Feb. 26, 1946. R. H. GODDARD 2,395,406

COMBUSTION APPARATUS

Filed Nov. 18, 1941 2 Sheets-Sheet 1

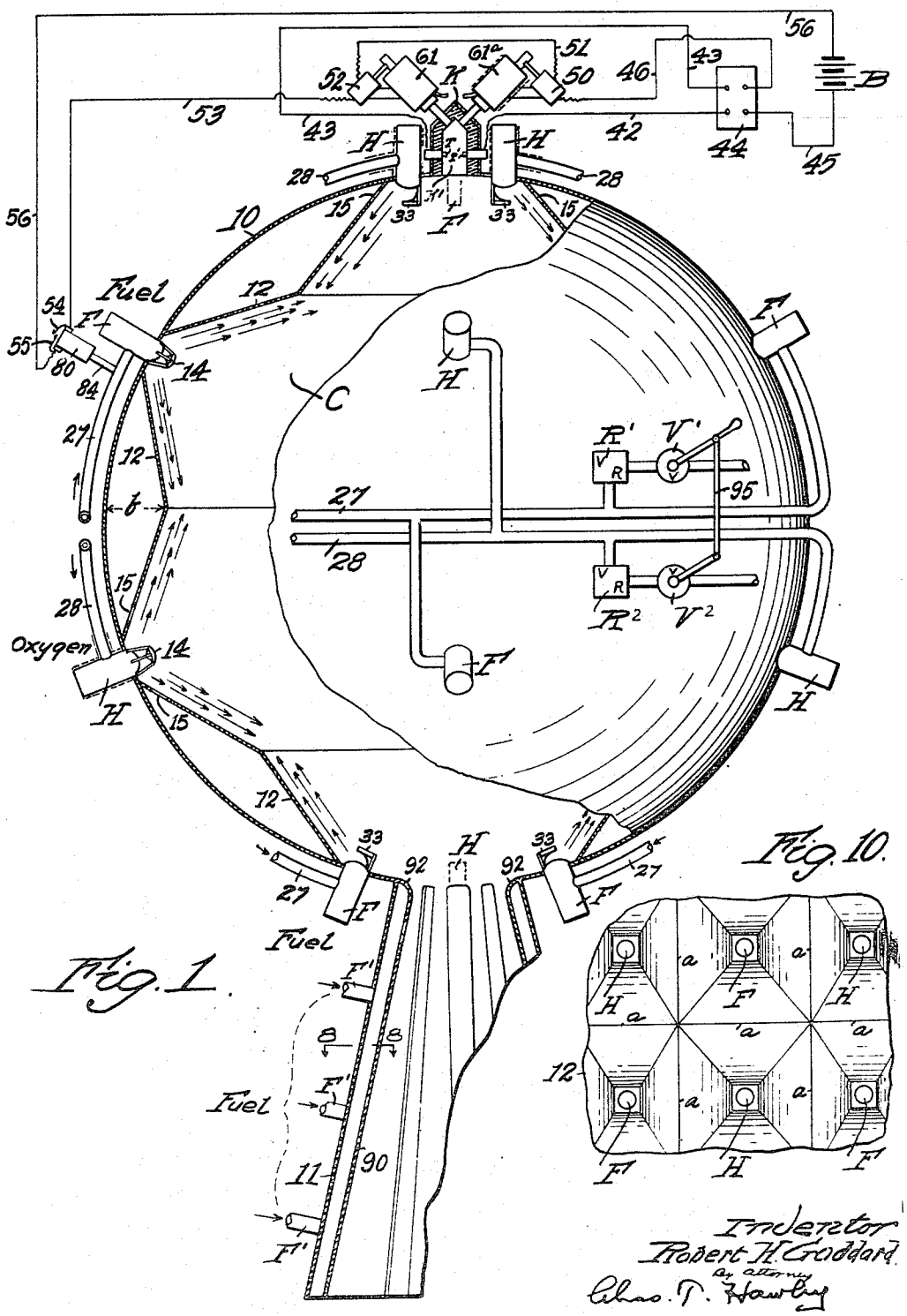


Fig. 1.

