(12) UK Patent Application (19) GB (11) 2 315 100 (13) A

(43) Date of A Publication 21.01.1998

(21) Application No 9714471.1

(22) Date of Filing 09.07.1997

(30) Priority Data
(31) 19627759 (32) 10.07.1996 (33) DE

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(51) INT CL[6]
F02C 9/26 9/46 // F02C 9/28 9/32

(52) UK CL (Edition P)
F1G GND G801 G805 G806 G811 G821 G822

(56) Documents Cited
GB 2300451 A GB 1226942 A GB 1141113 A
GB 1058927 A EP 0436513 A1 EP 0399437 A2

(58) Field of Search
UK CL (Edition O) F1G GNB GND
INT CL[6] F02C 9/00 9/26 9/32 9/38 9/46
ONLINE WPI

(54) **Fuel regulator for turbojet engines**

(57) A fuel-metering device (8, fig. 1) is connected between a fuel pump (21) and an engine burner (5), and an engine regulator (19) is provided which, depending on an engine rotor speed, supplies to the metering device control variables Ys/Ym representing the fuel throughflow. The metering device has two metering valves 11, 12, connected in series, each with a respective pressure regulating valve 14,15. A multiplier (18) is incorporated in the control of the downstream metering valve 12 so that the control variable Ys applied to this valve is greater than the control variable Ym applied to the upstream metering valve 11. In the normal case the downstream metering valve 12 therefore operates with a slightly larger opening and has no effect; in the case of the upstream metering valve 11 sticking open, the possible fuel throughflow is positively limited by the downstream valve. Speed overshoots can thus be kept within tolerable limits and reaction times are less than when engine sensors are used.

