Nov. 16, 1971 J. H. ROGERS ET AL 3,620,013

NOISE ABATEMENT METHODS RELATING TO FLAME AND JET PRODUCTION AND ASSOCIATED APPARATUS

Filed Oct. 31, 1969 5 Sheets-Sheet 1

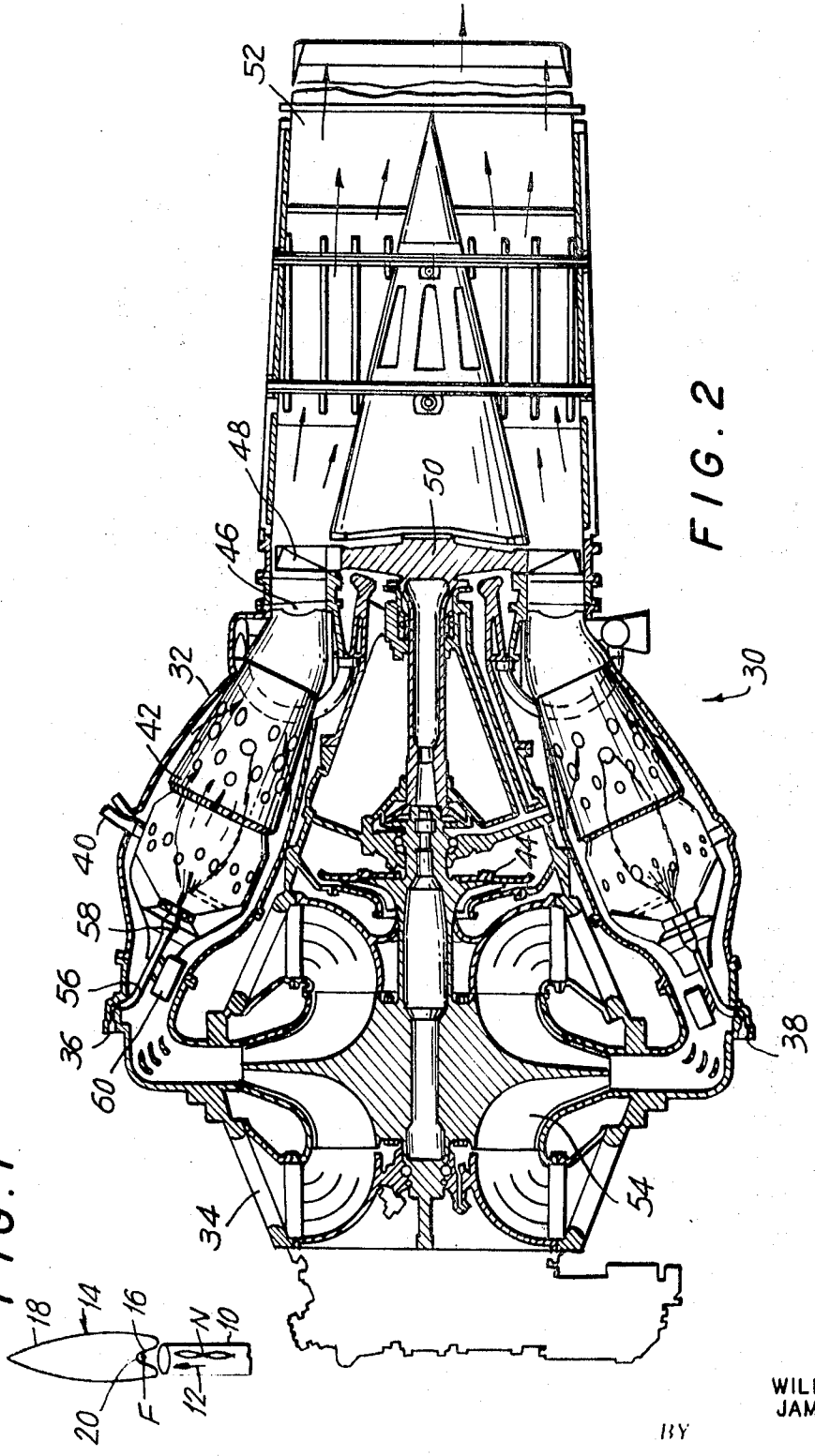


FIG. 2

FIG. 1

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Nov. 16, 1971 J. H. ROGERS ET AL 3,620,013
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Filed Oct. 31, 1969 5 Sheets-Sheet 2

