

June 21, 1960

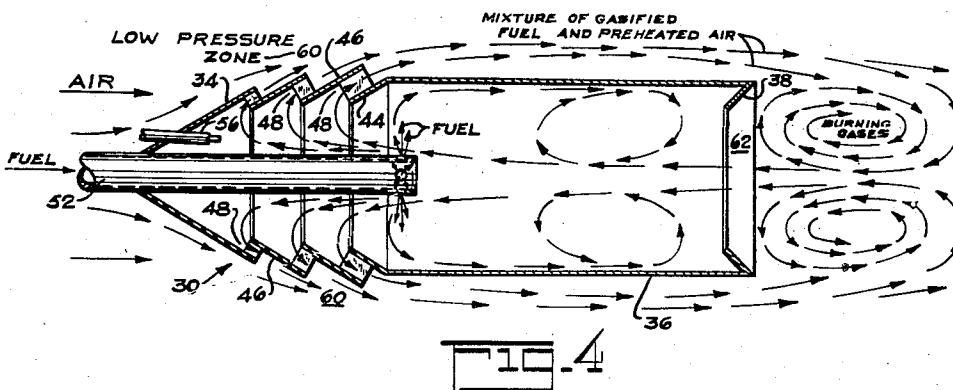
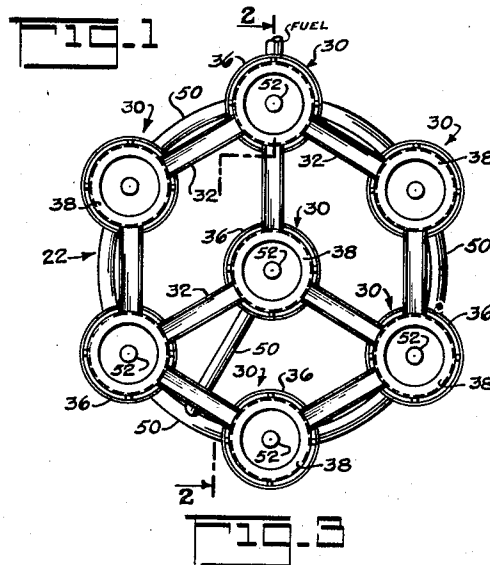
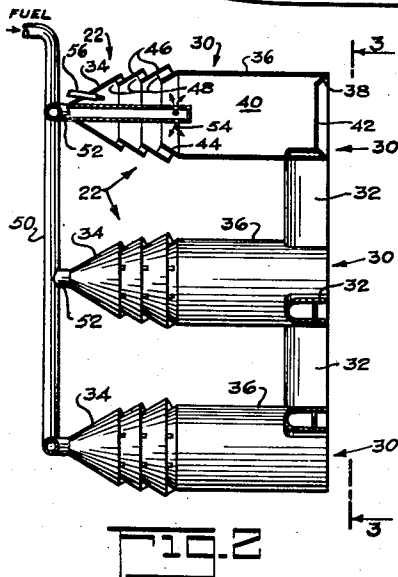
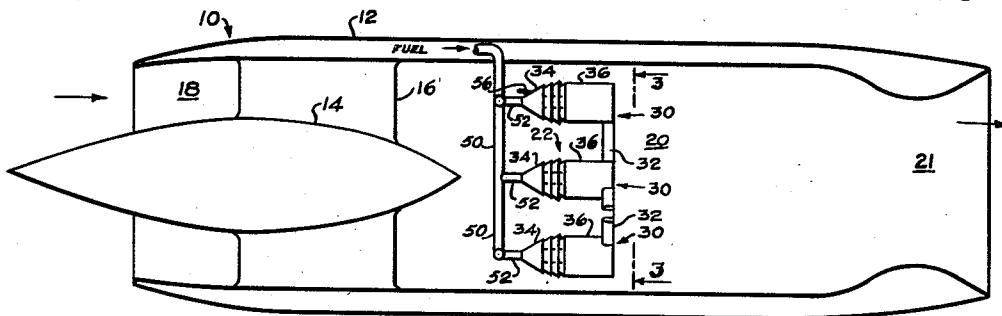
F. W. BAILEY

