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 (72) Inventor: ROBERT NOEL PENNY

(19)



## (54) CENTRIFUGALLY CONTROLLED FUEL SYSTEM

(71) We, NOEL PENNY TURBINES LIMITED, a British Company of Siskin Drive, Toll Bar End, Coventry, West Midlands, do declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to a centrifugally controlled fuel system for use with gas turbine engines or other engines, where it is necessary to provide variable fuel flow corresponding to different operating conditions. An object of the invention is to provide a fuel system by which different predetermined fuel delivery for different rotational speeds may readily be obtained.

According to the invention, the fuel system comprises a tubular shaft arranged to be rotated at engine speed or at a speed proportional thereto and having a fuel inlet through which fuel is introduced into the interior of the shaft during operation of an engine to which the fuel is to be supplied, a port in the peripheral wall of the shaft communicating externally of the shaft with a combustion region of the engine, resiliently-supported valve member mounted on the outside of the peripheral wall of the shaft in registration with the port therein and arranged to move away from the shaft centrifugally as the speed of rotation of the shaft increases, thereby to open the port and thus to allow fuel to flow through the port to the combustion region.

Preferably several of said ports are spaced apart around the peripheral wall of the shaft, each port having a resiliently-supported valve member in registration therewith. The said resiliently-supported valve members may be arranged to open the associated ports at different speeds, whereby as the speed of rotation changes, a different number of ports will be opened and hence a different flow of fuel will be

admitted to the combustion region. The resiliently-supported valve members may be so designed that the collective opening of the associated ports will produce a predetermined relationship of fuel flow to rotational speed of the shaft.

Conveniently, the or each valve member is supported by a resilient blade and is arranged to move away from the shaft centrifugally as the speed of rotation of the shaft increases and thereby to open the or the respective port, the or each respective blade being engageable with overspeed stop means to limit centrifugal movement of the or each blade and the associated valve member away from the shaft, the or each blade when in engagement with the overspeed stop means being arranged to close the communication between the or the respective port and the combustion region to prevent fuel from flowing to the combustion region, the resilience of the resilient blade supporting the or each valve member acting to return the respective valve member towards the position in which the corresponding port is closed when the speed of rotation of the shaft decreases below the speed at which the valve member enters into engagement with the overspeed stop means. The overspeed stop means may be positioned to limit the movement away from the shaft of the respective resilient blade and therefore the centrifugal movement of the or the respective valve member at different shaft speeds, thereby to reduce the total fuel flow in accordance with a predetermined relationship between fuel flow and shaft speed. The overspeed stop means may be defined by a cam surface, for example a shaped circumferential surface of a sleeve. The sleeve or other cam surface may be adjustable, whereby the movement away from the shaft of the or each resilient blade and therefore the centrifugal movement of the or the respective valve member is

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limited by a variable amount. Such movement may be effected manually either as a pre-adjustment before operation of the engine or during operation of the engine, or automatically in response to a variable operational condition of the engine.

Additionally or alternatively to the provision of the overspeed stop means, the or each port may be associated with a further centrifugally and resiliently operable valve member mounted on the inside of the shaft, the or each further valve being arranged to open the associated port when the shaft is stationary and being arranged to move centrifugally to close the associated port at a predetermined rotational speed, thereby to act as an overspeed stop. Where there is a plurality of ports and a plurality of said resiliently-supported and further resiliently operable valve members, each further valve member may be arranged to close the associated port at a different speed greater than the speed at which the associated resiliently-supported valve member will open the port, thereby to reduce the collective fuel supply in accordance with a predetermined relationship with shaft speed, following the supply of the collective fuel supply through the ports, in accordance with a predetermined relationship to shaft speed.

By variation of the port sizes, the centrifugal characteristics of the resiliently-supported valve members, the settings of the overspeed stop means, where provided, and/or the centrifugal characteristics of the further valve members, where provided, any desirable characteristic of fuel supply with shaft speed may be produced.

In a gas turbine engine, the shaft may conveniently be a main shaft of the engine, that is a shaft on which a compressor provided to supply air to the combustion region and a turbine provided to drive the compressor are mounted, although another shaft elsewhere in the engine or a shaft in a separate unit and arranged to run at the main shaft speed or a speed proportional thereto may be employed as the shaft of the aforesaid fuel system.