Fig. 10.

Inventor
Robert H. Goddard
by attorney
Chas. T. Hawley

Feb. 26, 1946. R. H. GODDARD 2,395,406

COMBUSTION APPARATUS

Filed Nov. 18, 1941 2 Sheets-Sheet 2

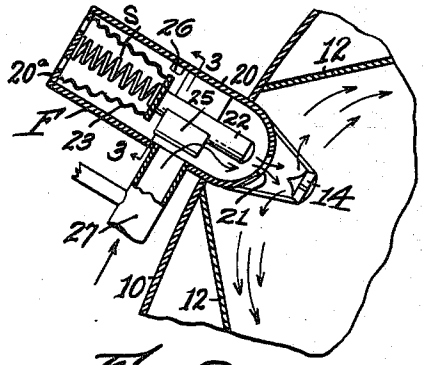


Fig. 2.

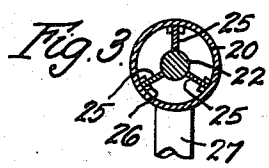


Fig. 3.

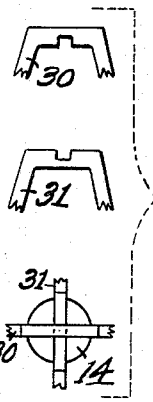
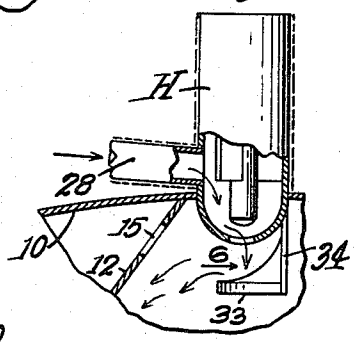


Fig. 4.

Fig. 5.



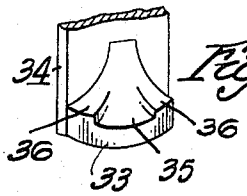


Fig. 6.

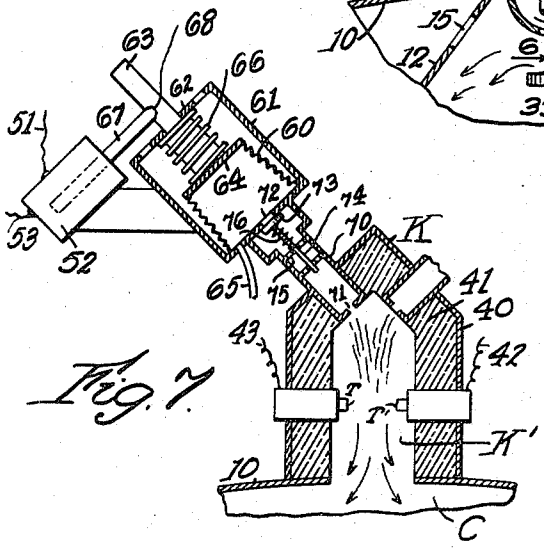


Fig. 7.

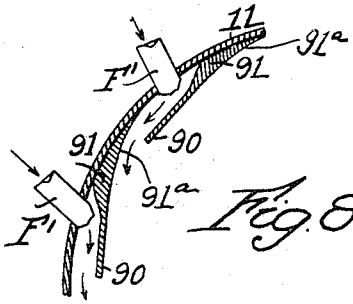


Fig. 8.

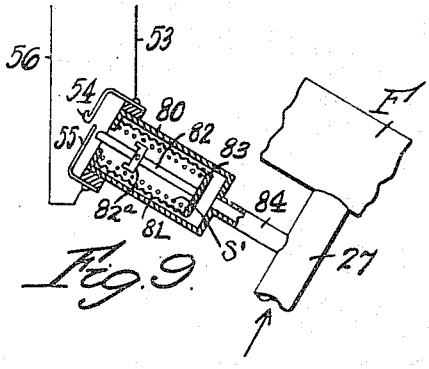


Fig. 9.

