Sept. 15, 1942. F. DALLENBACH ET AL 2,296,023

BURNER

Filed March 3, 1941 2 Sheets-Sheet 1

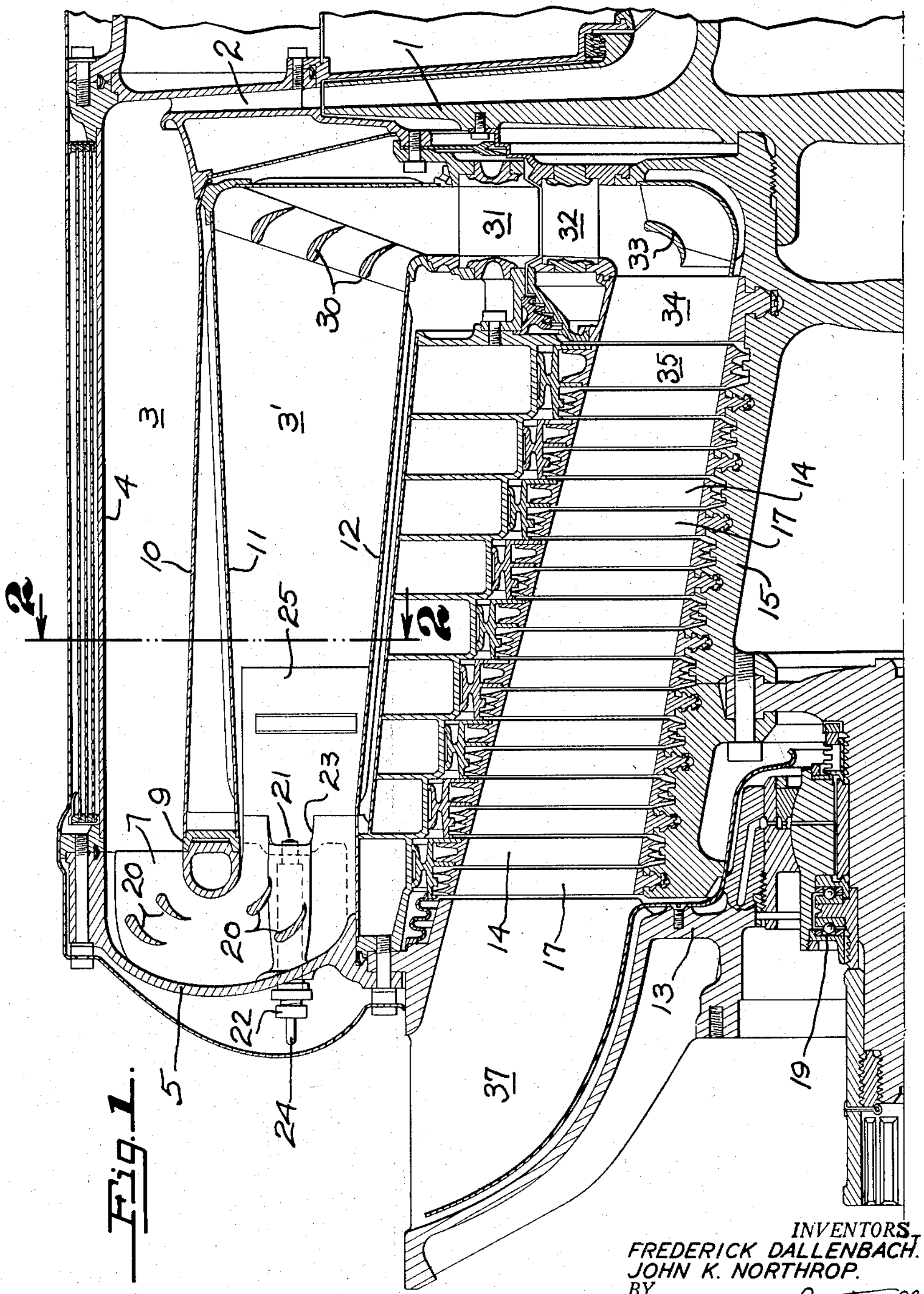

Fig. 1.

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Fig. 2.

