PATENT SPECIFICATION

(11) 1 588 124

1 588 124

(21) Application No. 44792/76 (22) Filed 28 Oct. 1976
(23) Complete Specification filed 28 Sept. 1977
(44) Complete Specification published 15 April 1981
(51) INT CL[3] G05D 7/06//F02C 9/00
(52) Index at acceptance G3R A33 A34 BG29 C282 C292 C293 C294 C295
(72) Inventor BRIAN EDMUND SPARKS

(19) THE PATENT OFFICE LONDON

(54) GAS FLOW CONTROL SYSTEM

(71) We, LUCAS INDUSTRIES LIMITED, a British Company of Great King Street, Birmingham B19 2XF, do hereby 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:—

This invention relates to a gas flow control system, and in particular to such a system when intended for control of a fuel gas supply to a gas turbine engine. In gas flow control systems in which control is effected by means of a variable orifice, it is known to maintain the pressure up-stream of this orifice substantially constant, in order that flow shall be a known function of the effective area of the metering orifice. In such systems it is commonly the practice to regulate the aforesaid up-stream pressure by means of a pressure control device up-stream of the metering orifice.

The present invention relates to a gas flow control system in which the requirement for a separate pressure control device is avoided.

According to the invention a gas flow control system comprises a variable flow metering valve, a passage communicating with an outlet of said valve, said passage having an orifice through which the gas is, in use, discharged prior to its combustion, means for generating a first signal which is a function of a desired gas flow, means for generating a second signal which is a function of the gas pressure in said passage, means for generating a third signal which is a function of a pressure difference across said orifice, multiplying means for generating a fourth signal which is proportional to the product of said second and third signals, and actuator means, responsive to a difference between said first and fourth signals, for varying the effective flow area of said metering valve.

An embodiment of the invention will now be described by way of example only, and with reference to the accompanying drawings in which:—

Figure 1, is a block diagram of a system for controlling flow of fuel gas to a gas turbine engine and,

Figure 2, shows diagrammatically, a variable metering device forming part of the system of Figure 1.

As shown in Figure 1 a flow of gaseous fuel to a gas turbine engine 10 is controlled by a variable metering device 11. The outlet of the metering device 11 communicates, via a passage 12 with a burner manifold 13 of the engine 10. The manifold is provided with a plurality of burner orifices 14 through which the gas is discharged for combustion.

The variable metering device 11 has a valve control element 15 which is axially slidable by means of a double-acting piston 16. Piston 16 is urged in opposite directions by pressures applied to respective lines 17, 18, these pressures being controlled by an electro-hydraulic valve 19 which is responsive to an electrical control signal on a line 20. Hydraulic supply pressure and return lines 21, 22 communicate with the valve 19 and with a hydraulic pressure source 23, the lines 21, 22 being interconnected by a relief valve 24. A linear displacement transducer 25 is responsive to the position of the control element 15 to provide on a line 26, a signal A proportional to the gas flow area of the metering device 11.

A transducer 30 provides, on a line 31 a signal P2 proportional to the delivery pressure of a compressor of the engine 10, the compressor delivery pressure being equal to the pressure downstream of the orifice 14. An analog to digital converter 32 provides on a line 33, a digital signal equivalent to the signal P2.

A circuit 34 is responsive to the P2 signal on line 33, and to other engine operating parameters, for example engine speed N and combustion temperature Tc, to generate, on a line 35, a digital signal corresponding to a desired fuel flow Q_D

to the engine 10. Circuit 34 is also responsive to a signal θ on a line 36, the signal θ corresponding to a desired speed of the engine 10.

A transducer 40 is responsive to the gas temperature in the passage 12 to generate, on a line 41, a signal T proportional to this temperature. An analog to digital converter 42 is responsive to the signal on line 41 to generate, on a line 43, a digital equivalent of the signal T. A circuit 44 is responsive to the signal on line 43 to generate, on a line 45 a signal proportional to $1/\sqrt{T}$.