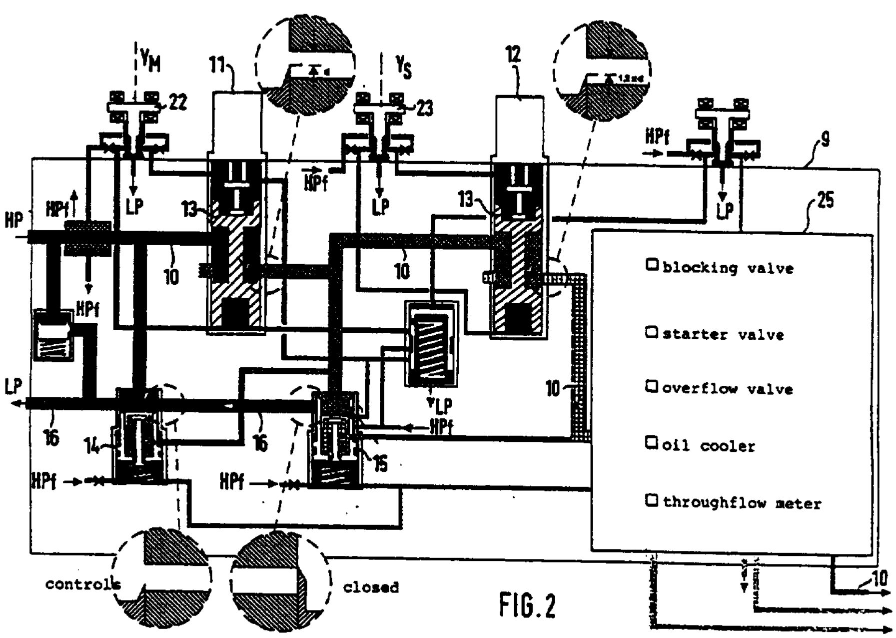

FIG.2

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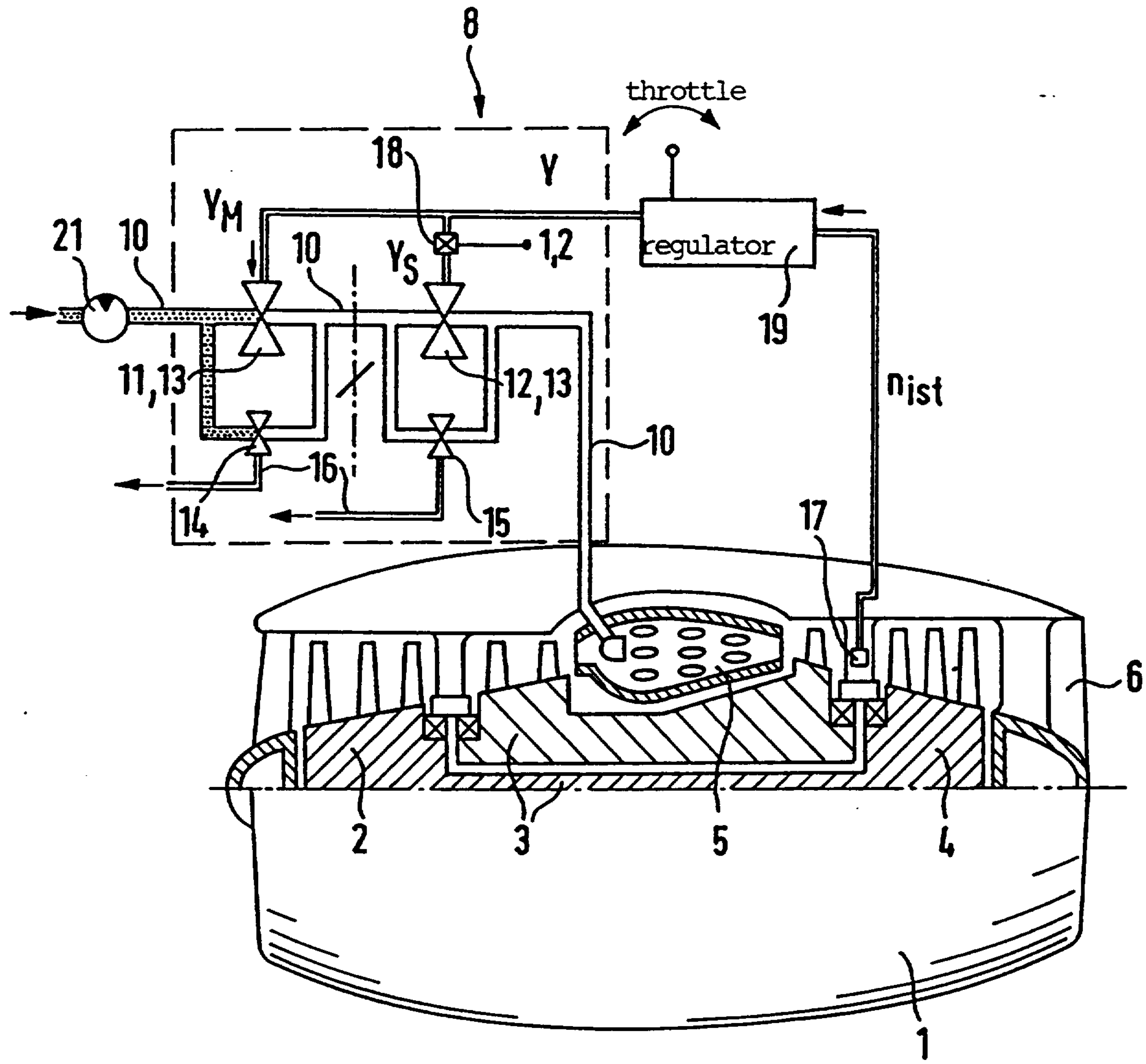
FIG.1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throttle
18
Y
Y_M
21
10
10
Y_S
1,2
regulator
19
11,13
12,13
n_{ist}
10
16
14
15
17
6
2
3
5
4
1

