

March 8, 1960

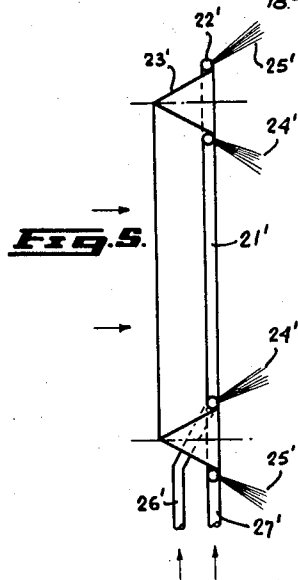
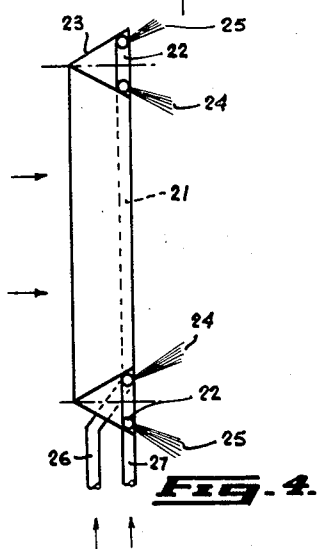
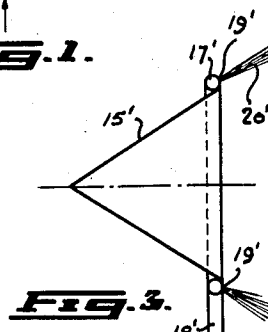
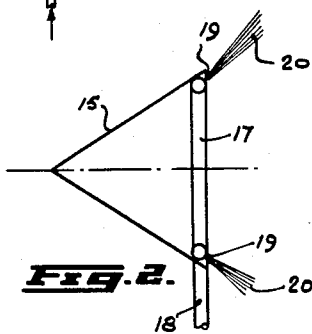
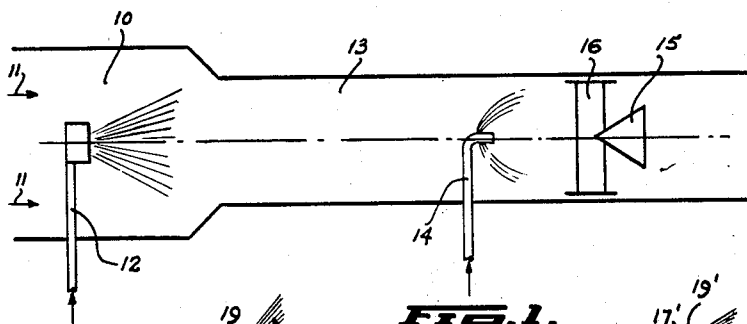
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2,927,423

PREVENTION OF SCREECHING COMBUSTION IN JET ENGINES

Filed Feb. 9, 1956

3 Sheets-Sheet 1



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PREVENTION OF SCREECHING COMBUSTION IN JET ENGINES

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3 Sheets-Sheet 2

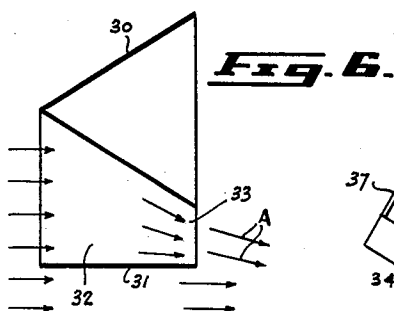


Fig. 6.

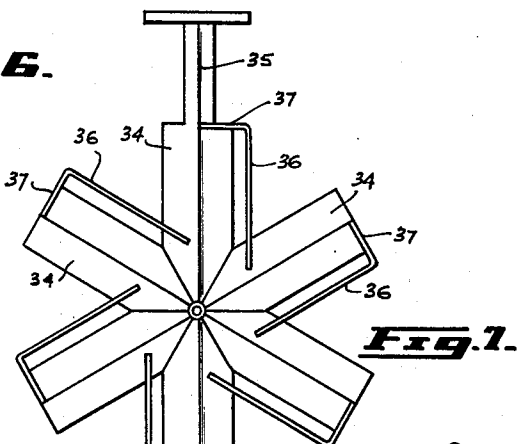


Fig. 7.

