Aug. 1, 1950 F. C. MOCK ET AL 2,517,015

COMBUSTION CHAMBER WITH SHIELDED FUEL NOZZLE

Filed May 16, 1945 2 Sheets-Sheet 1

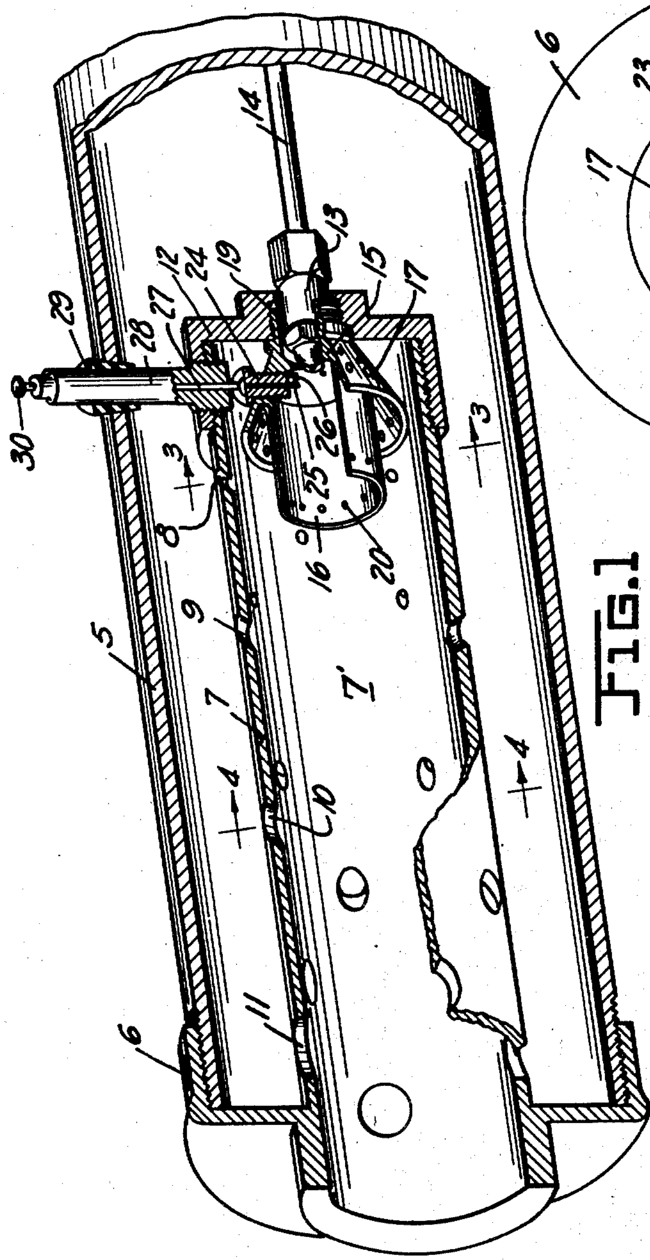

FIG.1

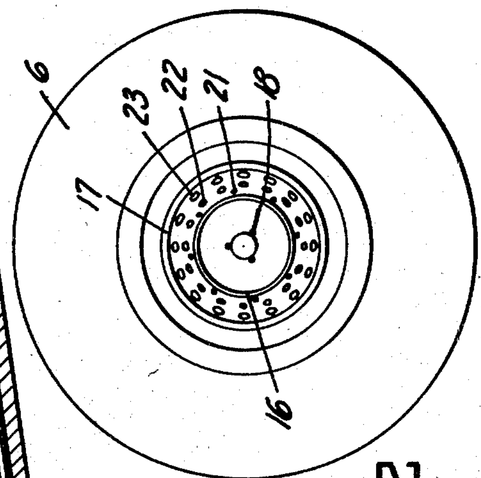

FIG.2

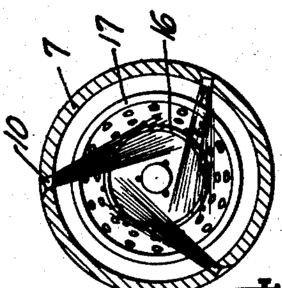

FIG.4

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COMBUSTION CHAMBER WITH SHIELDED FUEL NOZZLE

Filed May 16, 1945 2 Sheets-Sheet 2

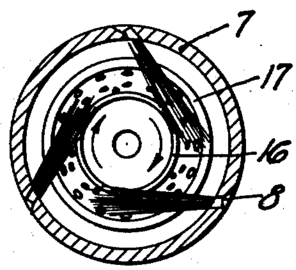

FIG. 3

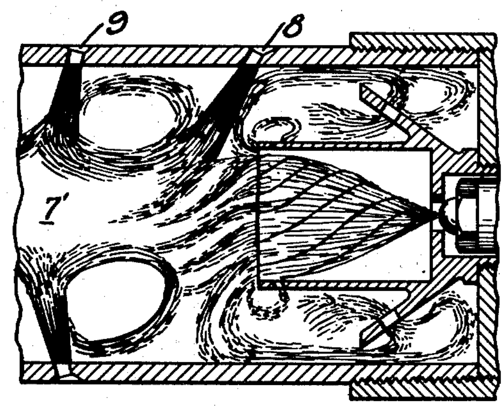

FIG. 5

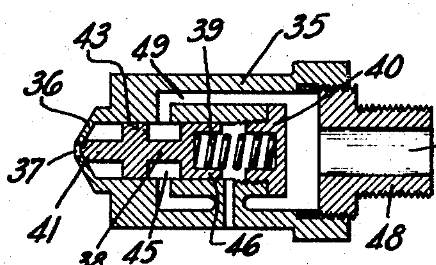

FIG. 6

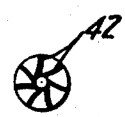

FIG. 7

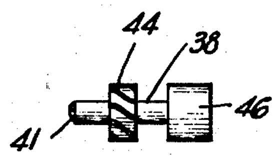

FIG. 8

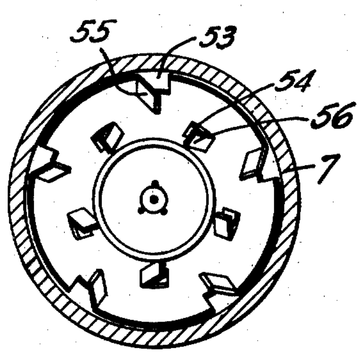

FIG. 10

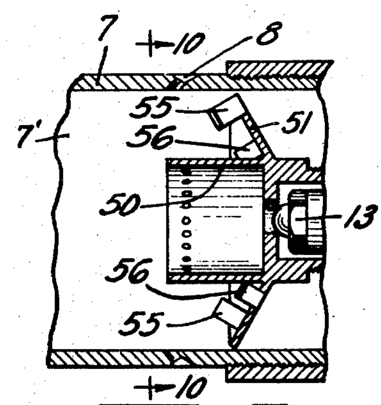

FIG. 9

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UNITED STATES PATENT OFFICE

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COMBUSTION CHAMBER WITH SHIELDED FUEL NOZZLE

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Application May 16, 1945, Serial No. 594,006

9 Claims. (Cl. 60—44)

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This invention relates to burners, and particularly to burners wherein a fuel, either gaseous, liquid or powdered solid fuel, is injected into and burned in a moving column of air. The invention is particularly adapted for, but not limited to, use in aircraft power plants of the gas turbine and jet propulsion types wherein air is compressed into a chamber constituting part of a generator, at which point it is heated by the combustion of fuel and the expanded air and products of combustion discharged through a gas turbine for driving an air compressor and/or a propeller, after which the gases may be discharged through a reaction tube to propel the aircraft or to assist the propeller in propelling the aircraft.

A burner constituting part of such power plants is ofttimes subjected to conditions which render it extremely difficult to maintain stable operation of the burner, or to obtain proper flame propagation and an effective fuel/air ratio over the wide range of air flows to which the burner is subjected. Thus, flow of fuel to the burner may at times be suddenly reduced to reduce engine speed, resulting in a low flame at the burner nozzle while at the same time the momentum of the engine may momentarily produce a high air flow tending to blow out the flame. At such times, the burner flame may fail unless properly protected, resulting in faulty engine operation and necessitating reignition under adverse conditions. Again, it is desirable that the burner ignite or start quickly and easily under all conditions of air flow, both at the start of a flight and during flight of an aircraft. If there is delay in igniting the burner during the initial starting operation, excess fuel accumulates in both the burner tube and adjacent chambers, and then when the engine does start, there is an intense flame and heat produced while the accumulated fuel is burning which tends to burn and warp parts in the immediate region of the flame.

