

[54] **RECIRCULATING COMBUSTION
APPARATUS JET PUMP**

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[22] Filed: **July 16, 1973**

[21] Appl. No.: **379,448**

[52] U.S. Cl. **60/39.65**, 60/DIG. 11, 239/DIG. 7,
417/171, 417/197, 417/198, 431/116

[51] Int. Cl. **F02c 3/00**

[58] Field of Search 60/39.52, 269, 271, 231,
60/39.65, DIG. 11; 417/196-198, 171, 151,
194; 239/DIG. 7, 265.17; 137/803; 431/116;
244/42 CD

[56] **References Cited**
UNITED STATES PATENTS

3,041,010	6/1962	Foster	417/171 X
3,319,692	5/1967	Reba et al.	431/116

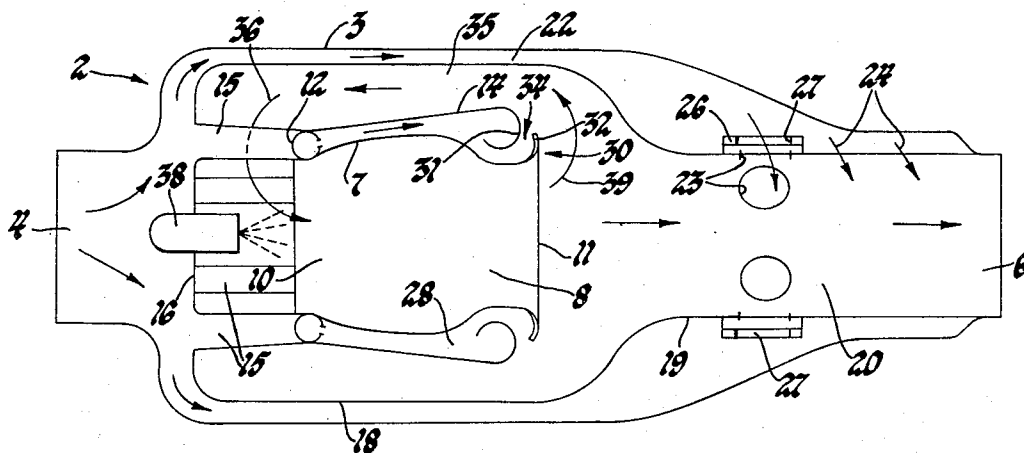
3,744,242 7/1973 Stettler et al. 60/DIG. 11

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[57] **ABSTRACT**

A combustion apparatus for a gas turbine engine includes a Coanda effect jet pump by which air introduced for combustion recirculates combustion products into the combustion zone of the apparatus. The jet pump is effective to improve the recirculation ratio while maintaining an acceptably low pressure drop in the combustion apparatus. The combustion air flows through the interior of the body of the Coanda nozzle and over a wall which terminates in a lip converging toward the radial surface of the Coanda nozzle body. A ring of vanes bridges the nozzle and aligns the nozzle walls. The vanes are at an angle to the radial direction to impart swirl to the primary air and improve jet pump performance.

