Feb. 13, 1951 R. J. McGARRY 2,541,171

AIR INLET STRUCTURE FOR COMBUSTION CHAMBERS

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Fig. 1

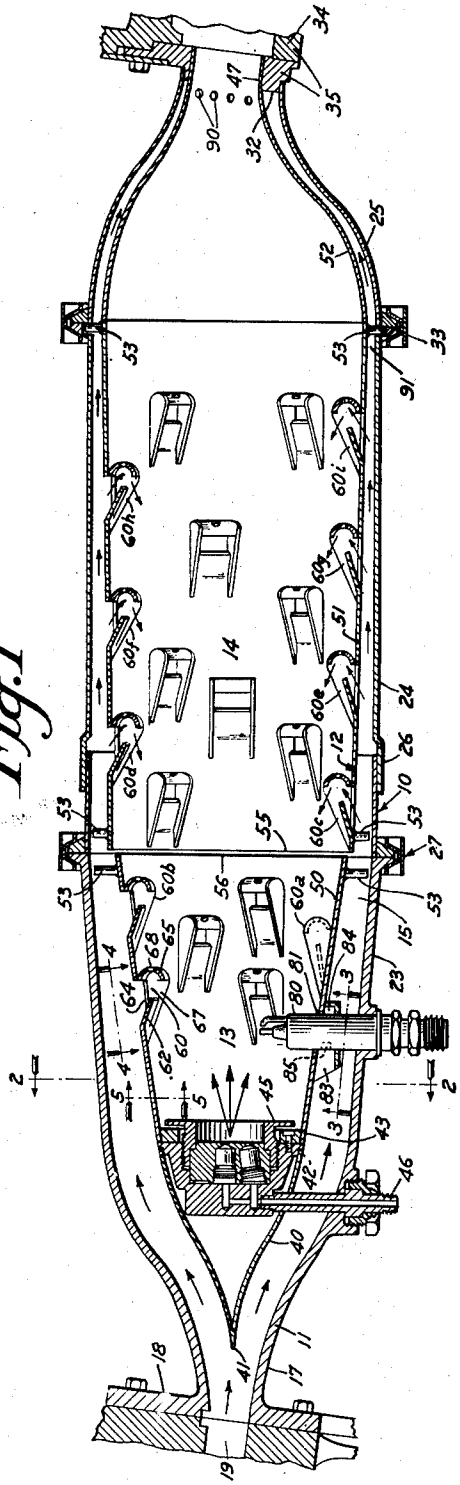


Fig. 3

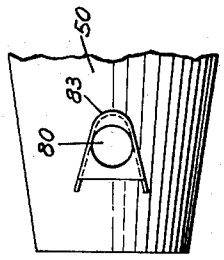
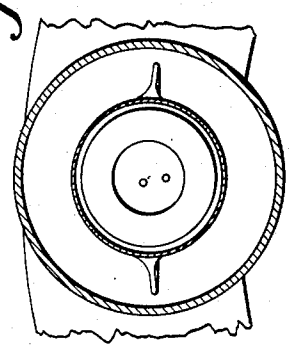


Fig. 2



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AIR INLET STRUCTURE FOR COMBUSTION CHAMBERS

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Fig. 4

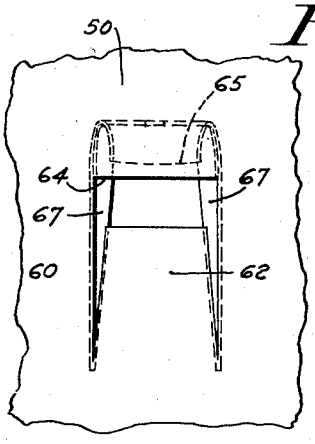
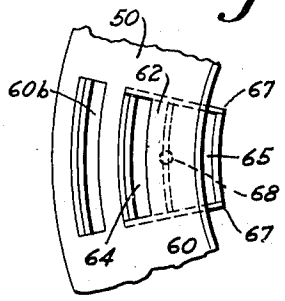