An object of the present invention is to improve and render more efficient burners or heat generators.

Another and more specific object is to provide an improved burner or generator unit particularly adapted for power plants of the type specified.

Other objects include:

The provision of means into a burner for creating a stable flame (usually blue or bluish in color with hydrocarbon fuels such as fuel oil or gasoline) of relatively complete combustion and low radiation characteristics; a burner wherein the burner flame may be maintained stable under varying conditions of air flow; a burner wherein effective flame propagation may be had over a wide range of power conditions without burner failure; a burner wherein unburned fuel, instead of being driven by the air blast straight toward the discharge end of the burner tube or chamber, is circulated through the breech portion of said chamber to promote more effective combustion; a burner wherein the ignition element such as a spark plug is coordinated with a particular type of baffle structure to obtain prompt ignition under all conditions of burner operation; and to generally improve burners wherein the burner flame is subjected to air at varying velocities.

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The foregoing and other objects and advantages will become apparent in view of the following description taken in conjunction with the drawings, wherein:

Figure 1 is a broken longitudinal perspective view of a burner embodying the features of the invention;

Figure 2 is a view in end elevation of the burner;

Figure 3 is a transverse section taken along the line 3—3, Figure 1, the view being marked with air flow lines to illustrate the turbulent action of the air and products of combustion in this region;

Figure 4 is a section taken on the line 4—4, Figure 1;

Figure 5 is a schematic sectional diagram which further illustrates the action of the air and products of combustion;

Figures 6, 7 and 8 are detail views in section and elevation of a preferred type of fuel discharge nozzle for liquid fuels;

Figure 9 is a fragmentary longitudinal section of a burner provided with a modified form of flame shield and circulation control member; and

Figure 10 is a section taken on the line 10—10, Figure 9.

Referring to the drawings in detail and first to Figures 1 to 4, inclusive, an outer shell or housing is generally indicated at 5. This shell may constitute part of a generator unit and is adapted to have air supplied to the inlet end thereof under pressure, as by a compressor or due to the forward movement of an aircraft in which the unit may be installed. An example of such installation is illustrated in a copending application of Frank C. Mock, Serial No. 557,812, filed October 9, 1944.

At the burner discharge end, the shell 5 is screw threaded to receive a cap 6 adapted to support a burner tube 7 defining an elongated burner chamber 7' and provided with a series of holes 8, 9, 10, 11 for admitting precombustion and dilution air to said chamber, said holes having a predetermined angular disposition with respect to the longitudinal or major axis of the tube and being of progressively increasing flow capacity as they approach the discharge end of the tube; and at least those holes which affect the air in the region of initial flame propagation, for example, the series 8 and 9, note Figures 3 and 4, have a predetermined tangential component with respect to a circle bounding said axis, for purposes to be explained.

The inner end of the tube 7 is threaded into a fitting 12 provided with a hub formed with an axial opening in which is inserted a burner nozzle, generally indicated at 13, adapted to receive fuel through a feed tube or pipe 14. This nozzle may be and preferably is of the type shown in Figures 6, 7 and 8, to be described.

A breech circulation control and low flame shield unit 15 has an externally-threaded rear end screwed into an axial socket formed in the hub of the fitting 12; it includes a cylindrical cup-shaped shield 16 projecting forwardly around and beyond the nozzle 13, and an outer cone-shaped wall 17 which affects the action of the air and products of combustion in this region in the manner illustrated in Figure 5 and briefly outlined in the description of the operation of the burner.

At spaced points around the end of the nozzle 13 where it projects into shield 16 are a plurality of small air feed ducts or holes 18, note Figure 2, shown as three in number in the present instance spaced approximately 120° apart, precombustion air being supplied to these holes through longitudinal passages 19, Figure 1, which may be calibrated to obtain a predetermined pressure potential (the pressure difference causing air flow) of the air supplied to the ducts 18. Additional precombustion air is supplied to the flame in the cup 16 through holes 20 at the forward extremity of the cup beyond the end of the cone-shaped wall 17, and at which point a relatively small pressure differential exists with respect to the space between the cone and cup, the region the end of the cup and the chamber in rear of the cone.

