Aug. 28, 1956 P. L. JURISICH 2,760,339

FLAMEHOLDER

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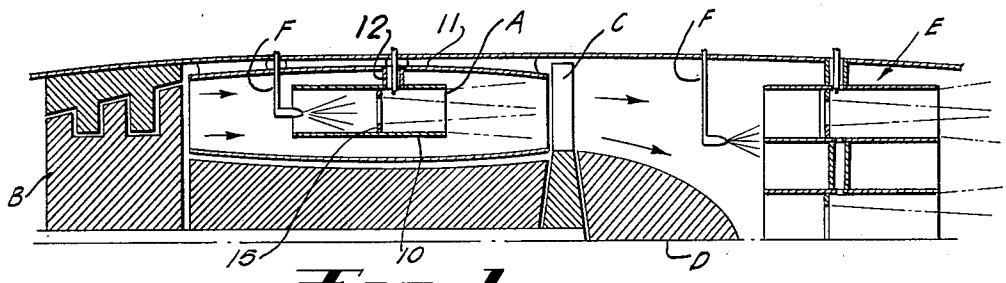


Fig. 1

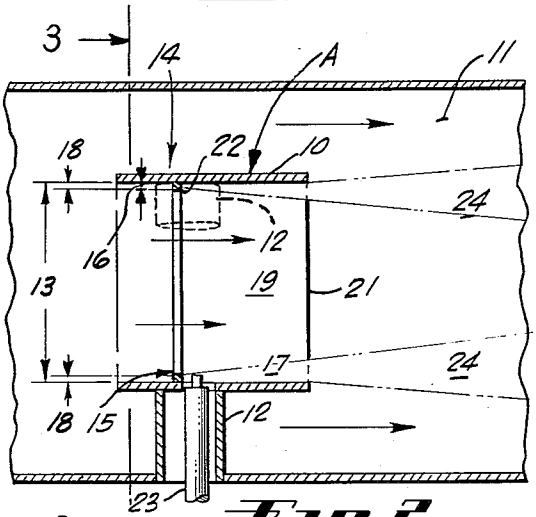


Fig. 2

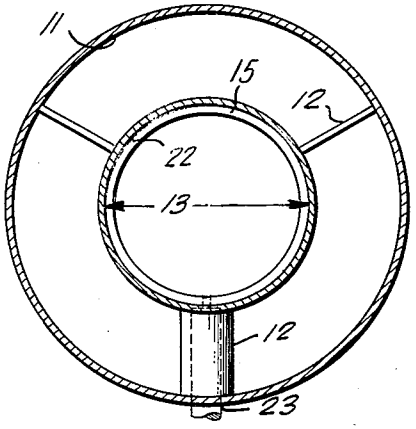


Fig. 3

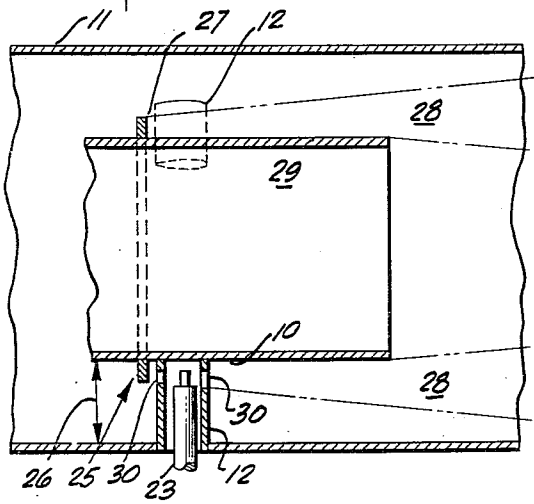


Fig. 4

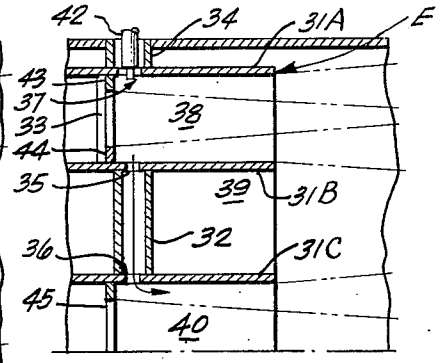


Fig. 5

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FLAMEHOLDER

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1 Claim. (Cl. 60—39.72)

This invention relates to combustion apparatus, such as jet engines, internal combustion heaters, and the like and is particularly concerned with the burners, or flameholders, thereof.

