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F1G GNB G807 G811 G819

(56) Documents Cited
US 4646733 A **US 4556174 A**
US 4442755 A **US 4199295 A**
US 4193149 A **US 3937252 A**

(58) Field of Search
UK CL (Edition R) **F1G GNB , F4T TAT , G3H HAC HBY HDA HDX**
INT CL[7] **F02C , F15B , G10K**
ONLINE: EPODOC, JAPIO, WPI

(54) Abstract Title
Flow control valve

(57) A flow control valve for a combustion unit includes a first member (48) located in a fuel or air flow path so as to define an annular flow therearound. A second member (68) is mounted so as to be rotatable substantially around the first member and a flow path is defined between the first and second members. Rotation of the second member (68) about the first member (48) causes a cyclical variation of the effective cross sectional area of the flow path, with a single cycle of relative rotation of the first and second members causing the effective cross sectional area of the flow path to pass through a plurality of maxima and minima. Fuel leaving the valve thus has a steady component defined by the minimum fuel flow and an unsteady component defined by the variable fuel flow. The unsteady component may be brought into antiphase with a detected noise or vibration level, in order to minimise such noise or vibration.

Fig.3.

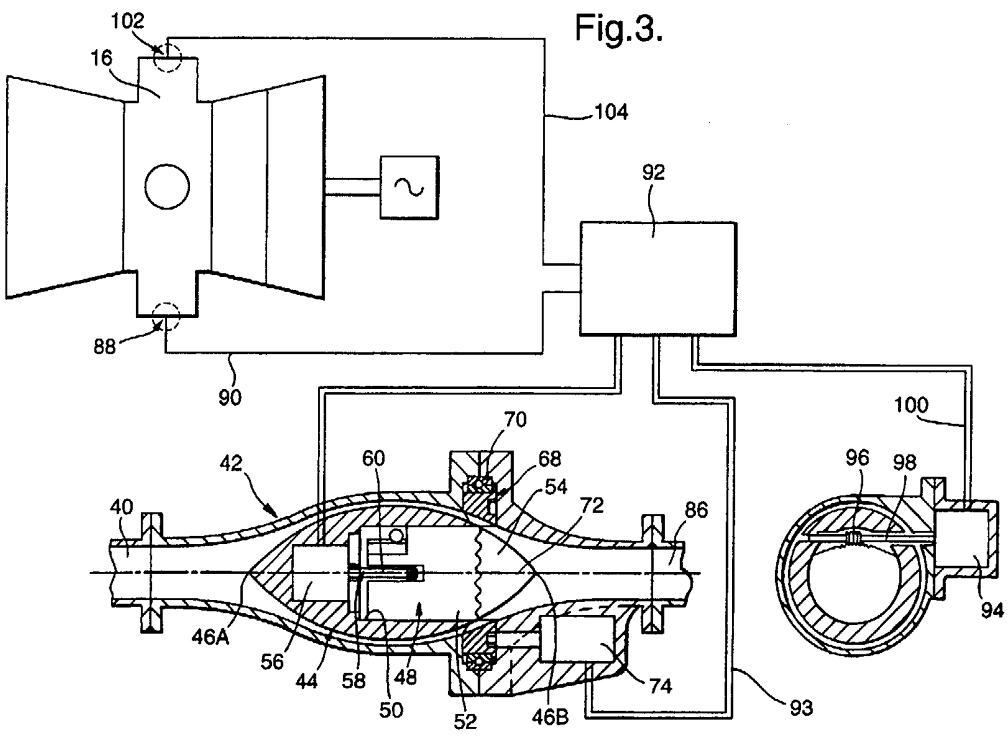

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Fig.1.

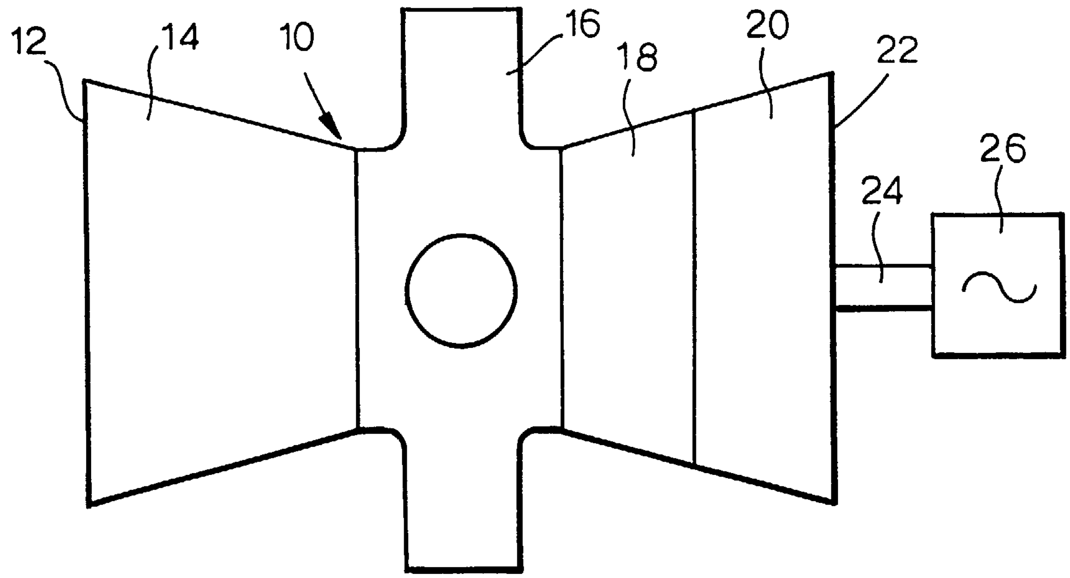


Fig.2.