2,941,362

FLAME HOLDER CONSTRUCTION

Filed Nov. 2, 1953

3 Sheets-Sheet 1



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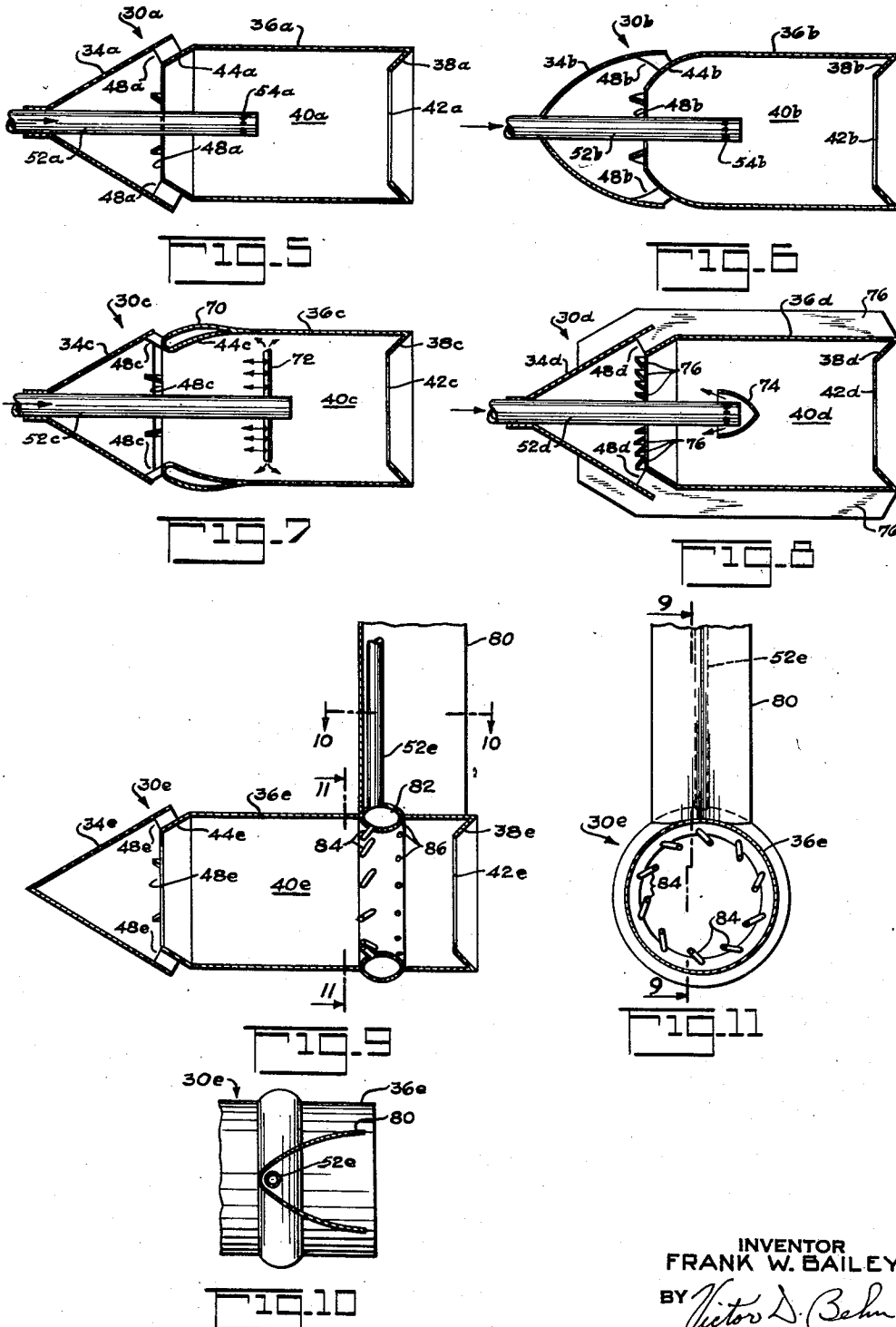
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FLAME HOLDER CONSTRUCTION

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FLAME HOLDER CONSTRUCTION

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3 Sheets-Sheet 3

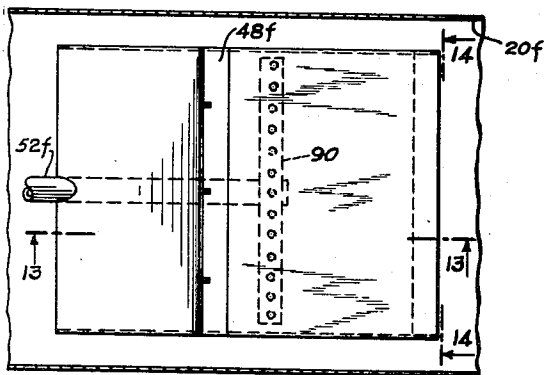


FIG. 12

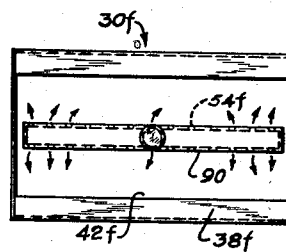


FIG. 14

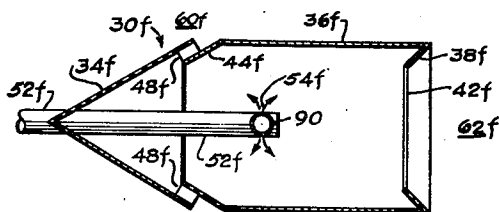


FIG. 13

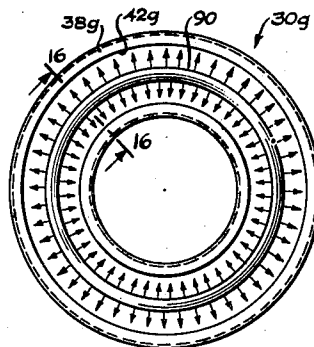


FIG. 15

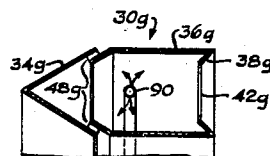


FIG. 16

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FLAME HOLDER CONSTRUCTION

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16 Claims. (Cl. 60—39.72)

This invention relates to combustion apparatus and is particularly directed to combustion flame holder apparatus for jet engines.

