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AIR INLET ARRANGEMENT FOR COMBUSTION
CHAMBER FLAME TUBES
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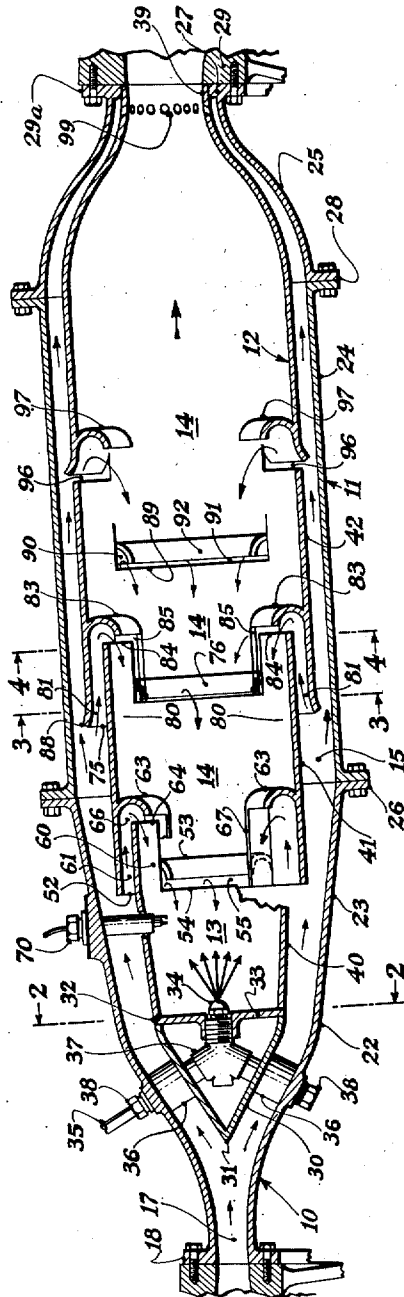


Fig. 1

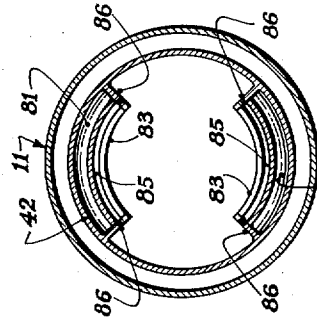


Fig. 4

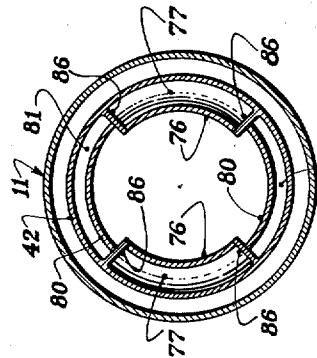


Fig. 3

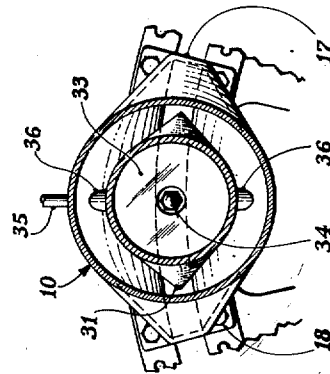


Fig. 2

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AIR INLET ARRANGEMENT FOR COMBUSTION CHAMBER FLAME TUBES

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The present invention relates to combustion units of the general character in which fuel in finely divided form is injected into a chamber or furnace 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 gas turbine plants.

One object of the present invention is 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. A combustion unit of this improved type constructed to follow the method of the present invention, is especially advantageous in a gas turbine system because it occupies a minimum of space, and because it permits compact layouts in connection with other units of the system while allowing minimum of thermodynamic losses.

A further object of the present invention is to provide a new and improved combustion unit of the general type referred to, in which the combustion air inlet and the exhaust are designed and located to permit the compact arrangement of said combustion unit in line with other units of a plane, while affording high combustion rates and low pressure drops. A combustion unit of this improved type is particularly useful in connection with certain proposed aircraft practices in which the principal elements of a gas turbine plant, as for example, the compressor, combustion unit and gas turbine, are arranged in line.