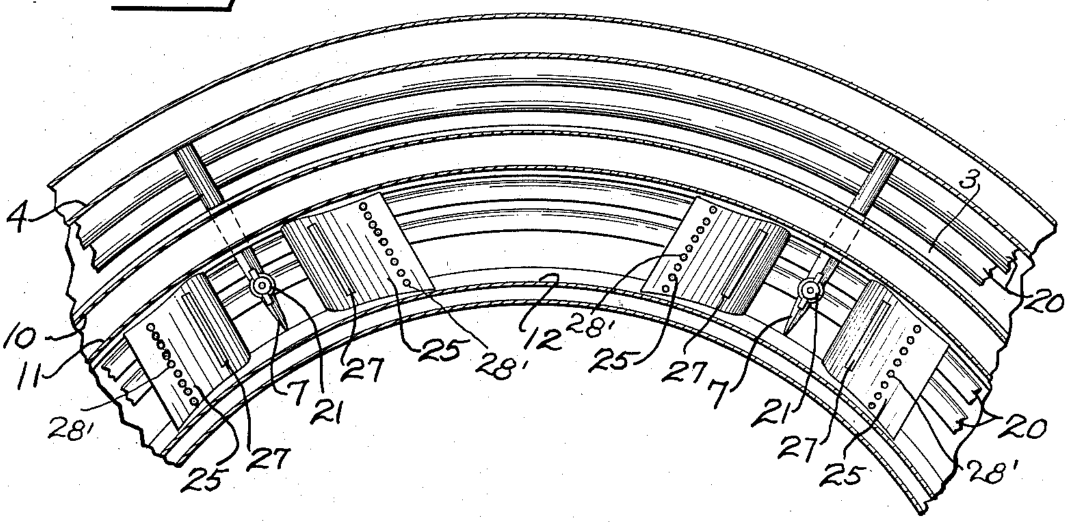


Fig. 3.

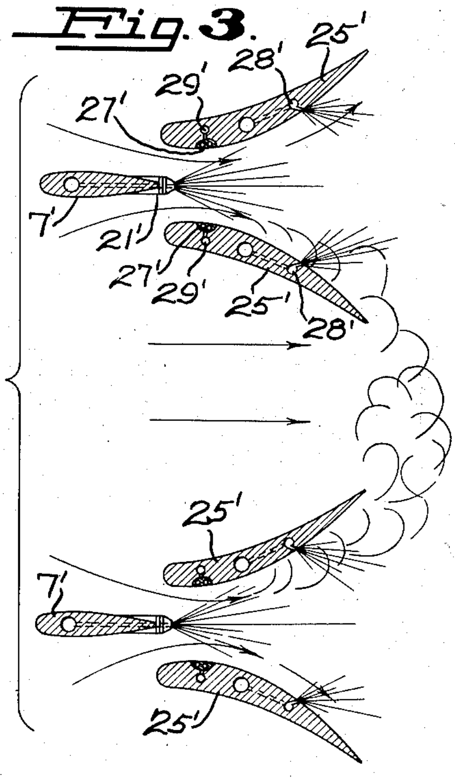
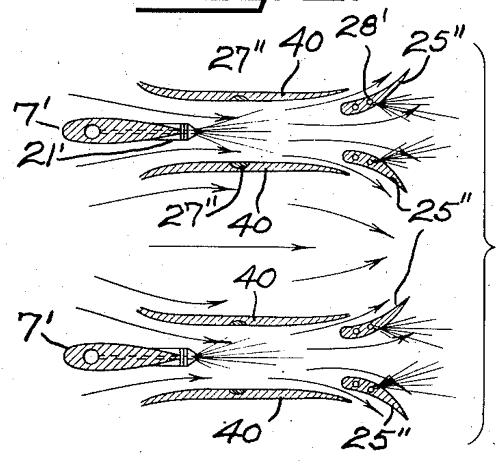


Fig. 4.



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BURNER

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Application March 3, 1941, Serial No. 381,522

18 Claims. (Cl. 60—46)

This invention relates to burners and particularly to burners for producing complete combustion of liquid or pulverized fuel in continuous flow gas turbines.

