

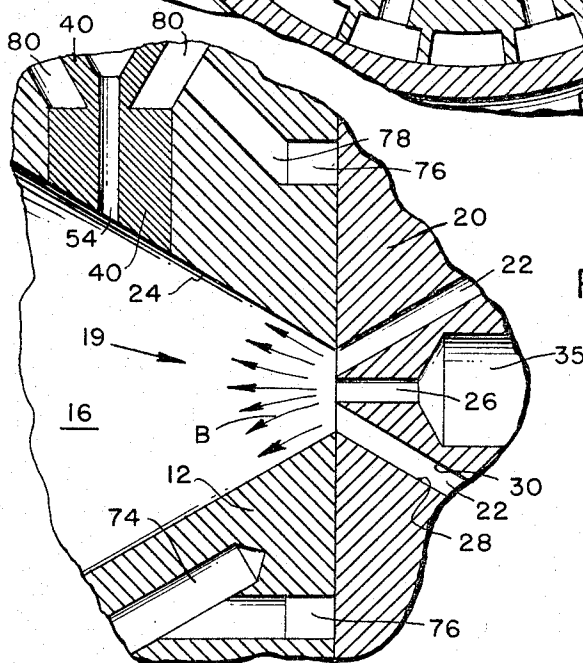
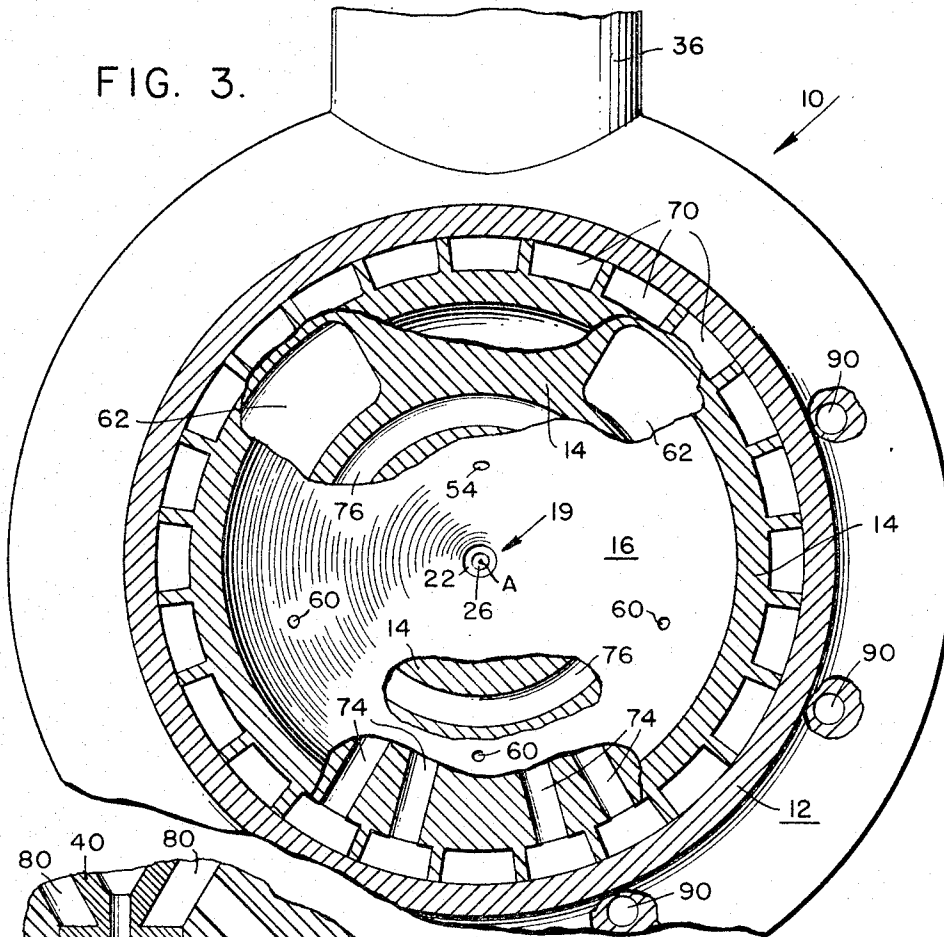
Oct. 4, 1966

C. A. REISMAN ET AL
COMBUSTION CHAMBER AND INJECTOR UNIT FOR A COMBINATION
OF LIQUID AND GASEOUS PROPELLANTS

3,276,205

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2 Sheets-Sheet 2



INVENTORS.
COLEMAN A. REISMAN
WILLIAM D. WHITE
DONALD N. JACKLEY
BY
Michael F. Oglo
ATTORNEY.