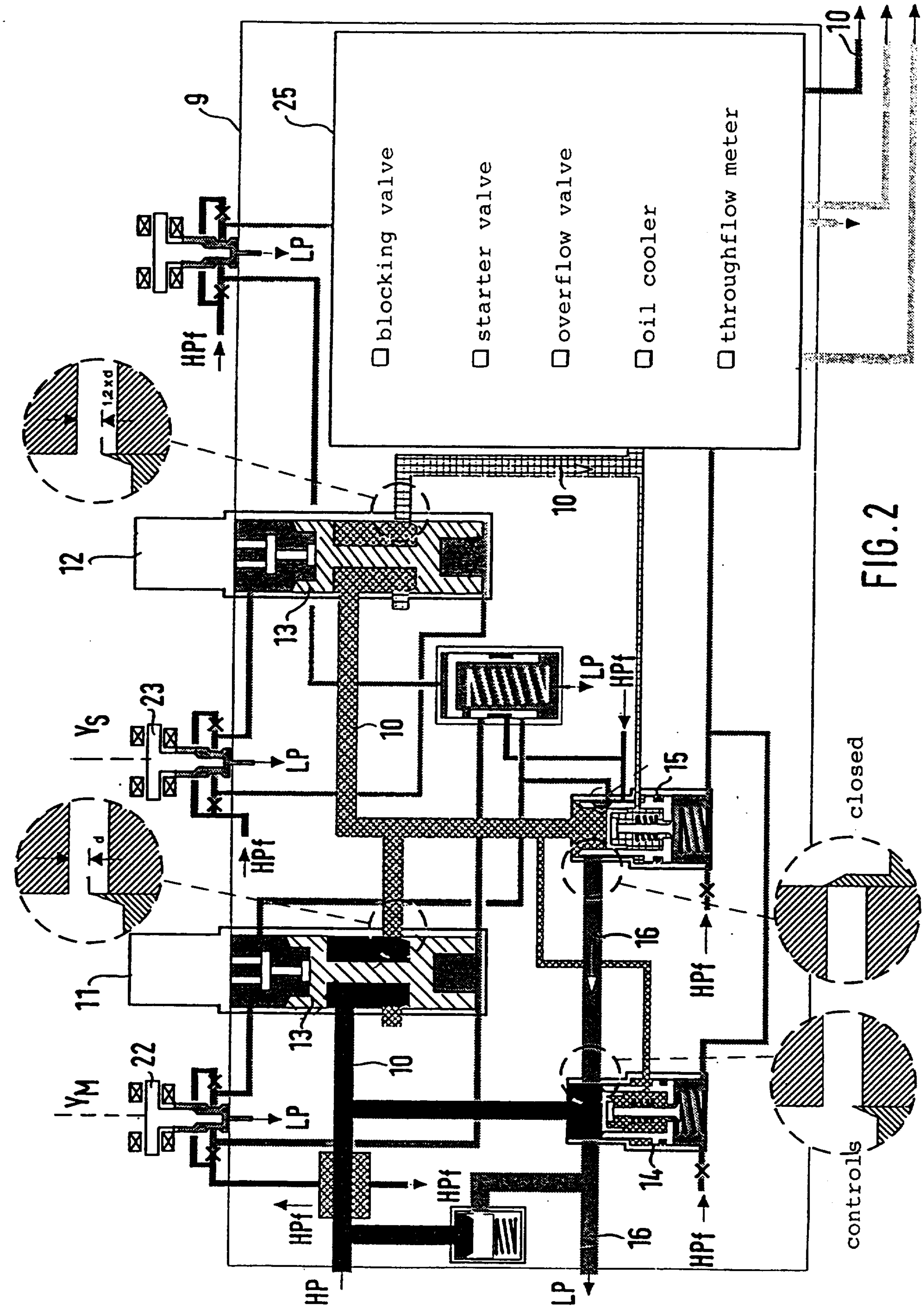
blocking valve
starter valve
overflow valve
oil cooler
throughflow meter
closed
controls
HP
LP
HPf
Y_M
Y_S
12xd
d
9
10
11
12
13
14
15
16
22
23
25