Fig. 5



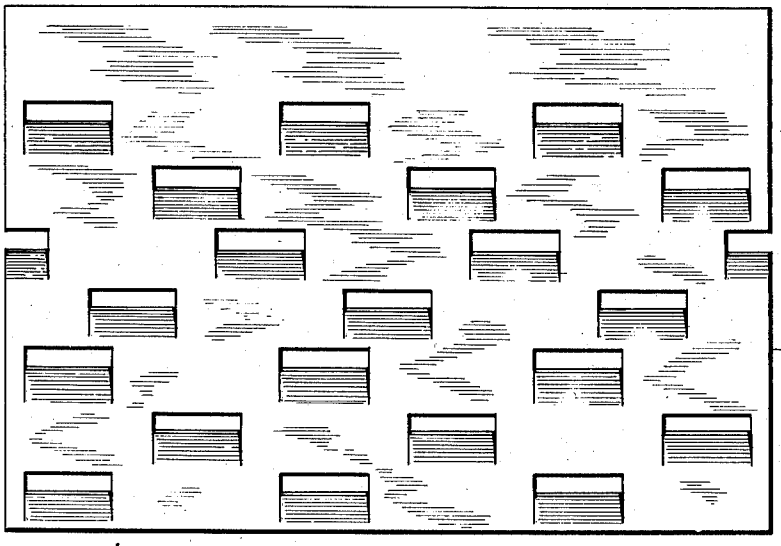


Fig. 6

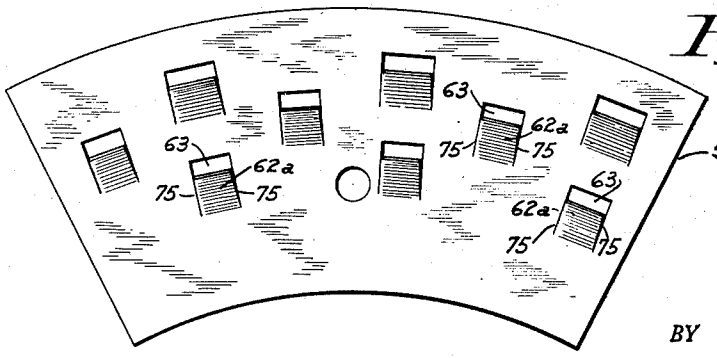


Fig. 7

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AIR INLET STRUCTURE FOR COMBUSTION CHAMBERS

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Application January 25, 1947, Serial No. 724,414

12 Claims. (Cl. 60—44)

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This application contains subject matter similar to that disclosed in Patent Number 2,531,810, issued November 28, 1950, with the same assignee. The invention described in the present application relates to combustion units of the general character in which fuel in finely divided form is injected into a chamber and burned in the presence of air, and although it has a wide range of utility, it is particularly useful, as for example, in connection with gus turbine plants.

Combustion systems such as those employed in connection with gas turbines for aircraft, must meet certain severe requirements. For example, they must secure complete fuel combustion, with a minimum of combustion pressure loss, and they must be of minimum weight and size to permit compact layouts. Hence, the combustion system must release heat at rates far in excess of those normally encountered in conventional combustion systems. For that purpose, the combustion system must be designed to control the heat liberation and the resulting temperatures in a manner that will permit said system to be constructed of readily available and easily workable materials, and to be operated with a minimum of destructive action on said materials.

Such a combustion system is required to perform dependably under all turbine load conditions and under all atmospheric conditions encountered in flight. The demands in this respect are especially broad.

Another essential consideration in connection with a combustion system of the general type referred to, is the ease and facility with which the system ignites and loads up in starting, and the stability of the flame, especially at low fuel deliveries.

Among the objects of the present invention are to provide a new and improved combustion unit, of the general character referred to, which permits the attainment of high combustion rates with comparatively low pressure drops, and which effectively meets the requirements of efficiency, complete combustion and proper temperature distribution, and the usual aircraft volume and weight limitations.

Other objects of the present invention are to provide a new and improved combustion unit which starts easily, positively and consistently, without difficult manipulations, which affords flame stability over a wide range of operation and at all speeds, altitudes and throttle positions, and which is suspectible to easy and close regulation.

In accordance with certain features of the present invention, a rich fuel-air mixture is created in the forward end of a furnace chamber and ignited, and the resulting burning mixture is projected toward the discharge end of said chamber. The furnace chamber is enclosed in an outer housing wall forming an annular air flow passage with the inner chamber walls. The air stream as it flows through the annular passage, has portions thereof diverted into spaced regions of the furnace chamber to create in said chamber flame propagating fuel-air mixtures. At the same time, the air passing through the annular air flow passage cools the outer housing wall and also the chamber wall.

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To prevent the flame from being localized axially of the furnace chamber, and to assure the efficient creation and rapid distribution of the inflammable mixtures throughout the entire cross-section of the portion of said chamber in which combustion takes place, the air is projected into successive spaced regions therealong in such a manner that the air in one region is admitted through one or more air inlets angularly displaced from or staggered with respect to the air inlets of adjoining regions.

As a further feature of the present invention, the air streams are directed into the furnace chamber in a direction obliquely countercurrent to the direction of flow of the burning mixture in said chamber, and towards the active flame region, to afford a high degree of air turbulence in the axial region of the chamber, and thereby to achieve the desired high liberation of energy within a small combustion volume.

As another feature, the air inlets are arranged and distributed to attain effective air turbulence and diffusion around the axial zone of the chamber, without extinguishing the flame even at low fuel rates.

As a further feature, the furnace chamber wall and the outer housing wall defining the annular air flow passage are substantially free from obstructions tending to cause turbulence and the air inlets are designed to divert air from the annular air flow passage into the inner furnace chamber with a minimum of turbulence in said passage, whereby the impact or velocity head of the air as it flows through said passage is conserved as fully as possible, and the air pressure loss in the combustion unit is reduced to a minimum.