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2 Sheets-Sheet 1

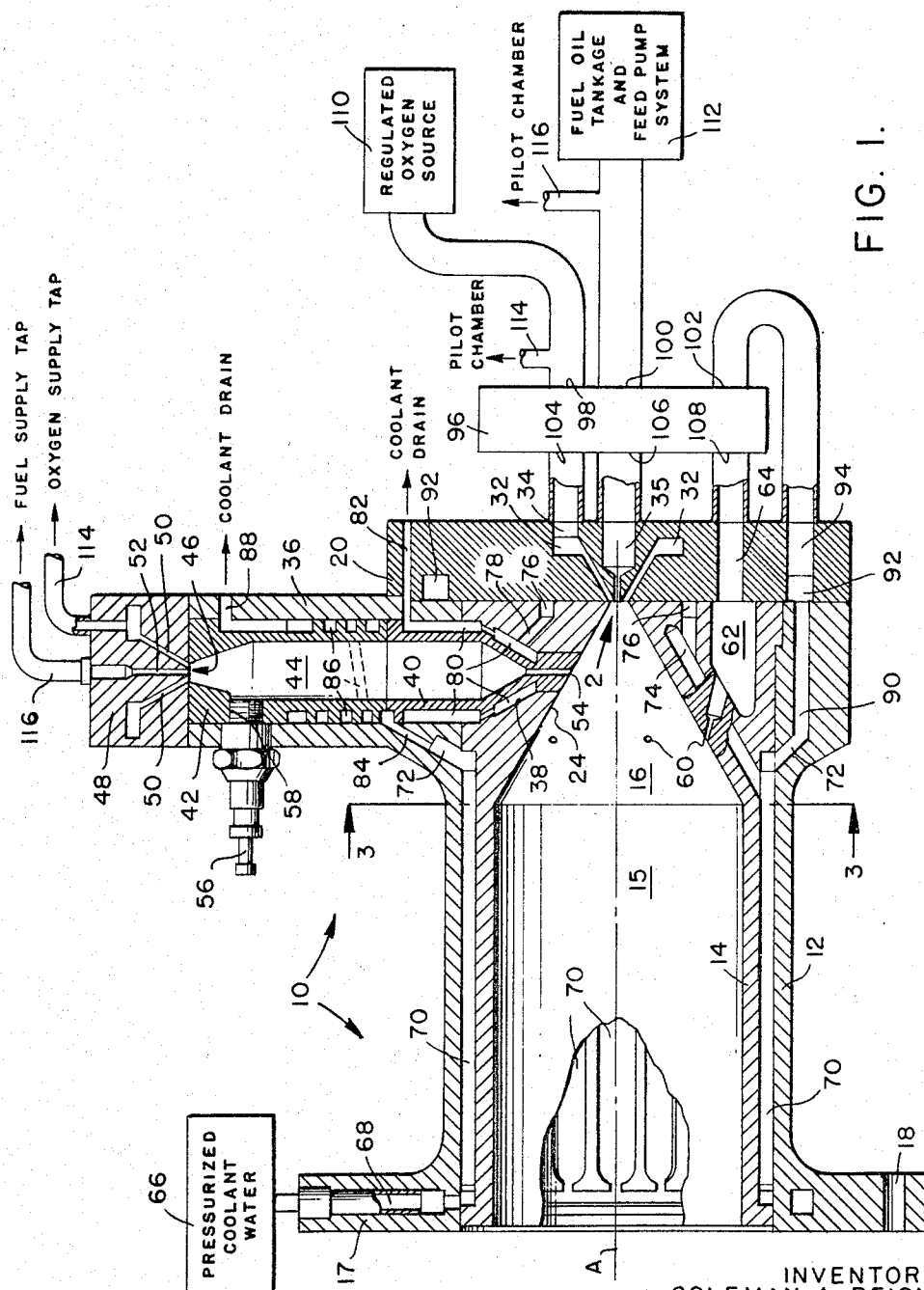


FIG. 1.