By way of example, a fuel system for a gas turbine engine, in accordance with the invention, and a modification of fuel system are now described by way of example with reference to the accompanying drawings, in which:-

*Figure 1* is an axial section through the fuel system showing the position of resiliently-supported and resiliently operable valve members when the shaft is stationary;

*Figure 2* is a section on the line II-II in *Figure 1*;

*Figure 3* is a section on the line III-III in *Figure 1* through a sleeve only, carrying the aforesaid resiliently-supported valve members;

*Figure 4* is a view similar to *Figure 1* but showing typical positions of said resiliently-supported and resiliently operable valve members at a first shaft speed;

*Figure 5* is a view similar to *Figures 1* and *4* but showing typical positions of said resiliently-supported and resiliently operable valve members at a higher shaft speed;

*Figure 6* is a view similar to *Figures 1, 4* and *5* but showing all said resiliently-supported and resiliently operable valve members closed at a still higher shaft speed; and

*Figure 7* is a view similar to *Figure 1* showing the aforesaid modification of the fuel system shown in *Figures 1-6*.

Referring to *Figures 1* and *2*, the fuel system comprises a tubular shaft 1 through which liquid fuel is arranged to flow in either direction from a fuel inlet. The shaft is arranged to run co-axially within a pair of stationary walls 12 defining between them an annular combustion region 13 or a passage leading thereto. The shaft may be a main shaft of the engine on which compressor and turbine rotors (not shown) are mounted or it may be a shaft driven by the engine at the same speed or at a speed proportional to the speed of the main shaft.

The interior of the shaft 1 communicates through a plurality of valve-controlled ports 14 with an annular space 15 defined between the shaft 1 and a pair of co-axial sleeves 2 and 6 surrounding the shaft 1 and which are splined at 5 and 8 to rotate therewith co-axially within the walls 12 defining the combustion region 13. The annular space 15 communicates with the combustion region 13 through a plurality of fuel spray holes 11 in the sleeve 6. Although four holes 11 are shown in *Figure 2*, any greater or smaller number, including one only, may be provided. An orifice (not shown) of a size required to determine a maximum flow of fuel to be delivered to the engine through the shaft 1 to the ports 14 and the holes 11 may be fitted in the shaft 1.

The radially inner sleeve 2 carries a plurality of (e.g. four as shown) resilient blades 3, or only one blade 3, extending parallel with the axis of rotation of the shaft 1. The or each blade 3 carries a valve member, defining the aforesaid resiliently-supported valve member, arranged to close a respective port 14 when the shaft 1 is stationary or when the shaft 1 is rotating below a predetermined speed. The or each valve member is conveniently a ball 4 or part-spherical member. The resilience of each blade 3, determined by the thickness of the blade, and the weight of the associated ball 4 are such that the associated ball 4 will move outwardly under centrifugal force when the shaft 1 is rotating at or above the predetermined speed of rotation to open the

5 respective port 14. When the shaft 1 is stationary all the ports 14 are closed by the respective balls 4, but when the shaft 1, together with the sleeves 2 and 6, rotates, at or above said predetermined speed one or more of the balls 4 will move outwardly to open the respective port or ports 14 to admit fuel through the respective open port or ports 14 into the annular space 15. By 10 employing blades 3 of different thicknesses and/or balls 4 of different weights, any desired fuel flow/rotational speed relationship may be provided. For example, the fuel flow may be increased in steps by arranging for the balls 4 to move outwardly successively as the shaft speed increases. Figures 4 and 5 respectively show that at successively higher speeds at least one ball is moved outwardly to open the respective port 14 and at least one port 14 is closed by the respective ball (Figure 4) and at least two balls are moved outwardly to open the respective ports 14 (Figure 5).

25 As the speed of rotation of the shaft 1 increases, each blade 3 will continue to move outwardly until its further movement is arrested by the blade 3 coming into contact with the outer sleeve 6. When each blade 3 has engaged the outer sleeve 6, the maximum fuel flow permitted by the ball 4 carried by that blade will have occurred. The maximum travel of each blade 3 and hence of the associated ball 4 may be adjustable by providing a cam surface 16 on the inside of the outer sleeve 6 and turning or moving the sleeve 6 axially with respect to the inner sleeve 2. The splines at 8 between the outer sleeve 6 and the inner sleeve 2 may be used for axial adjustment but would not be provided where there is to be rotational adjustment of the sleeve 6. Adjustment of the outer sleeve 6 on the inner sleeve 2 may be made manually, e.g., by a lever mounted on the outer sleeve 6, either before or during operation of the engine or automatically in response to an operating condition of the engine.

35 The blades 3 may be of such shape that when they have reached their maximum permitted movement and have engaged the inner surface of the outer sleeve 6, the associated spray hole 11 will be closed by the respective blade 3, for example, an edge or rim on the blade 3 may completely embrace the hole 11, and so fuel in the space 15 cannot flow through the hole 11. In this way the fuel flow to the combustion region will be cut-off or progressively reduced as successive blades 3 close the respective holes 11. This provision thus provides an overspeed fuel cut-off facility.