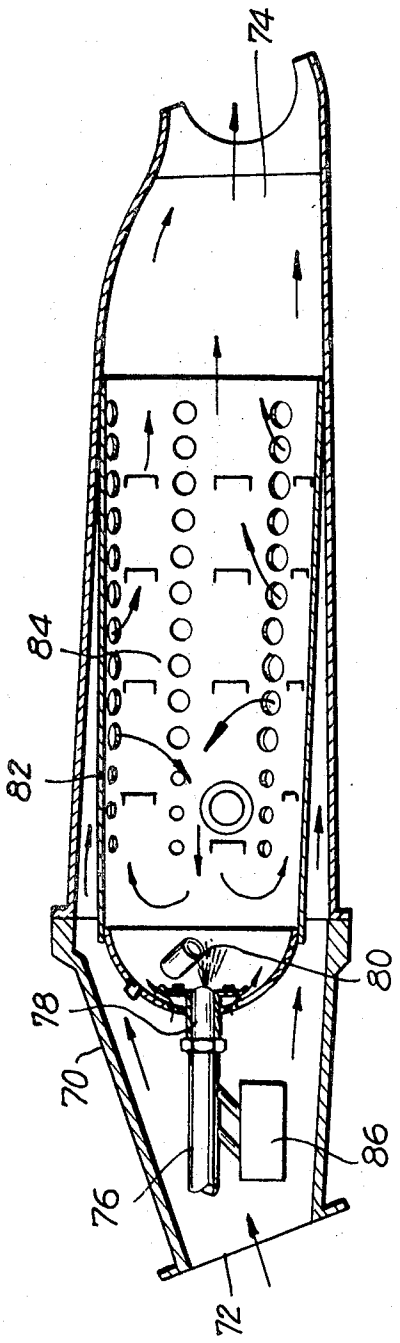


FIG. 3

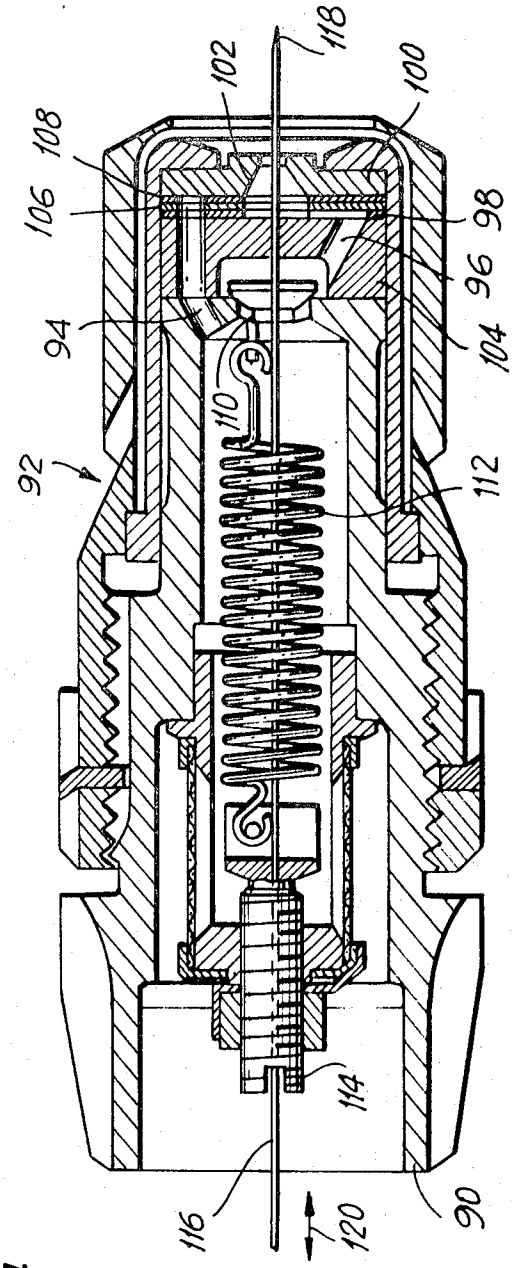
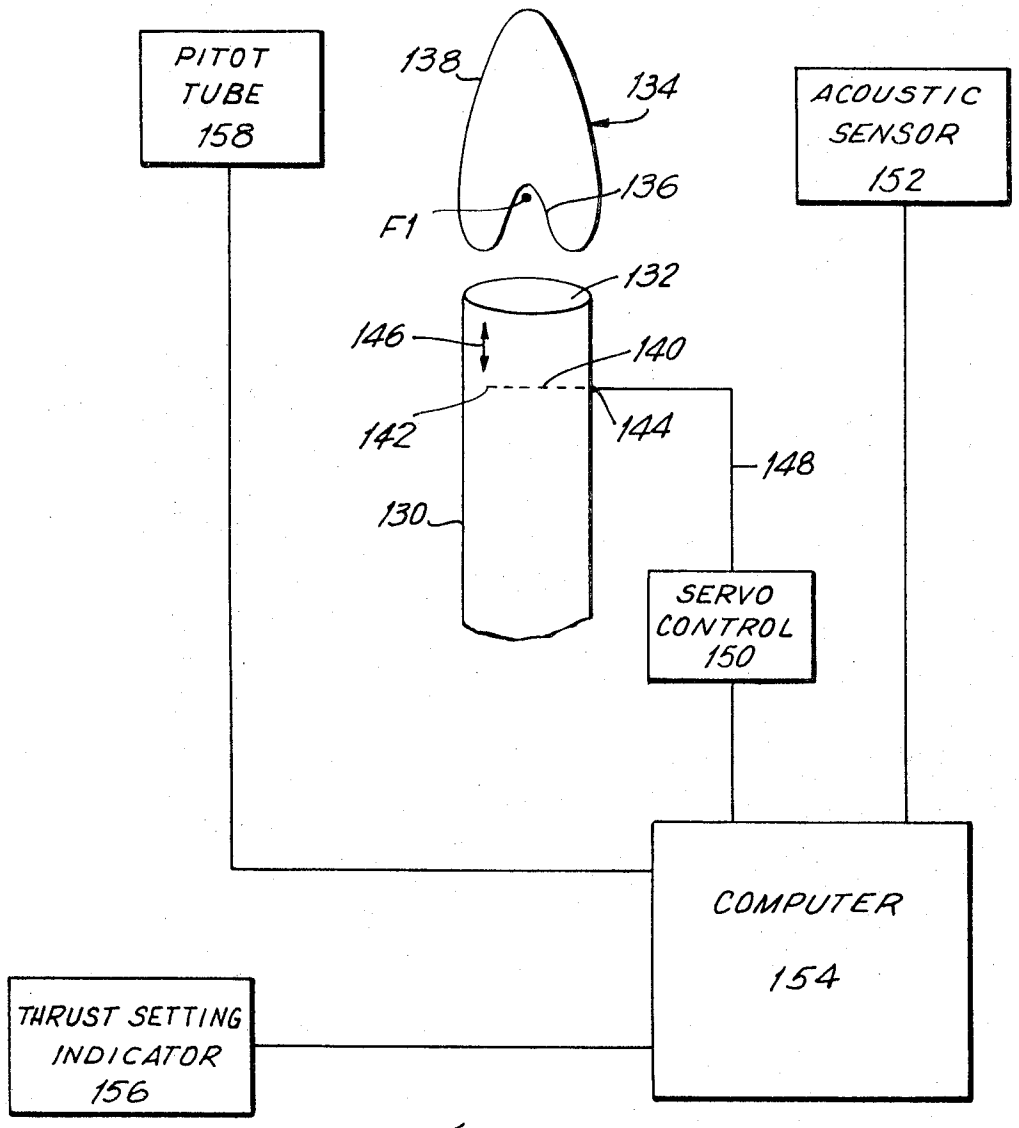