Contemporary such flameholders are of the type that essentially consists of an annular metallic member, or ring, which is strut-mounted coaxially in the combustion chamber with its outer periphery radially spaced inwardly from the inner periphery of the wall of the combustion chamber. The radial dimension of the body of this annular flameholder is ordinarily of considerable extent relatively to the outside diameter of the annular flameholder. Such flameholder thus exposes transversely to the main fuel-air stream a surface which is so wide relatively to the inside diameter of the annulus that in its wake, the vortices formed are relatively large and have a high energy content. Unburned fuel-air vortices passing the annulus continually enter between the widely spaced burning wake vortices and pass downstream from the flameholder into the main theretofore unignited body of the fuel-air stream. There they are ignited by contact with burning vortices which intermittently collide with them. Thus sporadic local ignition propagates in the main fuel-air stream in the form of detonations, or "backfiring." Among the well-known consequences of this action is the fact that it may, under certain circumstances, extinguish the burner flame.

The rather wide radially extending surfaces that the conventional annular flameholder presents to the fuel-air stream may also result in "buzz-burning," which malfunctioning seriously diminishes the thermodynamic efficiency of the combustion apparatus. Buzz-burning, or resonant burning, occurs when the natural frequency of oscillation or pulsation of a flaming gas stream happens to coincide with the natural frequency of a disturbing force applied to this stream. Conventional flameholders of the type aforementioned create such a disturbing force. The aforementioned relatively large, high-energy vortices established in the wake of the flameholder often have, because of their size and "strength," a pulsation-frequency that coincides, or resonates, with that of the large body of gas located downstream thereof. The resultant buzz-burning seriously diminishes the thrust of the engine.

This invention obviates both detonation and buzz-burning by providing improved flameholder means and novel ignition methods that establish stable burning in the combustion chambers of combustion apparatus and maintain this stability over a wide "burning range." The present flameholder accomplishes these and other advances without at all increasing the drag on the working fluid of the combustion apparatus. Indeed, in most structural embodiments of the invention, the drag of the flameholder is of the order of no greater than half that of a conventional flameholder of the same size employed at the same maximum stream velocity.

The now-preferred general configuration for accomplishing these and other advances essentially comprises a tubular member adapted to be mounted coaxially in the

combustion chamber and having an upstream end arranged and adapted to segregate from the unburned fuel-air stream a radial segment thereof. A portion of this segment is later ignited downstream in the tubular member to create the flamefront for establishing combustion in the downstream portion of the main fuel-air stream. The inner periphery, or the outer periphery, as the case may be, of the tubular member, at a predetermined longitudinal location on the member that lies considerably upstream from the downstream end of the member, is radially enlarged inward or outwardly, as the case may be. The radial extent of this enlargement is small relative to the diameter of the tubular member but is sufficiently great to decelerate the radial segment it defines in the segregated portion and to form a wake downstream of it in which the vortices are relatively small and slow moving. This enlargement deflects this segment towards the "skirt" defined on the inner surface of the tubular member between the radial enlargement and the downstream end of the tubular member. A "starter" type ignition device, such as a "single-shot" spark plug, is mounted in operative adjacency to the radially defined segment of the segregated fuel-air stream. The plug may lie either upstream or downstream of the radial enlargement, preferably in the latter position, and soon after it initiates ignition, the skirt on the tubular member becomes heated. Thereafter, it serves as a constant igniter which completely ignites all the aforesaid segregated portion that impinges upon it. The emitted flame front is homogeneous, containing no unburned fuel-air vortices and seldom, if ever, resonates with the pulsating downstream portion of the main fuel-air stream.

Thus, the likelihood of backfiring or buzz-burning occurring is rather small.

The likelihood of buzz-burning occuring is still further reduced by so proportioning the transverse dimension of the ring or body, or "solid" part, of the annulus to its outside diameter and to stream diameter and maximum velocity that the wake vortices are never large or active enough to have a frequency that falls into phase with that of the main airstream.

In order to further clarify the inventive concepts, several of the presently-preferred embodiments of apparatus, capable of use in performing the methods of this invention, by way of example only, are illustrated in the accompanying drawings and are described hereinafter in conjunction with these drawings.

In these drawings,

Figure 1 is a fragmentary longitudinal section of a turbo-compressor jet engine incorporating in the primary combustion chamber a plurality of the "single" type of the present flameholder and also incorporating, in the secondary combustion chamber, one of the present "triple" type flameholders;

Figure 2 is an enlarged, fragmentary longitudinal section of a combustion chamber incorporating one of the present flameholders;

Figure 3 is a cross-section on line 3—3 of Figure 2;

Figure 4 is an enlarged, fragmentary longitudinal section of a combustion chamber incorporating another form of the present flameholder, and

Figure 5 is an enlarged fragmentary longitudinal section of the "triple-type" of flameholder indicated in Figure 1.