Among the objects of this invention are to provide a burner which will promote the combustion of liquid or powdered fuel in a flow of air under high compression and of relatively high velocity; to provide a burner which will produce maximum turbulence in the air stream with minimum air resistance consistent with the production of such turbulence; to provide a burner wherein actual combustion takes place at very high temperatures, and wherein, after combustion is complete, the products thereof are thoroughly mixed with large quantities of cooler air to provide a uniform flow of the mixed gases at a temperature which is reduced to the point where they may be employed in blading constructed of available materials; to provide a burner which is adapted for mounting in the turn of a reflexed air duct, without inducing undue resistance to flow in such duct; to provide a burner which is adapted to the injection of water into the burned gases, thereby permitting the use of fuel in larger quantities than normal for the production of excess power during short periods, such as the periods of takeoff of an airplane; to provide a burner having igniter means incorporated therein, and, generally, to provide a burner giving high thermal and thermodynamic efficiency in gas turbines, particularly such as are adapted for aircraft use.

Our invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing our novel method. It is therefore to be understood that our method is applicable to other apparatus, and that we do not limit ourselves, in any way, to the apparatus of the present application, as we may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

Referring to the drawings:

Fig. 1 is an axial half section through the turbine unit and a portion of the compressor unit of a gas turbine embodying our invention.

Fig. 2 is a sectional view through the reflexed portion of the air ducts of the turbine of Fig. 1, the plane of section being indicated by the line 2—2 of the first figure.

Fig. 3 is a partially schematic developed circumferential section of a burner of the general type shown in Figs. 1 and 2.

Fig. 4 is a schematic view similar to that of Fig. 3 showing a form of the burner as modified to give a longer combustion chamber.

In turbines of the type contemplated by the present invention, air is compressed adiabatically to a relatively high pressure, e. g., a pressure of the order of six and a half atmospheres, fuel oil is injected into the compressed air stream and there burned to add thermal energy to its flow, and the products of combustion are expanded in turbine blading to provide the energy necessary to precompress the air plus excess useful power. The maximum temperatures thus produced, if combustion is to be complete and high efficiency thereby obtained, are greatly in excess of those which can be borne by materials available at the present time. In order to reduce such temperatures to reasonable limits, large quantities of excess air are provided. It is highly desirable that the excess air be thoroughly mixed with direct products of combustion, and to accomplish such mixing the flow in the mixing region should be highly turbulent. Turbulence also promotes the completion of combustion itself due to the mixing action of the fuel oil and air particles, as does the fact that combustion takes place under high pressure. Turbulence after combustion produces a more uniform distribution of temperature throughout the combustion chamber in a shorter time as a result of the increased convection of heat.

Considered broadly our invention comprises a nozzle mounted in the duct and directed in the general direction of flow to produce a jet or spray of oil traveling with the flow. Placed adjacent to the discharge of the nozzle is a pair of vanes preferably mounted symmetrically with respect to the axis of the nozzle and diverging from the leading to the trailing edges of the pair to produce a "stalled" condition. Preferably the nozzle is supported by a streamlined body, having the general characteristics of an airfoil mounted in neutral relation to the flow and with the nozzle discharging from its trailing edge. The divergent vanes are also preferably of airfoil section, since such section produces minimum obstruction to a flow even though the airfoil be stalled. Where relatively large quantities of fuel are to be consumed additional vanes may be supplied, also preferably of airfoil section, and mounted generally parallel to the axis of the nozzle, thus forming a subsidiary passage with the nozzle directed into its entrance and the divergent vanes adjacent its outlet. The nozzle should produce a divergent spray, and igniter means may be incorporated in the faces of the vanes where this spray impinges upon them, and, for cases where overload capacity is to be provided by the addition of water vapor, the divergent vanes are provided with water passages and jets in their proximal surfaces, whereby steam is produced in the portion of the air flow which is at maximum temperature and which has maximum turbulence.

Even a perfectly flat and unstreamlined plate will exhibit the characteristics mentioned in some degree. The values of lift and drag will, however, be very different betwen a true airfoil section and a flat plate, and at the minimum angles at which complete or nearly complete stalling occurs the drag on an airfoil section will be materially less than that on a flat plate, although, when fully stalled, they will produce equal turbulence.