FIG. 4

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NOISE ABATEMENT METHODS RELATING TO FLAME AND JET PRODUCTION AND ASSOCIATED APPARATUS
Filed Oct. 31, 1969 5 Sheets-Sheet 3

FIG. 5



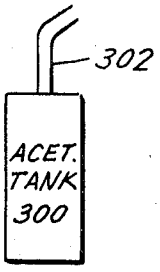
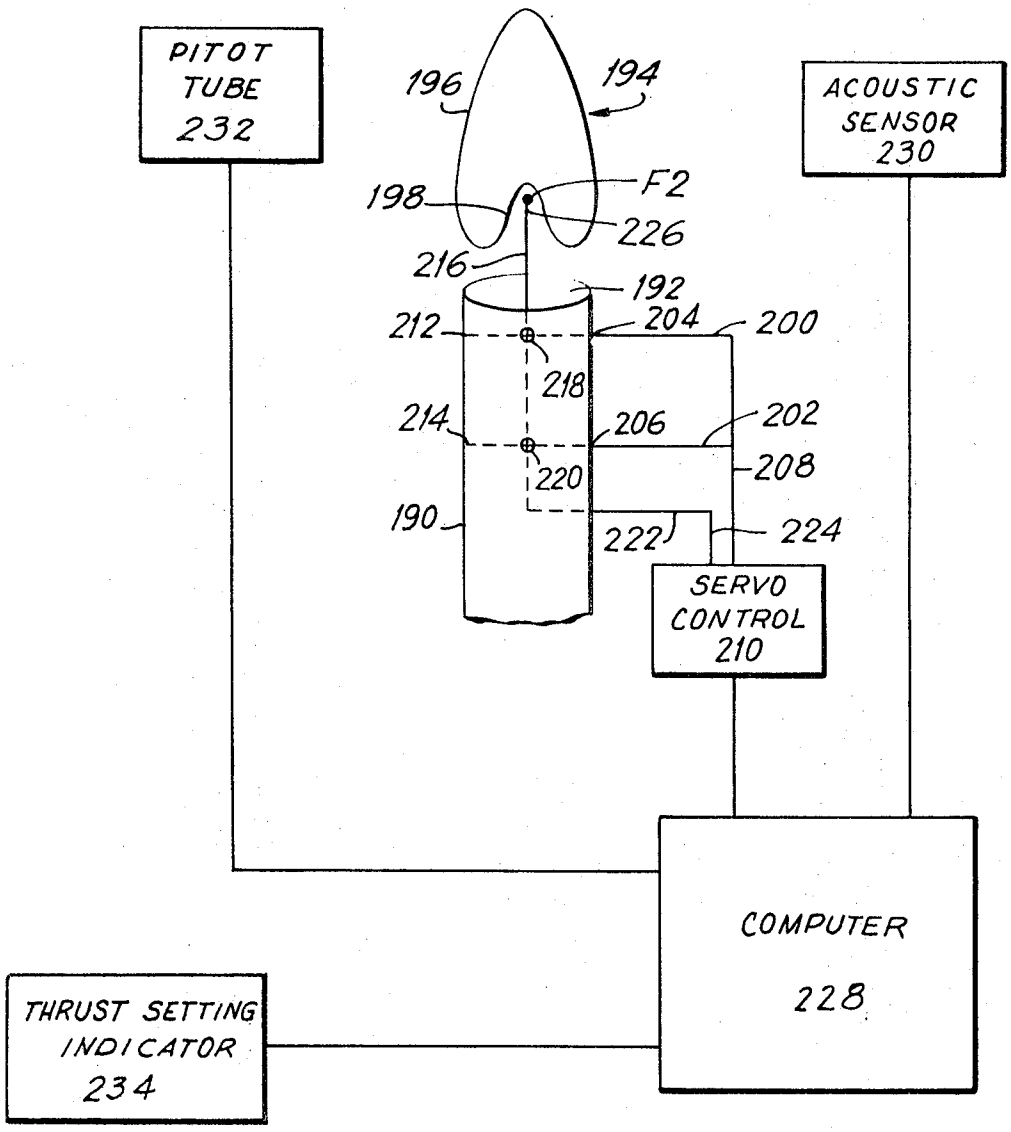