FIG.2

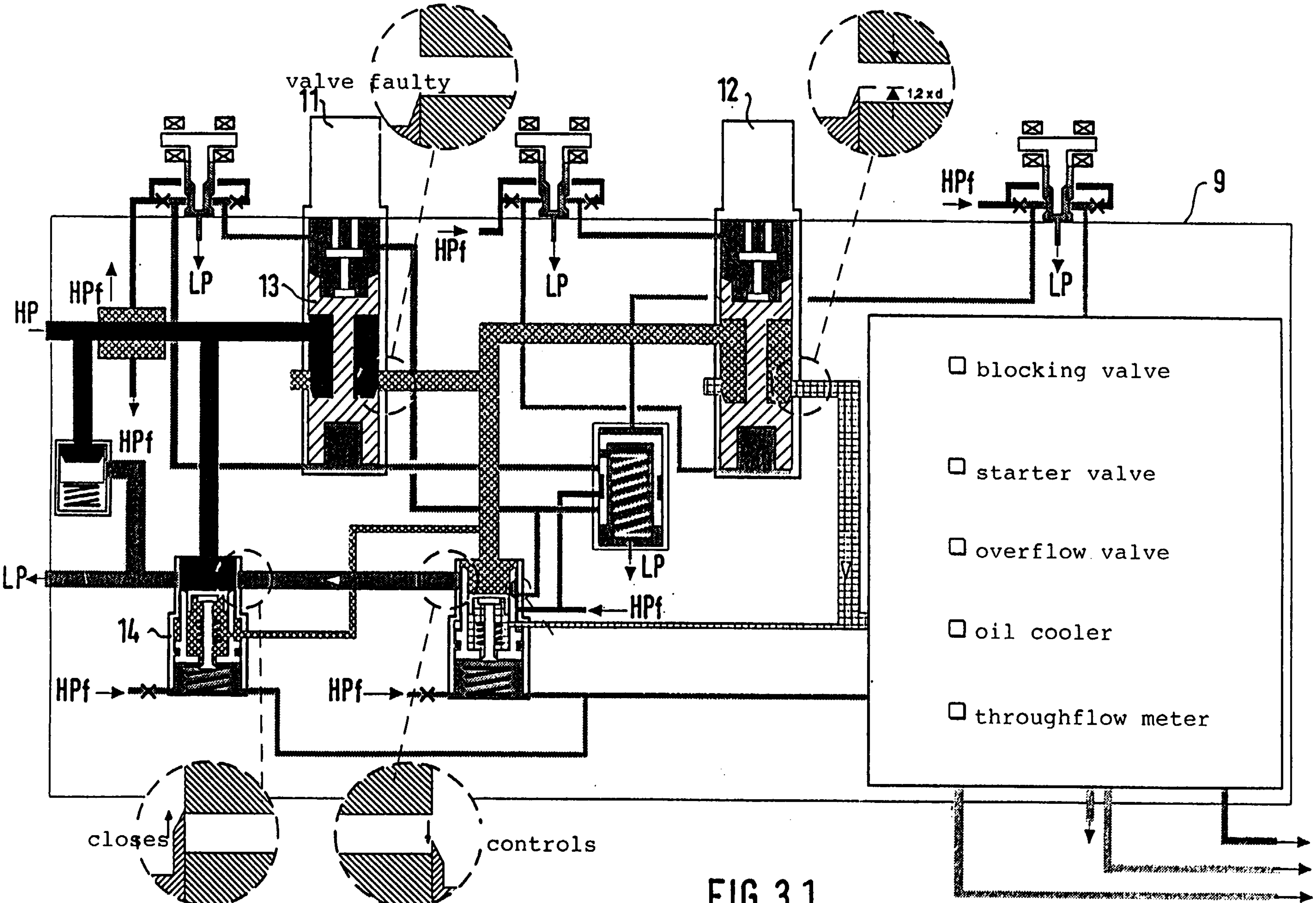
valve faulty
11
12
13
14
9
HP
HPf
LP
1.2xd
blocking valve
starter valve
overflow valve
oil cooler
throughflow meter
closes
controls