INVENTORS.
COLEMAN A. REISMAN
WILLIAM D. WHITE
DONALD N. JACKLEY

BY

Michael F. Oglo

ATTORNEY.

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Coleman A. Reisman, Sherman Oaks, William D. White,
Pasadena, and Donald N. Jackley, Monrovia, Calif.,
assignors to the United States of America as represented
by the Secretary of the Navy

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4 Claims. (Cl. 60—39.55)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to combustion chamber and injection apparatus for so called "chemical propellant" fueled thermal powerplants, and more particularly to apparatus for combusting gaseous oxygen and a liquid hydrocarbon, and thence introducing sufficient diluent water into the combustion chamber to cool the resulting products of combustion down to temperatures at which they are useful in the steam generator unit of a steam system.

An object of the invention is to provide combustion chamber and injection apparatus of the type referred to, and which provides efficient dispersion and mixing of the propellants over a very wide throttling range.

Another object is to provide apparatus in accordance with the previous objective, which further has a stop and restart capability.

A still further objective is to provide combustion chamber and propellant injection apparatus of the type referred to, and having a coolant system which does not detract from the efficiency or heat available from propellants when used in conjunction with a closed cycle steam powerplant of the type disclosed in U.S. Patent 3,145,508 to H. E. Karig, entitled, "Closed Cycle Power Plant." In the latter type of steam powerplant system the latent heat of vaporization of the injected diluent water is recovered by condensation during transfer of the heat to the steam side of the steam generator.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a central section of the subject of the invention, certain of the appurtenant equipment being shown schematically;

FIG. 2 is an enlarged detail of FIG. 1, indicated by arrow 2, FIG. 1; and

FIG. 3 is an enlarged transverse section taken along line 3—3, FIG. 1, and cut away at various places to show internal chambers.

Referring now to the drawings and in particular to FIG. 1, the subject of the invention is a combustion chamber and injector unit 10 for generating propulsion gases for a steam-type thermal powerplant, by burning gaseous oxygen and a liquid hydrocarbon, and introducing diluent water into the combustion chamber. The liquid hydrocarbon may consist of ordinary fuel oil. The introduction of diluent water is necessary to cool the products of combustion of gaseous oxygen and liquid hydrocarbon from their intrinsic stoichiometric-adiabatic flame temperature of approximately 6,000° F., down to a range of temperatures of the order of 2,500° F.—3,000° F., which is the upper limit of combustion propulsion gas temperatures which can be withstood by the materials normally used in the construction of the steam generator, or "boiler," unit of a steam system. Unit

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10 generally comprises a cylindrical outer shell 12 having an axis A and made of a ferrous material such as a suitable stainless steel. An inner heat transfer liner 14 is fitted within the bore of outer shell 12 and made of a cupreous material which exhibits good oxidation resistance qualities, and good high temperature strength characteristics, such as hardened zirconium copper alloy. The cupreous liner 14 forms a concentric combustion chamber 15, which is open at its left (as shown on the drawing) end, and which is shaped to form a conical flame chamber 16 at its right end. An integral flange 17 is provided on the outer liner 12, adjacent to the open end of inner liner 14. The flange is provided with a ring of bolt holes 18 (only one of which is shown) for attachment to a matching flange on the hot gas input port of the steam generator (not shown), or other device utilizing the hot gases. The conical wall of the flame chamber 16 converges to a small circular injector face aperture 19, best shown in FIGS. 2 and 3, where the interior wall of the liner intersects the end face of the liner. An injector face and end plate 20, of ferrous material, is disposed contiguous to the end face of the liner. The left or open end of chamber 15 constitutes the combustion gas delivery end of the chamber, and the apex end of conical chamber 16 constitutes the propellant injection end of the chamber.