FIG. 8

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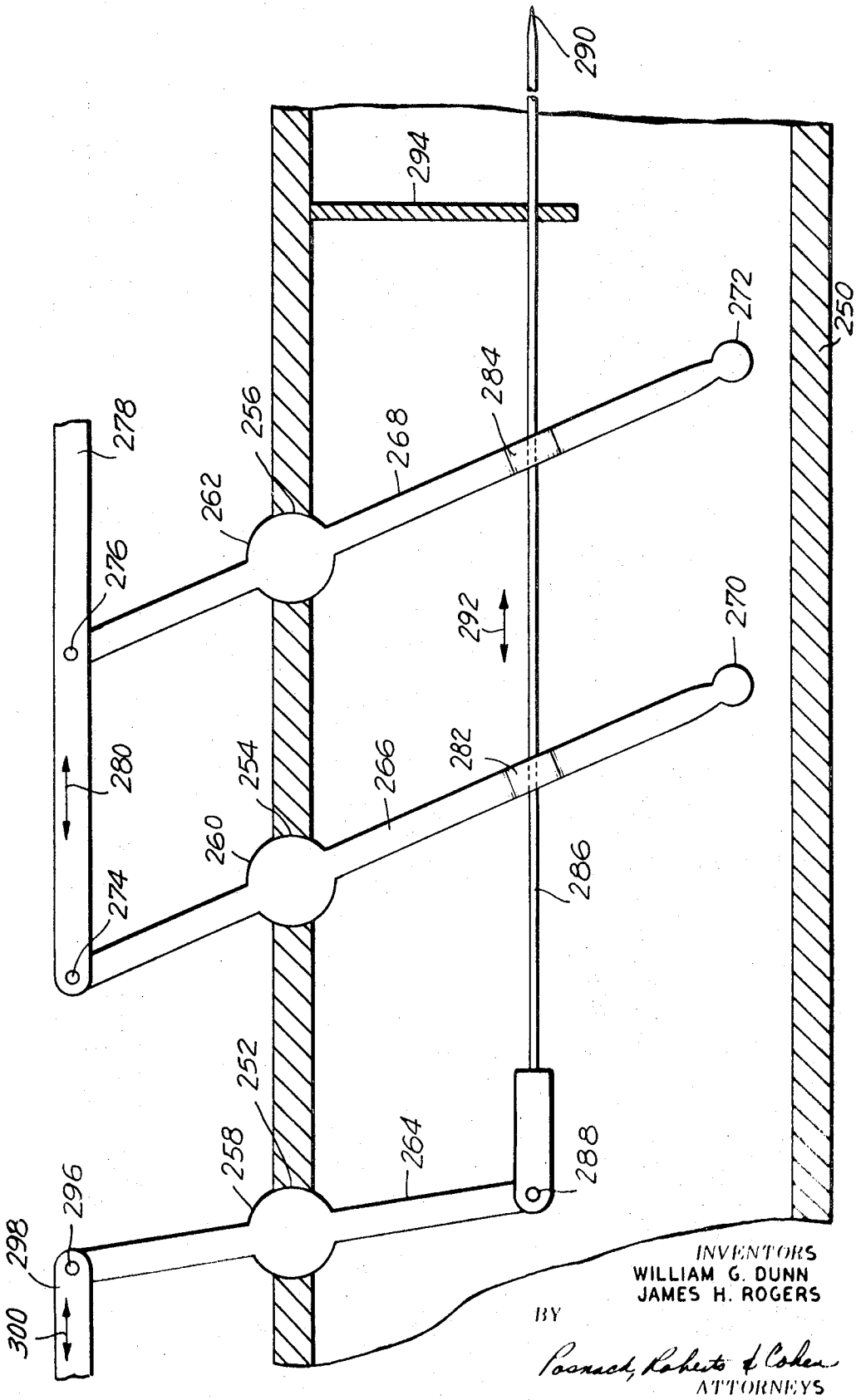
FIG. 6



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Nov. 16, 1971 J. H. ROGERS ET AL 3,620,013
NOISE ABATEMENT METHODS RELATING TO FLAME AND JET PRODUCTION AND ASSOCIATED APPARATUS
Filed Oct. 31, 1969 5 Sheets-Sheet 5

FIG. 7



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3,620,013

NOISE ABATEMENT METHODS RELATING TO FLAME AND JET PRODUCTION AND ASSOCIATED APPARATUS

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ABSTRACT OF THE DISCLOSURE

Two noise abatement techniques are employed in connection with flame generation and the production of jets. One of these techniques involves introducing a disruption rod or needle at the focal point of the parabolic section of the apex of the inner cone of a flame. The other involves using a rod or rods for cancelling the resonant node or nodes developed in a supply tube by a combustible medium passing therethrough to the flame production zone. The apparatus uses the above techniques separately or in combination and provides controls for adjusting node cancelling rods and/or disrupting rod or needle performing the aforesaid functions. The controls take into account that the nodes and focal point vary according to fuel supply rate and other factors relating to ambient and associated conditions.

FIELD OF INVENTION

This invention relates to noise abatement and suppression techniques and to associated apparatus and, more particularly, to the suppression of noise generated incidental to the production of flames and jets.

In general sense, the invention further relates to the suppression of noise such as may be generated by jet engine, but the invention is equally applicable to the suppression of noise in other types of apparatus involving the use of production of jets such as in acetylene torches and the like.

BACKGROUND

The description of various embodiments of the invention as appears hereinafter will be discussed on the basis of resonant chambers and the peculiar characteristics of flames as pertains to flame construction and the interaction of flames and noise. As a consequence, it is essential to an understanding of the invention to explore to a modest degree some prior investigatory work which has been previously effected by others in connection with the phenomena of sensitive flames and in connection with the sounds produced by a fluid such as a gas moving through a column.

In the "Theory of Sounds," volume 2, by Lord Rayleigh, Section 322(*h*), as well as in other sections thereof, there is discussed the sounds emitted by a jet of hydrogen or other gas burning in a pipe which is open at both ends. It is therein noted that Farraday proved that other gases were competent to take the place of hydrogen and it is furthermore noted that Sondhauss has provided the most detailed examination of the circumstances under which the sound is produced.

Attention is directed to the fact that sounds cannot be obtained from a supply tube which is plugged with cotton in the neighborhood of the jet although no difference can be detected between a flame thusly obtained and others which are competent to excite sound.