60 Alternatively or additionally, another overspeed fuel cut-off device may be provided by providing, as shown in Figures 1, 2 and 4, 5 and 6, within the shaft 1 an internal

sleeve 9 keyed to the shaft and provided with one or a plurality of resilient arms 10 of which the outer end portions are arranged to close the inner end of an associated port 14 at speeds greater than a predetermined speed. The arms 10 define the aforesaid further resiliently operable valve members. When the shaft 1 is stationary or is rotating at less than the predetermined speed, the arms 10 are spaced from the ports 14 as shown in Figures 1, 4 and 5; but when a predetermined speed has been reached the or at least one of the arms 10 will move outwardly under centrifugal force and close a respective port 14, thereby preventing fuel from entering that port 14, as shown in Figure 6. By using arms 10 of different thickness the ports 14 can be closed successively as the shaft speed increases or all the ports 14 can be closed by the respective arms 10 substantially simultaneously when a predetermined overspeed has been reached.

85 In some applications, either the arms 10 or the aforesaid fuel cut-off facility by the blades 3 themselves may be provided. Figure 7 shows a modification where the arms 10 are not provided; instead a shaped portion 17 on the outside of each blade 3 would in the overspeed position close the holes 11. In other applications both overspeed facilities may be provided.

95 By appropriate design of the blades 3, the balls 4 and the cam surface 16, the overspeed facility provided by the blades 3 engaging the cam surface 16, where provided, and of the arms 10, where provided, any desired fuel flow characteristics with shaft speed may be provided.

#### WHAT WE CLAIM IS:-

105 1. A fuel system comprising a tubular shaft arranged to be rotated at engine speed or at a speed proportional thereto and having a fuel inlet through which fuel is introduced into the interior of the shaft during operation of an engine to which the fuel is to be supplied, a port in the peripheral wall of the shaft communicating externally of the shaft with a combustion region of the engine, a resiliently-supported valve member mounted on the outside of the peripheral wall of the shaft in registration with the port therein and arranged to move away from the shaft centrifugally as the speed of rotation of the shaft increases, thereby to open the port and thus to allow fuel to flow through the port to the combustion region.

115 2. A fuel system as claimed in claim 1 in which several of said ports are spaced apart around the peripheral wall of the shaft, each port having a resiliently-supported valve member in registration therewith.

125 3. A fuel system as claimed in claim 2 in which said resiliently-supported valve members are arranged to open the associated 130

ports at different speeds, whereby as the speed of rotation changes, a different number of ports will be opened and hence a different flow of fuel will be admitted to the combustion region.

4. A fuel system as claimed in any preceding claim in which the or each valve member is supported by a resilient blade and is arranged to move away from the shaft centrifugally as the speed of rotation of the shaft increases and thereby to open the or the respective port, the or each respective blade being engageable with overspeed stop means to limit centrifugal movement of the or each blade and the associated valve member away from the shaft, the or each blade when in engagement with the overspeed stop means being arranged to close the communication between the or the respective port and the combustion region to prevent fuel from flowing to the combustion region, the resilience of the resilient blade supporting the or each valve member acting to return the respective valve member towards the position in which the corresponding port is closed when the speed of rotation of the shaft decreases below the speed at which the valve member enters into engagement with the overspeed stop means.

5. A fuel system as claimed in Claim 4 in which the overspeed stop means is positioned to limit the movement away from the shaft of the respective resilient blade and therefore the centrifugal movement of the or the respective valve member at different shaft speeds, thereby to reduce the total fuel flow in accordance with a predetermined relationship between fuel flow and shaft speed.

6. A fuel system as claimed in Claim 4 or 5 in which the overspeed stop means is defined by a cam surface.

7. A fuel system as claimed in Claim 6 in which the cam surface is a shaped circumferential surface of a sleeve.

8. A fuel system as claimed in Claim 6 or 7 in which the cam surface is adjustable, whereby the movement away from the shaft of the or each resilient blade and therefore the centrifugal movement of the or the respective valve member is limited by a variable amount.

9. A fuel system as claimed in Claim 8 in which the cam surface is adjustable manually.

10. A fuel system as claimed in Claim 8 in which the cam surface is adjustable automatically in response to a variable operational condition of the engine.

11. A fuel system as claimed in any preceding claim in which the or each port is associated with a further centrifugally and resiliently operable valve member mounted on the inside of the shaft, the or each further valve being arranged to open the associated

port when the shaft is stationary and being arranged to move centrifugally to close the associated port at a predetermined rotational speed, thereby to act as an overspeed stop.

12. A fuel system as claimed in claim 11 having a plurality of ports and a plurality of said resiliently-supported and further resiliently operable valve members, each further valve member being arranged to close the associated port at a different speed greater than the speed at which the associated resiliently-supported valve member will open the port, thereby to reduce the collective fuel supply in accordance with a predetermined relationship with shaft speed, following the supply of the collective fuel supply through the ports, in accordance with a predetermined relationship to shaft speed.