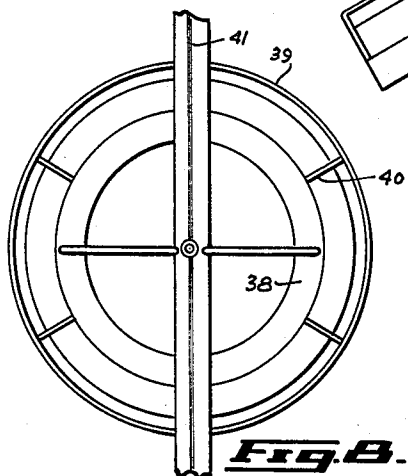


Fig. 8.

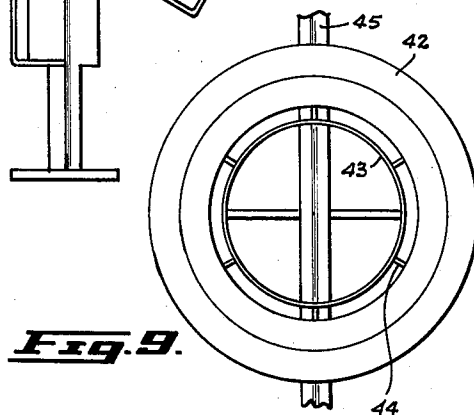


Fig. 9.

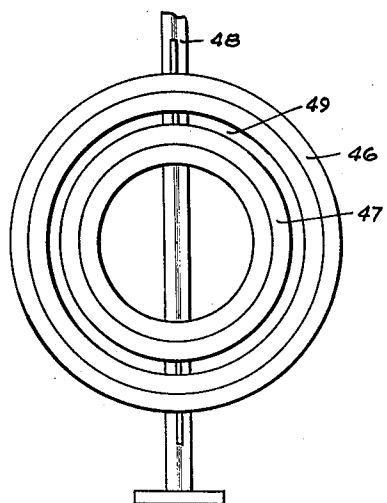


Fig. 10.

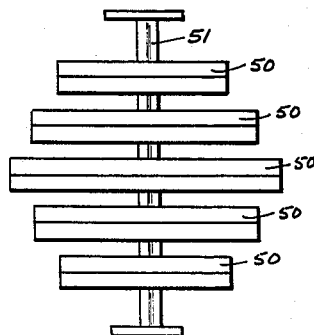


Fig. 11.