A transducer 46 is responsive to the gas pressure in passage 12 and also to the compressor delivery pressure to generate, on a line 47, a signal DP proportional to the pressure drop across the burner orifices 14. An analog to digital converter 48 is responsive to the signal on line 47 to generate, on a line 49, the digital equivalent of the signal DP. An adder circuit 50 is responsive to the signals on lines 33 and 49 to provide, on a line 51, a signal P proportional to the pressure in passage 12.

A dividing circuit 52 is responsive to the signals on the lines 49 and 51 to provide, on a line 53, a signal proportional to DP/P. A circuit 54 is responsive to the signal on line 53 to provide, on a line 55, a signal proportional to $\sqrt{DP/P}$.

A function generator 60 is responsive to the signals on line 53 to provide, on a line 61, a signal corresponding to ϕ_2, where,

$$\phi_2 = \sqrt{\left(\frac{2}{\gamma - 1}\right)\left(\left[\frac{P_2}{P}\right]^{\frac{2}{\gamma}} - \left[\frac{P_2}{P}\right]^{\frac{\gamma + 1}{\gamma}}\right)\left(\frac{\gamma}{2\,(1 - P_2/P)}\right)}$$

γ being the ratio; specific heat at constant pressure/specific heat at constant volume.

A store 62 can be set to contain a value A_b corresponding to the known effective flow areas of the burner orifices 14, and a constant K_2 corresponding to the characteristics of the gas to be supplied. The product A_bK_2 of these constants can be read out on a line 63.

A multiplier 64 is responsive to the signals on the lines 45, 51, 55, 61 and 63 to supply, on a line 65, an output corresponding to the actual mass flow Q_F of the gas, where

$$Q_F = K_2 A_b \phi_2 \sqrt{P.DP} \Big/ \sqrt{T}$$

An analog to digital converter 66 is responsive to the signal on line 26 to provide, on a line 67, a digital equivalent of the signal A from the transducer 25. An adder circuit 68 is responsive to the signals on lines 65, 67 to provide, on a line 69, a signal corresponding to Q_F+A. This signal is converted into analog form by a digital to analog converter 70.

Signals from the converter 70 are supplied to one input of a comparator circuit 71. A digital to analog converter 72 supplies, to a second input of the comparator 71, analog signals corresponding to the Q_D signals on line 35.

Operation of the electro-hydraulic valve 19 may be expected to be very rapid and to cause correspondingly rapid movement of the control element 15 of the metering device 11. Since, as indicated, the greater part of the operations performed in the control system are digital, these operations, together with analog to digital or digital to analog conversion may take up to 20 milliseconds to complete, during which time the control element 15 may have moved appreciably. Accordingly, therefore, the signal A from the transducer 25 is supplied to the comparator 71 to provide a feedback control. This feedback signal A is subtracted from the Q_F+A signal from the converter 70 and the result compared with the Q_D signal from the converter 72. The comparator circuit 71 is such that it provides no signal on its output line 73 when the result of this latter comparison is zero, that is when $Q_F=Q_D$. An amplifier 74 is responsive to the signals on line 73 to provide the control signal on line 20 to the electro-hydraulic valve 19.

The valve 19, and consequently the control element 15 of the metering device 11, are thus in equilibrium when actual flow Q_F is equal to demanded flow Q_D.

WHAT WE CLAIM IS:—

1. A gas flow control system comprising a variable flow metering valve, a

passage communicating with an outlet of said valve, said passage having an orifice through which the gas is, in use, discharged prior to its combustion, means for generating a first signal which is a function of a desired gas flow, means for generating a second signal which is a function of the gas pressure in said passage, means for generating a third signal which is a function of a pressure difference across said orifice, multiplying means for generating a fourth signal which is proportional to the product of said second and third signals, and actuator means, responsive to a difference between said first and fourth signals, for varying the effective flow area of said metering valve.

2. A system as claimed in Claim 1 which includes means for generating a fifth signal which is a function of the flow area of said outlet, said multiplying means being responsive to said fifth signal.

3. A system as claimed in Claim 2 in which said fifth signal generating means comprises means for generating said fifth signal as a product of said flow area function and of a constant which is dependent on the gas to be controlled by the system.