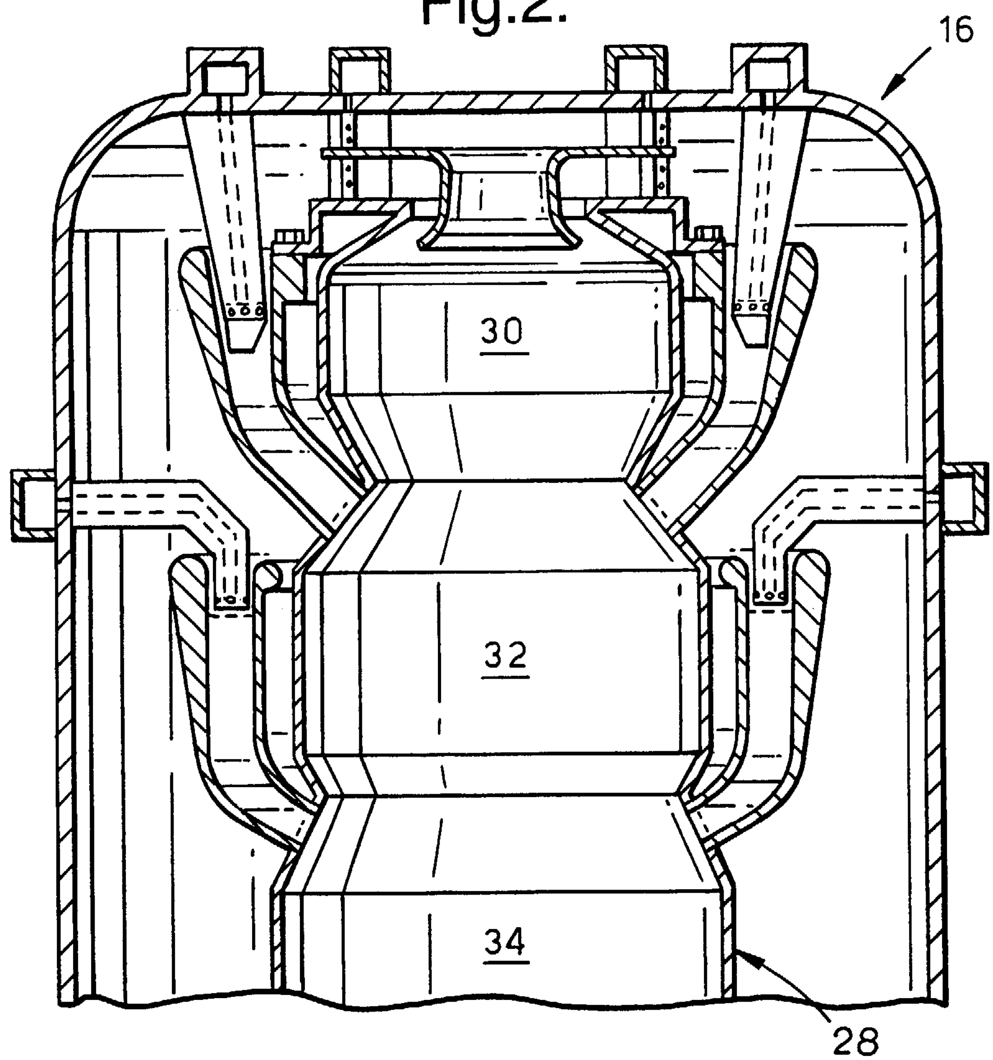
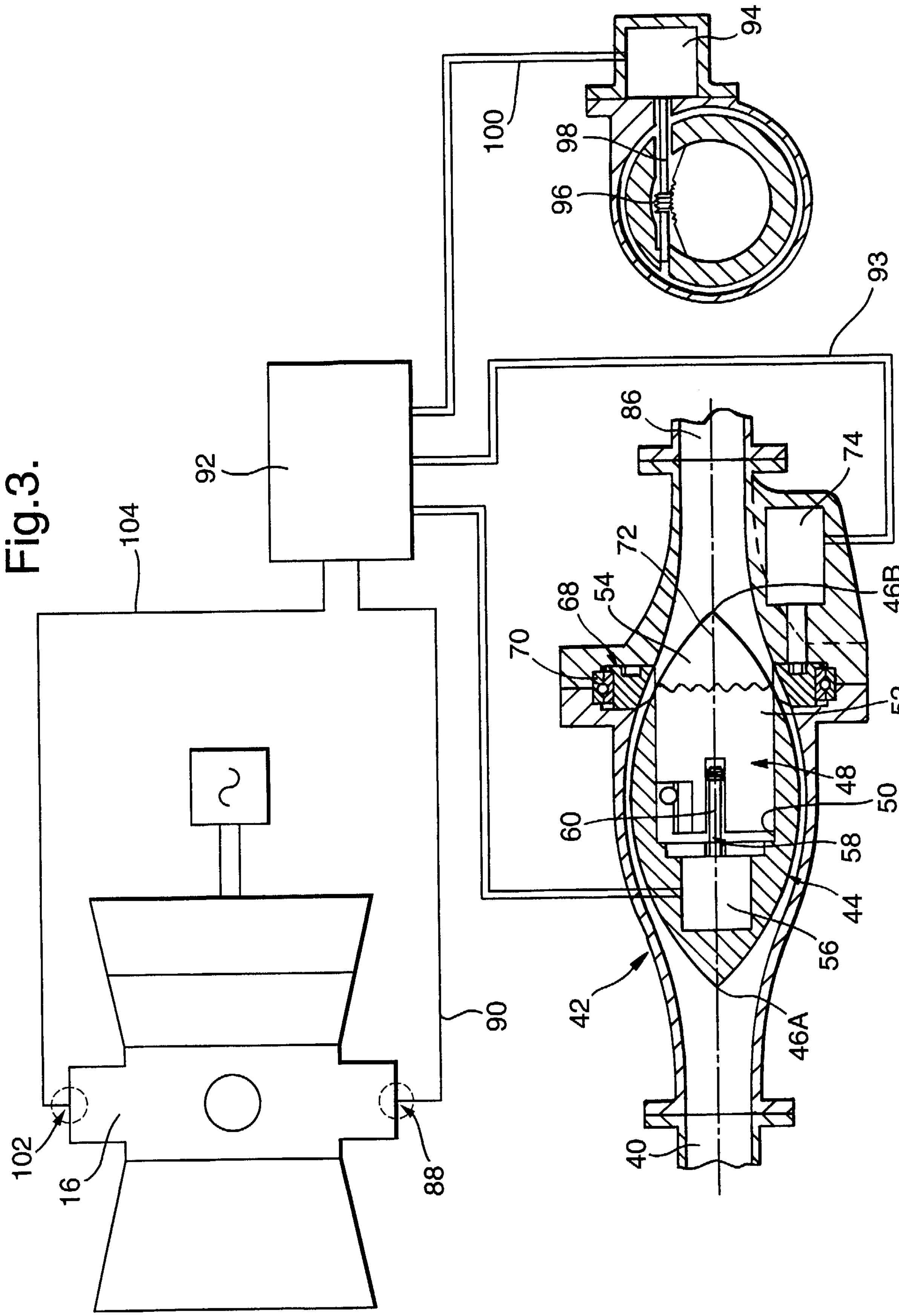