Inventor
Robert H. Goddard
by attorneys
Chas. T. Hawley

Patented Feb. 26, 1946 2,395,406

UNITED STATES PATENT OFFICE

2,395,406

COMBUSTION APPARATUS

Robert H. Goddard, Roswell, N. Mex., assignor of one-half to The Daniel and Florence Guggenheim Foundation, New York, N. Y., a corporation of New York

Application November 18, 1941, Serial No. 419,617

10 Claims. (Cl. 60—35.6)

This invention relates to apparatus particularly designed for the combustion of a mixture of liquid fuel, as gasoline, and a liquid oxidizing agent, as liquid oxygen or liquid air. While certain features of the invention are capable of general application, the invention is of exceptional value in connection with the propulsion of rockets or rocket craft, in which gases are continuously produced under pressure in a combustion chamber and are continuously ejected through a rearwardly open discharge nozzle.

It is one object of my present invention to provide an effective liquid screen for the thin metal walls of a combustion chamber, shown herein as of spherical shape.

To the accomplishment of this object, I provide a plurality of relatively large feed nozzles, somewhat widely spaced apart in the wall of the combustion chamber, and similar nozzles in the frustro-conical wall of the discharge nozzle.

Another object is to provide pressure-controlled means for simultaneously admitting gas and liquid oxygen to the combustion chamber through a plurality of nozzles mounted in spaced relation in the combustion chamber walls.

Another object of the invention is to provide means to produce a large ignition flame for a very brief period, beginning just prior to the admission of gasoline and liquid oxygen when starting the apparatus. I also provide improved feeding nozzle constructions, improved devices for cooling the wall of the discharge nozzle, and an improved guard construction for the inner face of the combustion chamber wall.

My invention further relates to arrangements and combinations of parts which will be hereinafter described and more particularly pointed out in the appended claims.

A preferred form of the invention is shown in the drawings, in which

Fig. 1 is a side elevation, partly in section, of my improved combustion apparatus;

Fig. 2 is a sectional side elevation of a fuel feeding nozzle;

Fig. 3 is a detail sectional view, taken along the line 3—3 in Fig. 2;

Fig. 4 is a collective view, showing structural details of a deflector shown in Fig. 2;

Fig. 5 is a side elevation, partly in section, of an oxygen feeding nozzle;

Fig. 6 is a perspective view of a special deflector, looking substantially in the direction of the arrow 6 in Fig. 5;

Fig. 7 is a partial sectional elevation of an igniter;

Fig. 8 is a partial sectional view of the discharge nozzle, taken along the line 8—8 in Fig. 1;

Fig. 9 is a sectional side elevation of a circuit-closing device to be described; and

Fig. 10 is a partial side elevation of the inner wall of the combustion chamber.

Referring to Fig. 1, my improved combustion apparatus preferably comprises a substantially spherical casing 10 and a discharge nozzle 11. A plurality of liquid fuel nozzles F and liquid oxygen nozzles H are mounted in spaced relation in the spherical side wall of the combustion chamber. Each nozzle F or H is also located at the depressed apex of a rectangular pyramidal metal shield or guard structure 12.

The liquid fuel or liquid oxygen issuing from each nozzle is diverted by a deflector 14 and flows laterally therefrom and substantially parallel to the surfaces of its pyramidal shield 12. The sprays of fuel and oxygen intermingle at the edges *a* of the substantially square areas defined by the shields 12, as indicated in Fig. 10, and along these edges combustible mixtures are formed and combustion largely takes place.

It will be noted in Fig. 1 that the combustion areas thus formed at the intersections *a* of the pyramidal guards or shields 12 are substantially spaced inward from the cylindrical casing 10, as indicated at *b*. Overheating of the casing is thus prevented. Openings 15 in the shields 12 equalize the pressures on the opposite faces thereof.

The detailed construction of one of the fuel feeding nozzles F is shown in Figs. 2, 3 and 4. Each nozzle consists of a tube 20 having a rounded inner end welded or otherwise secured in an opening in the casing 10 and having a feed outlet 21. A valve rod 22 is secured at the inner end of a bellows member 23, and the outer end of the bellows member is secured to the perforated outer end 20a of the tube 20. A compression spring S holds the member 23 normally distended.