As shown in Figure 1, single-type burners of the present invention may be employed, as shown at A, in the primary combustion chamber of a turbojet engine, where is shown one of a plurality of circumferentially arranged burners which are disposed radially outwardly of the central longitudinal structure of the engine, just aft of the air compressor B and just forward of the turbine C. Aft of this

turbine and disposed outwardly of the longitudinal center line D of the engine is mounted a triple-type form E of the present burner. A fuel injection nozzle F is provided in operative adjacency to the inlet portion of each of the burners A and E.

The "single-burner" type of flameholder A, shown in the primary combustion zone of the engine in Figures 1 and 2 combines together with other parts a metallic tubular member **10** which is short and broad and is coaxially mounted in a combustion chamber **11** by means of struts **12**. The tubular member is open at both ends and its open upstream end is discrete and adapted to segregate from the unburned upstream fuel-air mixture a radial segment **13** thereof and entrain it into the tubular member. At a location **14** lying longitudinally closer to the upstream end of member **10** than to the downstream end thereof, a flat-faced, or rectangular-section, annulus **15** is coaxially mounted to the inner surface of the tubular member.

The inside diameter of this annulus is greater in proportion to its outside diameter than is usually the case in other ring-type flameholders, so that the ratio of the radial extent of the body, or "solid" part, of the annulus to the overall diameter is considerably and critically smaller than in the conventional bare annular flame holder. This radial extent **16** is also proportioned suitably to the diameter of the segregated stream-portion **13** and to the maximum velocity of the stream.

All these factors cooperate in producing a wake **17** on the downstream side of the annulus in which the vortices are smaller than is usually the case with a burner of the same outside diameter and at the same maximum stream velocity. The wake is considerably decelerated in velocity from that of the entering stream. These vortices are also slower-moving and have a lower kinetic energy, than conventional such vortices.

The annulus thus defines a radial segment **18** (of the same dimension as radial extent **16**) in the segregated portion **13**, decelerates it on its downstream side, and deflects or urges it toward the inner, downstream side **19**, of the tubular member **10**.

The cylindrical surface, or skirt, **19** lying longitudinally between the downstream edge **21** of the tube **10** and the downstream face **22** of the annulus **15** is, of course, metallic and this skirt is adapted to be heated and hold heat.

In order to effect this heating as well as to "start" the heater, a "starter" plug **23** of the "single-shot" type is mounted longitudinally in a strut **12** with its sparking terminals protruding into the wake **17**.

Soon after the spark plug is operated, the skirt **19** becomes heated and thereafter serves continuously as a constant igniter and as the sole source of ignition in the flameholder. The heat-exchange properties and area of the skirt **19** are such as, in combination with the decelerating and small-vortices forming characteristics of the annulus **15**, as to effect complete ignition of the unburned fuel-air vortices in the wake **17**. That is, the flaming gases **24** that leave the downstream end of the flameholder are homogeneous and contain no occlusions of any nature, so that detonation is obviated.

Since the vortices in the wake **17** usually have a frequency far lower than that of the main fuel-air stream, no exciting forces exist in the flameholder that could cause buzz-burning.

The species shown in Figure 4, as essentially compared to that of Figure 2 reverses the location of the annulus or baffle with respect to the inner surface of the strut-supported tubular member **10** and therefore reverses the radial location of the wake and flame front with respect to the unburned main body of the fuel-air stream as it passes through the flameholder. Its construction essentially comprises, coaxially mounted to the outer surface of the tube **10**, which is equal in diameter to that of Figure 2, a rectangular-section annulus **25**. This annulus extends into the radially outwardly segregated portion **26** of the combustible stream. This portion **26** is to constitute the flame front of the combustion device when ignited and obviously consists of a hollow cylinder, or radial segment or outer ring of the main stream body. In this ring **26** the annulus **25** defines a smaller radial segment **27**; decelerates it in the form of a downstreaming wake **28**, and deflects this wake onto the skirt **29** of the tubular member **10**.

Mounted to extend longitudinally into a strut **12** is an igniter like that designated **23** in Figure 2. This strut is preferably streamlined and bears inlet and exit apertures **30** to enable the plug to ignite the fuel-air mixture in the wake.

Essentially, the functioning of this form of the invention is substantially the same as that shown in Figure 2.

One of the critical ratios at present contemplated by the invention for use in proportioning the radial extent of the annulus **15** to the adjacent diameter of the tubular member **10** is of the order of 1 to 64. Thus, the radial width of the body of the annulus may be of the order of ⅛" and the proximal diameter of the tubular member may be of the order of 8".