Fig.3.



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102
16
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Fig.4.

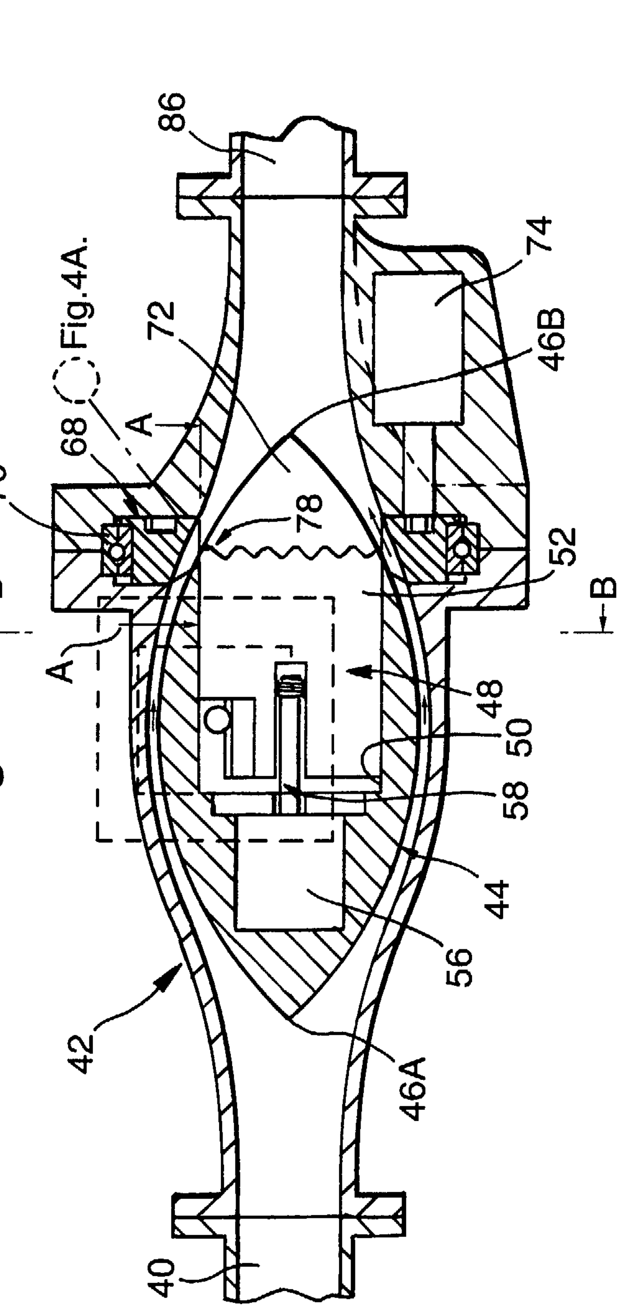


Fig.4B.