It is also noted in the aforesaid publication that when the supply tube is unobstructed the sounds obtainable by varying the resonator are limited as to pitch and divide themselves into distinct groups and that in the intervals

between these groups no action can be taken which will induce a maintained sound.

It is also noted that variations capable of being maintained need not always be self-starting, but may be commenced by an initial impulse such as might result from a physical blow administered to the resonator or by a cross-current directed across the mouth of the tube.

Lord Rayleigh furthermore indicates that experiments conducted by Sondhauss show that a relationship of proportionality exists between the lengths of the supply tubes and of the sounding columns related thereto. He states that when the nature of the gas is varied in the same supply tube, the minimum lengths of the sound columns are approximately proportional to the square roots of the density of the gas. Lord Rayleigh observes that a connection is thus established between the natural note of a supply tube and the notes which can be sounded with its aid.

It is also noted that, as a consequence of the variable pressure within the resonator, the issuance of gas and therefore the devolpment of heat, varies during the vibration and a question is raised as to under what circumstances the variation may be of the kind necessary for the maintenance of the vibration.

It is not essential to an understanding of the present invention to go more fully into Lord Rayleigh's studies except to point out that he further observes that if the length of the supply tube amounts to exactly one quarter of the wave-length of the note generated in the supply tube, the stationary vibration within the same will be of such a character that a node is formed at the burner, the variable part of the pressure just inside of the burner being the same as in the interior of the resonator. Under these circumstances, it is observed, there is nothing to make the flow of gas or the development of heat variable and therefore vibration cannot be maintained. When, however, the supply tube is somewhat longer than one quarter of the wave-length, the motion of the gas passing through the supply tube differs materially and the greatest outward flow of gas from the supply tube follows at a quarter period interval the phase of greatest condensation. The node is therefore located within the supply tube and this is a characteristic with which the present invention is concerned.

In Section 370 of the Theory of Sound, volume 2, by Lord Rayleigh, there is discussed the phenomena of sensitive flames. Although reference is made to the resonance phenomena discussed above, an additional phenomena is discussed with respect to which there is an interaction between flames and sounds. Thus, for example, attention is directed to the work of Professor Leconte who noticed the movement of a flame in response to certain notes of a violoncello.

Attention is also directed to the work of Tyndall who found that under the influence of sound of a suitable pitch a flame could be made to roar and drop down to perhaps half its original height, it being demonstrated that the seat of sensitivity could be located at the root of the flame.

It is not essential to examine further the phenomena of sensitive flames other than to note that the present invention finds its basis partially in the phenomena and in an extension of this phenomena as will be discussed in greater detail hereinunder.

SUMMARY OF INVENTION

An object of the invention is to provide improved methods and apparatus for the suppression of noise by utilizing factors relating to the resonance produced by gasses passing through a supply tube and to the interaction between flames and noise.

More particularly, it is an object of the invention to provide for improved noise suppression in apparatus

generating flames and jets based upon the theory, but not limited thereto, that gas flowing through a supply tube will generate noise which noise will have interplay with the flame generated at the outlet of the supply tube in an undesired manner.

More specifically, the invention works upon the principles that noise is inherently generated by the flow of gas through a supply tube and that such noise is amplified in a critical region of the related flame. It is an object of the invention to interfere with the generation of noise within the supply tube by providing for node cancellation within the supply tube and cumulatively or in the alternative to provide a disturbance in the flame which will prevent or materially influence the amplification of noise by the flame itself.

As will be shown in greater detail hereinunder, there is provided, in accordance with the invention, a technique for preventing amplification of noise by a flame, but providing for a disturbance in the flame at a precisely determined point. As will also be discussed in greater detail hereinafter, a flame consists of at least two coaxial and interrelated cones, the inner of which has an apex which is not a precisely pointed apex, but which is better described as being in the shape of a parabola. It has been found, in accordance with the invention, that the introduction of a physical mass, solid or otherwise, at the focal point of this parabola, will have the effect of preventing noise amplification.

Similarly, it has been found, in accordance with the invention, that the positioning of a physical entity, solid or otherwise, at the node point or points within a supply tube through which a combustible fuel is passing, will have the affect of materially reducing or completely (or almost completely) suppressing the generation of sound in such supply tube. It can be appreciated from what has been stated above that the suppression of the generation of noise and the concomitant suppression or abatement of the amplification of such noise will have a significant result in respect to integrated noise level. It will also be appreciated that these two factors can be utilized separately to achieve greatly superior results compared to results which have heretofore been obtainable in noise suppression.

As will be understood from the detailed explanation of some preferred embodiments of the invention which follows hereinbelow, the noise suppression techniques of the invention are readily adapted for use in connection with jet engine. It will furthermore be understood that these improvements may be incorporated into other types of apparatus such as acetylene torches and the like.

Generally speaking, there is provided in accordance with the invention a reduced-noise jet producing apparatus comprising a source of combustible material with nozzle means operatively associated with such source and defining a jet producing zone whereat is generated a flame including inner and outer cones. This source is located, naturally, upstream of said zone and the combustible material flows from the source downstream through the nozzle means to such zone. Thus, based on what has been stated hereinabove, noise abatement means will be provided, in accordance with the invention, which noise abatement means will be located in or upstream of the inner cone of the flame which is being generated. This noise abatement means may include a member extending into the inner cone to a position in juxtaposition to the apex of such inner cone or it may include a means extending into the supply tube to a position for cancelling the node or nodes therein. Moreover, the noise abatement means of the invention may include both of the types of noise abatement devices noted above.

It has been stated that the noise abatement means related to the inner cone of the flame will extend to a position juxtaposed to the apex of such cone. More particularly, this position will preferably be at the focal point of the parabola which constitutes such apex.