As another feature, the air inlets are designed to prevennt seepage of liquid fuel therethrough, or accumulation of this fuel thereabout, thereby preventing combustion in the annular air flow passage, which combustion usually causes dan-

gerous overheating of the walls defining said passage and undesirable changes in the operating conditions.

Various other objects, features and advantages of the invention will be apparent from the following particular description, and from an inspection of the accompanying drawings, in which:

Fig. 1 is a longitudinal axial section of one form of combustion unit embodying the present invention;

Figs. 2, 3, 4 and 5 are different sections or views of the combustion unit of Fig. 1, taken on lines 2—2, 3—3, 4—4 and 5—5 respectively of Fig. 1;

Fig. 6 is a plan view of the development or blank of the conical downstream section of the inner shell; and

Fig. 7 is a plan view of the development or blank of the conical upstream section of the inner shell.

Referring to the drawings, the combustion unit of the present invention is shown of the type which is particularly adaptable for use in connection with gas turbine plants. However, it must be understood that as far as certain aspects of the invention are concerned, the unit of the present invention may be adapted for other combustion uses or for other air heating installations where a high energy release rate and low pressure loss are required.

The combustion unit of the present invention shown in the embodiment of Figs. 1–7, comprises in general, an outer housing wall 10, which includes an air duct portion 11, and an inner furnace wall 12 defining therein a combustion chamber formed of zones 13 and 14. The inner furnace wall 12 forms with the outer housing wall 10 an annular flow passage 15 for the air. The inner furnace wall 12 and the outer housing wall 10 are sectionalized, and mainly of thin, rolled metal shell construction, although part are of heavier forged or cast metal shell construction, as will be made apparent.

Air duct portion 11 is provided at its inlet end 17 with a flange 18 for bolting connection to the outlet 19 of an air compressor. Air duct portion 11 is of the type especially useful in connection with modern air compressors which discharge compressed air with relatively large velocity head, and has its cross-section increasing progressively in area in the direction of flow in the form of a streamlined diffuser to recover a large part of the velocity head and convert it into pressure head suitable for the conditions existing in the different combustion zones 13 and 14, while at the same time maintaining the necessary velocity to afford high rate of combustion in said zones.

The shape of the air duct portion 11 is shown of a specific design suitable for application to a gas turbine layout proposed in connection, for example, with an aircraft installation. In such a power plant, all of the principal elements of the plant, as for example, the compressor, the combustion unit and the gas turbine, would be arranged in line. In the particular layout shown in the drawings, the compressor would be disposed near the front of the combustion unit with its end connected to the air duct inlet 17, while the gas turbine would be disposed at the exhaust end of the combustion unit. There usually is a number of these combustion units circularly arranged around the axis of the turbine wheel.

The outer shell 10 is made of three sections 23, 24, and 25 of generally circular cross-section connected coaxially end to end. The inlet shell section 23, usually cast or forged, is of conical or flaring shape, and is preferably integral with the air duct portion 11. The duct 11 is shown elongated in a circumferential direction at its inlet end, to follow the curvature of the compressor outlet 19, as shown in Fig. 2, and changes gradually from this elongated shape, to merge with the generally circular cross-section of section 23.

The intermediate shell section 24 is generally cylindrical and is made of thin sheet metal; the joint or joints are preferably welded. The intermediate shell section 24 has an expansion joint 26 permitting endwise movement of the joined shell parts, and is removably connected to the inlet shell section 23 as by a coupling 27 of usual construction.

The discharge shell section 25 desirably of sheet metal construction, is of progressively reduced diameter downstream, and terminates in a neck 32. The section 25 is removably connected to the intermediate shell section 24 by a separable joint 33 also of usual construction, and it is removably connected to a conduit 34 by a studded flange connection 35. Conduit 34 may be any unit of the system or plant, and may, for example, be the conduit member leading to the gas turbine of the aircraft.

The inner shell 12 has at its inlet end a streamlined head 40 flared to follow substantially the flaring curvature of the air duct portion 11, and shaped to extend from an elongated arcuate edge 41 at one end to a circular cross-section at its downstream end 42. Clamped between the end 42 of head 40 and the upstream end 43 of the inner shell 12 is a fuel spray nozzle device 45 connected to a fuel inlet line 46. Nozzle device 45 is shown of the mechanical type adapted to project liquid fuel in the form of a conical spray under pressure into the combustion zone 13, and to atomize said fuel in said zone.