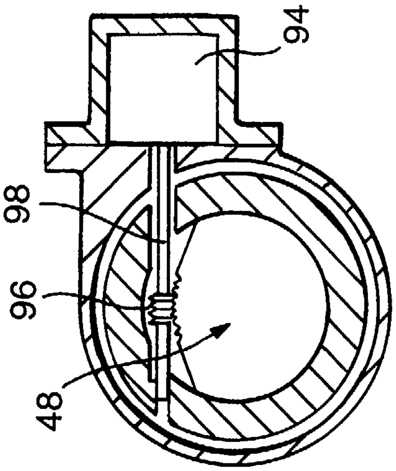


Fig.4A.

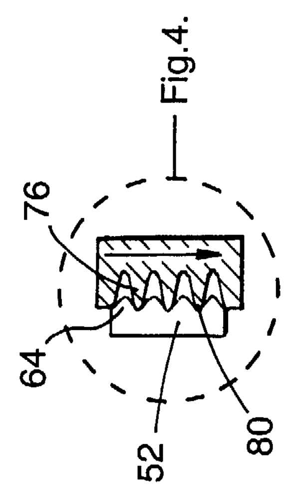


Fig.5A.

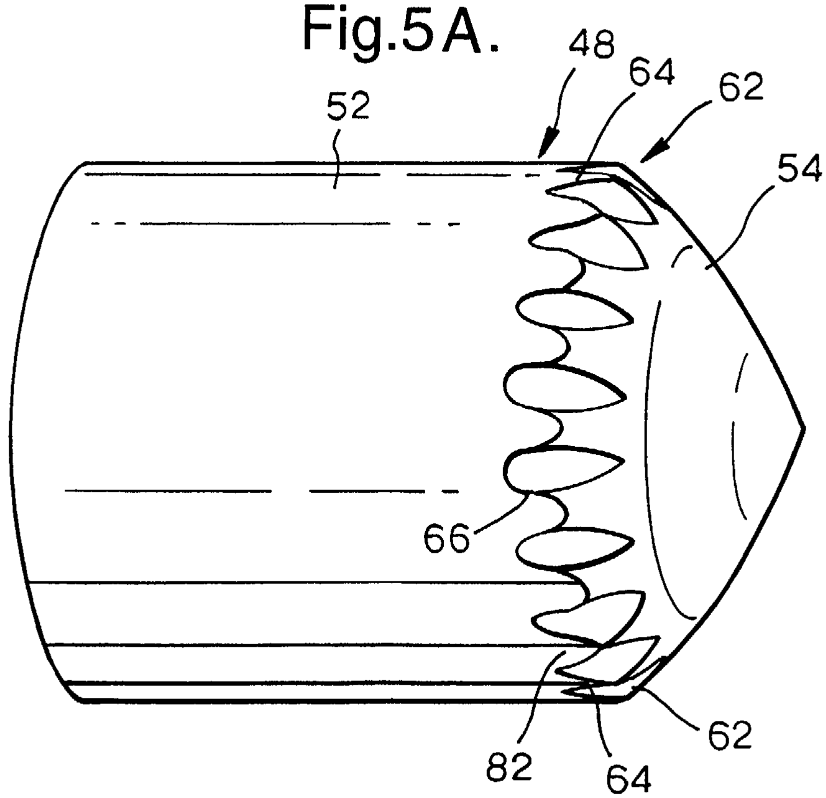


Fig.5B.

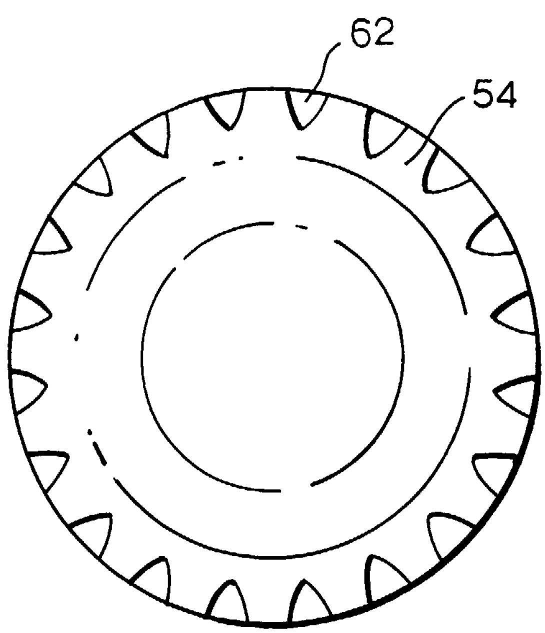
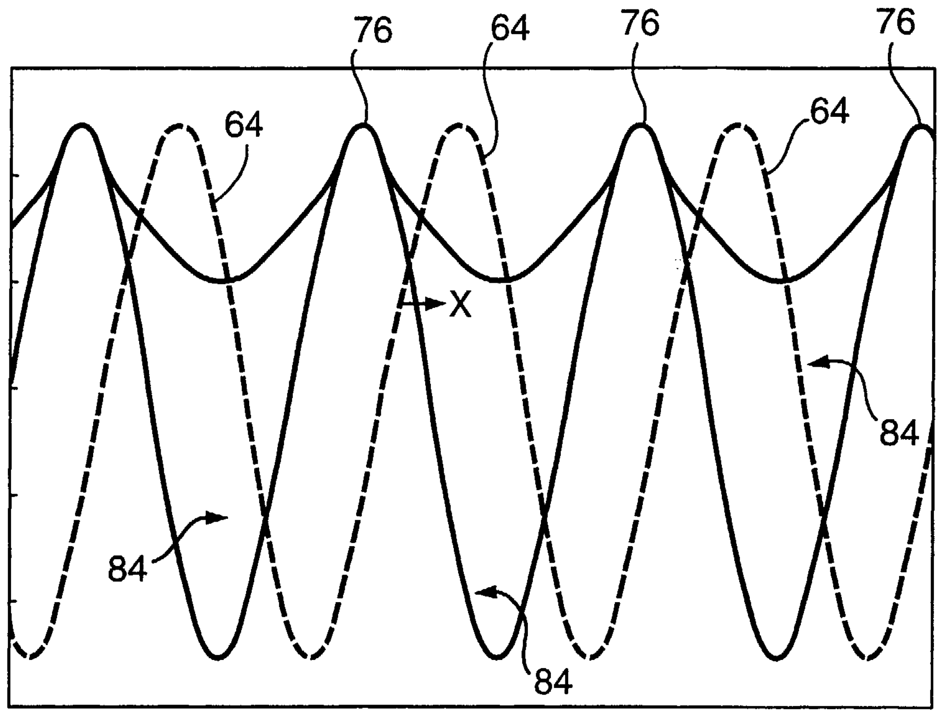