The invention has been designed for use with jet engines in which maintenance of stable and efficient combustion is difficult particularly because of the high velocity of flow through the combustion chamber. In the case of combustion chambers having a high velocity gas flow, the flame holder apparatus generally comprises some form of bluff object disposed across the flow path of the combustible gases for stabilizing the flame in the wake of the flame holder. It is generally believed that the flame is stabilized in the wake of such a flame holder because of the eddying of the burning or hot gases in this region with these gases recirculating back to the flame holder where they function as a continuous source of ignition to the unburned combustible gases flowing past the flame holder. The flame stability of such a bluff object flame holder is increased by increasing its lateral dimensions, that is, by increasing its dimensions across the flow path of the combustible mixture. Any increase of the lateral dimensions of the flame holder is objectionable, however, because the extent to which the flame holder blocks the gas flow is then increased thereby increasing the pressure drop across the flame holder.

An object of the present invention comprises the provision of novel and simple flame holder apparatus capable of providing stable and efficient combustion in high velocity gas streams with minimum blockage of the flow. A still further object of the invention comprises the provision of flame holder apparatus which takes advantage of the pressure gradient between the wake of the flame holder and a minimum pressure region on the surface of the flame holder to help induce recirculation of the hot or burning gases back to the flame holder.

For various reasons jet engines generally burn fuels which are liquid instead of gaseous at normal or room temperatures. In liquid fuel systems the fuel is generally sprayed into the air stream upstream of the flame holder apparatus so that liquid fuel impinges on said apparatus. It has been found that in such liquid fuel systems the flame is stable only so long as there is an accumulation of liquid fuel on the surface of the flame holder. If the flame holder surface becomes too hot any fuel on said surface immediately vaporizes off said surface and this apparently results in the concentration of fuel in the wake of the flame holder becoming insufficient to support combustion. In the case of gaseous fuel systems, however, heating the flame holder surfaces has been found to greatly increase the flame stability. Accordingly a still further object of the present invention comprises the provision of flame holder apparatus for a liquid fuel system in which the fuel is discharged within the apparatus and is at least partly gasified therein by hot gases recirculating therein from the wake of the flame holder apparatus and said gasified fuel is carried out of the flame holder apparatus by said recirculating gases for flow over

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the outer surfaces of the flame holder which are heated by said recirculating gases.

Other objects of the invention will become apparent upon reading the annexed detailed description in connection with the drawing in which:

Fig. 1 is a schematic view of a jet engine embodying the invention;

Fig. 2 is an enlarged view of the combustion apparatus of Fig. 1;

Fig. 3 is a view taken along line 3—3 of Figs. 1 and 2;

Fig. 4 is a further enlarged view of one of the tubular flame holder units of Figs. 1—3 and illustrating the adjacent flow conditions;

Figs. 5, 6, 7 and 8 are views illustrating modified forms of the tubular flame holder units of Figs. 1—4;

Fig. 9 is a view of a further modified form of flame holder unit;

Figs. 10 and 11 are sectional views taken along lines 10—10 and 11—11 of Fig. 9;

Fig. 12 is a view of a further modification in which the flame holder unit is channel shaped instead of tubular;

Figs. 13 and 14 are views taken along lines 13—13 and 14—14 of Fig. 12;

Fig. 15 is a view of a still further modification in which the flame holder unit is annular; and

Fig. 16 is a sectional view taken along line 16—16 of Fig. 15.

Referring first to Fig. 1 of the drawing there is illustrated a ram-jet engine 10 comprising a duct-like member 12 having a center body 14 supported therein by struts 16 adjacent the forward end of the engine. The engine has an annular air inlet passage 18 and a combustion chamber 20 to which air is supplied from said inlet passage 18 and to which fuel is supplied by combustion flame holder apparatus 22. From the combustion chamber the gases discharge rearwardly from the duct member 12 through a nozzle 21 into the surrounding atmosphere to provide the engine with forward propulsive thrust.

Except for details of the structure of the combustion flame holder apparatus 22, as hereinafter described, the structure of the ram-jet engine 10 as described is conventional. As will become apparent, however, the combustion flame holder apparatus of the present invention is not limited to ram-jet engine use. Instead, said apparatus is of general use for stabilizing combustion in high velocity gas streams. For example, the combustion apparatus of the invention could be used in a turbo-jet engine, either as the main combustion apparatus and/or as the afterburner combustion apparatus.

As best seen in Figs. 2 and 3, the combustion flame holder apparatus 22 comprises a plurality of flame stabilizing tubes 30 interconnected by flame cross-over tubes or channels 32. Each flame stabilizing tube 30 has a closed, conical upstream part 34 and a cylindrical downstream part 36. As herein used upstream and downstream refer to the general direction of the air and other gas flow through the combustion chamber 20 over the outside of the flame stabilizing tubes 30.

The conical upstream part 34 of each flame stabilizing tube 30 has its apex directed in an upstream direction so that its walls diverge in a downstream direction. The cylindrical part 36 of each flame stabilizing tube 30 has its cylindrical wall and axis extending substantially parallel to the general direction of the adjacent fluid flow outside said wall through the combustion chamber 20. In addition the cylindrical part 36 of each flame stabilizing tube 30 has an inturned annular flange 38 at its downstream end providing the tube chamber 40 with a restricted opening 42 at its downstream end. As illustrated the annular flange 38 is inclined so that it is conical and extends in an upstream direction as well as inwardly. The upstream end of each cylindrical part 36 also has

an inturned annular flange 44 which is inclined in generally the same direction as the flange 38 such that the surface of the flange 44 is conical and is substantially parallel to and spaced from the adjacent conical surface portion of the upstream part 34 to form an annular passage therebetween. Preferably one or more annular rings 46 are supported between the flange 44 and the adjacent end of the upstream conical part 34, to divide said annular passage into a plurality of side-by-side annular passages 48, said rings having a conical shape so that their surfaces are substantially parallel to the flange 44 and to the conical part 34. Because of the conical slope of the upstream tube closure part 34 and of the rings 46 and flange 44, the annular passages 48 have their outer or discharge ends directed in a downstream direction relative to the adjacent flow over their flame stabilizing tube 30.