From what has been described above, it may be inferred that the position of a node in a supply tube or the position of the focal point of the parabola are fixed. This is not accurate with respect to the actual case where ambient conditions will vary and the positions of the node or nodes or apex will vary. It is therefore a further provision and feature of the invention to provide for adjustment of the node cancelling means and the apex disturbing means so that conditions which vary the positions thereof can be taken into account.

Still a further feature of the invention is to provide for a servo-control of the two types of means described above whereby conditions affecting the nodes or apices can be automatically taken into account and an automatic locating of the two types of aforesaid means automatically performed.

THE PRIOR ART

There are various devices heretofore conceived which consider the possibility of positioning, in a flame, a mechanical device which interferes with the flame and constitutes a means whereby noise can be reduced in a burner. One such device, for example, appears in Pat. 3,087,532 which issued Apr. 30, 1963 and relates to a method of reducing noise in an oil burner. Such device, however, does not remotely consider the possibility of cancelling the node or nodes in a supply tube through which a combustible fuel is passed and, moreover, does not take into account the possibility of preventing noise amplification by placing a disturbance at the focal point of a parabola constituting the apex of the inner cone of a flame.

We are also aware of other patents relating to noise abatement. These patents include Patents 3,174,581; 2,613,758; 2,334,502; 3,187,135; and 3,187,501. These patents show axially disposed devices relating to sound suppression but do not take into account the techniques disclosed hereinabove.

Furthermore, we are familiar with Patents 3,036,429; 3,120,877; 3,159,238 and 3,191,380 which show radial or transverse members in a plane perpendicular to the axis of a nozzle for purposes of sound suppression. These patents likewise do not take into account the two principles employed in accordance with the invention.

We are also familiar with the fact that Patents 3,120,-877 and 3,159,238 provide members which are longitudinally adjustable. Since these patents, however, do not take into account the features of the invention which have been described, they are not believed pertinent to the subject matter of the present invention.

DRAWING

Preferred embodiments of the invention are described in the accompanying drawing in which:

FIG. 1 diagrammatically illustrates a supply tube and the flame which issues therefrom;

FIG. 2 is a diametral and diagrammatic section of a jet engine in which the improvements of the invention are employed;

FIG. 3 is a diagrammatic and diametral section of a second jet engine in which the improvements of the invention are employed;

FIG. 4 is a diametral section through a burner nozzle in connection with which one of the improvements of the invention is employed;

FIG. 5 diagrammatically illustrates a supply tube for a burner in association with a node cancelling device having a servo-control in accordance with the invention;

FIG. 6 diagrammatically illustrates a supply tube and flame with which the node cancelling and focal point disruption devices of the invention are employed along with a servo-control therefor;

FIG. 7 shows diagrammatically and on enlarged scale a construction for node cancellation and focal point disruption as provided in accordance with the invention; and

FIG. 8 diagrammaticaly shows a further embodiment of the invention.

DETAILED DESCRIPTION

In FIG. 1 appears a supply tube **10** through which passes a cmbustible medium or fuel as indicated by arrows **12**. The supply tube is the fundamental equivalent of a supply tube as appears in a jet engine, or such as may constitute the supply tube of an acetylene torch or the like. No nozzle appears in FIG. 1, but the presence of a nozzle will not disturb the generalized form of the flame which appears at **14**. This flame consists, as is well known, of an inner cone **16** and an outer cone **18**. It is within the outer cone **18** or at the outer surface thereof that combustion is principally effected and it is known that within the inner cone **16** temperatures are significantly reduced from those within or surrounding outer cone **18**. The node or nodes referred to hereinabove occur along the length of supply tube **10** as described by Lord Rayleigh and are the nodes which are cancelled in accordance with the invention as described hereinafter. One such node is indicated at N. The apex of inner cone **16** is indicated at **20**. In idealized form the apex could be a sharp peak. However, in practice this apex more accurately has the form of a parabola, the focal point of which is indicated generally at F and is a focal point at which a disruption is placed in accordance with the invention.

In FIG. 2 appears a Nene turbo-jet engine **30**. It has an outer casing **32** in which is provided an air intake **34** and, for example, fuel supplies **36** and **38**. There are also provided a plurality of flame igniters **40** and a plurality of combustion chambers **42**. A cooling fan **44** is incorporated into the engine and there are also included nozzle guide vanes **46** which function in well known manner. The turbine blades appear at **48** and the turbine driving impeller at **50**; and the engine has an outlet **52** through which passes gas energy as a pure jet. The engine may incorporate a double-sided impeller as indicated at **54**. In addition to the aforesaid components which are all notoriously well known, and the functions of which are equally as well known, there are the supply tubes for fuel as indicated, for example, at **56**, the burner nozzles for these supply tubes being indicated, for example, at **58**. The provisions of the invention are associated with supply tubes **56** and **58** and are diagrammatically indicated for the uppermost supply tube at **60**. The details thereof will be discussed in greater detail hereinafter.

Before a more detailed discussion of the provisions of the invention is undertaken, however, it will be next indicated with reference to FIG. 3 that the features of the invention may readily be incorporated into other types of jet engines. Thus, for example, in FIG. 3 is diagrammatically indicated the General Electric J33 combustor, such combustor comprising a casing **70** having an inlet **72** and an outlet **74**. Within the casing is comprised supply tube **76** having a burner nozzle **78**, there being produced a jet flame at **80** located within an inner casing **82** perforated as at **84** providing for the influx and mixture of air. The improvement of the invention is indicated at **86**, the details thereof following hereinafter.