FIG. 3.1

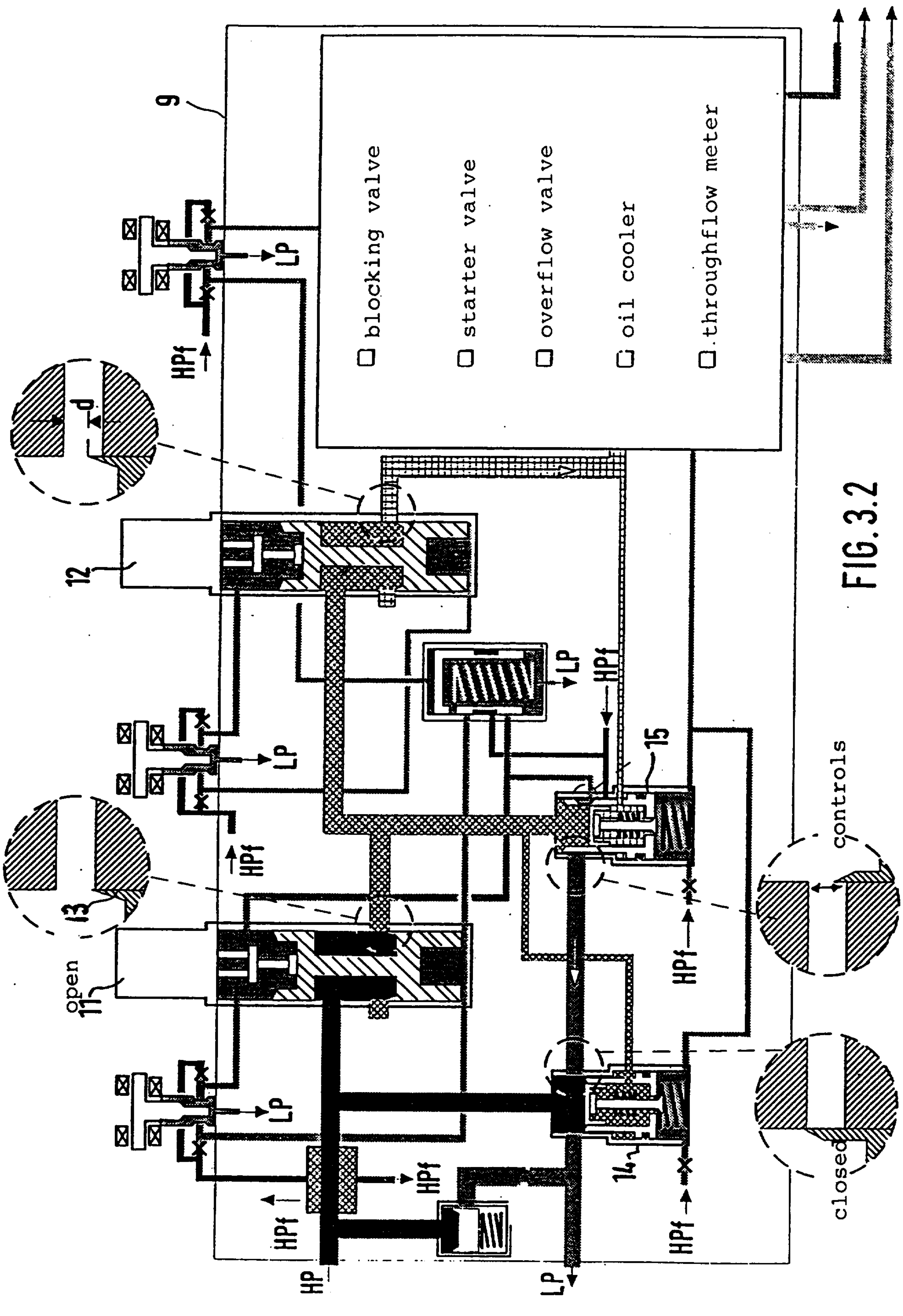
9
blocking valve
starter valve
overflow valve
oil cooler
.throughflow meter
12
11
open
13
d
15
14
controls
closed
LP
HP
HPf