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PREVENTION OF SCREECHING COMBUSTION IN JET ENGINES

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3 Sheets-Sheet 3

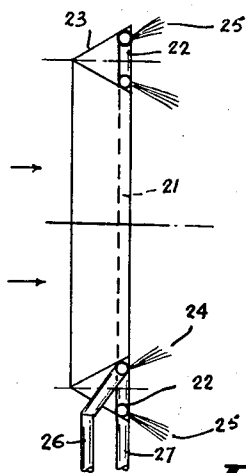


Fig. 12

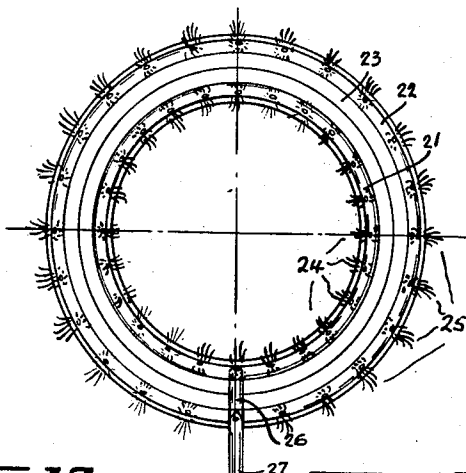


Fig. 13

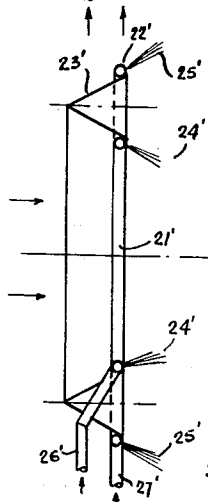


Fig. 14

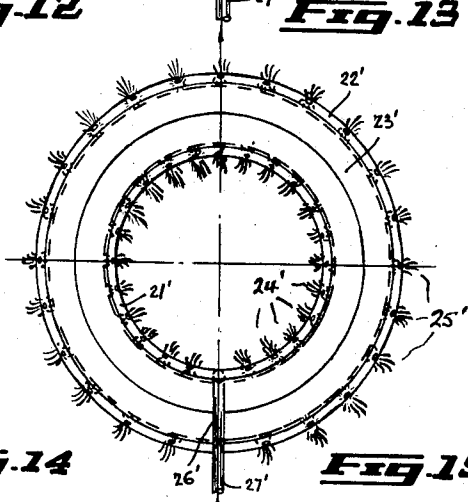


Fig. 15

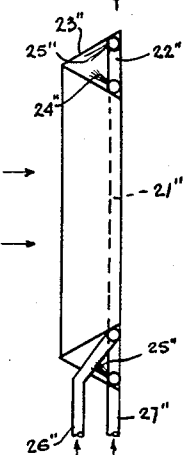


Fig. 16

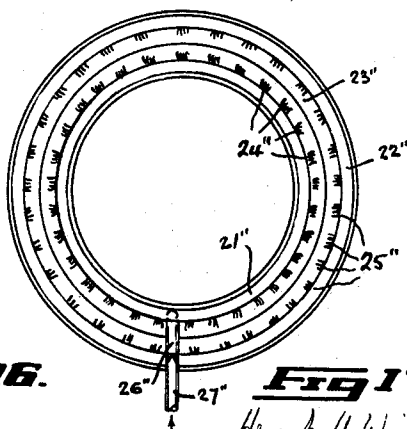


Fig. 17

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PREVENTION OF SCREECHING COMBUSTION
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Application February 9, 1956, Serial No. 564,574

1 Claim. (Cl. 60—35.6)

This invention relates to improvements in jet engines and is directed towards the avoidance of the phenomenon known as screeching combustion (also known as "screaming" or "howling"). This condition may be encountered in any kind of jet engine, but is particularly prevalent in the jetpipe of turbojet engines operating with reheat (or afterburning).

Screeching in the jetpipe of a turbojet engine is a noise which is produced by high frequency oscillations of the gas column in the jetpipe. The oscillations that give rise to screeching take place in a direction transverse to the longitudinal axis of the jetpipe and they often exert a destructive effect on various components of the engine as well as being accompanied by an increase in the rate of heat transfer. Screeching combustion has been known to lead to the destruction of the metal of jetpipes and flameholders, to crack open welded seams and bosses, to break igniters and thermocouples and to loosen bolts. Screeching combustion is normally encountered when the rate of flow of reheat fuel is high and this phenomenon may thus represent a limiting factor in the quantity of reheat fuel that can be employed, being thus effective to limit the augmentation of engine thrust that can be obtained by means of reheat.

Prior investigations have already shown that the vibrations in question are high frequency gas oscillations extending transversely across the jetpipe and it has been proposed to suppress screeching by placing longitudinal ribs in the jetpipe. It has also been suggested to use perforated or corrugated inner liners. Such measures are, however, cumbersome and uncertain as to operation, and it is the primary object of the present invention to provide a simpler method for inhibiting screeching combustion under reheat conditions in the jetpipe.

It has now been discovered that the gas oscillations which cause screeching originate on the flameholder (sometimes known as the stabilizer). It follows that the formation of such oscillations might well be prevented if the conditions in the neighbourhood of the flameholder conducive to the formation of such oscillations could be modified.

Furthermore, it has now been discovered that the oscillations originate at the downstream edge of the flameholder and the present invention consists of the introduction of streams of fluid into the path of the combustion gases flowing rearwardly from the downstream edge of the flameholder, so as to disturb the normal flow conditions of gases in the jetpipe at this point. The fluid of these streams may be a separate fluid such as fuel, or water, or some introduced gas such as air, or it may be a portion of the combustion gases themselves.

Experiments have confirmed that the introduction of such streams of fluid produces very satisfactory results in preventing screeching.

In the case where a separate fluid is used and this fluid is fuel, it is preferred to direct it in a manner such that the streams will initially be inclined both to the direction of travel of the combustion gases and to the trans-

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verse direction in which the oscillations take place, although it has been found that the boundaries between which the fluid may be directed and still provide improvement in avoidance of screeching, are not critical. The stream of fuel may, with advantage, be projected rearwardly and outwardly of the downstream edge of the flameholder, and may be such as approximately to form a continuation of the surface of the flameholder. However, when water is used as the fluid, the best results are obtained by directing the streams towards the inside of the flameholder.