Another object of the present invention is to provide a new and improved combustion unit which is designed to assure thorough, rapid, turbulent mixing of the air and fuel, which afford positive ignition and combustion stability over a wide range of operation, and which afford easy and close regulation.

Another object of the present invention is to provide a new and improved combustion unit which is comparatively light, simple and inexpensive to manufacture, and which, in spite of its high energy release characteristics, has a comparatively long useful life.

In accordance with certain features of the present invention, a rich fuel-air mixture is created in the primary combustion zone of a furnace chamber and ignited, and the resulting burning mixture is projected into the secondary combustion zone of said chamber. The furnace chamber is enclosed in an outer housing wall forming an annular air flow passage with the inner chamber wall. The combustion air stream as it flows through this passage, has successive

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spaced portions thereof diverted into respective regions of the combustion zones to create in said chamber flame propagating fuel-air mixtures.

To prevent concentration of the propagated flame along the center of the furnace chamber, and to assure the efficient creation and rapid distribution of the inflammable mixtures throughout the entire cross-sections of said chamber, the combustion 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 combustion air streams are directed into the furnace chamber in a direction obliquely counter-current to the direction of flow of the combustion gases in said chamber.

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

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

Figs. 2, 3 and 4 are different transverse sections of the combustion unit taken on lines 2-2, 3-3 and 4-4, respectively, of Fig. 1.

Referring to the drawing, 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 where a high energy release rate is required.

The combustion unit of the present invention comprises an air duct 10, an outer housing wall 11, and an inner furnace wall 12 defining therein a primary combustion chamber or zone 13 and a secondary combustion chamber or zone 14. The inner furnace wall 12 forms with the outer housing wall 11 an annular flow passage 15 for the combustion air. Duct 10 and walls 11 and 12 are desirably in the form of thin metal shells.

Air duct 10 extends coaxially with respect to the inner and outer shells 11 and 12, and is provided at its inlet end 17 with a flange 18 for bolting connection to the outlet of an air compressor. Air duct 10 is shown of the type especially useful in connection with modern air compressors which discharge compressed air with relatively large velocity head. Air duct 10 is

therefore shown with its cross-sectional area increasing progressively in the direction of flow in the form of a streamlined diffuser to recover a large part of this 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 10 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 11 is made of three circular sections 23, 24 and 25. The outer shell section 23 is of conical or flaring shape welded, or otherwise made integral, at its smaller inlet end with the outlet end 22 of the air duct 10. The intermediate outer shell section 24 is cylindrical and removably connected to the outer shell section 23 by a bolted flange joint 26. The outer shell section 25 is of progressively reduced diameter downstream, and terminates at its outlet end in a neck 27. At its inlet end, outer shell section 25 is removably connected to the intermediate outer shell section 24 by a bolted flange joint 28, and at its other end it is removably connected to a conduit member 29 by a studded flange connection 29a. Conduit member 29 may be any unit of the system or plant, and may, for example, be the conduit member leading to the gas turbine.

The inner shell 12 has at its inlet end a streamlined head 30 flared to follow substantially the curvature of the wall of the air duct 10. At the downstream end of the head 30, there is mounted a circular plate 33 having a hole through which extends a fuel spray nozzle 34 connected to a fuel inlet line 35. Nozzle 34 is shown of the mechanical type adapted to project liquid fuel under pressure into the interior of the primary combustion chamber or zone 13 in the form of a hollow cone, and to atomize said fuel in said chamber.