Referring now to FIG. 2, in conjunction with FIG. 1, the injector mechanism for introducing the oxygen and liquid hydrocarbon to the combustion chamber is formed as inlets through plate 20 opening into the circular injector face aperture 19. The gaseous oxygen inlet is formed as a concentric annular slit 22 which converges in the direction toward the combustion chamber at an angle of convergency relative to axis A which is equal to that of the conical interior wall 24 of flame chamber 16, but with the convergency in the opposite axial direction. A liquid hydrocarbon inlet is formed as an axial cylindrical bore 26 opening directly into the center of the injector face. The lateral walls of the annular oxygen inlet slit are formed from uniformly-spaced inner and outer frustoconical surfaces 28 and 30, respectively. The circular loci where outer wall 28 of the oxygen gas inlet slit and the face of plate 20 meet, coincides with circular aperture 19 of the liner 14. The circular loci where the inner lateral wall 30 and the face of plate 20 meet, coincides with the circular edge of the periphery of the hydrocarbon inlet bore 26. Thusly formed, the periphery is shaped as a sharp circular knife-shaped edge in the direction facing the combustion chamber. As the result of this knife-edged configuration, no significant transverse surface area of the face of plate 20 is exposed to the combustion chamber, where such a transverse surface area would be exposed to erosive and corrosive effects of the combustion chamber gases. Oxygen is supplied to slit 22 from a concentric conduit chamber 32 which in turn is fed from a port 34 opening to the rear face of injector plate 20. Liquid hydrocarbon is supplied to inlet bore 26 through a larger diameter supply bore 35, which also serves as the port opening into the opposite side of plate 20.

A radially extending tubular housing 36 is formed as an integral portion of outer shell 12 adjacent flame chamber 16. A radially aligned generally conical cavity 38 is formed in liner 14 in co-axial radial alignment with the bore of tubular housing 36, with the inner end of cavity 38 opening into conical flame chamber 16. Tubular housing 36 and co-axially aligned cavity 39 serve to house components of a pilot flame chamber consisting of a pilot flame chamber lower liner section 40, and a pilot flame chamber upper liner section 42. Lower and upper liner

sections 40 and 42 together form a pilot flame chamber 44 which is cylindrical along the majority of its length, but has conical upper and lower ends. A small circular aperture 46 is formed where the conical lateral wall of the upper liner section 42 meets the liner end face. An injector block 48 is affixed to the upper end face of housing 36 and liner section 42. Injector block 48 contains a convergent annular oxygen gas inlet slit 50, and a central liquid fuel inlet bore 52, which are scaled down replicas of slit 22 and circular opening 26 into the main combustion chamber. A narrow cylindrical passage 54 communicates the bottom of the conical lower end of the pilot flame chamber 44 and the flame chamber 16. A suitable sparkplug 56 for igniting the gaseous oxygen and liquid hydrocarbon, is threadedly disposed in a sparkplug port 58, which opens into pilot flame chamber 44 near its upper end. Excellent results have been obtained using a Champion UJ-17V cold surface gas sparkplug, modified by having its gap widened to $\frac{1}{16}$ inch by turning down the outside electrode on a lathe, with the plug powered by a conventional sparking coil for starting diesel engines. As an alternative to use of a sparkplug igniter, it has been found that ignition can be obtained by applying sufficient heat directly to the injector passages to raise the temperature of the propellants to their auto-ignition temperature. This can be done, for example, by placing conventional electric heating rods, not shown, of approximately 1000 watts capacity, sufficiently close to the propellant passage structure to elevate the propellant temperature. The propellants will ignite where they impinge upon one another in the combustion chamber.

Referring now to FIG. 1 in connection with FIG. 3, the diluent water is introduced into the flame chamber 16 through a set of five injection orifices 60. Orifices 60 are arranged in a ring about the conical wall 24 of flame chamber 16 in angular spaced relation about axis A. The ring of injector orifices is axially spaced from the injector aperture 19 by a distance chosen to be slightly in excess of the zone in which the primary combustion reaction between the oxygen and hydrocarbon occurs, so that the diluent water cools the products of combustion of the reaction, but does not affect the reaction itself. The orifices are supplied the diluent water from a diluent supply chamber 62, which in a transverse section to axis A, has a concentric arcuate expanse of approximately 300°. The gap of 60° between the arcuate ends of the chamber coincides with the radial location of the pilot flame chamber structure. The diluent water is, in turn, introduced into arcuate chamber 62 from a conduit passage 64 extending through injector face plate 20. Passage 64 forms a port for receiving the diluent water where it opens into the rear face of plate 20.

The coolant water from a pressurized supply 66 enters outer shell 12 through a radial inlet port 68 in the flange portion 17 at the open end of outer shell 12. Suitable manifold passages communicate the coolant from port 68 to a plurality of longitudinal coolant slots 70 formed in the periphery of liner 14 and equiangularly spaced about axis A. The coolant flows through these slots in the direction toward the injector end of unit 10. After the coolant reaches the end of the slots, it is collected in a circular manifold ring 72, from which it follows any one of three possible branches of the coolant passage system as follows.