Holes or ports 21, 22 and 23 are formed through the cone-shaped wall 17 which are preferably of progressively increasing flow capacity or diameter as they approach the forward end (left end in Figure 1) of said cone, and the function of these holes will also be described in connection with Figure 5.

An igniter in the form of a spark plug or analogous electrical sparking device is indicated at 24. Preferably, the igniter is located at the base of the cup-shaped shield 16 and the cone 17 and is provided with a positive electrode 25 and a negative electrode 26, the latter grounding through the wall of the unit 15, which may be made of conducting material such as heat-resistant alloy steel. It will be obvious, however, that any suitable grounding circuit may be utilized. The body of the spark plug 24 may be made of suitable insulating material such as porcelain, and a conductor 27 is extended through an insulator 28, shown projecting through a bushing 29 of heat-resistant shock-absorbing material mounted in the shell 5 and provided with a terminal 30 adapted to be connected to an ignition circuit, not shown.

The burner tube and coacting parts should obviously be made of suitable heat-resistant material capable of withstanding the high temperatures to which they may be subjected.

The nozzle 13 is shown more or less in detail in Figures 6, 7 and 8; it consists of a nozzle body 35 having a nose 36 formed with a discharge orifice 37. A valve member 38 is mounted for sliding movement in the body 35 and is normally urged to seated position by a spring 39 removably held in place by retainer nut 40. The valve member 38 has a contoured end 41 adapted to seat in the orifice 37 and formed with a series of spiral grooves 42; and back from said end 41 is an annulus 43 formed with a series of spiral grooves 44 which coact with but are of greater flow capacity than the spiral grooves 42. An inlet chamber 45 is defined by the annulus and a rear enlargement 46, and fuel is supplied to this chamber by way of conduit 47 formed in a nipple 48 adapted to be connected to the fuel line 14, and passages 49 formed in the body 35.

At low fuel pressures, the valve member 38 remains seated and discharge of fuel is through the spiral end grooves 42, which grooves are relatively fine or small and cause the fuel to be discharged at increased velocity and in a swirling spray. As pressure of the fuel increases, the valve member 38 moves back and discharge is by way of the spiral grooves 44 and orifice 37, the swirling action still being maintained while the diffusing action varies. The flow capacity of the grooves 44 will determine the discharge capacity of the nozzle unless clearance is provided between the annulus 43 and adjacent wall of the nozzle chamber. Improved fuel spraying or atomization at all pressures, a variable spray cone or diffusion angle and elimination of separate low pressure nozzles and connections therefor are some of the advantages of a nozzle of the type shown in Figures 6, 7 and 8.

In operation, liquid fuel is supplied to the nozzle 13 through the tube 14, as by means of the fuel-feeding device illustrated in copending application Serial No. 557,812 above noted, while air may be supplied under pressure to the shell 5 by a compressor or other suitable means, depending upon the type of power plant or heat generating unit with which the burner may cooperate. To start the burner, electric current supplied to the spark plug 24 ignites the fuel as it issues from the nozzle in the form of a fine swirling spray. Irrespective of the velocity or pressure of the air flowing to the burner through the shell 5 and holes 8–11, it will be at a predetermined relatively reduced velocity within the shielded low flame region of the burner, or in the cup 16, due to the calibrated ducts or holes 18 and 20 which ensure the proper amount of air to produce a highly combustible mixture for ignition and maintenance of a low flame or pilot light at minimum or low fuel and air flows, and at which time a somewhat carrot-shaped yellow flame projects from the cup 16.

As the flow of liquid fuel is increased, the flame is propagated outwardly through the cup 16, and if the burner constitutes part of a generator for a power plant utilizing an air compressor driven by a turbine in turn driven by the expanded gases issuing from the burner tube 7, there will be an immediate increase in turbine and compressor speed and a corresponding increase in air velocity and pressure in the outer shell 5. At normal engine or compressor speeds, the pressure in the outer chamber or shell 5 may, for example, be from one to three pounds higher than the pressure in the burner tube 7, this differential diminishing to a relatively small increment at low speeds. As the propagation or intensity of the burner flame increases, it is fed more and more by the air passing in through the holes 8, 9, 10 and 11 until maximum burner capacity or power condition is reached.