It should be appreciated that, when fuel is used for this purpose, it only forms a small proportion of the total additional fuel used for reheat purposes. The main reheat fuel is always introduced upstream of the flameholder. Moreover, it is not intended that this fuel, or other fluid when air or water is used, should necessarily be continuously projected from the downstream edge of the flameholder. Normally this operation will only require to be initiated temporarily when screeching is encountered, either by manual control, or automatically by suitable means sensitive to the screeching condition.

When the streams of fluid are formed from a portion of the combustion gases themselves, it is convenient to produce such streams by means of structural alteration to the flameholder. For this purpose a vane may be disposed adjacent said flameholder to form therewith a passageway converging in the downstream direction and terminating in a narrow slot adjacent the downstream edge of the flameholder. The combustion gases that enter this passageway will be accelerated and will issue from the slot at a higher velocity than the remainder of the combustion gases flowing past and around the flameholder.

The accompanying drawings are provided to illustrate the two basic ways in which the invention may be carried into practice.

Figure 1 shows diagrammatically a portion of the general layout of a turbojet engine;

Figure 2 is a detailed side elevational view of a cone type of flameholder embodying means according to the invention;

Figure 3 is an elevation view of Figure 2 as seen from the right, i.e. from the downstream side;

Figure 4 is a view similar to Figure 2 showing a modified form of flameholder;

Figure 5 is a view similar to Figure 3 but showing the flameholder of Figure 4;

Figure 6 shows in side elevation the invention applied to an annular type of flameholder;

Figure 7 is an elevation view of the flameholder as seen from the right of Figure 6, i.e. from the downstream side;

Figure 8 is a view similar to Figure 6 of a modified form of annular flameholder;

Figure 9 is a view similar to Figure 7 but showing the flameholder of Figure 8;

Figure 10 is a side elevation view of a still further modified form of annular flameholder;

Figure 11 is a view of the flameholder of Figure 10 seen from the downstream direction;

Figure 12 shows diagrammatically a cross-section of a fragment of a V gutter type of flameholder modified in accordance with the second aspect of the invention wherein a portion of the existing combustion gases are employed to form the introduced streams of fluid;

Figure 13 shows an elevation view of a complete flameholder of the V-gutter type modified as in Figure 12 and seen from the upstream side;

Figure 14 is a similar upstream elevation view of V-ring type of flameholder modified in the manner of Figure 12;

Figure 15 is an elevation view seen from downstream

of a V-ring flameholder also constructed in accordance with this second aspect of the invention;

Figure 16 is an elevation view seen from downstream of a composite form of flameholder constructed in accordance with a modified form of the second aspect of the present invention; and

Figure 17 is an elevation view seen from the downstream side of another such composite form of flameholder.

Figure 1 illustrates diagrammatically the combustion chamber and other parts of the jet engine. In the case of a turbojet engine, for instance, air is blown into the main chamber 10 from a compressor 8 travelling in the direction of the arrows 11, the main fuel being injected into the combustion chamber 10 from a pipe 12. The hot combustion gases thus produced pass through the turbine 9 and into the jetpipe 13. The reheat fuel is injected into the jetpipe from a pipe 14 situated somewhat upstream from a flameholder 15, shown in Figure 1 as being of the cone type. This flameholder is supported in the jetpipe 13 by a strut 16. Figure 1 thus illustrates very diagrammatically the basic elements of a conventional turbojet engine operating with reheat.

Figures 2 and 3 show the flameholder 15 modified according to the first aspect of the invention. Such modification comprises the arrangement of a hollow tube 17 extending around the inner downstream edge of the flameholder 15. This tube 17 is connected to a supply pipe 18 and is formed with a series of holes 19 at its rearward surface, such holes 19 being arranged to form nozzles that will direct a closely spaced series of fluid sprays which combine to form a conical spray 20 that approximates to a continuation of the conical shape of the flameholder 15 itself. That is to say the mean angle between the conical spray 20 and the longitudinal axis of the jetpipe 13 would be of the order of 45°.

A slightly modified form of this construction is seen in Figures 4 and 5, where a tube 17' is situated on the outside of the downstream edge of a flameholder 15'. The tube 17' is similarly provided with a series of holes 19' adapted to form a conical rearwardly projecting spray 20'. The fluid is supplied by a pipe 18' as before.