Fig.6.


76
64
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84
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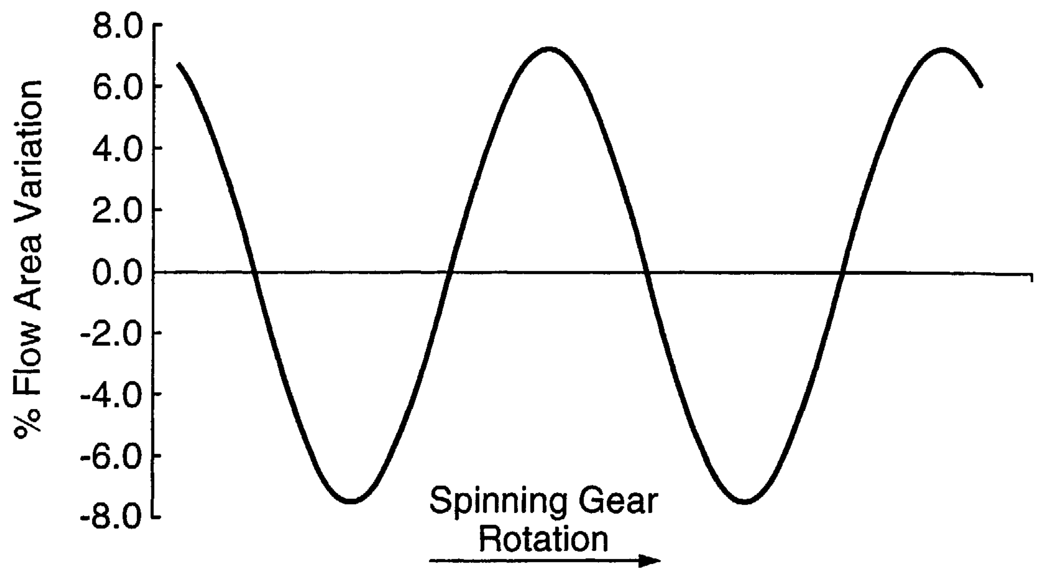
84

Fig.7.


8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
% Flow Area Variation
Spinning Gear
Rotation

Flow Control Valve

The invention relates to flow control valves, particularly for combustion units, especially premixed fuel lean burn combustion units designed to produce low emissions.

Combustion processes often generate noise, that is, they emit energy in the form of high frequency pressure perturbations. These perturbations are generally of regular or semi-regular form, such that at a given flame condition a stable perturbation, of regular amplitude and frequency, is generated.

The relationship between the noise and the combustion process is often circular. Though it may be an initial unsteadiness in the combustion process which generates noise perturbation, this noise perturbation then causes the fuel supply to the combustion process or the heat release from the combustion process to become unsteady, which then generates more noise. This process may increase until damagingly high levels of noise (which can cause rapid failure of combustor parts) are achieved.

It has previously been proposed to reduce noise by controlling the unsteady heat release from the combustion chamber through modulation of the fuel supply to bring the maximum fuel supply into antiphase with the maximum noise level. However, previously proposed arrangements for modulating fuel supply have employed reciprocating flow control valves which are prone to wear, fatigue and bouncing problems at the operating frequencies required.

According to the invention, there is provided a flow control valve including first and second members defining a flow path therebetween and means for establishing continuous relative rotation of the first and second members, wherein during relative rotation of the members the effective cross sectional area of the flow path varies cyclically at a rate dependent upon the relative speed of rotation of the members.

Preferably the first and second members are able to rotate at a relative rotational frequency of at least about 400 Hz.

Preferably during a single cycle of relative rotation of the first and second members, the effective cross sectional area of the flow path passes through a plurality of maxima and minima. The ratio of the minimum effective cross sectional area to the maximum effective cross sectional area is preferably between 60% and 95%, thus providing a steady component and an unsteady component of fluid flow through the device.

Preferably during rotation a face on the first member at least partially overlaps and slides against a face on the second member. At least one of the members may be provided with a plurality of projections and recesses giving the overlapping face of the member an irregular edge, the recesses defining a part of the flow path. Preferably the other member is also provided with a plurality of projections and recesses giving the overlapping face of the member an irregular edge, such that relative movement of the respective faces causes variation in the effective cross sectional area of the flow path. Preferably the projections and recesses on at least one of the members are substantially sinusoidal in sectional shape.