The inner shell 12 is centrally supported, at its inlet end, with respect to the air duct 10 by means of spacers 36 between the wall of air duct 10 and the wall of head 30. Spacers 36 are desirably streamlined in the direction of air flow thereover, and are diametrically arranged. To permit the easy removal or assembly, spacers 36 are hollow and are held in position by pipes, connected to a fitting 37 which supports nozzle 34, passing through said spacers to the outside of the air duct 10, where they are threadedly engaged by nuts 38. One of these pipes is the fuel inlet line 35. One branch of fitting 37 is closed so that the fuel admitted through line 35 can only flow to nozzle 34. At the outlet end, the inner shell 12 is of progressively reduced diameter downstream, and terminates in a throat 39 snugly embraced by the neck 27 of the outer shell 11. Thus inner shell 12 is supported centrally or axially with respect to the air duct 10 and outer shell 11, and can be easily mounted therein or

removed therefrom as a unit, when the outer shell has been demounted in a manner already made apparent.

The inner shell 12 is preferably circular in cross-section, and is made up of several sections 40, 41 and 42 coaxially mounted. The first section 40 is slightly cone-shaped at its fore end and cylindrical at its outlet end, and has its upstream end connected to the head 30 and closed by the plate 33. The intermediate section 41 is cylindrical in shape; the end section 42 is cylindrical in shape, except for its exhaust end, which is of progressively decreasing diameter downstream, as already described. The cylindrical part of the section 42 is larger in diameter than section 41, while section 41 is larger in diameter than the downstream end of the section 40.

Sections 41 and 42 are arranged to be telescoped over their respective adjacent sections 40 and 41 to define between the overlapping parts annular spaces from which the necessary air inlet openings for the different successive combustion regions are determined. For admitting air into the zone 13 for primary combustion, the section 41 has its inlet end overlapping the smaller outlet end of the section 40 to form annular space 52. Along diametrically opposite sides of annular space 52 are two transversely curved deflector vanes 53 circularly bent in their longitudinal or circumferential direction to fit snugly in the interior of the cylindrical shell section 41, and secured at their outer peripheral edges to said shell section, as for example, by welding. Deflector vanes 53 are sufficiently wide in a transverse direction to extend across and around the circular edge 54 of the shell section 40 in the path of flow of the air through the annular space 52, and are spaced from said edge to define therewith primary air inlets 55. Each of vanes 53 extends angularly in its longitudinal or circumferential direction a distance of about 90°, and is transversely curved to direct the air admitted through the corresponding inlet 55 in a reverse direction towards the zone of fuel injection obliquely of the axis of the injected fuel cone. The vane structure of the unit described is similar to that further downstream shown in transverse section in Figs. 3 and 4.

The primary combustion air is admitted through the vaned inlets 55 towards the mixing zone of the primary combustion chamber 13 in the form of two arcuate diametrically opposed streams, each extending substantially 90° circumferentially of the axis of the unit.

Additional primary combustion air is admitted from a transverse region of the inner shell 12 further downstream towards the mixing region of the primary combustion zone 13. The additional primary combustion air is projected into zone 13 in the form of two streams circumferentially displaced or staggered with respect to the air streams projected through the air inlets 55. For that purpose, the circumferential portions 60 of the shell section 40 between the vane inlets 55 are extended in a downstream direction into the cylindrical shell section 41, and each of said extended portions forms with shell section 41 a longitudinal flow passage 61 communicating with the corresponding part of the annular space 52 between the vanes 53. In the path of flow of the air through each of these passages 61 is a transversely curved deflector vane 63 circularly bent in a longitudinal direction to fit snugly in the interior of the section 41, and secured at its outer peripheral edge to said shell section, as for ex-

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ample, by welding. Each of the deflector vanes 63 is sufficiently wide in a transverse direction to extend across and around the arcuate edge 64 of the corresponding shell extension 60 and in the path of flow of the air through the corresponding longitudinal flow passage 61, and is spaced from said edge to define therewith an air inlet 66. Each of vanes 63 extends angularly in its longitudinal direction a distance of about 90°, which corresponds approximately to the circumferential width of the shell extensions 60, and is transversely curved to direct the air admitted through the corresponding inlet 66 in a direction back towards the zone of fuel injection, and obliquely with respect to the axis of the injected fuel.