One of the three branches of the coolant system, which carries approximately 15% of the coolant flow, comprises a group of four pilot flame heat removal passages 74, which extend beneath and parallel to the frustoconical surface 22 in a generally axial direction toward the apex end of the conical chamber. At the apex end of passages 74, the coolant is collected by a manifold arrangement including a concentric coolant conduit ring 76. Conduit ring 76 delivers the coolant water to a small connection passage 78 positioned generally beneath the surface of the portion of the liner across from the open-

ing 54, from the pilot flame chamber 44. The connection passage 78, in turn, delivers the coolant water to an annular coolant flow space 80 for removing heat from the lower portion of the pilot flame chamber, and formed between lower pilot flame chamber liner section 40 and tubular housing 36. The annular coolant flow space 80 extends upwardly to a position near the junction of lower and upper liner sections 40 and 42. In order to provide desired structural strength, the construction and arrangement of space 80 is such that the flow space is somewhat compartmented with small flow passages extending through the dividing structure. A coolant drain passage 82, through housing portion 36 and end plate 20, communicates the coolant to the outer face of plate 20, where suitable means (not shown) conveys same back to the reservoir for the coolant water supply.

The second of the three branches of the coolant system, which carries approximately 10% of the coolant flow, comprises a small passage 84 which taps into the circular manifold ring 72, near pilot chamber 44. Passage 84 communicates the coolant to spiral passage 86, which winds upwardly between upper flame chamber liner section 42 and the tubular housing portion 36. Another drain passage 88 carries the coolant from the upper end of spiral passage 86 to the exterior of housing portion 36 where it is thence suitably conveyed to the coolant water reservoir.

The third branch of the coolant system carries the majority of coolant (approximately 75%), but only during times when combustion is present in the main chamber 15. The third branch consists of a plurality of axially extending passages 90, which are angularly spaced about axis A. Another conduit ring 92, formed in the inner face of injector face plate 20, collects the coolant from passages 90, and communicates same to an outlet passage 94 in plate 20. Passage 94 forms the coolant outlet port at the outer side of plate 20.

A throttling valve unit 96 has an inlet side having oxygen, fuel, and diluent water inlet ports 98, 100, and 102, respectively, and an output side having oxygen, fuel, and diluent water outlet ports 104, 106, and 108, respectively. Gaseous oxygen under predetermined pressure from a regulated pressurized source 110 is ducted to port 98, and fuel oil under predetermined pressure from a tankage and feed pump system 112 is ducted to port 100. Diluent water is ducted from coolant water outlet passage 94 at the outer face of plate 16 to port 102. Unit 96 responds to a control stimuli, to meter the oxygen and fuel with a constant proportion of flow rates therebetween, and to vary the proportion of diluent water flow to propellant flow in an approximately linear manner, all simultaneously. Control stimuli may, for example, consist of an operator's manual control panel. The flow rate proportions of the three fluids for maximum and minimum flow conditions for one highly successful embodiment of unit 10 are given in the following table:

	Oxygen	Fuel	Diluent Water
Maximum flow, lb./sec.-----	0.752	0.223	1.291
Minimum flow, lb./sec.-----	0.030	0.0089	0.775

The foregoing table represents operation with a range of combustion chamber pressures of 1000-3000 p.s.i.; and a range of temperature of hot gas output of 2500° F.-3000° F. Valving unit 96 also provides start and stop control by including a closed valve condition in its range of operation.

One type of throttling valving unit 96 found to provide highly satisfactory results comprises three conventional slotted cylindrical pintle and metering block sets (structure not shown), one for metering each of the fluids. Each pintle slides in a lap-fitted cylindrical bore of a metering block. A tapered bottomed, rectangular cross sectioned, slot is formed in each pintle. The meter-

ing orifice is formed on three sides by the pintle slot and one side by the wall of the metering block bores. The three pintle members are ganged together for simultaneous positioning by the control stimuli, and the taper and size of the pintle slots are chosen to provide the correct flow and injection pressures for maintaining the stoichiometric oxygen-fuel ratio, and the desired linear relationship of diluent to propellant, as listed in the foregoing table.