In our invention the turbulence produced by the stall is utilized to mix the combustion products with the relatively cool pure air. The burner ordinarily comprises a plurality of units, each consisting of nozzle and divergent vanes. Preferably the spacing of the units is considerably greater than the spacing between the vanes comprising each pair. The flow between the units is smooth until it passes the trailing edges of the stalled vanes, but at this point there is a sudden discontinuity of flow, inducing a turbulence which augments and is, in fact, a part of the turbulence induced between the vanes of the pair. The turbulence causes a pressure drop which represents a loss of energy, but this loss is a minimum with vanes of airfoil section and hence it is desirable that all of the vanes be made of such section, even though the device would be operative were flat plates used instead.

Fig. 1 of the drawings shows a portion of a turbine embodying this invention. At the right hand side of the drawing is shown a final centrifugal stage 1 of the compressor unit of the turbine, this stage not being shown completely as it does not relate directly to the present invention and is completely described in the copending applications of Pavlecka and Northrop, Serial No. 403,338, filed July 21, 1941, and of Pavlecka, Serial No. 385,105, filed March 25, 1941.

The centrifugal rotor 1 discharges through diffuser 2 and thence into an annular duct 3 formed within a cylindrical outer casing 4 of the turbine. The duct 3 discharges into a substantially semi-toroidal end casing 5 which forms a reflexing turn of the duct. The casing 5 is provided at uniformly spaced intervals with spoke-like vanes 7 which support an inner annular core 9. The core 9 serves as an abutment or mounting for a tubular barrier having double walls 10 and 11, the wall 10 forming the inner wall of the duct 3 and the wall 11 forming the outer wall of an annular duct 3' which forms a continuation of the outer duct beyond the reflexing turn. The inner wall of the duct 3 is formed by a conical casing 12, supported on a frame 13 which carries the stator blading 14 of the turbine. A rotor 15 of the turbine carrying blading 17 rotates within this frame on bearings 19, but since the turbine structure proper is not involved in the present invention it will not here be described in detail.

The spoke-like vanes 7 are formed of streamlined or airfoil section, mounted neutrally with respect to the flow of the air stream induced by the compressor unit. In order to guide the flow around the reflexing turn there are provided a plurality of guide vanes 20, annular in the direction of span, and supported on the vanes 7.

The vanes 7 also carry burner nozzles 21, which terminate in fittings 22 which enter through the end casing 5. The trailing edges of the vanes 7 are notched as is shown at 23, and the nozzles, supplied with oil under pressure through the pipes 24, discharge a conical or pyramidal spray of oil in the direction of flow of the air in the duct.

Disposed on either side of the axis of the nozzle is a pair of vanes 25, only one of which is shown in Fig. 1. The shape and disposition of these vanes can more clearly be seen from Fig. 3, which is a simplified development of a similar arrangement. In this latter figure the streamlined vane 7 in the toroidal passage has been replaced by an equivalent but shorter vane 7' carrying a nozzle 21'. With this exception the diagrammatic representation of Fig. 3 may be taken as though it were a circumferential section taken on the mean radius of the duct 3', the vanes 25' occupying the same relative position with respect to the discharge of the nozzle 21' as the vanes 25 occupy with respect to the nozzle 21.

As has been indicated in the general discussion, above vanes 25' are of airfoil section, mounted at an angle with respect to the airflow, which angle is equal to the angle of complete or nearly complete stall for such vanes in a medium of the density of the compressed air in which they are to work.

In the diagram there is shown, somewhat roughly, the effect of the vanes, thus mounted, on the airflow. Considering the vanes as though they were airplane wings, the flow along the "lower" or distal surfaces is substantially laminar or streamlined up to the trailing edge of the airfoils. On the "upper" or proximal surfaces of the airfoils, however, the streamlined flow breaks away from the surface, causing a high degree of turbulence in the flow for the latter two-thirds or more of the surfaces of the airfoils. Considered in the direction of flow, therefore, the greater part of the space between the proximal surfaces of the pair of vanes is turbulent, and this turbulence extends past the trailing edges and is increased by the expansion of the airflow from the distal surfaces as the flow between adjacent pairs passes the trailing edges of the wings. A short distance beyond the ends of the vanes, therefore, the entire flow becomes turbulent, resulting in a very complete mixture of the burned gases with the relatively cool air from both adjacent pairs of vanes.