Fuel is supplied to the flame stabilizing tubes 30 from an annular fuel manifold 50 from which fuel conduits 52 extend co-axially into the flame stabilizing tubes 30. Each fuel conduit 52 terminates within its flame stabilizing tube chamber 40 at a point between the annular passages 48 and the open end 42 of said tube. The end of each fuel conduit 52 is closed but said tube has a plurality of side openings 54 adjacent said end for spraying fuel laterally therefrom into the chamber 40 of its tube 30. At least one of the flame stabilizing tubes 30 also has an igniter 56 which as illustrated may be a conventional spark plug type igniter.

The flame stabilizing tubes 30 may be supported within the combustion chamber 20 by the fuel conduits 52 or, for example, suitable struts (not shown) may be provided to support said tubes from the wall of said combustion chamber.

It is not essential that all the fuel burned within the combustion chamber 20 be introduced within the tubes 30. For example, at least some of the fuel burned in the combustion chamber 20 could be introduced into the airstream upstream of the flame stabilizing tubes 30 in which case the fluid approaching and flowing over the upstream ends 34 of the flame tubes 30 would comprise a mixture of fuel and air instead of just air. Thus it is also within the scope of the invention to introduce all the fuel into the airstream upstream of the flame tubes 30. Preferably, however, at least some of the fuel is introduced into each flame tube 30 because, as hereinafter described, the burning or hot gases recirculating back through said tube helps to vaporize the fuel introduced in said tube.

The manner in which the flame tubes 30 function to stabilize combustion is diagrammatically illustrated in Fig. 4 in connection with one of said tubes. When air flows over a tube 30 the velocity of the air adjacent thereto increases from the upstream end or apex of the tube to an annular zone 60 adjacent to the junction of its conical upstream part 34 and its cylindrical part 36 thereby creating a relatively low static pressure condition in said zone 60 adjacent to and about the outer ends of the annular passage 48. In addition a high pressure zone 62 of eddying and circulating air is created in the wake of the flame tube 30 whereby a static pressure differential exists between the zones 62 and 60 which induces recirculation of air back through the open end 42 of the tube 30 into the tube chamber 40 and out through the annular passages 48. Upon discharge of fuel from the fuel conduit 52 this recirculating air carries the fuel with it with the result that upon ignition, by the igniter 56 or from a flame cross-over channel 32, the zone 62 in the wake of the flame tube 30 becomes filled with burning gases, as illustrated in Fig. 4. The static pressure differential between the zones 60 and 62 causes these burning gases to recirculate back through the tube 30 to gasify the fuel discharging from the tube 52 into the chamber 40 whereupon this gasified fuel is carried out through the passages 48 to be ignited in the zone 62 by the eddying burning gases in this zone. This recirculation is helped

by the educer action of the air flowing over the downstream directed outer ends of the annular passages 48. Thus the passages 48 may be termed educer passages. The burning gases recirculating back through the tube 30 also heat up the cylindrical wall 36 of said tube thereby further increasing the flame stability. Initially the igniter 56 serves to ignite some fuel within its flame tube 30. However, after combustion has been established little or no burning may take place within a flame tube 30 of the fuel discharging from its fuel conduit 52, most of the burning taking place downstream of the tubes 30.

The annular flange 38 at the open end of each tube 30 helps to prevent the fuel discharged into a tube chamber 40 as well as other fluid within said chamber from flowing out through the open end 42 of said tube along its wall 36 and interfering with the afordescribed recirculation of the burning gases back through said tube from the high pressure zone 62 in the wake of said tube. In addition, as illustrated, the flange 38 induces eddying of the gases within the tube chamber 40 thereby increasing the heat transfer to the wall 36 of said tube from the hot gases recirculating back through said tube. For these reasons the diameter of the tube opening 42 should be no more than about 90% of the adjacent internal diameter of the tube chamber 40 and, at least in the case of tubes 30 having the dimensions hereinafter specified, preferably is no more than about 75% of said adjacent diameter. Since the rate of recirculation of hot and/or burning gases back through the tube opening 42 into the tube chamber 40 depends on the size of said opening and the temperature of the wall 36 of said chamber depends on the amount of gases so recirculating, the size of the opening 42 may have to be further limited to prevent the temperature of the wall 36 from becoming excessive. The wall 36 of a tube 30 is cooled both by the fuel discharged into its chamber 40 and by the fluid flow over the outside of said wall, the heat transfer from said wall to said fluid increasing with increase in the length of said wall and with decrease in the temperature of the fluid. It is clear therefore if the flame stabilizer tube 30 is used in an environment where the temperature of the fluid flow thereover is quite high (as in the case of a turbo-jet afterburner), if only a small percentage of the fuel burned is discharged into said tube, and/or if the tube is relatively short, that the permissible size of the tube opening 42 may be limited by the maximum allowable temperature of its wall 36.