4. A system as claimed in any preceding claim which includes means for generating a sixth signal which is a function of the gas pressure in said passage, of the pressure downstream of said orifice and of the ratio of the specific heats volume, said multiplying means also being responsive to said sixth signal.

5. A system as claimed in any preceding claim in which said first signal generating means is responsive to operating conditions of the engine.

6. A system as claimed in any preceding claim which includes means for generating a seventh signal which is a function of the temperature of the gas in said passage, said multiplying means being responsive to said seventh signal.

7. A system as claimed in claim 6 in which said seventh signal generating means comprises means for generating said seventh signal proportional to the reciprocal of the square root of said temperature.

8. A system as claimed in any preceding claim which includes means for generating an eighth signal proportional to the flow area of said flow metering valve, said actuator means being responsive to said eighth signal.

9. A system as claimed in claim 8 which includes means for summing said fourth and eighth signals said actuator means being responsive to an output from said summing means.

10. A system as claimed in claim 9 in which said actuator means is responsive to the difference between the output of said summing means and the sum of said first and eighth signals.

11. A system as claimed in any preceding claim in which each said signal is an electrical signal.

12. A system as claimed in Claim 11 in which said signals are digital signals.

13. A gas flow control system substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

MARKS & CLERK,
Alpha Tower,
ATV Centre,
Birmingham B1 1TT,
Agents for the Applicants.

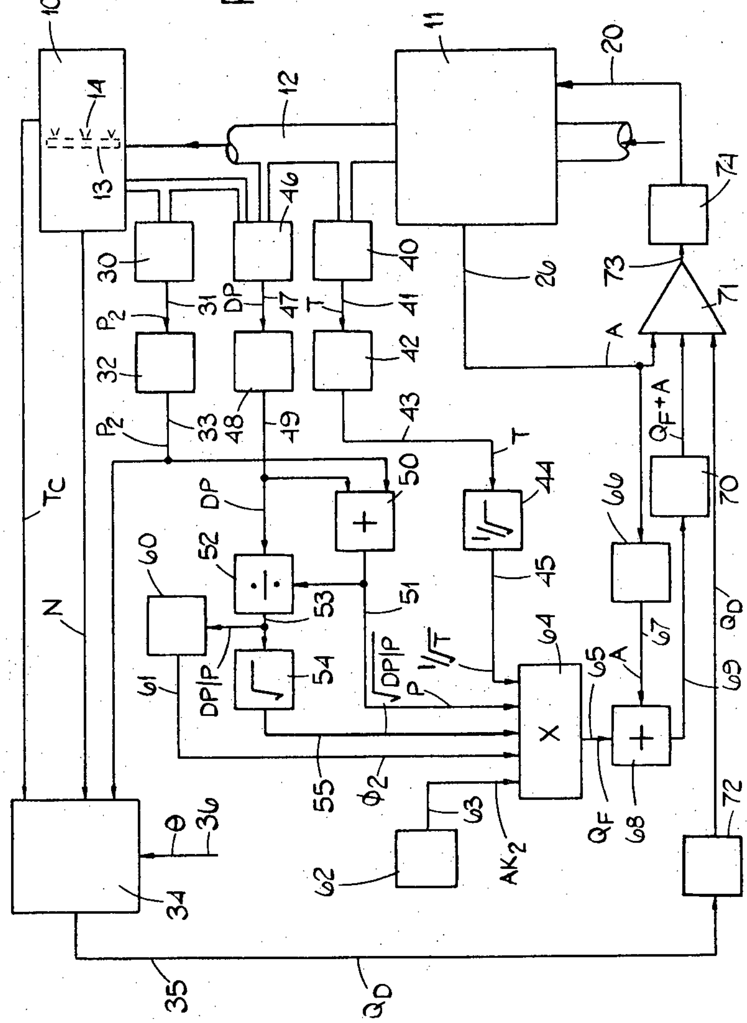
Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1588124 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1.



1588124 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

FIG. 2.