For closing the sides of the longitudinal flow passages 61, channeling the air deflected from the vanes 53 and 63 towards the zone of fuel injection, there are provided thin narrow partition members 67 extending longitudinally along the side edges of the shell extensions 60 between the vanes 53 and 63, and projecting substantially radially of said shell sections from the inner periphery of the section 41, and radially inwardly from said shell extensions 60. Partition members 67 are fast to the section 41, desirably by welding them to the inner periphery of section 41 and to the sides of the vanes 53 and 63.

For initiating the flame near the ignition zone 13, there is fitted into the peripheral wall of the housing shell 11 a spark plug 70 projecting through an opening in the section 40, and extending with its sparking end at a region near the outer margin of the conical fuel stream projected from the spray nozzle 34. Spark plug 70 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 can be continued during the operation of the combustion unit.

As the air flows through the annular flow passage 15, part of this air passes through the annular space 52 between the sections 40 and 41. A portion of this diverted air goes through the air inlets 55, and is deflected back into the interior of the shell section 40 towards the point of fuel injection. Other portions of this diverted air go through the longitudinal flow passages 61, and through the inlets 66, and are deflected by the vanes 63 back inwardly into the interior of the shell section 40 towards the point of fuel injection. The four air streams projected into the interior of the shell sections 40 by means of the two sets of vanes 53 and 63 merge and 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. The inflammable mixture created around the fuel cone forms a pilot flame by which ignition is continuously maintained even though the operation of the spark plug 70 should be discontinued.

The ignited exhaust stream rich in fuel elements is projected from the primary combustion zone 13 towards the secondary combustion zone 14, where it impinges and is thoroughly, rapidly and intimately intermixed with the injected combustion air streams, to form therewith flame propagating mixtures. For admitting combustion air into the secondary combustion zone 14, the inlet end of the section 42 is disposed adjacent the outlet end of the section 41 of smaller

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diameter, and defines therewith an annular space 75. Along diametrically opposite sides of this annular space 75 are two transversely curved deflector vanes 76 circularly bent in their longitudinal direction to conform substantially with the peripheral curvature of the section 42, and secured to the inlet end of said shell section, as for example, by welding, to define respective secondary air inlets 77. Deflector vanes 76 extend in their longitudinal direction an angular distance of about 90°, and are located in substantial alignment along the shell 12 with the vanes 53 respectively. The transverse curvature of vanes 76 is such as to direct the air admitted through the corresponding inlets 77 in a direction obliquely countercurrent to the general direction of flow in the secondary combustion zone 14, and desirably at an angle of about 45° with the axis thereof.

Combustion air is admitted from the annular flow passage 15 and through the vaned inlets 77 for oblique countercurrent impingement against the axially flowing burning mixture in the secondary combustion zone 14. This air is projected into secondary combustion zone 14 through the vaned inlets 77 in the form of two arcuate diametrically opposed streams, each extending approximately 90° circumferentially of the axis of the unit.

Combustion air is admitted into the secondary combustion zone 14 further downstream in the form of two diametrically opposed streams circumferentially displaced or staggered with respect to the air streams admitted through the air inlets 77. For that purpose, the circumferential portions 80 of the section 41 between the vaned inlets 77 are extended into the section 42, and each of said extended portions forms with section 42 a longitudinal flow passage 81 communicating with the corresponding part of the annular space 75 between the vanes 76. In the path of flow of the air through each of longitudinal flow passages 81 is a transversely curved deflector vane 83, circularly bent in its longitudinal direction to fit conformably in the interior of the section 42, and secured at its outer periphery to said section, as for example, by welding. The deflector vanes 83 are sufficiently wide in their transverse direction to extend across and around the arcuate edges 84 of the corresponding extended portions 80 and in the path of flow of the air through the corresponding longitudinal flow passages 81, and are spaced from said edges to define therewith secondary air inlets 85 respectively. Each of these deflector vanes 83 extends angularly in its longitudinal direction a distance of about 90°, which corresponds to the circumferential width of the corresponding extended portions 80, and is transversely curved to direct the air admitted through the corresponding inlet 85 in an oblique countercurrent direction with respect to the flow of combustion gases through the secondary combustion zone 14, and at an angle with the axis of said zone of approximately 45°.