From what has been said it is apparent that the size of the opening 42 of a tube 30 is restricted by its flange 38 to induce eddying within the tube chamber 40, to prevent fuel and gases from flowing out through the open end of the tube and possibly to prevent the temperature of the tube wall 36 from becoming excessive. Preferably the tube opening 42 is made as large as permitted by these limitations in order that the recirculation of hot and/or burning gases back through said tube opening into the tube chamber 40 is a maximum.

The invention is not limited to the specific size, number and lateral spacing of the flame stabilizing tubes 30 illustrated in the drawing. For example, a smaller number of larger flame stabilizing tubes could be substituted and the use of but a single such tube in a combustion chamber is within the scope of the invention. A large number of small tubes 30 is, however, preferred to a smaller number of larger tubes because, in general, with the smaller tubes a given degree of flame stability can be obtained with less flow blockage. For ram-jet engine use the preferred physical shape of the tube 30 is one in which its cylindrical wall 36 has a length of four inches and a diameter of two inches, its tube opening 42 has a diameter of one and one-half inches and the wall of the conical end closure part 34 makes an angle of 30° with the cone axis.

The position of the annular low static pressure zone 60 about a flame stabilizing tube 30 may shift somewhat

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along said tube with changes in the rate of air flow over the flame tubes 30. Hence it is desirable that each tube 30 have a plurality of annular educer passages 48, as illustrated in Figs. 1-4, in order that at least one of said passages has its discharge or outer end at said minimum pressure zone. Actually, however, one such annular passage 48 may be satisfactory in which case the rings 46 would be eliminated and a single educer passage would be formed between and by the flange 44 and the adjacent portion of the conical part 34. Such a modification is illustrated in Fig. 5. For ease of understanding, the parts of Fig. 5 have been designated by the same reference numerals as the corresponding parts of Figs. 1-4 but with a subscript *a* added thereto. The flame stabilizing tube 30*a* of Fig. 5 is like the flame stabilizing tube 30 of Figs. 1-4 except the tube 30*a* has but one educer passage instead of a plurality of such passages. Hence no further description of Fig. 5 appears to be necessary.

The shape of each flame stabilizing tube is not limited to that illustrated in Figs. 1-5. For example, the upstream end closure part, instead of being conical, may have a more streamlined shape. In addition, the annular flange forming a wall of the educer passage could likewise have a curved cross-section. Such a modification is illustrated in Fig. 6. The parts of Fig. 6 have been designated by the same reference numerals as the corresponding parts of Figs. 1-4 but with a subscript *b* added thereto. The operation of the flame stabilizing tube 30*b* is obviously similar to that of the flame stabilizing tubes of Figs. 1-5. The curvature of the upstream end 34*b* of the tube 30*b* may result in a larger maximum flow velocity over the tube thereby reducing the pressure in the minimum pressure zone 60.

A still further reduction in this pressure may be possible by providing a lip on the flange forming a wall of the educer passage. Such an arrangement is illustrated in Fig. 7. The parts of Fig. 7 have been designated by the same reference numerals as the corresponding parts of Figs. 1-4 but with a subscript *c* added thereto. In Fig. 7 the flange 44*c* is provided with an annular lip 70 projecting slightly out into the airstream over the tube 30*c*. Also in Fig. 7 the fuel conduit is provided with a plurality of fuel tubes 72 extending radially therefrom into the tube chamber 40*c*. Each fuel tube 72 has a fuel discharge opening at its radially outer end and also has a plurality of fuel discharge openings on its side facing the annular educer passage 48*c* to aid fuel flow toward said passage. Except for the differences noted the structure and operation of the flame stabilizer tube 30*c* is like the flame stabilizer tubes 30.

Most of the fuel supplied to the chamber of each flame stabilizing tube is preferably discharged into said chamber in a direction other than toward the open end 42, 42*a*, 42*b* or 42*c* of said chamber in order that said fuel discharge does not interfere with or oppose the recirculation of the burning or hot gases back through said tube from the high pressure zone downstream of said open end. Thus in Figs. 1-6 the fuel is discharged laterally into the chamber of each flame stabilizing tube while in the flame stabilizer tube of Fig. 7 most of the fuel is discharged into the tube chamber toward the educer passage of said tube. Fig. 8 illustrates a further modification having means for directing the fuel away from the open end of the tube. In Fig. 8 the end of the fuel conduit is provided with a cap 74 for directing the fuel away from the open end of the fuel stabilizing tube and toward the educer passage of said tube. In addition the flame stabilizer tube of Fig. 8 is provided with a plurality of circumferentially-spaced external fins 76 to help cool its cylindrical wall. Except for the addition of the cap 74 and fins 76, the flame stabilizer tube of Fig. 8 is like that of the tube 30 of Figs. 1-4. The parts of Fig. 8 have been designated by the same reference numerals as the corresponding parts of Figs. 1-4 but

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with a subscript *d* added thereto. The addition of the cap 74 results in a decrease in the fuel flowing along the internal surface of the tube cylindrical wall 36*d* whereby the cooling effect of the fuel on said wall is decreased. Hence the addition of the fins 76 at least partially compensates for said decreased cooling effect of the fuel.