The rod 22 is provided with vanes or guide members 25 (Fig. 3) by which it is loosely centered in the tube 20 but is freely slidable therein. Stops 26 are engaged by the vanes 25 to limit outward movement of the rod 22. A pipe 27 provides liquid fuel from any suitable source of supply, such as a pressure tank, through a shut-off valve V' and reducing valve R', both of usual commercial construction.

When the fuel pressure is sufficient to overcome the resistance of the bellows member 23 and the spring S and the atmospheric pressure exerted on the bellows, the plunger 22 will be

withdrawn from the outlet 21 and fuel will be admitted to the combustion chamber.

The construction of the oxygen feeding nozzles H is exactly the same as that of the fuel feeding nozzles F, except that the oxygen nozzles and connections are preferably jacketed to prevent evaporation of the liquid oxygen, which might otherwise cause gas bind in the apparatus. One of the oxygen feeding nozzles H is shown in Fig. 5, in which the jacket covering of the nozzle H and of its supply connection is indicated in broken lines. The liquid oxygen may be supplied from a second storage tank through a shut-off valve V^2, reducing valve R^2 and pipe 28, all as previously described.

The liquid feeding devices F and H are all constructed to open at the same pressure, and the reducing valves R' and R^2 maintain the liquid fuel and liquid oxygen always at equal pressures. Consequently, when the liquid pressure rises to a predetermined point, all of the feeding devices F and H will open simultaneously and will feed their respective liquids into the combustion chamber.

The deflector 14 provided for each feeding nozzle preferably comprises an inwardly pointed copper disc held in spaced relation to the opening 21 by supporting members 30 and 31, which members are notched and crossed as indicated in Fig. 4 and have their depending legs secured to the inner ends of the tubes 20. The members 30 and 31 are seated in slots in the deflecting disc and are preferably secured and protected by brazing material, such as copper, applied to the outer face of the disc.

The fuel feeding devices F and the oxygen feeding devices H are alternately arranged in the inner surface of the casing 10, so that fuel and oxygen will intermingle along each dividing line *a* between adjacent pyramidal depressions (Fig. 10).

The supporting members 30 and 31 are mounted on the nozzle tubes 20 in such angular positions that the depending legs thereof are aligned with the corners of the pyramidal guards or shields 12, so that very little gasoline or oxygen is sprayed along these corner surface intersections and consequently like liquids intermingle only slightly at the corners of the square deflecting areas shown in Fig. 10.

The fuel and oxygen feeding devices adjacent the discharge nozzle 11 and also adjacent the igniter K to be described are substantially the same as the nozzles previously described, except for the provision of special deflectors which divert the injected liquids in certain directions only, rather than in all directions as with the form previously described.

One of these special deflectors is shown in Figs. 5 and 6 and comprises a deflecting element 33 mounted on a plate 34 which is secured to the inner end of the associated nozzle. The member 33 covers only a semi-circumference or less and is provided with a middle portion 35 and raised edge portions 36. With this construction, the liquid will be diverted toward the adjacent sprayed areas and away from the adjacent discharge outlet or ignition device. The raised edge portions 36 reduce the density of the spray at the edges of the sprayed area and in this respect act similarly to the legs of the members 30 and 31 of the deflector 14 previously described.

These raised edge portions 36 also serve to reduce the amount of sidewise spray, where the nozzles F and H and the deflectors 33 are placed close together, as around the igniter K of Fig. 1. Substantially the same density of spray is thus obtained along all the lines of intermingling, such as the lines *a* in Fig. 10.

The construction of the igniter K is clearly shown in Fig. 7 and comprises an ignition chamber K' having a steel casing 40, provided with a refractory lining 41 and welded or otherwise secured to the casing 10 opposite the discharge nozzle 11. Spark terminals T and T' are mounted at opposite sides of the casing 40 but are suitably insulated therefrom and extend through the refractory lining 41. Wires 42 and 43 (Figs. 7 and 1) connect the terminals T and T' to the secondary winding of a spark coil 44.