Preferably one of the first and second members is not continuously rotatable in use, but means are provided for adjusting its angular orientation.

In a preferred embodiment of the invention, the first member is substantially circular in cross section, defining a substantially annular flow path therearound. The second member may be approximately annular in shape and rotatable substantially around the first member, such that an inner face of the second member at least partially overlaps and slides against an outer face of the first member.

The ratio of the minimum effective cross sectional area to the maximum effective cross sectional area is preferably variable. The ratio may be varied by varying the extent of overlap of the two faces.

Preferably the flow control valve further includes means for controlling the speed of relative rotation of the members in dependence upon a variable input signal.

Thus according to the invention there is further provided a flow control valve including means defining a fluid flow passage of a predetermined effective cross sectional area, non-reciprocating valve means operable to rapidly and continuously vary the cross sectional area of the flow path and means for controlling operation of the valve means in response to a variable input signal.

According to the invention there is also provided apparatus for minimising noise or vibration in a combustion chamber, the apparatus including a valve as described in any of the preceding two paragraphs, and the variable input signal being dependent upon a detected noise or vibration frequency.

According to the invention there is also provided combustion apparatus including apparatus for minimising noise or vibration as described in the preceding paragraph. The combustion apparatus may include a premixed fuel lean burn combustion chamber. The valve may be located in a fuel pipe for the fuel injectors for the combustion chamber. Alternatively the valve may be located in an air flow pipe for the combustion chamber.

An embodiment of the invention will now be described for the purpose of illustration only, with reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of a gas turbine engine;

Fig. 2 is a diagrammatic cross section through the combustion chamber of the gas turbine engine of Fig. 1;

Fig. 3 is a diagrammatic representation of an arrangement incorporating a flow control valve according to the invention in use to control noise in a combustor;

Fig. 4 is a diagrammatic cross section on the flow control valve of Fig. 3; Fig 4A is section on the line A-A in Fig. 4; and Fig. 4B is a section on the line B-B in Fig. 4;

Fig. 5A is a diagrammatic view of the cone portion of the flow control valve of Figs. 3 and 4; and Fig. 5B is a diagrammatic end view of this cone portion;

Fig. 6 is a diagrammatic illustration of the relative movement of the teeth in the flow control valve of Figs. 3 and 4; and

Fig. 7 is a graph illustrating the variation in cross sectional flow area of the valve.

An industrial gas turbine engine 10, shown in Fig. 1, comprises in axial flow series an inlet 12, a compressor section 14, a combustion chamber assembly 16, a turbine section 18, a power turbine section 20 and an exhaust 22. The turbine section 18 is arranged to drive the compressor section 14 via one or more shafts (not shown). The power turbine section 20 is arranged to drive an electrical generator 26 via a shaft 24. However, the power turbine section 20 may be arranged to provide drive for other purposes.

The combustion chamber assembly 16 comprises a plurality of, for example nine, tubular combustion chambers 28 (Fig. 2) arranged with their axes generally radially to the axis of the gas turbine engine. Each of the tubular combustion chambers 28 includes a primary combustion zone 30, a secondary combustion zone 32 and a tertiary combustion zone 34. The products of the first combustion stage flow into the second combustion stage and the products of the second combustion stage flow into the third combustion stage. Fuel is supplied to each combustion zone by a fuel injector (not shown). A combustion chamber assembly of this construction is described in more detail in European Patent Application No. EP0687864.

Fig. 3 illustrates diagrammatically the use of a valve 42 to minimise noise, in a combustion chamber assembly 16 such as that illustrated in Fig. 2. Fig. 4 is a cross section of the valve 42, with Figs. 4A and 4B being sections along the lines A-A and B-B of Fig. 4 respectively. Referring to Fig. 3, fuel travelling towards a combustor fuel injector passes down a pipe 40 towards a valve 42. The valve 42 includes an inner member 44 which is generally circular in section across the flow direction of the fuel and generally lenticular in section in the direction of flow of the fuel, terminating in a point at each of its ends 46A and 46B. At the trailing end of the inner member 44 a cone portion 48 is slidably mounted within a recess 50 in the end of the inner member 44. The cone portion 48 consists of a generally cylindrical part 52 and a substantially conical part 54. The cone portion 48 may be moved axially within the remainder of the inner member 44, for a purpose which is described in more detail below. A stepper motor 56 may be used to effect such movement. The stepper motor 56 is connected via a screw jack 58 to the cone portion 48 of the inner member, so that rotation of a shaft 60 of the stepper motor 56 causes axial movement of the cone portion 48.

The shape of the cone portion 48 of the inner member is illustrated in Fig. 5. The region 62 where the cylindrical part 52 meets the conical part 54, the cone portion 48 includes a plurality of recesses 62 defining a set of teeth 64. The teeth 64 comprise a plurality of sinusoidal projections extending generally in the flow direction of the fuel. Thus a sinusoidal edge 66 is defined on the cone portion at the junction of its cylindrical end conical parts 52 and 54.

Referring again to Figs. 3 and 4, an annular outer member 68 is rotatably mounted within a bearing 70 such that the outer member 68 is able to rotate freely about a central axis 72 of the valve. The outer member 68 is driven by a small, variable speed electric motor 74.