The most convenient arrangement for introducing the fuel into the flame stabilizing tubes is probably, as illustrated in Figs. 1-8, from a fuel conduit disposed centrally within the tube chamber. The central portion of the flame stabilizing tube chamber, however, has a relatively high temperature and if said temperature becomes too high fuel will carbonize in the fuel conduit 52, 52*a*, 52*b*, 52*c* or 52*d* and/or in its fuel discharge passages or openings. In order to minimize any tendency of the fuel to so carbonize some air may be introduced through the fuel conduit along with the fuel and/or the fuel conduit and its discharge openings may be located along the relative cool outer wall of the flame stabilizing tube. This latter arrangement is illustrated in Figs. 9-11 which is otherwise similar to Fig. 5.

The parts of Figs. 9-11 have been designated by the same reference numerals as the corresponding parts of Fig. 5 except a subscript *e* has been used in Figs. 9-11 instead of the subscript *a* of Fig. 5. In Figs. 9-11 the flame stabilizing tube 30*e* is supported at one end of a channel member 80 the other end of which is secured to a wall of the combustion chamber (for example the chamber 20 of Fig. 1) or to a strut extending across said combustion chamber for supporting the flame stabilizing tube 30*e* within said chamber. The fuel supply conduit 52*e* for the flame stabilizing tube 30*e* extends along and within the channel member 80. The fuel conduit 52*e* terminates in an annular passage 82 formed about the flame stabilizing tube 30*e* intermediate the ends of its cylindrical part 36*e*. In addition a plurality of short fuel discharge passages 84 are provided for discharging fuel from the annular passage 82 into the chamber 40*e* of the flame stabilizing tube 30*e*. Each of the fuel passages 84 is inclined inwardly and toward the educer passage 48*e*. Also, as illustrated in Fig. 11, each of said passages 84 is tangentially inclined so that a swirling motion is imparted to the fuel as it discharges into the flame stabilizing tube chamber 40*e*. Small additional fuel discharge openings 86 may also be provided to insure some fuel cooling of the flange 38*e* and the portion of the wall 36*e* between the annular passage 82 and said flange and/or fins (not illustrated) such as the fins 76 of Fig. 8 may be added about the wall 36*e* for helping to cool said wall. The flame stabilizing operation of the tube 30*e* of Figs. 9-11 is essentially the same as that of the flame stabilizing tubes of Figs. 1-8. The length of the fuel discharge passages 84 has been exaggerated in the drawing in order to illustrate the orientation of said passages.

In each of the modifications of Figs. 5-11, the flame stabilizing apparatus preferably comprises a plurality of the flame stabilizing tubes interconnected by flame cross over tubes or channel as in Figs. 1-3.

It is not essential that the flame stabilizing apparatus of the invention comprise one or more tubular units, such as 30, 30*a*, 30*b*, 30*c*, 30*d* or 30*e*, as in Figs. 1-11. For example each flame stabilizing unit instead of being tubular could have the shape of a linear or annular channel. Figs. 12-14 illustrate a flame stabilizing apparatus in which each flame stabilizing unit has the shape of a linear channel. For convenience of understanding the parts of Figs. 12-14 have been designated by the same reference numerals as the corresponding parts of Figs. 1-4 but with a subscript *f* added thereto.

Figs. 12-14 illustrate flame stabilizing apparatus comprising one or more flame stabilizing channel units 30*f* disposed in a combustion chamber 20*f*. Said apparatus may comprise a single unit 30*f* or a plurality of such

units in side-by-side relation. Each flame stabilizing unit 30f comprises a channel 34f and flat side wall extensions 36f of said channel part. The channel part 34f is of V-shaped cross-section and closes the upstream end of the unit 30f. The side wall parts 36f extend downstream from the ends of the channel part 34f to form the side walls of a chamber 40f within the flame stabilizer unit 30f, said wall parts 36f being substantially parallel to the direction of the adjacent flow through the combustion chamber 20f. Each of the side walls 36f has an inturned flange 38f at its downstream end forming a restricted opening 42f for one end of the chamber 40f, the other end of said chamber being closed by the part 34f. As illustrated each flange 38f is inclined inwardly and toward the channel part 34f end of the chamber 40f. In addition each of the side walls 36f has an inturned flange 44f at its other end substantially parallel to and spaced from the channel part 34f to form an educer passage 48f therebetween. A fuel conduit 52f extends into the chamber 40f of the flame stabilizing unit 34f and a fuel tube 90 extends along said chamber laterally from the conduit 52f. A plurality of fuel openings 54f are provided in the fuel tube for discharging fuel toward the side plates 36f. A suitable igniter (not shown) may be provided for igniting the combustion mixture in a manner similar to that described in connection with Figs. 1-4.

The flame stabilizing operation of the unit 30f is substantially the same as that of the flame stabilizing tubes 30. Thus the fluid flow through the combustion chamber 20f over the flame stabilizing unit 34f produces a zone 60f of low static pressure along the outer or discharge end of each educer passage 48f. In addition the eddying of the gases in the wake of the unit 34f produces a relative high static pressure zone 62f so that recirculation of combustion gases is induced back into the chamber 40f of the unit 34f and out through the educer passage 48f.

