end plates and (d) optimizing the perimeter/area ratio. Each of these design factors is readily exercised with the cylindrical burner configuration described. Although the preferred embodiment is the right circular cylinder construction, the term "cylinder" broadly embodies the surface generated by the movement in a closed curve of a first line parallel to a second straight line.

Apparently, the aforementioned problem of dense material formation does not occur when bronze shot is used or when burners of significantly greater diameter are prepared. Thus, providing that operation is to be at atmospheric pressure it is preferable to prepare both the burner cylinder 12 and the cooler-condenser 13 of bronze shot.

Cooler-condenser 13 is made in the same manner as has been described for burner cylinder 12.

The manifolding for coolant flow through burner cylinder 12 is entirely external to the generator 10 making for very simple adaption of the individual generators to the preparation of larger generators by assembly of smaller generator modules.

The performance of the generator construction shown was evaluated and found satisfactory at about 1 atmosphere using input mixtures ranging from about 11 to about 14 percent methane making gas at about 100 cu. ft./hr.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In an exothermic gas generator comprising in combination means for burning an explosive gas-oxidant mixture supplied thereto, flame-arrester means disposed between the flame in said burning means and the source of explosive gas-oxidant mixture to prevent premature ignition thereof and means in flow communication with the flame region of said burning means to cool the gaseous products of combustion and condense the water vapor produced during combustion, the improvement comprising in combination:

(a) a closed hollow cylindrical burner structure adapted to receive a flow of hydrocarbon gas-air mixture into the central hollow portion of said burner structure through one end thereof, the cylindrical wall of said

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burner structure being made of sintered porous metal the voids of which have an effective pore size smaller than 0.2 mm.,

(b) first means embedded in part in said burner cylindrical wall for circulating coolant fluid therethrough,

(c) a hollow cylindrical cooler-condenser located with said burner structure disposed in the central hollow portion thereof and spaced therefrom, the cylindrical wall of said cooler-condenser being made of sintered porous metal,

(d) second means embedded in part in said cooler-condenser cylindrical wall for circulating coolant fluid therethrough,

(e) means for enclosing said burner structure and said cooler-condenser and sealing the space between the outer surface of said burner structure and the inner surface of said cooler-condenser, said enclosing means defining a volume with the outer surface of said cooler-condenser,

(f) means forming part of said enclosing means adapted to receive ignition means for location thereof in communication with said space between said burner structure and cooler-condenser,

(g) means in flow communication with said enclosing means for removing gases from said volume, and

(h) means in flow communication with said enclosing means for removing condensate from said volume.

2. The improvement of claim 1 wherein ignition means are located in the receiving means.

3. The improvement of claim 1 wherein the burner structure is made of sintered copper particles.

4. The improvement of claim 1 wherein the outlet of the second means for circulating coolant is connected in flow communication with the inlet to said first means for circulating coolant.

5. The improvement of claim 1 wherein both the burner structure and the cooler-condenser are in the shape of right circular cylinders.

6. The improvement of claim 1 wherein both the burner structure and the cooler-condenser are made of sintered copper.

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