For closing the sides of the longitudinal flow passages 81, channeling the air deflected from the vanes 83 in its flow towards the burning mixture, there are provided thin narrow partition members 86 extending in their longitudinal direction along the side edges of the extending portions 80 between the vanes 76 and 83, and extending substantially radially of sections 41 and 42 from the inner periphery of section 42, and radially inwardly from the sides of the extending portions 80. Partitions 86 are fast to the section 42 de-

sirably by welding to the inner periphery of the section 42, and to the sides of the vanes 76 and 83. To facilitate entry of air towards the inlets 77 and 85, the inlet end 88 of the section 42 is flared in the form of a bell-mouth.

Additional air is admitted into the interior of the secondary combustion zone 14 through air inlets which are located further downstream in a succeeding transverse region of said zone, and which are staggered with respect to the inlets 85. For that purpose, the section 42 has two diametrically opposite circumferential slits 89, and the peripheral portion 90 on the downstream side of each slit is flared radially outwardly to define a pair of diametrically opposite inlet openings 91. Mounted in each of these inlet openings 91 is a deflector vane 92 circumferentially curved to correspond at its outer periphery substantially with the curvature of the corresponding flared portion 90 of the section 42, and firmly secured to said portion, as for example, by welding. Vane 92, as in the case of the vanes 76 and 83, is transversely curved to direct the air admitted through the opening 91 obliquely countercurrent to the direction of flow of the burning mixture through the unit, and at an angle which is desirably about 45° with respect to the axis of said unit. The deflector vanes 92 extend substantially circumferentially an angular distance of about 90°, and are disposed in substantial alignment with the respective vanes 76 lengthwise of the shell 12. Partitions (not shown) may be secured to the sides of each vane 92, as for example, by welding, and also to the peripheral wall of the section 42, so that the air streams as they pass through the inlets 91 are confined along their sides and are protected therefrom in predetermined cross-sectional form.

Further downstream in a succeeding transverse region of the secondary combustion zone 14, there are provided arcuate inlet openings 96 with vanes 97 in the section 42 constructed and arranged as described in connection with the inlets 91 and the vanes 92, but circumferentially displaced or staggered with respect thereto. The vanes 97 are curved and arranged to direct the air obliquely countercurrent to the burning mixture along the unit, and at an angle which is desirably about 45° with respect to the general direction of flow of said burning mixture.

As a result of the staggered arrangement of the air inlets lengthwise and circumferentially of the chamber shell 12 as described, the combustion is not confined to the center of the chamber. As the combustion or flame is extended or propagated along the shell 12, it is spread, fanned out or distributed outwardly in radially opposite directions by the admission of air at one transverse inlet region of the chamber, and then spread or distributed outwardly in radially opposite directions, but approximately at right angles to the first mentioned directions by the admission of air at the next succeeding transverse inlet region. This 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 before the gas stream reaches the outlet end of the unit. The converging character of the inner shell 12 at its outlet or exhaust end 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 passage 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 with the products of combustion, by means of holes 98 near the throat 27 of the inner shell 12, to control the outlet temperature of these products.

Annular flow passage 15 and the air inlets from it into the combustion chamber are so proportioned that the proper quantity of air is admitted through each pair of air inlets to promote the combustion of the fuel elements of the burning mixture while maintaining the burning mixture above the extinction temperature until combustion of the unburnt fuel elements of the mixture is substantially complete.

The extinction temperature may be defined as that temperature below which the combustion velocity falls to a negligible level and depends on the instantaneous air-fuel ratio, the magnitude of heat losses, the constituents of the atmosphere produced by previous stages of the combustion process, etc.