Figs. 15-16 illustrate a flame stabilizing unit which is substantially the same as that of Figs. 12-14 except instead of each channel unit being linear it is annular. Hence for ease of understanding the parts of Figs. 15-16 have been designated by the same reference numerals as the corresponding parts of Figs. 12-14 except a subscript g has been added. One or more such units 30g may be used in a single combustion chamber. A plurality of such units 30g of different radius can be used in a combustion chamber by mounting the units concentrically, the radii of the units being such that they can be concentrically mounted with an annular space therebetween. No further description of Figs. 15-16 appears to be necessary.

At this point it should be obvious that the distinctive features of the modification described could be combined like permutations and combinations. For example a plurality of side-by-side educer passages, as in the flame stabilizer tube 30 of Figs. 1-4, could be provided in each of the other flame stabilizer tubes 30a, 30b, 30c, 30d and 30e as well as in the flame stabilizer channel units 30f and 30g. Furthermore the end closure part of each of the other modifications could have a curved cross-section like the end closure part 34b of Fig. 6 instead of the V-shaped cross-section illustrated. Likewise fins, such as the fins 76 of Fig. 8, and/or the lip construction 70 of Fig. 7, obviously could be added to any of the other flame stabilizing tubes and to the flame stabilizing channel units of Figs. 12-16. Also either the fuel distributing means 72 of Fig. 7 or the fuel deflecting means 74 of Fig. 8 obviously could be added to the flame stabilizer tubes or channel units of the other modifications. In addition instead of introducing fuel from the center of the flame stabilizer tubes or channel units the fuel could be introduced from a passage formed along a wall of said tube or unit as disclosed in the case of the flame tubes 30e of Figs. 9-11.

While I have described my invention in detail in its present preferred embodiment, it will be obvious to those skilled in the art, after understanding my invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. I aim in the appended claims to cover all such modifications.

I claim as my invention:

1. In combination with a main combustion chamber having an entrance end through which air is supplied for combustion therein and having a discharge end through which gases discharge from said chamber; flame stabilizing means mounted within said chamber and comprising a wall structure forming an auxiliary chamber having a closed upstream end and an open downstream end relative to the direction of flow of main chamber gases over said stabilizing means, said wall structure comprising an upstream wall part diverging in a downstream direction relative to said flow and a side wall part extending substantially parallel to said flow and said wall structure having passage means therethrough intermediate the ends of said auxiliary chamber and directed outwardly from said auxiliary chamber in a generally downstream direction relative to said flow; and means for discharging fuel into said auxiliary chamber so that unburned fuel flows from said auxiliary chamber through said passage means for combustion with air supplied to said main chamber.
2. The combination recited in claim 1 in which said wall structure passage means is disposed between said diverging upstream wall part and said side wall part.
3. The combination recited in claim 1 in which said wall structure passage means extends substantially entirely about said auxiliary chamber and is disposed between said diverging upstream wall part and said side wall part.
4. The combination recited in claim 1 in which said wall structure passage means is disposed so as to open into the adjacent main chamber flow over said flame stabilizing means in a zone along said flame stabilizing means at which the static fluid pressure in said flow is relatively low.
5. The combination recited in claim 1 in which each end of said side wall structure part has an inturned flange inclined upstream relative to said main chamber flow, the flange at the downstream end of said side wall structure part forming a restricted downstream opening for said auxiliary chamber and the flange at the upstream end of said side wall structure part cooperating with the adjacent portion of said upstream wall structure part to form the walls of said passage means.
6. The combination recited in claim 1 in which said wall structure passage means is disposed so as to open into the adjacent main chamber flow over said flame stabilizing means in a region along said flame stabilizing means at which the static pressure in said flow is relatively low and in which the opening at the downstream end of the auxiliary chamber is restricted so that the cross-sectional area of said opening is less than the cross-sectional area of said auxiliary chamber adjacent to said opening.
7. The combination recited in claim 1 in which said fuel discharge means comprises a plurality of fuel discharge openings disposed adjacent to and along said side wall part.
8. In a combustion chamber having an entrance opening through which air is supplied for combustion within said chamber and having a discharge opening for the products of combustion; the combination therewith of combustion apparatus mounted within said chamber; said apparatus comprising a tubular member disposed substantially parallel to the direction of the adjacent fluid flow through said chamber and over said member; means providing an opening of reduced diameter at the downstream end of said tubular member relative to said flow; means disposed across the upstream end of said tubular

member relative to said flow for closing said upstream end and for forming a substantially annular passage between said end closure means and said tubular member, said last mentioned means progressively increasing in diameter toward said tubular member so that said annular passage is directed in a substantially downstream direction relative to said flow.

9. In a combustion chamber having an entrance opening through which air is supplied for combustion within said chamber and having a discharge opening for the products of combustion; the combination therewith of combustion apparatus mounted within said chamber; said apparatus comprising a tubular structure disposed substantially parallel to the direction of the adjacent fluid flow through said chamber and having a closed upstream end, an open downstream end of reduced cross-sectional area relative to the cross-sectional area of the adjacent interior of said tubular structure and a substantially annular passage extending through the side wall of said tubular structure with the outer end of said passage being directed in a substantially downstream direction relative to the adjacent fluid flow over said tubular structure to thereby promote flow through said passage by eductor action; and means for discharging fuel into said tubular structure so that unburned fuel flows from the interior of said tubular structure through said annular passage for combustion within said chamber.