Built in means are provided for igniting the fuel. Embedded in the surface of each of the vanes 25 is a resistance type heater or glow rod 27. A similar igniter element is shown in Fig. 3, being indicated by the reference character 27'. At the time of starting the burning these elements can be raised to incandescence by current supplied through lead wires carried in the channels 29'. One end of the igniter element can be grounded to the vane and a single wire connected to the other end, insulated with refractory insulation such as is used in high temperature electric furnaces, the particular material and character of the igniter elements not being considered a portion of this invention, since such elements are known in the art, but their positioning within the vanes is so considered. Water may be supplied to the turbulent flow through conduit 28' in the stalled divergent vanes 25'.

Fuel spraying nozzles of the type used in this, as in most other burners, project a divergent cone of atomized fuel, and the igniters are preferably so placed as to be just within the limits of this cone. It is only necessary that these igniters be energized during the starting phases of the operation of the burner, since once ignition has taken place the vanes are rapidly raised to a temperature which is of itself sufficient to cause ignition, and the flame, moreover, is self-sustaining.

In the particular turbine shown in Fig. 1, owing to the large quantity of excess air supplied and its relatively high compression, combustion is completed a very short distance past the trailing edges of the vanes **25**, and the remaining length of the duct **3'** is available for completing the mixing of the combustion gases and the secondary air. At the outlet end of this duct the gases pass through another set of vanes **30**, which direct the flow radially inward to a set of impulse nozzles **31**, whence the gas is passed to the impulse buckets **32** of an inwardly-radial-flow turbine stage.

The gases are then redirected axially by a guide vane **33** to a set of expansion nozzles **34**, which are of the impulse type although they rotate as a unit with the impulse buckets **32**. Nozzles **34** in turn discharge into reaction type stator blades **35**. Nozzles **31** and buckets **32** thus form what may be considered as an impulse stage which feeds an inverted impulse or (theoretically) 100 per cent reaction stage constituted by the nozzles **34** and blades **35**. The gases are greatly cooled by their expansion through these two stages and thence fed into the more conventional reaction blading **14** and **17** already described and so to the exhaust **37**.

Although in the present turbine complete combustion can occur in the relatively short distance represented by the length of the vanes **25**, there are conditions where, because of different pressures, amounts of fuel to be consumed, or different quantity of secondary air, it is desirable to provide additional combustion space before complete turbulence is induced, and this can be accomplished by modifying the burner as is shown in Fig. 4.

This modification involves the use of an additional set of vanes **40**, mounted on either side of the nozzle axis. The vanes **40** are mounted generally parallel to the axis of the nozzle, and are preferably of airfoil section for reasons which have already been discussed. The nozzle **21''** projects well into space between the vanes **40** from the direction of their leading edges, and the camber of these vanes acts to some degree as a venturi, speeding the flow of the air past the discharge of the nozzle. In this case the igniters **27''** are mounted in the faces of the parallel vanes, within the range of the spray cone, instead of in the surfaces of the divergent vanes. The latter are mounted with their leading edges projecting slightly into the discharge end of the subsidiary passage formed by the parallel vanes **40**.

A portion of the burned gases will pass between the stalled divergent vanes **25''**, and be set into turbulence as in the case where these vanes are mounted immediately adjacent the nozzle. A further portion of the combustion products will pass without the divergent vanes, over their distal surfaces, but this latter portion will in general follow a streamline flow until it has reached the trailing edges of the divergent vanes, after which it is thoroughly mixed with the unburned air. In other words, it is not necessary to the action of the burner that all of the burned gases pass between the vanes, and that all of the air that passes on the outer side of the vane be relatively cold. The important point is that sufficient turbulence be set up to mix the burned gases and the secondary air completely before the mixed gas reaches the first turbine stage, and this is accomplished by the stalled vanes.

It is obvious that the water spray can be produced in the modification of the burner shown in Fig. 4 in the same manner as in the simpler form.

We claim:

1. A burner comprising a substantially unobstructed duct and means for causing an airflow therethrough in a substantially constant general direction, a nozzle for injecting a spray of fuel into said airflow in its general direction of motion and a vane positioned on each side of said airflow, said vanes having facing surfaces positioned on each side of said airflow at a substantially critical aerodynamic stalling angle of attack thereto, to produce turbulence in said airflow between said surfaces without substantial baffling thereof.