The inner shell 12 is centrally supported relative to outer housing wall 10 by means of spacers 53, shown in the form of radial lugs, welded or otherwise united to the sections of the inner shell 12 and engaging outer housing wall 10. At the outlet end, the inner shell 12 is of progressively reduced diameter downstream, and terminates in a throat 47 snugly embraced by the neck 32 of the outer shell 11, so that said inner shell 12 is firmly supported at this outlet end. The inner shell 12 aside from the head 40, is generally circular in cross-section, and is made of three sections 50, 51 and 52 coaxially mounted. The first or upstream section 50 is cone shaped, and has its upstream end connected to the head 40 through the spray nozzle device 45. The shell section 51 is slightly conical. The upstream end 55 of shell section 51 is larger in diameter than the corresponding downstream end 56 of the upstream inner shell section 50, to form an expansion joint between the two inner shell sections 50 and 51. The inner shell section 52 is of progressively reduced diameter downstream, and terminates in the throat 47, as previously described. The sections of inner shell 12 may conveniently be formed of sheet metal, or thin plate by rolling or similar forming operations into the curved streamlined form shown and the longitudinal seams closed by welding.

For admitting air from the annular passage 15 into the zone 13, and into the zone 14, the inner shell 12 is provided with a series of successive stages of louvred air inlets 60, 60*a*, 60*b*, 60*c*, 60*d*, 60*e*, 60*f*, 60*g*, 60*h* and 60*i*. In the embodiment of the invention now described ten of these

stages are employed. The number of air inlet stages employed in each case will depend on the conditions. However it can be stated that within limits better results are usually obtained with a larger number of stages than with a smaller number of stages.

Each of the primary air inlets **60** of the first stage comprises a tongue **62** usually integral with and cut out from the shell wall **50**. The tongue **62** has a sectio.. cut off its free end to define an opening **63** in the flat blank from which the shell section **50** is formed, as shown in Fig. 7, and is bent inwardly after the blank is rolled to define the port **64**. Thus the tongue **62** serves as a guide to lead the air towards the interior of the inner shell. Inside the inner shell **50** and along the circumferential downstream edge of the port **64** is a curved deflector vane **65**, welded to said edge. Vane **65** is substantially the same length as the circumferential width of the port **64**, and constitutes a segment of a tube curved to follow the peripheral curvature of the shell section **50**. The vane **65** has its ends sloped radially as shown in Fig. 5, and is transversely curved to direct the air admitted through the corresponding port **64** in a reverse upstream direction towards the zone of fuel injection, and obliquely of the axis of the injected fuel zone, thus promoting exceptional turbulence in the primary combustion region.

Each of the primary air inlets **60** has on each side a substantially ovate shroud-plate **67**, with its apex end substantially sharp, and with its broader end conforming substantially with the transverse curvature of the vane **65**, to cover one end of said vane. Shroud-plate **67** has one of its tapering sides extending along the side edge of the port **64**, and its other tapering side extending into the interior of the shell section **50** beyond the tongue **62**, and is rigidly secured to the end of the vane **65**, to the side of said tongue, and to the inner surface of said shell section by welding along contacting or abutting edges. The two shroud-plates **67** at each primary air inlet **60** will slope radially and flank the corresponding tongue **62** and vane **65** as shown in Figs. 4 and 5, and will serve to prevent spillage of air along the ends of said vane. The air is thereby channelled into the interior of the combustion chamber in well-defined streams having predetermined flow characteristics.

The shroud-plates **67** also prevent the flow of liquid fuel along the inside walls of the shell **12** and out through the air ports **64** into the annular space **15**, where burning fuel would defeat the cooling function of the annular arrangement, would upset the operating conditions for which the unit is designed and thereby reduce its efficiency and would create a fire hazard. To prevent the accumulation of the liquid fuel in the pocket defined by the curved vane **65**, said vane has an aperture **68** through which liquid fuel can readily escape. The incoming air passing through the port **64** and directed against the vane **65** helps to blow any liquid fuel deposited in said vane through the aperture **68**.

The air guiding structures of the other stages of air inlets **60***a*, **60***b*, **60***c*, **60***d*, **60***e*, **60***f*, **60***g*, **60***h* and **60***i*, are similar to those described in connection with the first stage of air inlets **60**, except that the dimensions are different, and in the later stages, the side shroud-plates may be absent, and the curved vanes may not be apertured for the escape of liquid fuel. The different stages of air inlets are correctly sized to compensate for the decrease in volume and pressure of the air in the annular passage **15** progressively downstream, to effect the proper distribution of the air in the flame region, and to cause the injected air to follow a desirable predetermined pattern of turbulence and diffusion. As the air inlets extend downstream, the tongue guides thereof are preferably progressively bent inwardly of the inner shell **12** to an increasing extent, to progressively increase the effective area of the air inlet.

In the section of the combustion chamber where the later stages of air inlets are located, the fuel is usually all in such condition and the flame so spread out that the shroud-plates and the apertures in the curved vanes are not necessary. If conditions require it, however, these features can be applied to all the stages of air inlets.