10. The combination with a combustion chamber of combustion apparatus mounted within said chamber; said apparatus comprising a tubular structure disposed substantially parallel to the direction of the adjacent fluid flow through said chamber and having a closed upstream end, an open downstream end of reduced cross-sectional area relative to the cross-sectional area of the adjacent interior of said tubular structure and a substantially annular passage extending through the side wall of said tubular structure with the outer end of said passage being directed in a substantially downstream direction relative to the adjacent fluid flow over said tubular structure; and means for discharging fuel into said tubular structure primarily in a direction other than toward the open downstream end of said structure for combustion within said chamber.

11. In a combustion chamber having an entrance opening through which air is supplied for combustion within said chamber and having a discharge opening for the products of combustion; the combination therewith of combustion apparatus mounted within said chamber; said apparatus comprising a tubular structure disposed substantially parallel to the direction of the adjacent fluid flow through said chamber and having an open downstream end of reduced cross-sectional area relative to the cross-sectional area of the adjacent interior of said tubular structure and having a wall closing the upstream end of said tubular structure and also having a substantially annular passage extending through the side wall of said tubular structure with the outer end of said passage being directed in a substantially downstream direction relative to the adjacent fluid flow over said tubular structure, said wall having an apex on the axis of said tubular structure and diverging in a downstream direction relative to said flow from said apex and said annular passage being disposed adjacent to the downstream end of said wall; and means for discharging fuel into said tubular structure so that unburned fuel flows from the interior of said tubular structure through said annular passage for combustion within said chamber.

12. In a combustion chamber having an entrance opening through which air is supplied for combustion within said chamber and having a discharge opening for the products of combustion; the combination therewith of combustion apparatus mounted within said chamber; said apparatus comprising a hollow cylindrical member disposed substantially parallel to the direction of the adjacent fluid flow through said chamber, said member

having an inturned annular flange at each end with each said flange being inclined to the axis of said member in an upstream direction relative to said flow and with the flange at the downstream end of said member forming an opening of reduced diameter compared to the internal diameter of said cylindrical member; a circular member closing the upstream end of said cylindrical member relative to the direction of said combustion chamber flow, said circular member having an apex on the axis of said cylindrical member and diverging in a downstream direction relative to said flow from said apex with the downstream end of said circular member being spaced from the upstream end of said cylindrical member to form an annular passage between said circular member and the flange at the upstream end of said cylindrical member; and means for discharging fuel into said hollow cylindrical member so that unburned fuel flows from the interior of said tubular structure through said annular passage for combustion in said chamber.

13. The combination recited in claim 12 in which the diameter of the open end of said cylindrical member is no more than 90% of the internal diameter of said cylindrical member.

14. The combination recited in claim 12 in which said fuel discharge means comprises an annular passage coaxially formed in the wall of said cylindrical member with fuel discharge openings spaced therealong.

15. In a combustion chamber having an entrance opening through which air is supplied for combustion within said chamber and having a discharge opening for the products of combustion; the combination therewith of combustion apparatus mounted within said chamber; said apparatus comprising a plurality of tubular structures spaced laterally across the fluid flow through said chamber with each tubular structure disposed substantially parallel to the direction of said fluid flow; each said tubular structure comprising a hollow cylindrical member disposed parallel to said flow direction and having an inturned annular flange at each end with each said flange being inclined to the axis of said member in an upstream direction relative to said flow and with the flange at the downstream end of said member forming an opening of reduced diameter compared to the internal diameter of said cylindrical member, and a circular member closing the upstream end of said cylindrical member relative to the direction of said combustion chamber flow, said circular member having an apex on the axis of said cylindrical member and diverging in a downstream direction relative to said flow from said apex with the downstream end of said circular member being spaced from the upstream end of said cylindrical member to form an annular passage between said circular member and the flange at the upstream end of said cylindrical member; and means for discharging fuel into the hollow cylindrical member of each of said tubular structures so that unburned fuel flows from the interior of each said tubular structure through its side wall annular passage for combustion in said chamber.

16. In a main combustion chamber having an entrance opening through which air is supplied for combustion within said chamber and having a discharge opening for the products of combustion; the combination therewith of combustion apparatus mounted within said chamber; said apparatus comprising a tubular member disposed substantially parallel to the direction of the adjacent fluid flow through said main chamber and having an end upstream wall and a side wall forming an auxiliary chamber therein with an open downstream end and with said end wall closing its upstream end, said tubular member also having means forming a passage through its auxiliary chamber side wall with the outer end of said passage being disposed and opening into the main chamber in a substantially downstream direction relative to the main chamber flow so that the fluid flow through said main chamber over said tubular member produces a pressure

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differential in said main chamber between that at the open downstream end of said auxiliary chamber and that at said side wall passage by eductor action so that fluid recirculates back into said auxiliary chamber through its open downstream end and out through its said side wall passage; means positioned downstream from said passage for discharging fuel into said auxiliary chamber so that said recirculation carries unburned fuel out through said auxiliary chamber side wall passage for combustion in said main chamber immediately downstream of said tubular member whereby said recirculating fluid includes hot combustion gases; the open downstream end of said auxiliary chamber having a reduced cross-sectional area compared to that of the adjacent interior of said auxiliary chamber, said upstream end wall having an apex on the

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axis of said tubular member with said end wall diverging in downstream direction from said apex to said side wall, and in which said side wall passage is disposed adjacent to the junction of said end and side walls and said side wall passage is substantially annular.

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