In FIG. 4 appears a section of a supply tube **90** and a burner nozzle **92**. A complex form of burner nozzle has been illustrated herein for purposes of demonstrating without limitation that the provisions of the invention can readily be incorporated into a system including a burner nozzle of complex construction.

The burner nozzle of FIG. 4 includes a primary flow port **94**, a main flow port **96** and a main flow plate **98**. There is also included an orifice plate **100** in which is provided orifice **102**. A distributor plate **104** is associated with the main flow port and in association with main flow plate **98** are a distance plate **106** and a primary flow plate **108**. At **110** is indicated a spring loaded relief valve engaged by a spring **112** attached to a bolt **114**.

A discussion of further details of this burner, which is known as a Duplex Type II burner, or of the function of the above parts, is not essential to an understanding of the invention. However, it is to be understood from the illustration in FIG. 4 that a pointed needle **116** is provided in accordance with the invention having a pointed end **118** which extends out of the burner nozzle into the inner cone of the flame generated thereby to constitute a disruption at the apex of the parabola constituting the apex of the inner cone. The fact that the needle **116** is adjustable in both longitudinal directions thereof is indicated by arrow **120**.

FIG. 5 diagrammatically illustrates one embodiment of the invention. Therein diagrammatically appears a supply tube **130** having an opening **132** from which issues a flame **134**. This flame has an inner cone **136** and an outer cone **138**, the focal point of the inner cone being indicated at F1. Extending through the wall of the supply tube **130** is a node cancelling rod **140**, the end of which is indicated at **142**. Rod **140** is pivoted at **144** so that the end **142** can be adjusted in two directions as indicated by arrow **146**. Such adjustment is effected through linkage **148** which is controlled by servo-control **150**.

Supply tube **130** becomes a resonant chamber under the Lord Rayleigh theory discussed above. One or more node points will appear in the supply tube **130** according to the flow of a fluid or gaseous medium such as a combustible mixture through said tube. In accordance with the invention, the node cancelling rod **140** is adjusted to be located at such node and this location of the rod **140** will prevent the generation of noise in the supply tube **130** or will materially suppress or abate such noise. This noise generated within the supply tube is the noise which is subsequently amplified and causes the intolerable noise levels created by jet engine or the like. It is also the noise which occurs during the use of acetylene torches and like apparatus.

It is to be understood that the location of the node point in a supply tube may not be a precise matter. For the purpose of accommodating this lack of precision, the possibility of adjustment of the rod **140** is provided. Such adjustment may be manual or automatic. An automatic system is indicated in the form of servo-control **150** which can be any well known servo-system.

In association with servo-control **150** is an acoustic sensor **152**. Such acoustic sensor **152** can be connected directly to servo-control **150** since it can directly detect a noise null and therefore can be employed for direct control of rod **140** which will hunt for the node until the null is produced. Alternatively, sensor **152** may be coupled to a computer **154** of the digital or analog type to which may also be fed additional information such as that coming from a thrust setting indicator **156** and pitot tube **158** having significance relative to jet engine. Thus, as is well known, the movement of fuel through tube **130** has relationship to ambient conditions in turn related to the information supplied by units **156** and **158** and perhaps other units, the details of which are not significant to an understanding of the present invention. What does constitute a feature of the invention is that the position of rod **140** can be either manually or automatically controlled and when automatically controlled, this can be related to the generation of noise directly and/or to ambient conditions related to the noise which will be generated.

FIG. 6 illustrates a second embodiment of the invention. In this figure appears the supply tube **190** having opening **192**, there being again generated a flame indicated at **194** having an outer cone **196** and an inner cone **198**, the focal point for which is indicated at F2.

In accordance with this embodiment of the invention, there are two node cancelling rods **200** and **202**, these being pivoted on the wall of tube **190** at **204** and **206**, a linkage **208** being provided which connects rods **200** and **202** together for simultaneous movement and also connecting this rod to a servo-control **210**. Rods **200** and **202** can also have separately controlled movements to account for the possibility of varying distances between the nodes.

Rods **200** and **202** have end portions **212** and **214** which are automatically or manually displaced to the position of the nodes in supply tube **190** to effect node cancellation and noise suppression. If desired, these rods can be extensible and retractable.

In accordance with this embodiment of the invention, there is provided a further rod **216** which may be termed a focal point disruption rod. This rod passes axially through tube **190** in which the rod is axially adjustable. It furthermore may pass through eyes **218** and **220** in rods **200** and **202** for puropses of guidance. Rod **216** is connected to linkages **222** and **224** which provide the aforesaid adjustment of rod **216**. End portion **226** of rod **216** is to be located at focal point F2 to provide for the noise abatement or suppression discussed hereinabove and more particularly to destroy the noise amplification which would otherwise be provided by flame **194**.

As discussed hereinabove with respect to the embodiment of FIG. 5, servo-control **210** may be controlled by computer **228**, in turn controlled by acoustic sensor **230** and/or by data received from pivot tube **232** and thrust setting indicator **234**.

A more detailed, but still diagrammatic illustration of the apparatus of the invention appears in FIG. 7, wherein supply tube **250** is provided with socket openings **252, 254** and **256** within which are accommodated spheres **258, 260** and **262** integral with rods **264, 266** and **268**. Bushings may be employed but are not shown.

Rods **266** and **268** are the node cancellation rods referred to hereinabove and include ends **270** and **272** in the form of small spheres although the geometrical form of these ends does not effect the ability to perform node cancelling functions. Rods **266** and **268** are pivoted by pins **274** and **276** to a linkage **278** which is longitudinally displaceable in opposite directions as indicated by arrow **280** to effect displacement of ends **270** and **272** in accordance with what has been stated hereinabove. Centrally located in rods **266** and **268** are eyes **282** and **284** through which pass focal point disruption rod or needle **286** which is pivoted at pin **288** to control rod **264** whereby the point **290** of the focal point disruption rod can be moved in and out as indicated by arrow **292**. Additional supports may be provided for rod **286** as indicated diagrammatically at **294**. Rod **264** is pivoted at pin **296** to linkage **298** which can be displaced in longitudinal directions as indicated by arrow **300**.