Turbulence of the air and products of combustion is of advantage, especially in the region of initial and intermediate flame propagation, since it tends toward a more effective mixture and therefore economy in fuel consumption, quick acceleration, better scavenging and increased efficiency generally.

The holes 8 are inclined at an angle such as will effect a discharge of precombustion and dilution air tangential to a core of burning gases in the tube 7 (note Figures 3 and 5), preferably at a tangent to a circle whose diameter is greater than that of the cup 16 and less than that of the tube, and they are also preferably inclined at an angle oblique to a plane perpendicular to said axis, the size and angular disposition of these holes as well as the holes 9, 10 and 11 being selected to control the whirling component of the air and products of combustion. Preferably, also, the whirl imparted to the fuel spray by the nozzle 13 coincides in direction with that resulting from the tangential arrangement of the holes 8.

The holes 9, 10 and 11 preferably are inclined at a progressively reduced angle to the tube radius with respect to the holes 8 (note Figures 4 and 5) or they in whole or in part may even have a reverse axial disposition or an oblique component directed away from the outlet of the tube 7.

The wall 17 is preferably but not necessarily cone shaped; it functions, among other things, to provide a partition between the swirl chamber around the cup 16 and the breech chamber or the area rearwardly and outwardly thereof. The amount of circulation through the breech chamber may be predetermined by selecting the area between the peripheral edge of the cone-shaped wall 17 and the adjacent inner surface of the burner tube, and also by selecting the flow capacity and/or angular disposition of the holes 21, 22 and 23.

In Figures 3 and 5 an attempt has been made to illustrate by arrows and flow lines the turbulent action of the air and products of combustion which takes place in the burner tube at, for example, intermediate to full power conditions, it being understood that the showing can only be an approximation due to the difficulties encountered in making tests and visually observing the operation of a device of this nature. As air flow increases due to a rise in pressure in the outer shell 5, the tangential action resulting from flow through the holes 8 generates a swirl around the end of the cup 16, which creates a depression in the center of the tube 7 and induces a gentle axial flow component towards the cup from air entering the tube through the holes 9 and 10 of reduced angle to the tube radius. This axial component meets the flame and fuel vapor issuing from the cup and the mixture swirls as it rolls forwardly toward the outlet of the tube, building up a swirling mass of blue flame around the interior of the tube, the tip of the carrot-shaped flame retracting as fuel and air flow increases from idling or minimum feed. Further increase of fuel feed and accompanying air flow fills the tube with an annulus of whirling blue flame having a yellow core. Just after starting, unvaporized fuel can be seen issuing from the cup 16 and moving almost radially toward the wall of the burner tube. This probably results from more fuel flowing into the cup 16 at feeds beyond idling than can be burned at this point due to lack of air supply; also with the heavier fuels it is more than can be vaporized due to lack of time for heating and the high vapor tension which would exist if vaporization were accomplished.

It will be observed from Figure 5 that there is a continual swirl or movement of air in the breech of the burner tube. This apparently results from the tangential swirl of air around the end of the cup 16 which creates a depression at this point and a higher pressure region radially outwardly thereof adjacent the wall of the tube, so that part of the air and products of combustion adjacent the cup are drawn, along with any excess fuel, back toward the breech end of the burner and flow through the annular space between the outer edge of the cone 17 and surrounding burner wall and then recirculate forwardly through the holes 21, 22 and 23 where they encounter the radial component around the end of the cup 16. Thus there is a breech chamber recirculation of flame, air and any unburnt fuel which further assists vaporization and complete combustion and maintains the cup and cone at a relatively high temperature so that discharge of unburnt liquid fuel toward the outlet of the burner is avoided. This is of considerable advantage, particularly when heavy fuels such as kerosene are used. Since the heat developed in the breech chamber is substantially proportional to the rate of fuel being fed, the ports or holes 21, 22 and 23 may be calibrated to control circulation in the region of the cup and cone in a manner such that these parts, even when made of moderately heat-resistant materials such as steel or iron or alloys thereof, will stay hot enough to effect vaporization of the fuel without burning away.