By properly proportioning annular flow passage 15 and the air inlets into the combustion chamber, complete combustion of the fuel elements may be obtained even in cases wherein very large proportions of excess air is employed.

The combustion unit of the present invention can be made to effectively afford outlet temperatures ranging from about 200° F. to as high as 3,000° F. The embodiment shown is best adapted to provide outlet temperatures ranging from 500° F. to a maximum of 1,800° F.

The unit of the present invention is susceptible of easy flexible control, allowing quick response to varying demands and close regulation.

The combustion unit of the present invention permits operation over a wide range of fuel to air ratio for varying loads without the necessity of adjusting the air flow. At the same time, the combustion unit avoids the deposition of soot and coke in the ignition zone, and is capable of operation with large quantities of fuel and air over a wide range of loads without smoking.

Furthermore, the unit of the present invention produces high rates of combustion while requiring only a very small drop of pressure of the air passing through the unit. The unit, therefore, does not become a drag on the over-all efficiency of the plant or system.

The unit of the present invention is especially suitable for use in gas turbine aggregates. It may also be used, however, for any application in which air is to be heated by burning finely divided fuel, such as liquid fuel in it, and it combines the advantages of low cost of maintenance, compactness, cleanliness of operation and small power requirements.

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 drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A combustion unit comprising a combustion chamber, means for injecting fuel into said chamber, ignition means in said chamber, a housing for said chamber defining with said chamber an annular air flow passage adapted to conduct combustion air generally parallel to the flow of ignited fuel in said chamber, a plurality of series of circumferentially spaced combustion air inlets

in the peripheral wall of said chamber, each series being spaced from, and staggered with respect to, its adjacent series, each inlet being adapted to admit combustion air from said air flow passage into said chamber in a direction generally parallel to the flow of said ignited fuel, and a plurality of vanes mounted on said chamber interiorly thereof, each of the vanes so mounted being positioned in said chamber so that it is aligned longitudinally of said unit with, and downstream from, one of the air inlets of said series, each vane being adapted to deflect the air streaming into the interior of said chamber through its respective air inlet obliquely counter-current to the flow of the ignited fuel to bring about thorough mixing of the fuel and combustion air in said chamber.

2. A combustion unit comprising a chamber wall structure defining a primary combustion zone and a secondary combustion zone in axial alignment, means for injecting finely divided fuel into said primary combustion zone, a housing wall structure enclosing said chamber wall structure and defining therewith an annular air flow passage extending along said chamber wall structure and having an inlet at its end adjacent said primary combustion zone and in substantial axial alignment with said combustion zones, said air flow passage being adapted to conduct combustion air from its inlet opening towards its other end, a plurality of series of inlet openings in the peripheral section of said chamber wall structure, the openings of each series being spaced circumferentially and the openings of adjacent series being staggered, said openings being adapted to admit combustion air from said air flow passage into said combustion zones in a direction generally parallel to the flow of air in said air flow passage, a plurality of vanes in said combustion zones and mounted on said chamber wall structure, each of said vanes being so positioned on said chamber wall structure that it is aligned longitudinally of said unit with, and downstream from, one of the air inlets, whereby combustion air entering said combustion zones through said air inlets is directed generally counter-current to the flow of said fuel to create thorough mixing of said fuel and said combustion air, and means for igniting the fuel-air mixture in said primary combustion zone.

3. A combustion unit comprising a chamber shell of substantially circular cross-section, and defining a primary combustion zone and a secondary combustion zone in axial alignment, a housing shell enclosing said chamber shell and defining therewith an annular air flow passage extending along said chamber shell and having an inlet at one end in substantial axial alignment with said combustion zones, means for injecting finely divided fuel into said primary combustion zone, ignition means in said zone, and transverse rows of circumferentially spaced vaned inlets in the peripheral section of said chamber shell spaced along said latter shell and communicating with said annular flow passage for directing the air from said passage into said zones at spaced sections therealong obliquely counter-current to the flow of the fuel in said zones, each of said rows comprising two inlets at diametrically opposite sides of the chamber shell, each inlet extending an angular distance of approximately 90°, and the inlets of alternate rows being circumferentially displaced approximately 90° with respect to the inlets of adjoining rows.