2. A burner in accordance with claim 1 wherein said vanes are of airfoil section.

3. A burner comprising a duct for carrying compressed air, a fuel nozzle positioned in said duct and directed in the general direction of air flow therein, and a pair of vanes positioned beyond said nozzle in the direction of said flow, said vanes diverging symmetrically from the axis of discharge of said nozzle to produce a stalled condition with relation to said flow.

4. A burner in accordance with claim 3 wherein said vanes are of airfoil section.

5. A burner in accordance with claim 3 comprising a plurality of said nozzles and vanes, the spacing between adjacent pairs of vanes being relatively large in comparison with the spacing between the vanes of each pair.

6. A burner comprising a compressed air duct, a pair of vanes forming a subsidiary passage within a portion of said duct, a fuel nozzle adapted to produce a divergent spray and discharging into one end of said passage and in the general direction of air flow in said duct, and igniter means for said fuel spray embedded in said vanes within the range of said spray.

7. A burner comprising a compressed air duct, a pair of substantially parallel vanes forming a subsidiary passage within said duct, a fuel nozzle discharging into the inlet end of said passage, and a second pair of vanes positioned with their leading edges adjacent the discharge end of said passage, said second vanes diverging to produce a stalled condition thereof with respect to air flow in said passage.

8. A burner in accordance with claim 3 including means for discharging a jet of water from the proximal faces of at least one of said divergent vanes.

9. A burner comprising an air duct, a streamlined vane positioned in neutral relation to air flow in said duct, a fuel nozzle mounted on said vane to discharge from the trailing edge thereof, and a pair of vanes positioned beyond said nozzle in the direction of said flow, said vanes diverging symmetrically from the axis of discharge of said nozzle to produce a stalled condition with relation to said flow.

10. A burner comprising an air duct reflexed within itself to form two coaxial annular pas-

sages, a plurality of vanes positioned at the reflexing turn of said duct, and supporting the division between said annular passages, fuel nozzles mounted in said vanes to discharge substantially at the trailing edges thereof, and a pair of vanes positioned beyond each of said nozzles in the direction of flow within said duct, said last mentioned vanes diverging symmetrically from the axes of discharge of said nozzles to produce a stalled condition with respect to said flow.

11. A burner in accordance with claim 10 wherein each of said vanes is of streamlined section.

12. A burner in accordance with claim 10 wherein the direction of flow is from the outer to the inner of said coaxial annular passages.

13. A burner in accordance with claim 10 including an annular guide vane for directing flow around said reflexing turn, said guide vane being supported upon said nozzle mounting vanes.

14. A burner in accordance with claim 3 wherein said duct is annular and wherein a plurality of said nozzles and vanes are equally spaced in said duct, the spacing between adjacent pairs of vanes being relatively large in comparison with the spacing between the vanes of each pair.

15. A burner in accordance with claim 3 wherein said duct is annular and wherein a plurality of said nozzles and vanes are equally spaced in said duct, the spacing between adjacent pairs of vanes being relatively large in comparison with the spacing between the vanes of each pair, and wherein said vanes are of airfoil section.

16. A burner comprising a substantially unobstructed duct for carrying compressed air in a substantially constant general direction, a fuel nozzle positioned in said duct and directed in the general direction of air flow therein, a member positioned on each side of and beyond said nozzle in the direction of said flow, said members having facing surfaces disposed at a substantially critical aerodynamic stalling angle of attack to said flow, creating a turbulence therein as said flow passes between said surfaces without substantial baffling thereof.

17. A burner comprising a duct for carrying compressed air, a fuel nozzle positioned in said duct and directed in the general direction of air flow therein, a member positioned on each side of and beyond said nozzle in the direction of said flow, said members having facing surfaces of airfoil profile disposed at an angle to said flow creating a stalling turbulence therein as said flow passes between said surfaces.

18. A burner structure comprising a substantially unobstructed duct therein for carrying an airflow in a substantially constant general direction, a fuel nozzle positioned at the entrance of said duct and directed in the general direction of said airflow, and facing surfaces forming opposite walls of said duct beyond said nozzle, said surfaces being shaped to present a substantially critical aerodynamic stalling angle of attack to said airflow to create turbulence in the airflow through said duct without substantial baffling thereof.

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