An outstanding feature of the burner as a whole is its ability to maintain a stable flame under varying conditions of operation. Since the recirculation of flame or air and products of combustion depends to a large extent upon the rate of fuel feed, and since the turbulence is light at low fuel feeds, it follows that the flame will be stable through a very wide range of air and fuel flows. At high air flows of say for example 120 feet per second through the ports or holes 8, 9, 10 and 11, the burner is stable to a lean air fuel proportion of, for example 1500 to 1, and it is also stable at a rich mixture of for example 15 to 1, the latter result being largely due to the arrangement of the cup 16 and wall 17 surrounding the fuel nozzle. Carbon formation is small due to high cup temperature and also because of substantially complete combustion as evidenced by the blue flame. For a given amount of fuel and air consumed, the heat radiation of the burner is lower by virtue of the blue flame than it would be with a red or yellow flame. Other advantages are positiveness in starting, both initially and with the air blast on, which is of considerable importance in jet propulsion engines or power plants since it is ofttimes desirable to restart in flight at high air flows. Easy starting is in part attributable to the close confinement of the fuel in the cup 16 and the location of the spark plug 24, which sparks across the adjacent area of the cup in the region of the confined fuel; also, the controlled temperature of the cup assists in maintenance of proper vaporization in this region. By using higher voltages than those employed in conventional practice, the effectiveness of the igniter may be increased.

Figures 9 and 10 illustrate an example of how the structure of the flame protecting and breech circulation control unit may be modified to obtain desired results. In this instance, the burner tube and fuel nozzle are similar to those of Figures 1 to 5, and are therefore given corresponding reference numerals. The low flame shield which corresponds to the shield 16 heretofore described is indicated at 50, and the forwardly flared wall which corresponds to the wall 17 is indicated at 51. In Figures 9 and 10, this wall extends outwardly to a point closely approaching the adjacent wall of the burner cup, leaving sufficient space to permit liquid fuel to be drawn back into the breech. Breech circulation and recirculation is controlled by a series of annularly-arranged, radially-spaced openings 53 and 54 formed in the wall 51, and deflectors or guide vanes 55 and 56 which overlie the openings 53 and 54, the outer and inner series of vanes extending in reverse directions so that the air and products of combustion may flow into the breech chamber through the series of openings 53, circulate around this chamber and then flow out through the openings 54, the vanes tending to produce a whirling action to the air and products of combustion in the chamber. By suitably calibrating these openings 53 and 54 and varying the angular position and relation of their coacting guide vanes, the breech circulation can be augmented or reduced to in turn control the heat of the cup 16 for use of fuels of different volatility.

Among other factors which affect control of main flame circulation is the angular disposition of the holes 9, 10 and 11. Thus the axial circulation of air towards the cup-like shield 16 or 50 can be increased by directing these holes substantially straight towards the center or axis of the burner and if necessary slanting them backward towards the breech. Similarly, axial flow away from the cup 16 or 50 can be decreased by slanting these holes more towards the mouth of the burner and giving them increased tangential components. For burners which operate under low air pressures, the holes 8–11 may be enlarged, while the tangential swirling and recirculation effect in the breech may be augmented either by enlarging the holes 21, 22 and 23 of Figures 1 to 5, inclusive, or the holes 53 and 54 of Figures 9 and 10 and/or by changing the impact angle of the vanes 55 and 56.

The wall 51 of Figure 9 may be disposed in contact with the adjacent wall of the burner tube, note the lower portion of said figure, thereby dissipating heat by conduction to the wall of the burner tube and thence by radiation to the outer chamber 5.

It will be understood that once those skilled in the art have been taught the theory of operation of the improved burner and the results obtained thereby, such results may be obtained by various modifications and rearrangements of parts other than those specifically enumerated herein. Hence no attempt has been made to describe all the advantageous features of the invention or the modifications which may be made in order to carry out or produce such advantages,

the scope of the invention being limited only by the appended claims.

We claim:

1. A tubular burner having walls defining an elongated burner chamber provided with an inlet end and a discharge end, a burner nozzle arranged to discharge fuel under pressure into the inlet and substantially axially of the burner chamber, means for igniting the fuel, a cup-like shield surrounding and projecting forwardly of the nozzle, said shield being provided with inlet ports for admitting precombustion air to the interior of the shield and said chamber walls being provided with longitudinally and circumferentially spaced inlet ports for admitting precombustion and dilution air to said chamber, said latter ports in the region of said shield being arranged to direct the entering air in jet-like streams at a tangent to a cylindrical area bounding the longitudinal axis of the burner chamber and through which area a core of burning gases is propagated outwardly from the shield when the burner is in operation.