13. A fuel system, in a gas turbine engine, as claimed in any preceding claim in which the shaft is a main shaft of the engine, that is a shaft on which a compressor provided to supply air to the combustion region and a turbine provided to drive the compressor are mounted.

14. A fuel system, in a gas turbine engine, constructed and arranged substantially as described herein and shown in Figures 1 - 6 or Figure 7 of the accompanying drawings.

WALFORD & HARDMAN BROWN,  
Chartered Patent Agents,  
Trinity House,  
Hales Street,  
Coventry,  
West Midlands,  
Agents for the Applicants.

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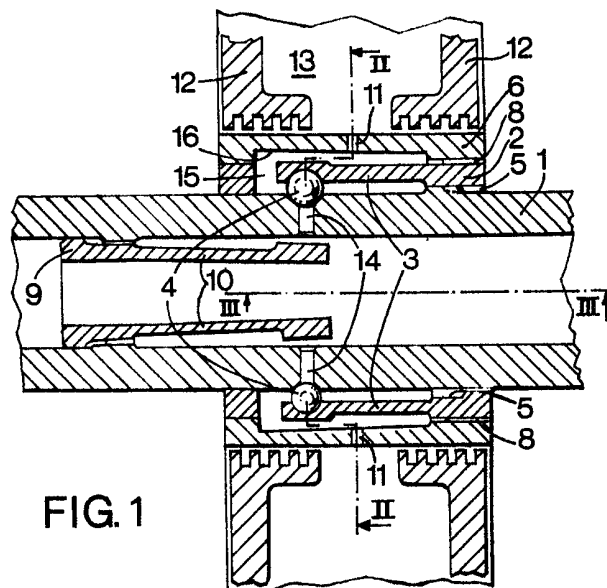


FIG. 1

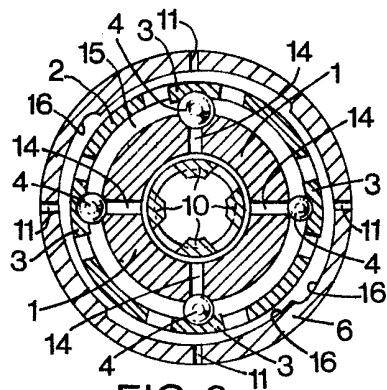


FIG. 2

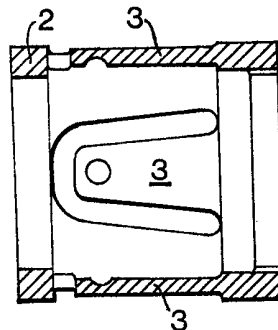


FIG. 3

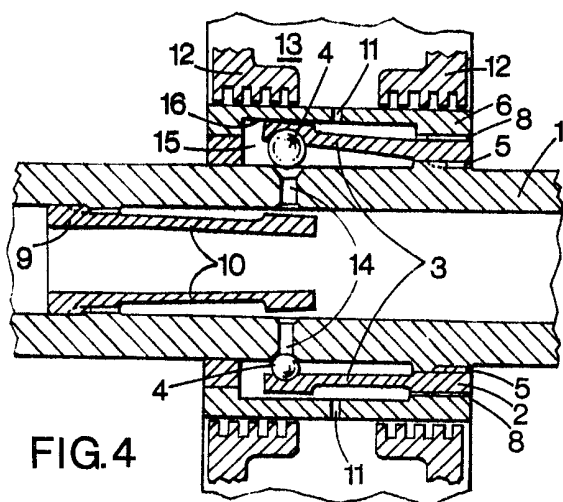


FIG. 4

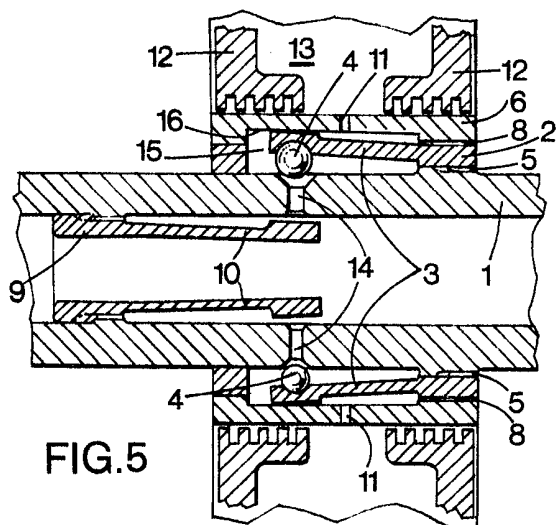


FIG. 5