1 Claim, 6 Drawing Figures



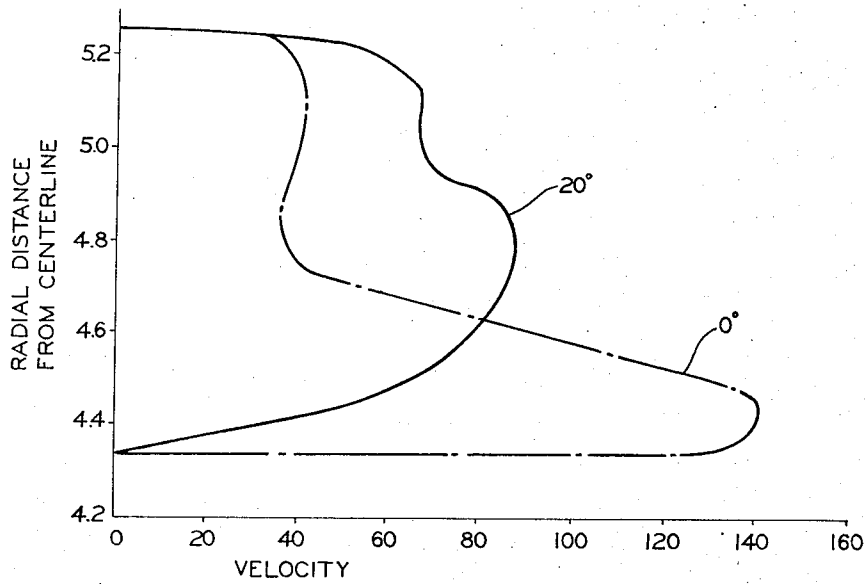


Fig. 4

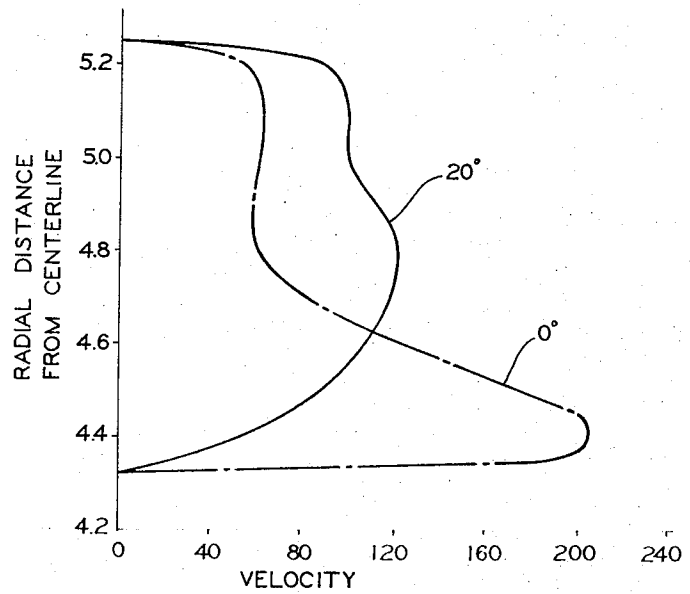


Fig. 5

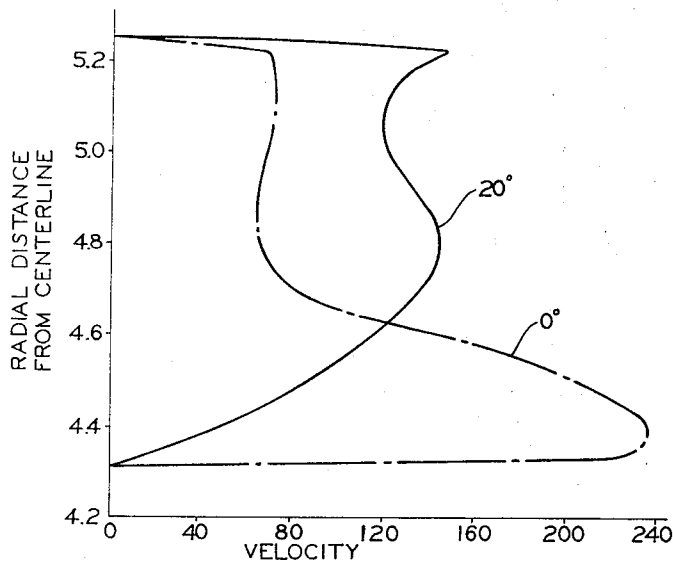


Fig. 6

RECIRCULATING COMBUSTION APPARATUS JET PUMP

Our invention is directed to combustion apparatus, particularly such as operates at substantially superatmospheric pressure; it is more particularly directed to an improved jet pump in such combustion apparatus for causing recirculation of combustion products from the outlet to the inlet of a zone in which combustion takes place.

Reba et al. U.S. Pat. No. 3,319,692, May 16, 1967, teaches recirculation of combustion products in an oil burner by a Coanda-type pump to obtain more complete combustion and thus minimize unburned hydrocarbons, carbon monoxide, and smoke.

Recirculation has also been proposed as a means to reduce nitrogen oxides generated in the combustion apparatus by the reaction of nitrogen and oxygen from the atmosphere in a high temperature combustion zone. The amount of nitrogen oxide generated increases with increased temperature and with increasing concentration of oxygen in the combustion zone; also with time of residence in the hot zone. By recirculating combustion products, the concentration of oxygen in the combustion zone may be lowered and also the temperature may be lowered to some extent. This concept is described in the copending applications of Stettler and Verdouw, Ser. No. 202,191 filed Nov. 26, 1971 for Combustion System and Ser. No. 220,607 filed Jan. 25, 1972, now U.S. Pat. No. 3,744,242, for Recirculating Combustor, both of common ownership with this application.