2. A burner as claimed in claim 1 wherein the fuel nozzle is of a type causing the fuel to issue therefrom in a whirling spray and the tangential component of the jet-like streams of air in the region of said shield coincides with the whirl component of the spray.

3. A burner as claimed in claim 1 wherein the ports in the burner wall outwardly beyond the region of the shield are set at a reduced angle to the tube radius with respect to those in the immediate region of the shield.

4. A burner as claimed in claim 1 wherein the ports in the burner wall outwardly beyond the region of the shield are not only set at a reduced angle to the tube radius with respect to those in the immediate region of the shield, but are also set to direct the streams of air at varying degrees of angularity with respect to the axis of the burner chamber to produce whirl or eddy components and differential pressure areas in the chamber.

5. A burner including a burner tube defining an elongated combustion chamber having an inlet end and a discharge end, a burner nozzle arranged to discharge fuel under pressure into the inlet end substantially axially of the chamber, means for igniting the fuel, a cup-like shield surrounding and projecting forwardly of the nozzle, said shield being provided with inlet ports for admitting precombustion air to the interior of the shield and said tube being provided with a multiple of longitudinally and circumferentially spaced inlet ports for admitting precombustion and dilution air to said chamber outwardly of said shield, said tube ports in the region of said shield being arranged to direct streams of air at a tangent to a cylindrical area bounding the longitudinal axis of the burner chamber and through which area a core of burning gases is propagated outwardly from the shield when the burner is in operation, other of said tube ports more outwardly remote from said shield being arranged to direct streams of air at varying angles into said cylindrical area, said tube ports being of progressively increasing flow capacity from the inlet to the discharge end of said chamber.

6. A burner having walls defining an elongated burner chamber provided with an inlet or breech end and a discharge end, a burner nozzle arranged to discharge fuel under pressure into the inlet end substantially axially of the chamber,

means for igniting the fuel, said walls being formed with a multiple of longitudinally and circumferentially spaced inlet ports for admitting air under pressure into the chamber, a substantially cup-shaped shield surrounding the nozzle and projecting forwardly thereof to protect the burner flame at low fuel discharge pressures, said shield being provided with calibrated air-inlet ports for feeding the flame controlled quantities of air at varying air flows, and means associated with said shield for establishing a predetermined circulation of air in the area between the shield and the surrounding wall of the burner chamber, said last-named means including a wall surrounding said shield and projecting forwardly and outwardly from the breech end of the shield toward the adjacent wall of the burner chamber and provided with calibrated flow ports or openings.

7. A burner having a burner tube defining an elongated burner chamber of generally circular contour in cross-section provided with an inlet or breech end and a discharge end, a burner nozzle arranged to discharge fuel under pressure into the inlet end substantially axially of the chamber, means for igniting the fuel, a substantially cup-shaped shield surrounding the nozzle and projecting forwardly thereof to protect the burner flame at low fuel discharge pressures, the wall of said tube being provided with a multiple of longitudinally and circumferentially spaced air-inlet ports arranged to direct individual jets or streams of air into the burner chamber, a wall surrounding said shield and projecting forwardly and outwardly from the breech end of the shield toward the adjacent wall of the burner tube and provided with calibrated flow ports functioning to establish a predetermined circulation of air and products of combustion in the breech end of said chamber between the shield and the surrounding wall of the tube and said air-inlet ports in the region of the shield being disposed at angles with respect to the projected burner flame conducive to the desired circulation.

8. A burner including a burner tube defining an elongated combustion chamber provided with an inlet or breech end and a discharge end, a

burner nozzle arranged to discharge fuel under pressure into the inlet or breech end substantially axially of the chamber, a generally conical-shaped wall surrounding the nozzle, a substantially cylindrical cup-like flame shield projecting forwardly from the base of the cone defined by said wall, the wall of said tube having a multiple of longitudinally and circumferentially spaced air inlet openings for directing air under pressure into said chamber in the region of said shield and forwardly thereof and said conical wall being provided with a series of calibrated openings designed to produce a predetermined circulation of air and products of combustion in the breech end of the combustion chamber around said shield.

9. A burner as claimed in claim 8 wherein the openings in said cone-shaped wall are of progressively increasing flow capacity from the base portion to the forward or outer edge of the cone.

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