Values of these relative orders all have been ascertained to give the advantageous results set forth above.

In Figure 5, the triple-type flameholder E of the present burner consists of a plurality of short, wide cylinders **31A**, **31B** and **31C** arranged concentrically in the secondary combustion zone and united in radially spaced relationship so as to define a plurality of annular chambers therebetween, and the unit thereby formed spacedly supported radially inwardly from the inner surface of the wall of the jet engine, by, respectively, means **32**, **33** and **34**. The means **32** consist of a hollow, streamlined strut opening at its top and its bottom into the adjacent spaces by means of apertures **35** and **36** respectively. The means **33** consists of a thin solid strut, and the means **34** consists of a hollow streamlined strut united at its inner and outer ends to adjacent structure and having an opening **37** in its lower end. Mounted longitudinally inside strut **34** is a single-shot spark plug **42** with its sparking terminals extending into the annular space **38** between the outer and intermediate cylinders. Also mounted in space **38** are an annulus **43** substantially like that of Figure 2, and an annulus **44** like that of Figure 4, the front face of the annuli abutting the strut **33**. The annular space **39** between the intermediate cylinder and the innermost cylinder is unoccupied save for the strut **32** and is not employed as a flameholder. The cylindrical space **40** between the innermost cylinder and the longitudinal center line of the engine is employed as a flameholder and includes an annulus **45** substantially like that of Figure 2.

Gases ignited in space **38** by plug **42** form a downstreaming flamefront, as indicated, which is of the same characteristics as that of Figure 2. From space **38** a part of these flaming gases passes via strut **32** and apertures **35** and **36** into the cylindrical space **40**, the upper half, only, of which is shown. Some of the fuel emitted from the aft-located injector F is urged into space **40** by virtue of the radially-centerwardly directed component of the rearwardly directed exhaust from the turbine C, the rearward and centerward curvature of the portion D adding to the effect of this radial component and actually leading some of the exhaust centerwardly, as indicated by the curved arrow. This portion of the fuel-and-exhaust mixture is ignited in **40** by means of the igniting gases entering thru **32**; then from chamber **40** a flame front, as shown, issues downstream. The foregoing action will occur even with the aft injector's high representational position, as in Figure 1, but it is to be understood that in the actual design of the apparatus injector F will be radially located where found most efficient. At a certain point nearer the tail pipe of the engine, all these flame fronts merge to effect complete secondary combustion. This combustion, as before described, is stable, smooth, detonationless and resonantless.

Although several of the presently contemplated em-

bodiments of the invention have been described with reference to certain particularized parts and components and with especial application to turbo and ram jet engines, it is to be accepted that these specific exemplificatory parts and this illustrative use-application do not constitute the sole forms in which the invention may be embodied or preclude its adaptation to other types of combustion apparatus. For, the invention and its scope are defined and limited only by the scope of the sub-joined claim.

I claim:

An afterburner for the secondary combustion chamber of a turbo-compressor jet engine comprising a hollow, elongate casing including a fuel injector and said casing directing a hot gaseous mixture rearwardly from a primary combustion zone in said casing to a secondary combustion zone, in said casing, comprising: a plurality of concentric tubular-members mounted in said casing coaxially thereof, said tubular members being spaced radially apart to define a plurality of annular chambers therebetween, the upstream end portion of each of said chambers being discrete and free from the casing and extending parallel to the direction of flow of the injected fuel and the gaseous mixture, said end portion being directed in the axial direction of said casing; a cylindric surface of each of said tubular members bearing an annulus having a radial extent of the order of $\frac{1}{64}$ of the diameter of that tubular member which bears the annulus so as to predeterminedly fix the baffling effect of said annulus at an optimum with respect to the predetermined ignition-velocity of the high-velocity fuel-and-

gas mixture; the cross-section of said annulus projecting from said surface at right angles thereto, the remainder of said surface, from end-to-end thereof, being clear and devoid of protrusions; dual-nature, conduit-and-strut means extending radially between the radially spaced alternate ones of said tubular members so as to support and unite same in said spaced relationship; an aperture in the wall of the tubular member at each of the ends of said dual-nature member so as to radially connect the tubular members for flow of combustible therebetween; and radially extending ignition means penetrating the wall of the outermost one of said tubular members so as to effect ignition of the combustible contents of alternate ones of said tubular members; whereby to provide a rearwardly directed stable jet of burning gases augmenting the thrust of said engine's primary combustion.

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