Figures 6 to 9 illustrate similar constructions applied to the annular type of flameholder (sometimes called a V-ring flameholder or stabilizer). In Figures 6 and 7 a pair of perforated tubes 21 and 22 is provided, the tube 21 extending around the inner periphery of an annular flameholder 23 and the tube 22 extending around the outer periphery of such flameholder, so that, at any section through the flameholder, a spray 24 produced by the inner tube 21 and a spray 25 produced by the tube 22 will define rearward continuations of the tapering surfaces of the inner and outer sides of the flameholder. The tube 21 is fed from a supply pipe 26 and the tube 22 is supplied from a supply pipe 27. In practice, often only one of the tubes 21 or 22 will be used for eliminating screeching. They may both be used in cases of very intense screeching.

Figures 8 and 9 are identical, except that tubes 21' and 22' are positioned on the outer downstream edge of an annular flameholder 23' analogously with the arrangement of Figure 4. Supply pipes 26' and 27' feed the tubes 21' and 22' respectively, and sprays of fluid 24' and 25' are formed as before.

Figures 10 and 11 illustrate an annular type of flameholder modified for use with water. In this case the tubes, here designated 21'' and 22'', are positioned on the inner downstream edge of an annular flameholder 23'' generally similar to Figure 6, but the perforations which form the sprays are arranged to direct the water inwardly of the V-shaped annular cavity defined within the flameholder itself. These sprays of water are indicated at 24'' and 25'' analogously with the sprays shown in the previous example. In the case where water is used, the disturbance to flow past the flameholder that

inhibits screeching is then caused mainly by steam that is formed within the interior of the flameholder.

In accordance with the second aspect of the present invention, the streams of fluid may be derived from the combustion gases themselves. To do this, it is necessary to increase the velocity of a portion of these gases and then project the high velocity gases so obtained as streams of fluid from the downstream edge of the flameholder into the path travelled by the main portion of the combustion gases as they flow past and around the flameholder. This increase of velocity can best be obtained by passing some of the combustion gases through a passageway arranged to converge in the downstream direction and to terminate in a narrow slot, an effect which can readily be produced by the attachment of one or more vanes to the structure of the flameholder itself.

Figure 12 illustrates the theory of such modification by means of a simple single line diagram representing a section through the V-gutter of a flameholder. The gutter 30 has attached to it a flat vane 31 which extends along such gutter in a generally parallel relationship therewith and is secured thereto by one or more struts 32. The combustion gases that enter the space defined between the gutter 30 and the vane 31 are constricted in the slot 33 that these parts form, and issue from the downstream edge of the flameholder at a velocity greater than that of the remaining combustion gases that flow past the outside of the assembly and in eddies around behind it. These high velocity streams of fluid designated by the arrows A serve to disturb the normal flow conditions of the gases in the jetpipe in the vicinity of the downstream edge of the flameholder, and thus to break up the vortices that otherwise tend to appear in this area and give rise to screeching combustion conditions. As will appear from Figure 12, the high velocity gases tend, by reason of the inclined face of the gutter 30, to issue from the downstream edge at a slightly outwardly inclined angle, analogously with the inclination given to the spray 20 in Figure 2. Such outward inclination of the streams of gases is not an essential for alleviation of screeching combustion, but in most cases is the most satisfactory direction for issuance of the streams. The vane 31 is preferably arranged to lie in a plane parallel with the general direction of flow, so as to minimize its drag effect; but some inclination may be adopted, as is, in effect, what is done in the form of construction described later with reference to Figures 16 and 17.

Figures 13 to 17 illustrate various other types of flameholder that may be modified in accordance with this second aspect of the invention.

Figure 13 shows a view from upstream of a V-gutter flameholder having six radially extending V-shaped gutters 34 mounted on a main strut 35. An anti-screeching vane 36 is arranged along one side of each of the gutters 34, these vanes 36 each extending from the side of an adjacent gutter to an end strut 37 formed as a bent-around part of the vane itself. It is possible to employ anti-screeching vanes along both edges of such a gutter, but it has been found by experiment that a vane on one side is normally sufficient in practice to prevent the initiation of screeching combustion.

Figure 14 illustrates a V-ring flameholder 38, around the outer periphery of which an annular vane 39 is supported by radial struts 40. A main strut 41 is provided for the mounting of this flameholder in the jetpipe. Instead of mounting the anti-screeching vane around the outside periphery of such V-ring flameholder, it may be mounted around the inner periphery. Such a system is illustrated in Figure 15 which shows a downstream view of a V-ring flameholder 42 with an anti-screeching vane 43 secured thereto by struts 44. The main strut is shown at 45. Practical experiments have indicated that rather better results may be expected to be obtained with the Figure 14 arrangement than with that of Figure 15, but nevertheless the flameholder as modified in accordance

with Figure 15 provides significant reduction in the tendency of an engine to screech.