In FIG. 8 appears an acetylene tank **300** having a nozzle **302** producing a flame as discussed above. Noise reduction herein is accomplished in either or both of the ways mentioned above with respect to jets.

It will appear from what has been described above that the position of the node cancelling members and the focal disruption member can be controlled by linkages **278** and **298** and from what has been stated hereinabove, it will be understood that this control can be effected either manually or automatically.

The invention is based on, but not limited to, the principle that noise is generated in jet and flame producing mechanisms by a resonance created within the fuel supply tube and that this noise when so generated is amplified by the flame itself. The invention provides for noise suppression or abatement by providing for node cancellation with respect to the sound wave generated within the supply tube and by providing for disruption of the amplification mechanism constituted within the inner cone of the flame generated in the downstream end or burner nozzle of the supply tube.

The invention as described above produces a reduced-noise jet producing apparatus comprising a source of combustible medium with nozzle means operatively associated therewith and defining a heat producing zone whereat is generated a flame including inner and outer cones, the source being located upstream of the zone with the medium flowing from the source downstream from the nozzle to the zone. The invention supplies a noise abatement means located in or upstream of the inner cone of such flame. This noise abatement means may be constituted by a physical means extending into the inner cone into juxtaposition to the apex thereof and/or node cancellation means located in the supply tube to cancel the nodes in the sound waves generated therein.

According to the invention, the most critical position of the focal point disruption means is at the focal point of the parabola constituting the apex of the inner cone. Lesser results which are still acceptable will be produced if physical means are located not precisely at the focal point of the parabola but closely adjacent the same. Similarly, preferred results are obtained by positioning the node cancelling rods precisely at the node or nodes formed within the supply tube. However, lesser, but still acceptable results are obtained by approximately so locating the node cancelling rod or rods.

It is to be noted that the temperatures within the supply tube as well as within the inner cone are relatively low. Hence, it is unnecessary to use special heat-resistant materials for the aforesaid rods and ordinary steels may be employed.

There will now be obvious to those skilled in the art many modifications and variations of the features and techniques described hereinabove. These modifications and variations will not, however, depart from the scope of the invention if defined by the following claims.

What is claimed is:

1. Reduced-noise jet producing apparatus comprising a source of a combustible medium, nozzle means operatively associated with said source and defining a jet producing zone whereat is generated a flame including inner and outer cones, said source being located upstream of said zone and said medium flowing from said source downstream through said nozzle means to said zone, and noise abatement means located upstream of the apex of said inner cone, said noise abatement means including an elongated member extending axially into said inner cone and including a tip located within said inner cone in juxtaposition to the apex of the latter.

2. Reduced-noise jet producing apparatus comprising a source of a combustible medium, nozzle means operatively associated with said source and defining a jet producing zone whereat is generated a flame including inner and outer cones, said source being located upstream of said zone and said medium flowing from said source downstream through said nozzle means to said zone, and noise abatement means located upstream of the apex of said inner cone, said source including a supply tube coupled to said nozzle means and defining a chamber through which said medium flows and wherein at least one resonance node is formed depending upon the movement of said medium through said chamber, said noise abatement means including at least one node cancelling rod extending into said chamber into interfering relationship with said node.

3. Apparatus as claimed in claim **2**, wherein said noise abatement means further includes an elongated member extending axially into said inner cone and including a tip located within said inner cone in juxtaposition to the apex of the latter.

4. Apparatus as claimed in claim **1**, wherein the shape of the inner cone at the apex thereof is that of a parabola and said tip is located at the focal point of the parabola.

5. Apparatus as claimed in claim **1** comprising control means to adust the position of said tip.

6. Apparatus as claimed in claim **2** comprising control means to adjust the position of the node cancelling rod.

7. Apparatus as claimed in claim **3** comprising control means to adjust the position of said tip and further comprising control means to adjust the position of the node cancelling rod.

8. Apparatus as claimed in claim **5**, wherein said control means comprises a servo-control, computer means actuating said servo-control, and data supply means cou-

pled to said computer means and supplying to the latter information about conditions relating to the control of the noise abatement means whereby the servo-control is enabled to control said tip.

9. Apparatus as claimed in claim **6**, wherein said control means comprises a servo-control, computer means actuating said servo-control, and data supply means coupled to said computer means and supplying to the latter information about conditions relating to the control of the noise abatement means whereby the servo-control is enabled to control said rod.

10. Apparatus as claimed in claim **7**, wherein said control means comprises a servo-control, computer means actuating said servo-control, and data supply means coupled to said computer means and supplying to the latter information about conditions relating to the control of the noise abatement means whereby the servo-control is enabled to control said tip and rod.

11. Apparatus as claimed in claim **3**, wherein said elongated member and node cancelling rod are interengaged.

12. Apparatus as claimed in claim **1** further comprising a jet engine including a combustion chamber into which said nozzle means extends.

13. Apparatus as claimed in claim **1**, wherein said source includes a tank of acetylene gas and a bent supply tube connected to said tank.

14. Apparatus as claimed in claim **2** comprising a plurality of node cancelling rods.

15. Apparatus as claimed in claim **2** further comprising a jet engine including a combustion chamber into which said nozzle means extends.

16. Apparatus as claimed in claim **2**, wherein said source includes a tank of acetylene gas and a bent supply tube connected to said tank.

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