A comparatively large number of small air inlets are preferably employed instead of a small number of larger air inlets, as thereby better results and more stable operation are obtained. Highly localized and concentrated air streams have a tendency to extinguish the flame, especially at low fuel deliveries. By providing a large number of small inlets, the flame-quenching tendency is reduced to the point where stability of the flame is maintained within a wide operating range.

For this purpose, and by way of example, the combustion chamber described contains thirty separate air inlets of three different sizes, disposed in ten spaced transverse regions of said chamber. Each of these transverse regions or stages contains three air inlets spaced 120° apart. The air inlets of one stage are circumferentially staggered with respect to the air inlets of adjoining stages, and in the initial stages, the air inlet of one stage is displaced 60° with respect to the air inlets of adjoining stages. In the later stages, the angular relationship of the air inlets between successive stages may be different, and may be relatively displaced 30° apart as shown in Fig. 6 according to the pattern of air distribution desired.

Fig. 6 shows the development of a blank **51***a* designed to form the inner shell section **51**, and cut out to provide the seven stages of air inlets **60***c*, **60***d*, **60***e*, **60***f*, **60***g*, **60***h* and **60***i*. Blank **51***a* is slitted and cut, as in the case of blank **50***a*, and may be rolled and completed as described in connection with the blank **50***a* to provide these seven stages of air inlets.

Fig. 7 shows the development of a blank **50***a* designed to form the shell section **50**, and cut out to provide the three banks or stages of air inlets **60**, **60***a* and **60***b*. To that end, the blank **50***a* has a plurality of pairs of radial slits **75**. The slits **75** of each pair define therebetween a tongue **62***a* from which the deflector **62** is formed. This tongue **62***a* is shortened by cutting off its outer end to form the opening **63** in the blank. The blank **50***a* cut and slitted as shown and described, is rolled in conical shape and welded along its longitudinal seam. The tongue **62***a* may then be bent inwardly to define the air guides and the vanes and shroud plates welded in position to complete the air inlets **60**, **60***a*, and **60***b*.

For initiating the flame, there is fitted into the peripheral wall of the outer housing wall **10** a spark plug **80** extending through an opening **81** in the shell section **50**. Spark plug **80** is desirably operated only sufficiently long to properly initiate ignition. Thereafter, primary combustion will continue without the aid of the spark plug. However, if desired, the operation of the spark

plug 80 can be continued during the operation of the combustion unit.

Due largely to the correct disposition of air injection ports and the resulting distributed turbulence, as well as to the proper location of the ignitor spark plug 80, ignition is achieved and the flame is established immediately upon the supply of fuel, regardless of the established air flow rate or prevailing combustion system pressure.

As the air in the annular space 15 flows around the casing of the spark plug 80, a low pressure region is created on the downstream side of said casing, thus tending to cause the liquid fuel in the inner shell 11 to seep through the opening 81 into said space. To avoid this condition, there is provided a saddle 83 for the spark plug 80 secured to the outside of the shell section 50 by welding, and opened only at its upstream end. The air flowing into the chamber 84 defined around the spark plug 80 by the saddle 83 maintains said chamber under full air pressure, and thereby prevents seepage of the liquid fuel through the opening 81. The spark plug 80 may be of a usual type having a casing which defines an air passage for cooling the porcelain insulator, and which is provided on its upstream side and in the saddle chamber 84 with a hole 85 constituting the inlet of said air passage.

In the operation of the combustion unit, as the air flows through the annular space 15 from the compressor, part of the air is diverted through the first stage of inlets 60, and is reversely deflected obliquely back into the combustion zone 13 towards the point of fuel injection. Other portions of the air further downstream in the annular space 15 are diverted through the second stage of air inlets 60*a*, and are reversely deflected obliquely back into the combustion zone 13 towards the point of fuel injection. The air streams projected into the combustion zone 13 through the two close sets of air inlets 60 and 60*a*, assume somewhat the form of a vortex ring around the injected fuel cone. Sufficient amount of the fuel from this cone is drawn and diffused towards the annular axis of the air vortex ring, to form at said axis an inflammable mixture. This mixture created around the fuel cone forms a pilot flame by which ignition is continuously maintained, even though the operation of the spark plug 80 should be discontinued.

The ignited stream, rich in fuel, is projected from the combustion zone 13 towards the combustion zone 14, where it impinges and is thoroughly, rapidly and intimately intermixed with the progressively injected air streams from the air inlets 60*b* and from all the other air inlets further downstream, to form therewith flame propagating mixtures. The air inlets 60*b*, 60*c*, 60*d*, 60*e*, 60*f*, 60*g*, 60*h* and 60*i*, as well as the air inlets 60 and 60*a*, are designed to direct the air into the combustion chamber in a direction obliquely countercurrent to the general direction of flow in said chamber, and into the active flame region of said zone.