Oxygen and fuel are conveyed to the pilot flame chamber injector block 48 via small conduits 114 and 116, which tap into the oxygen and fuel supply lines, respectively, upstream of the inlet side of valve unit 96.

The procedure for starting device 10 is as follows. The throttling valve unit 96 is initially in its closed condition preventing flow of oxygen, fuel oil, and diluent into the main combustion chamber. Pressurized coolant water is initially applied to coolant system inlet port 68 in the flange 17 at the gas delivery end of outer shell 12. The sparkplug 56 is energized and pilot flame chamber propellant inlet valves, not shown, in oxygen and fuel oil lines 114 and 116, are opened. This applies these fluids to injector block 48, where the convergent oxygen slit 50 introduces the oxygen gas into the chamber in a conical sheet-like stream, which intermixes and disperses the steam of liquid fuel oil introduced through inlet bore 46. The intermixed and dispersed oxygen and fuel oil is ignited by sparkplug 56, and continuous combustion in pilot flame chamber 42 follows, so that the sparkplug may be then de-energized. The combustion in the pilot flame chamber results in the projection of a pilot flame out through flame outlet passage 54 into frustoconical flame chamber 18. The initial application of pressurized coolant water to the coolant passage system results in flow of water through two of the three branches of the coolant flow system, namely through the branch consisting of heat removal passages 74 beneath the surface of wall 24 and annular passage 80 about the lower end of pilot flame chamber 44, and through the branch consisting of passages 86 about the upper liner section 42 of the flame chamber. The flow through these two branches serves to effectively cool all the parts exposed to heat by operation of pilot flame chamber 44, including the heat applied to wall 24 of the main chamber across from opening 54. Since the throttling valve unit 96 is shut off, there is no flow of coolant water through the remaining branch consisting of manifold 62 and outlet passage 94.

To start combustion in the main chamber, valve unit 96 is actuated to an open condition, and propellants injected into the conical chamber 16, where they are intermixed and dispersed in the same manner as in the pilot flame chamber. The flame from chamber 44 ignites the propellants. Opening valve unit 96 also starts the injection of diluent water into the combustion chamber through orifices 60, and causes a corresponding increase of coolant flow through passages 70.

Exhaustive tests have revealed that the construction and arrangement of the conical chamber and the injector orifices permits a wide throttling range, including starts and stops. One highly successful embodiment permits a throttling range of propellant flow rates of 30:1. The arrangement also provides necessary resistance against structural damage by the extremely high reaction temperatures at the upstream portion of the conical flame chamber 16. It is believed that the resistance to heat damage is the result of the matching configuration of the oxygen injection orifices 22 and the wall 24 of the flame chamber 16. The gaseous oxygen stream from the convergent oxygen inlet slit 24 disperses the centrally introduced liquid hydrocarbon in a spray pattern, arrows B, FIG. 2, which conforms to the matching convergence angle of the wall 24 of the conical flame chamber. The match between the spray pattern, and the shape of the chamber wall prevents stagnation adjacent to the wall, 75

which would cause burning of the wall. The same principles apply to the configuration at the flame chamber injector inlets and the conical upper end of the pilot flame chamber 44.

An advantageous feature of unit 10 is realized when it is employed in conjunction with the closed cycle pilot plant described in previously mentioned U.S. Patent 3,148,508, in which the latent heat of vaporization of the injected diluent water is recovered by condensation during transfer of the heat to the steam side of the steam generator. When unit 10 is used in such a system, the heat absorbed by the approximately 75% of the coolant which emerges from the branch of the coolant consisting of manifold 62 and passage 94, preheats the diluent water closer to its vaporization temperature. It will therefore be appreciated that the heat removed by the coolant water does not detract from the efficiency or heat available from the propellants.