Referring to Fig. 4A, the outer member 68 includes a set of teeth 76 comprising a plurality of sinusoidal projections, extending generally against the flow direction of the fuel, and complementary recesses. Thus an inner face 78 on the outer member 68 has a sinusoidal edge 80. The teeth 76 are longer than the teeth 64 on the inner member.

The inner face 78 on the outer member 68 partially overlaps an outer face 82 defined by the sinusoidal edge 66 on the inner member 44. Referring to Figs. 6 and 7, it may be seen that the distal ends of the teeth 76 overlap the teeth 64. Recesses 84 formed between the overlapping teeth define a flow path for the fuel, the path having both radial and axial components. Fig. 6 shows the cross sectional flow area presented to the fuel when the distal ends of the teeth 76 meet the recesses formed by the teeth 64. It will be appreciated that this cross sectional flow area is smaller than that which is presented when the distal ends of the teeth 76 meet projections formed by the teeth 64.

As the outer member 68 rotates relative to the fixed inner member 44, the total cross sectional area made up of all the recesses 84 between the respective teeth varies sinusoidally, as shown in Fig. 7. The extent of overlap of the teeth 64 and 76 may be varied by axial movement of the cone portion 48 of the inner member 44. The cone portion 48 may be moved axially (generally in the direction of flow) by use of the stepper motor 56, to increase or decrease the overlap of the respective teeth 64 and 76 and hence the cross sectional area of the flow path.

In operation, fuel flows along the pipe 40 towards the valve 42. As the fuel meets the pointed end 46A of the inner member 44, the fuel is forced to separate and to follow an approximately annular path around the inner member 44. The pipe 40 is formed in a complementary shape to the inner member 44, thus defining the annular flow path.

The fuel subsequently encounters the two sets of teeth 64 and 76, which present the flow with the cross sectional area detailed in Figs. 4A and 6 and explained above. The annular flow is thus forced to separate into a plurality of discrete flow portions defined by the recesses 84 between the respective teeth. The flow through each recess 84 has both axial and radial (inwards) components.

During operation the motor 74 is activated such that the outer member 68 rotates around the inner member 44 at, for example, 6,000 rpm. This causes the faces 78 and 82 to slide over one another and to present the flow with a sinusoidally varying cross sectional area. In the case where there are twenty teeth on each gear, the cross sectional area varies between a maximum and a minimum at a frequency of approximately 2,000 Hz. Fig. 6 illustrates the teeth 76 in two different positions, shown respectively by bold and dotted lines. In the position shown in bold lines, the cross sectional area of the recesses 84 is at its minimum, while in the position shown in dotted lines, the cross sectional area of the recesses is between its minimum and maximum values.

Fuel entering a downstream area 86 of the pipe 40 thus has a steady component, defined by the minimum cross sectional flow area, and an unsteady component which has a frequency of about 2,000 Hz. The ratio between the steady and unsteady components may be varied by moving the cone portion 48 axially of the inner member 44 as described previously.

The fuel is fed into a combustion zone of the combustion chamber assembly 16. A dynamic pressure transducer 88 associated with the combustion chamber (see Fig. 3) sends a combustion noise measurement signal down a line 90 to a processor 92. The processor 92 sends a frequency control signal down a line 93, to adjust the rotational speed of the motor 74 in dependence upon the noise signal.

The processor 92 also sends a phase control signal down a line 100 to a stepper motor 94 (see in particular Figs. 3 and 4B). The phase relationship between the unsteady flow and the engine noise signal measured by the pressure transducer 88 may be controlled by the rotation of the cone portion 48 about its own centre line. The stepper motor 94 is connected to the cone portion

48 via a worm gear 96 and a shaft 98 and may be used to effect small changes in the rotational orientation of the cone member 48, to change the phase relationship between the unsteady flow and the measured engine noise signal. The processor 92 controls the stepper motor 94 to bring the unsteady component of the fuel flow into antiphase with the detected noise signal. This has the effect of reducing the noise level.

Continual monitoring ensures that the frequency of rotation of the outer member is continually adjusted to keep the fuel supply in antiphase with detected noise levels. Monitoring of the combustion noise is carried out by the pressure transducer 88 and monitoring of the unsteady fuel supply is carried out by a further pressure transducer 102 located in the fuel supply manifold. An unsteady fuel supply measurement signal is sent down a line 104 to the processor 92.

There is thus provided a system for minimising noise in combustion units which includes no reciprocating parts. This minimises wear and allows relatively high operating frequencies.

Various modifications may be made without departing from the invention. For example, the teeth need not be of sinusoidal shape, but for example, could be triangular or crescent shaped. The number of teeth on the outer and inner member may be varied and the two members need not have the same number of teeth. A typical number might be between ten and fifty. The overlap of the gear teeth need not be altered by sliding the inner member axially but could, for example, be altered by sliding the outer member axially or by other means. Either the inner or outer member may be movable axially and the means for effecting that movement need not be a stepper motor. For example the means for causing the inner or outer member to slide axially could be a mechanical linkage or pneumatic or hydraulic means.

The inner member, or both members, could be driven. The driving means need not be an electric motor, but could be, for instance, a pneumatic or hydraulic motor. In addition, the driven member need not be driven directly by the motor but could be driven via a bevel gear, or a series of gears. The motor need not be within the valve casing but could be placed external to the valve casing with the use of suitable seals.