As a result of the staggered arrangement of the air inlets lengthwise and circumferentially of the shell 12 as described, the combustion is not confined to the center of the chamber but is effectively distributed throughout the cross-section thereof. As the flame is extended or propagated axially along the combustion chamber, it is spread, fanned out, or distributed outwardly in different substantially radial directions by the admission of air at one transverse inlet region or stage of the chamber, and then spread or distributed outwardly in substantially radial directions in staggered relationship with respect to the first-mentioned directions by the admission of air at the next succeeding transverse inlet region or stage. This promotes turbulence in the zones of the chamber where it is most desirable and most effective, and thereby causes complete, thorough mixing of the fresh air with the fuel elements of the burning mixture in a comparatively small space, creates a short intense flame in the interior of the chamber, and assures complete combustion even at maximum loads before the gas stream reaches the outlet end of the unit. The converging character of the inner shell 12 at its outlet or exhaust section 52 serves to impart to the exit gases the necessary velocity, according to the use to which these gases are to be put.

Not all of the air which flows through the annular flow chamber 15 is diverted in the interior of the combustion chamber. Some of it is allowed to pass completely along the annular flow passage 15, and is discharged into the combustion chamber outlet through holes 90 near the throat 47 of inner shell section 52 to aid in the control of the outlet temperature.

The circular cross-section of the shell 12 assures a uniform distribution of air entering into the combustion chamber at any transverse region thereof; this promotes a more uniform flow of air into the chamber, and thus contributes to flame uniformity and stability.

The general conical shape of the shell sections 50 and 51 serves to present a surface to the air flowing through passageway 15 which is at an angle to the direction of the flow of said air. As a consequence, a portion of the kinetic energy or impact head of the entering air is employed to force the air to enter the air inlets, thus decreasing the air stream total pressure loss in the combustion unit. The conical angle of the shell sections 50 and 51 is so selected as to provide a minimum clearance 91 between the two shells 11 and 12 at the extreme downstream end of the active combustion part of the unit. The radial depth of this minimum clearance 91 controls the amount of air which by-passes the combustion chamber.

The angle of the cones of the shell sections 50 and 51 as well as the depth of the depressions of the air inlets as determined by the angle of inclination of the guide or tongue plates therein, determine the air flow characteristics in the regions of said air inlets, and consequently serve to control the quantity and velocity of air entering each air inlet.

The outer shell 11, which acts as a container for the assembly, and is therefore the stressed member, is cooled by the entering air as described. The inner shell 12 containing the flame, is also cooled and is under little or no stress. As a result, the entire assembly can be fabricated from thin sheets of heat-resistant material.

Since the air is injected into the interior of the combustion chamber through depressions in the conical surfaces of the shell sections 50 and 51 and said surfaces are straight and free of obstructions, a minimum of turbulence is created in the annular air stream in the space 15 adjacent to each air port. The preservation of the sense of direction of flow of the air in the space 15 resulting from this condition conserves to a maximum the impact head of said air, and consequent-

ly minimizes the air pressure loss in the combustion unit.

The combustion unit of the present invention can be made to effectively afford outlet temperatures ranging from about 200° F. to as high as 3000° F. The embodiment shown is best adapted to provide outlet temperatures ranging from 300° F. to a maximum of 1800° F.

Operating test data indicate that the combustion unit of the type shown in Figs. 1–7, which is particularly adapted for installation in an aircraft engine, performs most satisfactorily over the entire range of performance conditions dictated by the most extensive engine requirements. This performance range comprises a maximum heat release rate of over fifty times the minimum heat release rate, a maximum combustion chamber pressure better than twenty-five times the minimum combustion chamber pressure, and a maximum air flow rate better than fifteen times the minimum air flow rate. Smooth, stable, steady, dependable, soot-free performance was observed under all conditions, with a thermal efficiency measured close to 98% at every operating point.

As many changes can be made in the above apparatus, and many apparently widely different embodiments of this invention can be made without departing from the scope of the claims, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A combustion unit comprising a combustion chamber, the peripheral wall of which is provided with openings spaced therealong and circumferentially thereof, means for creating an inflammable, fuel-rich, fuel-air mixture, igniting said mixture and discharging the resulting ignited mixture rich in fuel elements into said chamber, a housing around said combustion chamber and defining therewith an annular airflow passage, said openings conducting a major portion of the air from said passage into said chamber for combustion therein, a curved vane entirely inside said chamber on the downstream end of each opening for deflecting the air admitted through said opening in the form of a jet generally countercurrent to the flow of said ignited mixture in said chamber to create thorough mixing in said chamber of said air and the ignited mixture to assure substantially complete combustion therein, and a guide plate extending in a general downstream direction from the upstream end of each opening and inclined inwardly from said end with respect to said peripheral chamber wall for directing the air admitted into said opening towards said vane.