Our present invention may be regarded primarily as an improvement on the combustion apparatus of Ser. No. 220,607, the improvement residing in a more efficient and effective Coanda effect jet pumping structure for recirculating the combustion products.

To minimize nitrogen oxides a relatively high recirculation ratio is desired, of the order of two or better. The recirculation ratio is the ratio of flow per unit time of recirculated combustion products to flow of primary combustion air entering the combustion apparatus. This is to be distinguished from dilution air which is mixed with the combustion products at the termination of combustion. It is important to effect the recirculation with a minimum of pressure loss in the combustion apparatus, because pressure drops in the combustion apparatus detract from the efficiency of the gas turbine engine. It is also desirable that the recirculation ratio remain substantially constant over a wide range of flow rates as the output of the combustion chamber is varied to vary engine power output.

The combustion apparatus described in Ser. No. 220,607 includes a jet pump of the Coanda type disposed near the downstream end of the combustion zone of the combustion apparatus to introduce the fresh combustion air and entrain with it combustion products which are recirculated into the upstream end of the combustion apparatus.

The principal object of our present invention is to provide an apparatus of the type described in Ser. No. 220,607 which is more efficient and better meets the requirements of practice. It is a further object to provide a jet pump for such an installation which has better efficiency than those previously known.

The nature of our invention and its advantages will be apparent to those skilled in the art from the succeeding

detailed description of the preferred embodiment of the invention and the accompanying drawings.

FIG. 1 is a schematic illustration of a gas turbine combustion apparatus in axial section view.

FIG. 2 is an enlarged axial sectional view of the jet pump portion of the combustion apparatus.

FIG. 3 is a fragmentary sectional view taken on the plane indicated by the line 3—3 in FIG. 2.

FIGS. 4, 5, and 6 are curves illustrating the effect of primary air swirl on jet pump operation.

FIG. 1 illustrates a combustion apparatus 2, which preferably is of circular cross section. The apparatus includes an outermost wall 3 which extends from an inlet 4 for combustion air substantially to an outlet 6 for combustion products from the combustion apparatus. An innermost wall 7 defines a combustion zone 8 having an upstream end at 10 and a downstream end at 11. At its upstream end the wall 7 is connected by a toroidal manifold 12 to an inner wall 14 generally surrounding the innermost wall 7. Manifold 12 is connected by a number of spaced combustion air tubes 15 (six as shown) to a forward wall 16 disposed near the air inlet 4.

The forward wall connects tubes 15 to an outer wall 18 lying closely within the outermost wall 3. Wall 18 is supported from wall 3 by means which need not be described. Wall 18 converges into a discharge portion 19 extending into the outlet 6 and which defines a dilution zone 20. Some of the air introduced through inlet 4 flows through the annular passage 22 between walls 3 and 18 and through holes 23 into the dilution zone. Additional air may flow through smaller openings as indicated by the arrows at 24. If desired, means may be provided for varying the quantity of dilution air, indicated schematically as a rotatable ring 26 having openings 27 variably registrable with the holes 23 in the wall 18.

The primary combustion air flows from the inlet 4 through tubes 15 into manifold 12 and then through a primary air passage 28 between walls 7 and 14 to a Coanda nozzle type jet pump 30. The pump includes a body 31 defined by the incurved downstream end of wall 14 and a lip 32 defined by the outcurved downstream end of wall 7. Primary air discharged through the nozzle 34 between the body and lip flows upstream through the recirculation passage 35 defined between walls 14 and 18 and then, as indicated by the arrow 36, between tubes 15 into the combustion zone 8. Fuel is introduced through a nozzle 38 supplied from any suitable source and is ignited by suitable means (not illustrated). Combustion products flow through the outlet at the downstream end 11 of the combustion zone. As indicated by arrow 39, a portion of these combustion products are entrained and pumped by the flow from jet nozzle 34 into the recirculating passage. Preferably, approximately $2\frac{1}{2}$ times as much combustion products are recirculated as the flow of primary combustion air through duct 28. The remainder of the combustion products flow to the dilution zone 20 where additional air is mixed with them and the resulting mixture is discharged through the outlet 6.