One side of the primary winding of the coil 44 is connected by a wire 45 to a battery B or other suitable source of current, and the other terminals of the primary is connected by a wire 46 through a solenoid 50, wire 51, second solenoid 52, wire 53, normally open contacts 54 and 55, and a wire 56 to the opposite pole of the battery B. The operation of these electrical connections will be hereinafter described.

In starting my improved combustion apparatus, it is desirable to have a relatively large volume of burning gases injected into the combustion chamber just prior to the admission of liquid fuel and oxygen through the nozzles F and H, so that the mingled sprays of these liquids may be immediately ignited, thus avoiding any danger of explosion. It is not necessary, however, that the ignition flame should continue after combustion is well started in the combustion chamber. Consequently, I provide the igniter K with special devices for feeding limited quantities of fuel and oxygen into the igniter chamber K' just prior to admission of fuel and oxygen to the combustion chamber C.

One of these special devices is shown in detail in Fig. 7, in which a bellows member 60 is mounted within an enclosing casing 61, the perforated outer end 62 of which forms a guideway for a rod 63 which extends outward from the plate 64 which forms the movable end of the bellows member 60. Gasoline is fed through a restricted connection 65 to the inside of the bellows member 60, which is thus normally filled with gasoline. A spring 66 is provided to deflate the bellows member 60 but this spring is normally prevented from operating by a latch or plunger 67 which is seated in a notch 68 in the side of the rod 63. The plunger 67 extends into the solenoid 52 previously described and is actuated thereby.

The casing 61 is mounted on a connection 70 extending through the igniter casing 40 and through the refractory material 41 and closed at its inner end, except for a relatively small opening 71. An opening 72 connects the interior of the bellows member 60 with the interior of the connection 70, and this opening 72 is normally closed by a valve 73 having a valve stem 74 slidable in perforated partitions 75 in the connection 70. A light spring 76 holds the valve 73 normally closed against the pressure of the liquid in the bellows member 60.

The construction of the fuel feeding device above described is duplicated for the liquid oxygen, as indicated at 61^a (Fig. 1), the construction being identical except for the addition of the usual jacket to the oxygen feeding device.

Means for timing the release of the liquids for the igniter K, with respect to the admission of

fuel and oxygen through the nozzles F and H to the combustion chamber C, is shown in Fig. 9, in which the normally spaced contacts 54 and 55 are shown as mounted at the outer end of a casing 80 which encloses a bellows member 81 having a rod 82 fixed to the movable end plate 83 of the bellows member 81 and slidable through an opening in the outer end of the casing 80. The space between the casing 80 and the bellows member 81 is connected by a tube 84 to the pipe 27 by which fuel is supplied to the fuel nozzles F. A compression spring S' holds the bellows member 81 normally distended.

When pressure is exerted in the pipe 27, the bellows member 81 will be compressed, causing the rod 82 to move the contact 55 into engagement with its associated contact 54, thus completing a circuit through the solenoids 50 and 52. As soon as these solenoids are energized, the solenoid plungers 67 are withdrawn, releasing the rods 63 so that the springs 66 may immediately deflate the bellows members 60 in the devices 61 and 61' and eject the liquids therein through the openings 71 to the ignition chamber K'. At the same time the spark coil 44 is energized, producing sparks between the terminals T and T'. The mixed liquids are thus ignited and the combustion gases are injected into the combustion chamber C as a large volume of flame which, however, is of relatively short duration.

The timing device shown in Fig. 9 is set to be deflated at slightly less pressure than the bellows members 23 in the fuel and oxygen nozzles F and H. Consequently, the flame will be injected into the combustion chamber C slightly before the fuel and oxygen are fed from the nozzles F and H. As soon as the ejecting action of the springs 66 and movable plates 64 has been completed, the valves 73 again close the openings 72 and prevent further operation of the igniter K.

It is important that the time elapsing between the beginning of the ignition flame and the admission of the liquids be a minimum, in order to avoid burning or melting of the thin metal structures in the chamber C before they can be protected by the sprays of liquids.