2. A combustion unit comprising an elongated combustion chamber, a housing enclosing said chamber and defining therewith an annular passage for conducting an air stream, the peripheral wall of said chamber being provided with openings spaced therealong and circumferentially thereof for the admission of a major portion of said air stream for combustion, means for creating an inflammable, fuel-rich, fuel-air mixture, igniting said mixture and discharging the resulting ignited mixture rich in fuel elements into said chamber for progressive combustion, a curved vane entirely inside said chamber on the downstream end of each opening for deflecting the air admitted through said opening in the form of a jet generally countercurrent to the flow of said ignited mixture in said chamber to create thorough mixing in said chamber of said air and the ignited mixture to assure substantially complete combustion therein, and a guide plate for said vane cut out from said peripheral chamber wall and integral therewith along the upstream end of each opening, said guide plate extending in a general downstream direction from said upstream end and inclined inwardly from said end with respect to said peripheral chamber wall for directing the air admitted into said opening towards said vane.

3. A combustion unit comprising an elongated combustion chamber, the peripheral wall of which is provided with openings spaced therealong and circumferentially therearound, means for creating an inflammable, fuel-rich, fuel-air mixture, igniting said mixture and discharging the resulting ignited mixture rich in fuel elements into said chamber, a housing surrounding said combustion chamber and defining therewith an annular passage for conducting an air stream in the direction of the flow of said ignited mixture, said openings directing the major portion of said air stream into said chamber for combustion progressively, a curved vane entirely inside said chamber on the downstream end of each opening for deflecting the air admitted through said opening in the form of a jet generally countercurrent to the flow of said ignited mixture in said chamber to create thorough mixing in said chamber of said air and the ignited mixture to assure substantially complete combustion therein, and a pair of shroud-plates in said chamber on opposite sides of each vane.

4. A combustion unit comprising a combustion chamber, a housing surrounding said chamber and defining an annular passage for an air stream the peripheral wall of said chamber being provided with openings spaced therealong and circumferentially thereof for the admission of a major portion of said air stream for combustion, means for creating an inflammable, fuel-rich, fuel-air mixture, igniting said mixture and discharging the resulting ignited mixture rich in fuel elements into said chamber for progressive combustion, a curved vane entirely inside said chamber on the downstream end of each opening for deflecting the air admitted through said opening in the form of a jet generally countercurrent to the flow of said ignited mixture in said chamber to create thorough mixing in said chamber of said air and the ignited mixture to assure substantially complete combustion therein, a guide plate extending in a general downstream direction from the upstream end of each opening and inclined inwardly from said end with respect to said peripheral chamber wall for directing the air admitted into said opening towards said vane, and a pair of shroudplates in said chamber on opposite sides of each vane and each corresponding guide plate.

5. A combustion unit comprising an elongated combustion chamber having a peripheral wall section rolled from a flat shell blank and slitted to define a series of tongues integral with said wall section along the upstream end of said tongues, means for creating an inflammable, fuel-rich, fuel-air mixture, igniting said mixture and discharging the resulting ignited mixture rich in fuel elements into said chamber for progressive combustion, said tongues being bent inwardly at their upstream ends at an acute angle with said wall section to define openings in said wall section for the admission of combustion air and to adapt

said tongues as guides for the air flowing through said openings, vanes entirely in said chamber opposite the downstream ends of said tongues respectively for deflecting the air passing through said openings obliquely countercurrent to the flow of said ignited mixture in said chamber, and a housing wall encircling said combustion chamber and defining an annular air flow passage with which said openings are in communication, said openings conducting a major portion of the air flow from said passage into said chamber for combustion in the form of jets, to bring about a thorough mixing of the added air and burning fuel-air mixture and to assure substantially complete combustion therein.

6. A combustion unit comprising an elongated combustion chamber, the peripheral wall of which is provided with openings spaced therealong and circumferentially thereabout, means for creating an inflammable, fuel-rich, fuel-air mixture, igniting said mixture and discharging the resulting ignited mixture rich in fuel elements into said chamber, a housing surrounding said combustion chamber and defining therewith an annular passage for conducting an air stream in the direction of flow of said ignited mixture, said openings directing a major portion of said air stream into said chamber in the form of jets to bring about a thorough mixing of the added air and burning fuel-air mixture and to assure substantially complete combustion therein, a curved vane entirely inside said chamber on the downstream end of each opening for deflecting the air admitted through said opening generally countercurrent to the flow of said ignited mixture in said chamber, said vane having an aperture to permit escape of liquid fuel from said vane into said chamber, and guide means for directing the air admitted through each of said openings towards the corresponding vane.

7. In a combustion unit, a combustion chamber having a peripheral wall with openings spaced therealong and circumferentially therearound for directing combustion air into said chamber, means for injecting fuel into one end of said chamber, a housing around said chamber and defining with said peripheral chamber wall an annular air flow passage, a fuel igniting unit passing through said passage and through an opening in said chamber wall and projecting into said chamber in position to ignite the fuel injected into said chamber, and a saddle around said unit in said passage and mounted against said peripheral chamber wall, said saddle being opened to said passage on the upstream side to maintain the region around said unit adjoining said chamber wall under sufficient pressure to resist seepage of fuel oil through the opening of said chamber wall through which said unit extends.