Except for the difference in the Coanda nozzle structure and the representation of control of dilution air, the structure described above is essentially the same as that described in structural detail in the prior application Ser. No. 220,607, and there is no need to enlarge

upon details of this structure to understand the present invention.

Referring now to FIGS. 2 and 3, the structure and proportions of the Coanda nozzle jet pump are more fully described. FIG. 2 shows the outer wall 18, inner wall 14, and innermost wall 7, the annular primary air passage 28, and the annular recirculating passage 35. Wall 7 terminates in a lip 32 which has a forward surface defining a bounding wall 40 of one side of the annular jet nozzle 34. The terminal portion of the outer wall 18 defines the body 31 of the jet pump which curves inwardly and terminates in the forward bounding wall 42 of the nozzle. It will be noted that walls 40 and 42 converge toward each other in the direction of flow so that the minimum width of the nozzle is at the point of discharge.

The nozzle 34 is bridged by a ring of small sheet metal vanes 44 which may be brazed or otherwise fixed to the body 31 and lip 32. The vanes preserve the concentricity of the walls 7 and 14 and maintain precise spacing of the walls of the nozzle around the circumference of the nozzle.

We have found that, by inclining the vanes 44 to the radial direction, the operation of the Coanda nozzle recirculating pump is improved. In the specific example described, the vanes are inclined at 20° to the radial direction as indicated in FIG. 3. The vanes should be close enough together to assure that they impart uniform swirl to the air being discharged and, in this case, the vanes are spaced 8° apart for a total of 45 vanes around the circumference of the nozzle. While the vanes could be streamlined, in the particular example illustrated they are simple sheet metal plates ½ inch long in the radial direction, 0.09 inch wide, and 0.03 inch thick.

In the operation of the combustion apparatus, the primary air admitted through passage 28 is discharged through the annular nozzle 34 with a circumferential component of velocity as well as the radial one. This air follows the surface of the body 31 through the Coanda nozzle throat at 46 and on into the diverging diffusing portion 47 of the recirculation passage 35. This primary air flowing over the body entrains with it combustion air which flows forwardly over the outer surface 48 of the lip 32.

It is believed that the improved performance of the Coanda nozzle with the swirl vanes may be due to the following reason. With the more or less spiral flow over the nozzle body, the contact surface between the primary and induced streams is significantly increased and the subsequent viscous forces between the two streams should be increased.

FIGS. 4, 5, and 6 are plots of measured velocity profiles at the throat 46 of the jet pump with primary air flow rates of 3/10, 4/10 and 5/10 pounds per second respectively. The abscissa is velocity and the ordinate is the radial distance from the centerline of the nozzle across the throat. As will be seen, with zero inlet swirl there is a quite non-uniform velocity distribution with quite high velocity over the inner half of the annulus and much lower velocity over the outer half. On the other hand, with the 20° inlet swirl, the velocity profile is much more uniform.

Comparative tests of air flow with strictly radial vanes and with the vanes inclined as illustrated in FIG. 3 indicate a significant increase in the ratio of secondary air to primary air with the swirling flow—an increase of the order of 10 percent.

The more uniform velocity profile and greater ratio of induced to primary air flow indicate the superiority of the Coanda nozzle configuration with the vanes 44 inclined to the radial direction.

The detailed description of the preferred embodiment of the invention for the purpose of explaining the principles of the invention are not to be considered in any limiting or restricting sense, as many modifications may be made by the exercise of skill in the art.

We claim:

1. A combustion apparatus comprising, in combination, an innermost wall defining a combustion zone having upstream and downstream ends, an inner wall defining an annular air passage with the innermost wall, an outer wall defining with the inner wall an annular recirculation passage from the downstream to the upstream end of the combustion zone and defining a discharge passage from the combustion zone, and an outermost wall defining a dilution air passage with the outer wall to conduct air into the discharge passage; the downstream end of the inner wall being curved inwardly and the downstream end of the innermost wall being curved outwardly to define a Coanda nozzle encircling the downstream end of the combustion zone between the said curved ends adapted to discharge into the recirculation passage and entrain combustion products discharged from the combustion zone into the recirculation passage; characterized by a Coanda nozzle structure in which the bounding walls converge radially from the combustor axis toward an annular radial outlet and including a ring of swirl vanes extending between the bounding walls and directed at an angle to the radial direction so as to deliver the air from the nozzle with a circumferential component of velocity.

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