In Figs. 1 and 8 I have shown the special construction which I provide for cooling the discharge nozzle 11. For this purpose I provide a series of longitudinally extending strips 90, each having a thickened edge portion 91 welded or otherwise secured to the inner surface of the nozzle 11 and each having its upper end curved over and secured as indicated at 92 in Fig. 1 to provide smooth entrance to the discharge nozzle. The inside surfaces of the edge portions 91 are curved, as at 91^a, (Fig. 8) in order to avoid abrupt changes in direction of the streams from the nozzles F'.

Fuel nozzles F' are provided in the frustro-conical wall of the nozzle 11, said fuel nozzles being spaced lengthwise of the discharge nozzle and also spaced apart circumferentially and being located behind the strips 90 as shown in Fig. 8. The nozzles F' may be the same in construction and method of operation as the nozzles F previously described, except that no deflector is required. The liquid issuing through the end opening of each nozzle engages the inner side of the adjacent strip 90 at an acuate angle and is deflected circumferentially of the discharge nozzle, as indicated by arrows in Fig. 8.

The inner surface of the discharge nozzle is thus effectively cooled, while at the same time there are no shoulders nor openings in the surface engaged by the ejected combustion gases and consequently free discharge of the gases is attained. The nozzles F' are commonly of reduced size and have smaller discharge openings than the nozzles F, so that only sufficient liquid fuel is discharged therethrough to cool the adjacent metal surfaces. Combustion in the discharge nozzle is not desired.

Having described the details of construction of my improved combustion apparatus, it is believed that the method of operation and the advantages thereof will be readily apparent.

In order to start the apparatus in operation, it is merely necessary to simultaneously open the valves V' and V^2 (Fig. 1), which valves are preferably connected by a link 95 and may be manually operated. The liquid fuel and liquid oxygen under pressure in the storage tanks then pass through the reducing valves R' and R^2 and into the distributing pipes 27 and 28. As the pressure rises in the pipes 27 and 28 and in the feeding nozzles F and H, the fuel under pressure will overcome the bellows member 81 and the spring S' (Fig. 9) and will thus complete the ignition circuit through the spark terminals T and T'. At the same time the solenoids 50 and 52 will release the rods 63 (Fig. 7), so that the bellows members 60 may discharge fuel and oxygen into ignition chamber K', where the mixed liquids are immediately ignited.

Such ignition takes place just prior to the opening of the valves F and H, as previously explained, so that a considerable volume of flame is present in the combustion chamber when the fuel and gasoline are admitted thereto. The igniter K then goes out of operation through exhaustion of liquids in the bellows members 60 and the igniter and solenoid circuits are broken by continued outward movement of the rod 82 (Fig. 9). A stop 82^a limits such outward movement.

The combustion gases in the combustion chamber C are then ejected through the discharge nozzle 11. The walls of the casing 10 and of the nozzle 11 are effectively cooled and protected during combustion by the shields 12 and the strips 90 respectively and by the liquid films associated therefor.

To stop operations, it is merely necessary to simultaneously close the valves V' and V^2, so that the feeding of fuel and oxygen to the combustion chamber will likewise be simultaneously stopped. This is desirable, as any residue of either liquid is objectionable and may cause damage to the apparatus, particularly if excess oxygen is present. Any residual fuel combining with any residual oxygen after the flow of cooling liquids has ceased may cause burning of the thin metal casings and shields and other light structures. It will be noted also that the perforations 15 in the shields 12 are all adjacent the oxygen nozzles H, so that no fuel will accumulate behind the shields and be present in the chamber after combustion has ceased.

The use of a relatively small number of feeding nozzles, spaced substantially apart, is an important improvement over the use of a large number of very small feeding orifices, which has been the previous practice. The larger outlets of the spaced nozzles substantially reduce friction losses.

The specific construction of the igniter and of the devices for feeding limited quantities of fuel and oxygen thereto is not claimed herein but forms the subject matter of a divisional applica-

tion Serial No. 635,996, filed December 19, 1945.

Having thus described my invention and the advantages thereof, I do not wish to be limited to the details herein disclosed, otherwise than as set forth in the claims, but what I claim is:

1. Combustion apparatus comprising a casing enclosing a combustion chamber, a plurality of fuel feeding nozzles and a plurality of liquid oxygen feeding nozzles arranged alternately and in spaced relation in the side wall of said casing, and means to deflect said liquids in flat sprays diverging from each nozzle, with unlike liquids meeting in defined linear combustion areas, and with one such linear combustion area positioned substantially midway between each pair of adjacent nozzles.