8. A combustion unit having an air intake end and an exhaust end comprising a combustion chamber having a substantially smooth outer surface, an outer housing for said chamber concentrically spaced therefrom, one end of said housing defining an air intake, said chamber flaring towards said housing in a direction away from said air intake whereby said chamber and said housing cooperate to form an annular air flow passage having a progressively smaller area from said air intake end toward said exhaust end, a plurality of circumferentially and longitudinally spaced air inlets formed in the flaring wall section of said combustion chamber for the successive admission of a major portion of the air flow from said air flow passage into said chamber for progressive combustion therein, a vane associated with each of said air inlets interiorly of said chamber for directing combustion air from said annular air flow passage in the form of jets generally counter current to the flow of ignited materials in said chamber.

9. A combustion unit having an air intake end and an exhaust end comprising a combustion chamber having a peripheral wall section flaring in a direction from said air intake end toward said exhaust end and presenting a substantially smooth outer surface, an outer housing for said chamber one end of said housing defining an air intake, said housing being concentrically spaced from said chamber to form therewith an annular air flow passage, the end of said chamber adjacent said air intake being closed, unitary means adjacent said closed end for introducing all of the fuel burned by said unit into said chamber for progressive combustion therein, a plurality of circumferentially and longitudinally spaced air inlets formed in the flaring wall section of said chamber for the successive admission of a major portion of the air flow from said air flow passage into said chamber for progressive combustion therein, a vane associated with each of said air inlets interiorly of said chamber, each of said vanes being capable of directing combustion air from said annular air flow passage in the form of jets in a direction generally counter current to the normal flow of fuel in said chamber to bring about a thorough mixture of said combustion air and said fuel and to assure substantially complete combustion therein.

10. A combustion unit having an air intake end and an exhaust end comprising a combustion chamber having a peripheral wall section flaring for a predetermined distance and constricting for a predetermined distance following said flaring portion to form an exhaust opening, said chamber presenting a substantially smooth outer surface, an outer housing for said chamber, said housing being concentrically spaced from said chamber to form therewith an annular air flow passage, said housing being so formed that it approaches said chamber as it extends from said air intake end toward said exhaust end, a plurality of circumferentially and longitudinally spaced vaned air inlets formed in the flaring wall section of said chamber for the successive admission of a major portion of the air flow from said air flow passage into said chamber for progressive combustion therein, said vanes being located interiorly of said chamber and being adapted to direct the flow of air entering said air inlet in the form of jets in a direction in said chamber which is substantially opposite to the direction of flow of air in said annular air flow passage.

11. In a combustion unit having a combustion chamber with a substantially smooth outer surface, an outer housing for said chamber concentrically spaced therefrom and forming with said chamber an annular air flow passage around said chamber, the combination with said chamber of a plurality of air inlets formed in the peripheral wall of said chamber and extending inwardly of said chamber whereby air is permitted to flow unimpeded around said combustion chamber, each of said air inlets comprising a tongue extending inwardly of said chamber from the peripheral wall thereof in a downtream direction for the successive admission of a major portion of the air flow from said air flow passage into said chamber for progressive combustion therein, a vane associated with the downstream end of

said air inlet and located entirely within said chamber, and a pair of shroud plates joining the ends of said vane and the sides of said tongue, said shroud plates and said tongue serving to guide combustion air from said annular air flow passage to said vane, said vane being adapted to change the direction of the combustion air thus directed against it to a direction generally counter current to the direction of air in said annular air flow passage.

12. A combustion unit comprising a combustion chamber having a conical peripheral wall section flaring downstream, an outer housing for said chamber defining with said chamber an annular air flow passage extending therealong, means for creating an inflammable, fuel-rich, fuel-air mixture, igniting said mixture and discharging the resulting ignited mixture, and a series of vaned openings in said conical chamber section spaced along and circumferentially around said chamber wall section and communicating with said flow passage for the successive admission of a major portion of the air flow from said air flow passage into said chamber for progressive combustion therein, the vanes associated with said openings being located entirely within said chamber and so positioned with respect to said openings that they deflect combustion air entering said chamber through said openings in the form of jets in a direction generally counter current to the flow of said ignited mixture in said chamber to create thorough mixing of said combustion air and said fuel elements and to assure substantially complete combustion therein, the peripheral wall of said housing around said

chamber wall section being generally cylindrical to cause the air in said passage to flow in a general direction tending to approach said chamber wall section, whereby a portion of the kinetic energy of the air in said passage is employed to force said air into said openings, the outer surface of said conical chamber wall section presenting a continuous conical surface substantially free from obstructions in the regions of said openings in said annular passage so that air can pass through said passage with minimum loss of kinetic energy.

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