4. In a combustion unit, a primary combustion

tion section comprising a shell defining a primary combustion zone, means for injecting a stream of finely divided fuel into said zone, a row of circumferentially spaced primary air inlets at a transverse region of said shell for streaming combustion air into said zone back towards the point of fuel injection, and a second row of circumferentially spaced primary air inlets at a transverse region of said shell spaced downstream from said first row of inlets, the inlets of one row being circumferentially displaced with respect to the inlets of the other row and in substantial alignment with the circumferential shell regions between the inlets of said other row.

5. In a combustion unit, a primary combustion section as described in claim 4, in which said shell is of circular cross-section, and each of said rows comprises two diametrically opposite inlets, each extending angularly approximately 90°.

6. In a combustion unit, the combination comprising a pair of shell sections of different transverse dimensions mounted together in axial alignment to define conjointly a combustion chamber, and forming therebetween an annular space around said chamber, one or more deflector vanes in said space forming therein air inlets for directing combustion air into the interior of said chamber, the shell section of smaller transverse dimension having one or more longitudinal extensions projecting into the other shell section and defining therewith respective air flow passages, and a deflector vane at the outlet end of each of said flow passages displaced peripherally of said chamber with respect to said inlets, and defining respective inlets for directing combustion air into the interior of said chamber, means for injecting fuel in said chamber for flow therealong, and means for igniting the fuel-air mixture created in said chamber.

7. In a combustion unit, the combination comprising a pair of shell sections of different transverse dimensions mounted together in axial alignment to define conjointly a combustion chamber, and forming therebetween an annular space around said chamber, a plurality of deflector vanes in said space separated peripherally of said shell sections and forming in said space respective inlets by which combustion air is streamed into said chamber, the shell section of smaller transverse dimension having between each pair of adjoining inlets a longitudinal extension projecting into the other shell section and defining therewith an air flow passage, a deflector vane at the outlet end of each flow passage for forming an inlet by which combustion air is directed into the interior of said chamber, means for injecting fuel in said chamber for flow therealong, and means for igniting the fuel-air mixture formed in said chamber.

8. In a combustion unit, the combination comprising a pair of shell sections of circular cross-section and of different diameters mounted in axial alignment, to define conjointly a combustion chamber, and forming therebetween an annular space around said chamber, a pair of diametrically opposed deflector vanes in said space forming therein respective air inlets by which combustion air is streamed into said chamber, the shell section of smaller diameter having between said inlets a pair of diametrically opposite longitudinal extensions projecting into the other shell section and defining therewith respective air flow passages, deflector vanes at the outlet ends respectively of said flow passages and forming respective air inlets by which combustion air is di-

rected into the interior of said chamber, means for injecting fuel into said chamber for flow therealong, and means for igniting the fuel-air mixture formed in said chamber.

9. In a combustion unit, a primary combustion furnace comprising a pair of shell sections of different transverse dimensions mounted together in axial alignment to define a primary combustion chamber, and forming therebetween an annular space around said chamber, a fuel injection nozzle in the shell section of smaller transverse dimension, a plurality of deflector vanes in said space separated peripherally of said shell section and forming in said space respective primary air inlets by which primary combustion air is streamed into said chamber back towards the region of fuel injection, the shell section of smaller transverse dimension having between each pair of adjoining inlets a longitudinal extension projecting into the other shell section and defining therewith a flow passage, a deflector vane at the outlet end of each flow passage forming an air inlet for directing primary combustion air into said chamber back towards the region of fuel injection, and means for igniting the fuel-air mixture formed in said chamber.