As an alternative to the constant pressure sources and the metering and proportioning valve unit 96, an effective throttling system may be constructed by use of positive displacement pumps and non-pressurized tankage for the fuel and diluent water supplies, use of a variable regulator with pressurized oxygen gas source, and use of means to simultaneously control the pumps and regulator to provide the desired flow rates and proportions throughout the desired throttling range.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. Combustion chamber and propellant injection apparatus for combusting gaseous oxygen and liquid hydrocarbon and introducing diluent water to reduce the temperature of the products of combustion of these propellants from their intrinsic stoichiometric-adiabatic flame temperature, which is in the order of 6000° F., down to a desired range of temperatures of the order of 2500° F.-3500° F., comprising;

(a) a cylindrical outer pressure combustion chamber shell made of ferrous material, said shell having opposite ends consisting of a combustion gas delivery end, and a propellant injection end,

(b) a combustion chamber annular heat transfer liner adapted to be fitted within the interior of the outer shell in contiguous relationship to its inner peripheral surface and made of cupreous material, said annular liner member having gas delivery and propellant injection ends co-adjacent to the corresponding ends of the outer shell member, said heat transfer liner comprising a first cylindrical axial section extending a predetermined axial distance inwardly from its gas delivery end, and a second axial section adjoining the inner end of the first cylindrical axial section and extending to the liner's propellant injection end, said second axial section having an increasing annular wall thickness in the direction of the propellant injector end to form a conical section of the combustion chamber, the walls of the conical combustion chamber section having a predetermined angle of convergency relative to the liner axis, said liner at its propellant injection end forming a transverse end face and the wall of the conical combustion chamber section intersecting said transverse end face at a first circular loci defining a central aperture in the transverse end face of the heat transfer liner, said first axial section of the heat transfer liner forming a cylindrical section of the combustion chamber adjoining and communicating with the large end of the conical combustion chamber section and through which the combustion gases flow prior to their emergence from the combustion gas delivery end of the heat transfer liner,

- (c) means forming coolant water passages in heat transfer relation to the liner and beneath the inner peripheral surface of the heat transfer liner,
- (d) a transverse injector face plate made of ferrous material disposed across the propellant injection end of the heat exchange liner, said injector wall having an inner face in abutting relationship to the transverse end face of the heat transfer liner,
- (e) a circular cross sectioned hydrocarbon injection bore for injecting liquid hydrocarbon into the conical combustion chamber section, said hydrocarbon injection bore being formed in the injector face plate and opening into the circular aperture in the transverse end face of the heat transfer liner, said hydrocarbon injection bore having a diameter less than that of said circular aperture,
- (f) a convergent annular oxygen injection slit for injecting gaseous oxygen into the conical combustion chamber section, said annular oxygen injection slit being formed in the injector face plate and opening into the circular aperture of the transverse end face of the heat transfer liner, said annular oxygen injection slit having an angle of convergency which is equal to the predetermined angle of convergency of the conical combustion chamber section, but with the slit converging in the axial direction opposite to that in which the conical combustion chamber section converges, said annular oxygen injection slit having its inner periphery intersecting the periphery of the hydrocarbon injection bore in the transverse plane of the inner face of the injector face plate, said intersection of the inner periphery of the annular oxygen injection slit and the periphery of the hydrocarbon injection bore defining a sharp circular edge, said annular oxygen injection slit having a slit thickness equal to the difference between the diameter of the central circular aperture in the transverse end face of the heat transfer liner and the diameter of the hydrocarbon injection bore so that the outer periph-

- ery of the oxygen injection slit intersects the inner face of the injector face plate at a second circular loci contiguous to the first circular loci, and
- (g) a plurality of angularly spaced liquid diluent injection orifices formed in the wall of the conical combustion chamber section for delivering diluent water into the conical combustion chamber section, said plurality of diluent injection orifices being disposed at an axial distance in excess of the nominal distance at which the majority of the combustion process has occurred.
- 2. Apparatus in accordance with claim 1, and further of the type operated to produce selectively variable rates of combustion gases over a range of flow rates having a ratio of maximum flow rate to minimum flow rate in excess of 10:1, and
- (h) means for delivering the gaseous oxygen and the liquid hydrocarbon to the annular oxygen injection slit and the hydrocarbon injection bore, respectively, at a fixed predetermined ratio of oxygen to fuel over said range of flow rates and for delivering said diluent water to said orifice means at a ratio of diluent water flow to propellant flow which decreases in an approximately linear manner over the range of flow rates.
- 3. Apparatus in accordance with claim 2, and further of the type having a stop and restart capability, and
- (i) means for introducing a pilot flame into said conical flame chamber.
- 4. Apparatus in accordance with claim 1, wherein,
- (j) the coolant water is delivered to the diluent injection orifice after absorbing heat in its flow through said coolant water passages.

No references cited.

CARLTON R. CROYLE, *Primary Examiner*.
R. D. BLAKESLEE, *Assistant Examiner*.