The shapes of the various members may be varied. For example, the inner member could have many different shapes although it is preferred that it is generally smooth and without regions which would cause unstable flow. The flow path around the inner member need not be annular and, by modifying the shape of the inner member, the flow path could be presented to the overlapping teeth as a series of discrete separate flow pipes, or a series of crescent shaped segments.

Whereas in the above described embodiment, the flow path has both axial and radial components at the point where it passes through the teeth, the flow could be entirely radial (inwardly or outwardly) or entirely axial. All flow need not pass between the teeth. Alternatively, a significant proportion of the flow could bypass the teeth either through a channel cut along the axis of the inner member or by other means external or internal to the valve body. In this case, the flow through the teeth could have a very small or even non-existent steady component, the steady component being provided by the flow bypassing the teeth.

More than one pair of overlapping teeth could be used. For example, the flow could be split into two or more concentric annular flow passages which would then each pass through two or more sets of paired teeth. Different pairs of teeth need not be in the same axial plane and need not be directly connected to the same driving mechanism.

In the above described embodiment, the bearing is shown to bound the outer member, but the bearing could be inboard of the outer member.

The valve need not be in the fuel pipe but may instead be in an air flow pipe to the combustion chamber. Indeed, the valve is suitable for providing flow modulation in any fluid, including fuel, water, air or another gas.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

Claims

1. A flow control valve including first and second members defining a flow path therebetween and means for establishing continuous relative rotation of the first and second members, wherein during relative rotation of the members the effective cross sectional area of the flow path varies cyclically at a rate dependent upon the relative speed of rotation of the members.

2. A flow control valve according to claim 1 wherein the first and second members are able to rotate at a relative rotational frequency of at least about 400Hz.

3. A flow control valve according to claim 1 or claim 2 wherein during a single cycle of relative rotation of the first and second members, the effective cross sectional area of the flow path passes through a plurality of maxima and minima.

4. A flow control valve according to any preceding claim wherein the ratio of the minimum effective cross sectional area to the maximum effective cross sectional area is between 60% and 95%, thus providing a steady component and an unsteady component of fluid flow through the device.

5. A flow control valve according to any preceding claim wherein during rotation a face on the first member at least partially overlaps and slides against a face on the second member.

6. A flow control valve according to claim 5 wherein at least one of the members is provided with a plurality of projections and recesses giving the overlapping face of the member an irregular edge, the recesses defining a part of the flow path.

7. A flow control valve according to claim 6 wherein the other member is also provided with a plurality of projections and recesses giving the overlapping face of the member an irregular edge, and relative movement of the respective faces causes variation in the effective cross sectional area of the flow path.

8. A flow control valve according to claim 7 wherein the projections and recesses on at least one of the members are substantially sinusoidal in sectional shape.

9. A flow control valve according to any preceding claim wherein one of the first and second members is not continuously rotatable in use, but means are provided for adjusting its angular orientation.

10. A flow control valve according to any preceding claim wherein the first member is substantially circular in cross section, defining a substantially annular flow path therearound.

11. A flow control valve according to claim 10 wherein the second member is approximately annular in shape and is rotatable substantially around the first member, such that an inner face of the second member at least partially overlaps and slides against an outer face of the first member.

12. A flow control valve according to any preceding claim wherein the ratio of the minimum effective cross sectional area to the maximum effective cross sectional area is variable.

13. A flow control valve according to claim 12 when appended to claim 5 or 11 wherein the ratio may be varied by varying the extent of overlap of the two faces.

14. A flow control valve substantially as herein described with reference to Figs. 3 to 7 of the drawings.

15. A flow control valve according to any preceding claim, further including means for controlling the speed of relative rotation of the members in dependence upon a variable input signal.

16. A flow control valve including means defining a fluid flow passage of a predetermined effective cross sectional area, non-reciprocating valve means operable to rapidly and continuously vary the cross sectional area of the flow path and means for controlling operation of the valve means in response to a variable input signal.

17. Apparatus for minimising noise or vibration in a combustion chamber, the apparatus including a valve according to claim 15 or claim 16, wherein the variable input signal is dependent upon a detected noise or vibration frequency.

18. Combustion apparatus including apparatus for minimising noise or vibration according to claim 17.

19. Combustion apparatus according to claim 18 including a premixed fuel lean burn combustion chamber.

20. Combustion apparatus according to claim 18 or claim 19 wherein the valve is located in a fuel pipe for the fuel injectors for the combustion chamber.

21. Combustion apparatus according to claim 18 or claim 19 wherein the valve is located in an air flow pipe for the combustion

chamber.

22. Combustion apparatus substantially as herein described with reference to Figs. 2 to 7 of the drawings.

23. Any novel subject matter or combination including novel subject matter disclosed herein, whether or not within the scope of or relating to the same invention as any of the preceding claims.

Application No: GB 0016997.9 12 **Examiner:** Trevor Berry
Claims searched: 1 to 22 **Date of search:** 22 December 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): F1G (GNB), F4T (TAT), G3H (HAC, HBY, HDA, HDX)

Int Cl (Ed.7): F02C, F15B, G10K

Other: ONLINE: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US 4646733	STROH-note figures 3 to 8	1 at least
X	US 4556174	SIEKE-note figure 9	At least 1 and 16
X	US 4442755	ROZYCKI	At least 1 and 16
X	US 4199295	RAFFY	At least 1 and 16
X	US 4193149	WELCH-note figures 10 and 11	1 at least
X	US 3937252	ISHIDA	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.