10. In a combustion unit, a primary combustion furnace comprising a pair of shell sections of circular cross-section and of different diameters mounted together in axial alignment to define conjointly a primary combustion chamber and forming therebetween an annular space around said chamber, a housing wall around said shell sections defining therewith an annular air flow passage, a fuel injection nozzle in the shell section of smaller diameter, a plurality of circumferentially spaced deflector vanes in said space which form therein respective air inlets communicating with said annular flow passage and which are adapted to stream primary combustion air into said chamber back towards the region of fuel injection, the shell section of smaller diameter having between each pair of adjoining inlets a longitudinal extension projecting into the other shell section and defining therewith a longitudinal air flow passage communicating with said annular flow passage, a deflector vane at the outlet end of each of said longitudinal flow passages forming an inlet for directing primary combustion air into said chamber back towards the region of fuel injection, and means for igniting the fuel-air mixture formed in said chamber.

11. A combustion unit comprising means for injecting finely divided fuel into a primary combustion zone, means for injecting towards said zone from a transverse region thereof a first pair of streams of combustion air on opposite sides of the general direction of flow of the burning mixture from said zone, means for injecting towards said zone from a transverse region of said zone further downstream a second pair of streams of combustion air on opposite sides of said flow direction and angularly displaced about 90° with respect to the streams of said first set, and means for igniting the fuel-air mixture formed in said zone.

12. A combustion unit comprising a chamber defining a primary combustion zone and a secondary combustion zone in communication, means for injecting finely divided fuel into said primary combustion zone, means for passing a main air stream over and along said chamber, means for diverting air from each of a plurality of successive regions of said main stream in the

form of two combustion air streams on opposite sides of the general direction of flow of the ignited mixture in said chamber, means for directing said combustion air stream into said zones obliquely countercurrent to said direction of flow, the combustion air streams at each region being angularly displaced approximately 90° with respect to the combustion air streams at adjoining regions, and means for igniting the fuel-air mixture formed at said primary combustion zones.

13. 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 whereby said chamber and said housing cooperate to form an annular air flow passage around said chamber, one end of said housing defining an air intake, 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 air inlets spaced circumferentially and longitudinally along 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 and located interiorly of said chamber, each of said vanes being capable of directing combustion air entering said chamber through said air inlets 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.

14. A combustion unit comprising a chamber consisting of an aligned elongated combustion section and a throat section, means for injecting fuel into said chamber for flow therealong, ignition means in said chamber, means for conducting a stream of air longitudinally over and along said chamber towards said throat section, series of air inlet means spaced circumferentially and lengthwise in the wall of said combustion section to admit for combustion a major portion of said air stream in a direction parallel to the flow of fuel therein, the final series of said air inlet means being spaced adjacent said throat section in the zone where combustion has been substantially completed, additional means positioned within said combustion section and aligned with said air inlet means to deflect the admitted combustion air in the form of jets obliquely countercurrent to the flow of fuel when ignited to bring about thorough mixing of the fuel and combustion air as the burning mixture progresses to the end of the combustion section, said series providing a continuous addition of air for combustion and agitation, and means for diverting the remaining portion of said air stream into said throat section.

15. A combustion unit comprising an elongated chamber consisting of a combustion section and a throat section at the exhaust end thereof in axial alignment, means for injecting fuel into said chamber at one end thereof for flow therealong, ignition means in said chamber, means for passing an air stream longitudinally over and along said chamber towards the exhaust end thereof, inlet means spaced circumferentially throughout the length of the wall of said combustion section coextensive therewith

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for the admission of a major portion of said air stream for combustion therein in a direction parallel to said flow of fuel when ignited, additional means mounted within said combustion section aligned with said last mentioned means to deflect the admitted combustion air in the form of jets obliquely countercurrent to said fuel flow to bring about thorough mixing of the ignited fuel and combustion air in said combustion section and to assure substantially complete combustion in the zone of the final air stream diversion means adjacent the throat section by continuous addition of diverted air, and means for diverting the remaining portion of said air stream into said throat section.

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