2. The combination in combustion apparatus as set forth in claim 1, in which the deflecting means for each nozzle comprises a deflecting disc and means to support said disc in alignment with the outlet of its associated nozzle.

3. The combination in combustion apparatus as set forth in claim 1, in which the deflecting means comprises a deflecting disc for each nozzle and means to support said disc in alignment with the outlet of its associated nozzle, and in which the supporting means comprises four depending supporting legs, each angularly positioned substantially midway between the center lines connecting adjacent and unlike nozzles and diverting the sprayed liquid from associated narrow areas.

4. The combination in combustion apparatus as set forth in claim 1, in which an inverted pyramidal shield is provided for each feeding nozzle, and in which the flat surfaces of each shield underlie said flat sprays and are substantially spaced from the casing wall at the combustion areas.

5. The combination in combustion apparatus as set forth in claim 1, in which an inverted pyramidal shield is provided for each feeding nozzle, the flat surfaces of each shield underlying said flat sprays and being substantially spaced from the casing wall at the combustion areas, and in which means is provided in each shield adjacent the fuel-feeding nozzles to equalize the pressures on the inner and outer faces of said shields.

6. In a combustion apparatus having a combustion chamber, in combination, a rearwardly-open frustro-conical discharge nozzle communicating with said chamber, a plurality of elongated metal strips extending longitudinally of said nozzle and each secured along one edge to the inner face of the nozzle wall and having the other edge spaced therefrom, and fuel feeding nozzles communicating with the elongated narrow open-edge spaces behind said strips and providing a liquid film to cool the nozzle wall and strips.

7. The combination in combustion apparatus as set forth in claim 6, in which the ends of the strips adjacent the entrance of the discharge nozzle are curved over and secured to the circumferential entrance edge of said nozzle to provide a smooth surface for the combustion gases as discharged from the combustion chamber.

8. Combustion apparatus comprising a casing enclosing a combustion chamber, a plurality of fuel feeding nozzles and a plurality of liquid oxygen feeding nozzles arranged alternately and in spaced relation in the side wall of said casing, said combustion chamber having a discharge nozzle and an ignition chamber both communicating therewith, means to deflect the liquids fed through nozzles adjacent said discharge nozzle and said ignition chamber in sprays covering not over a semi-circumference and directed away from said nozzle and ignition chamber, and means to deflect the liquids fed through the remaining nozzles in the side wall of said casing in sprays diverging in all directions.

9. Combustion apparatus comprising a casing enclosing a combustion chamber, a plurality of fuel feeding nozzles and a plurality of liquid oxygen feeding nozzles arranged alternately and in spaced relation in the side wall of said casing, said combustion chamber having a discharge nozzle and an ignition chamber both communicating therewith, means to deflect the liquids fed through nozzles adjacent said discharge nozzle and said ignition chamber in sprays covering not over a semi-circumference and directed away from said nozzle and ignition chamber, and means to deflect the liquids fed through the remaining nozzles in the side wall of said casing in sprays diverging in all directions, and all of said sprays engaging unlike sprays in linear combustion areas forming substantially a hollow square about each nozzle which is not adjacent said discharge nozzle or said ignition chamber.

10. Combustion apparatus comprising a casing enclosing a combustion chamber, a plurality of fuel feeding nozzles and a plurality of liquid oxygen feeding nozzles arranged alternately and in spaced relation in the side wall of said casing, said combustion chamber having a discharge nozzle and an ignition chamber both communicating therewith, means to deflect the liquids fed through nozzles adjacent said discharge nozzle and said ignition chamber in sprays covering not over a semi-circumference and directed away from said nozzle and ignition chamber, means to reduce the amount of said sprays directed sidewise to produce substantially the same density of spray of both liquids along all the lines of intermingling, and means to deflect the liquids fed through the remaining nozzles in the side wall of said casing in sprays diverging in all directions.

ROBERT H. GODDARD.