This would be an appropriate point to mention that the invention in its second aspect has been found to be not generally applicable to the simple cone type of flameholder illustrated in Figures 2 and 4. This is not because the use of vanes with a cone flameholder would not provide anti-screeching characteristics, but because the presence of a vane has been found normally to interfere with the basic flame-holding function of the flameholder. It would be necessary to modify the structure of a cone type flameholder in some other manner to overcome this difficulty, if a vane were to be employed for anti-screeching purposes.

Measurements have been made of the additional drag on the engine represented by vanes such as those described above, and the increase of drag recorded was of the order of 15%. This is 15% of the total drag of the flameholder unmodified, which total drag is equivalent to only about 1% of the engine thrust. Thus no great reduction of thrust is caused by the use of vanes.

In a modified construction, no separate vane is provided. Instead, two portions of a flameholder are arranged sufficiently closely to one another so that each performs the function of an anti-screeching vane in relation to the other.

Figure 16 shows such an arrangement employed in a V-ring type of flameholder seen from the downstream side. This flameholder is composed of two concentric V-rings 46 and 47 mounted on a main strut 48 to define between them an annular slot 49. This modification also is applicable to the gutter type of flameholder and such an arrangement is illustrated in Figure 17 where a main strut 51 is shown supporting a series of parallel V-shaped gutters 50, again seen from the downstream side.

Experiments have been conducted with a view to determining the width of slot between flameholder and vane, or between two sections of a flameholder, that is most satisfactory in inhibiting screeching. A comparatively narrow slot is normally desirable as yielding the greatest increase of gas velocity; and this is normally convenient structurally, because it provides a compact construction and avoids the need for long struts. The minimum width found practical has been approximately $\frac{1}{8}$ inch. On the other hand, it has been found that the maximum width of slot that may be used may depend on the downstream width of the flameholder itself. This applies especially with wide flameholders, in which case the maximum slot width has been found to be of the order of half the downstream width of the flameholder.

For example, with a V-ring flameholder such as shown in Figure 14 and having a gutter width of four inches the best results were obtained with a slot width between one and two inches. Above two inches, performance began to fall off. In another case, using a V-ring flameholder of only two inch gutter width, the best anti-screeching properties were obtained employing a slot between one and one and a half inches. On the other hand with a

six-arm star type of V-gutter flameholder such as illustrated in Figure 13, excellent results were obtained with slots of one-quarter inch width.

It will be evident that the slot width that will provide best conditions must always remain to some degree a question to be decided by trial and error for each individual design of engine and flameholder. Nevertheless it may be said that the practical range from which the optimum slot width may be selected will extend from approximately $\frac{1}{8}$ inch to whichever is the greater value between approximately $1\frac{1}{2}$ inches and approximately half the downstream width of the flameholder. In the case where the flameholder is in two or more sections, the situation could arise that these sections (gutters) would be of different downstream widths. In this case it would be the downstream width of the wider gutter that would serve to determine the maximum slot width.

This application is a continuation-in-part of application Serial No. 523,402 filed July 21, 1955, now abandoned.

I claim:

In a jet engine of the type having a main combustion stage, a generally cylindrical jetpipe, and a reheat combustion stage comprising a flameholder mounted in said jetpipe and means for introducing reheat fuel upstream of said flameholder, said flameholder being of sufficient size by itself to maintain continuous combustion under all engine reheat operating conditions, means for inhibiting screeching combustion by disturbing and directing the normal flow conditions of gases at the downstream edge of said flameholder in a direction other than normal comprising a vane disposed adjacent said flameholder to extend in substantial parallelism to the longitudinal center line of said jetpipe, the downstream end of said vane terminating adjacent the downstream edge of said flameholder whereby to form with said flameholder a passageway converging in the downstream direction and terminating in a narrow slot adjacent the downstream edge of said flameholder, said slot having a width lying within the range from approximately $\frac{1}{8}$ inch to whichever is the greater value between approximately $1\frac{1}{2}$ inches and approximately half the downstream width of the flameholder.

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