FIG.3.2

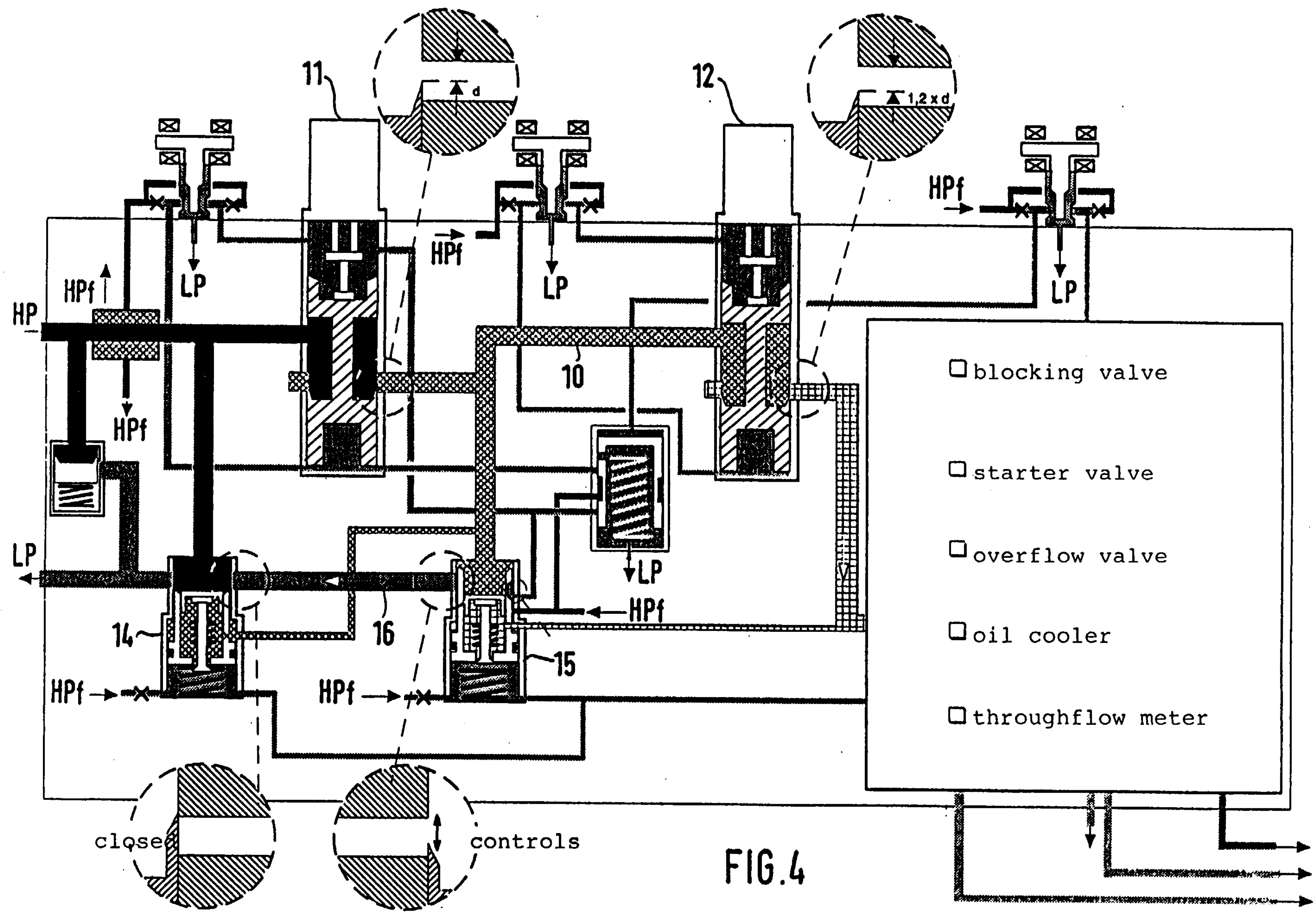
11
12
d
1,2 x d
HPf
LP
HP
10
16
14
15
blocking valve
starter valve
overflow valve
oil cooler
throughflow meter
close
controls

FIG.4

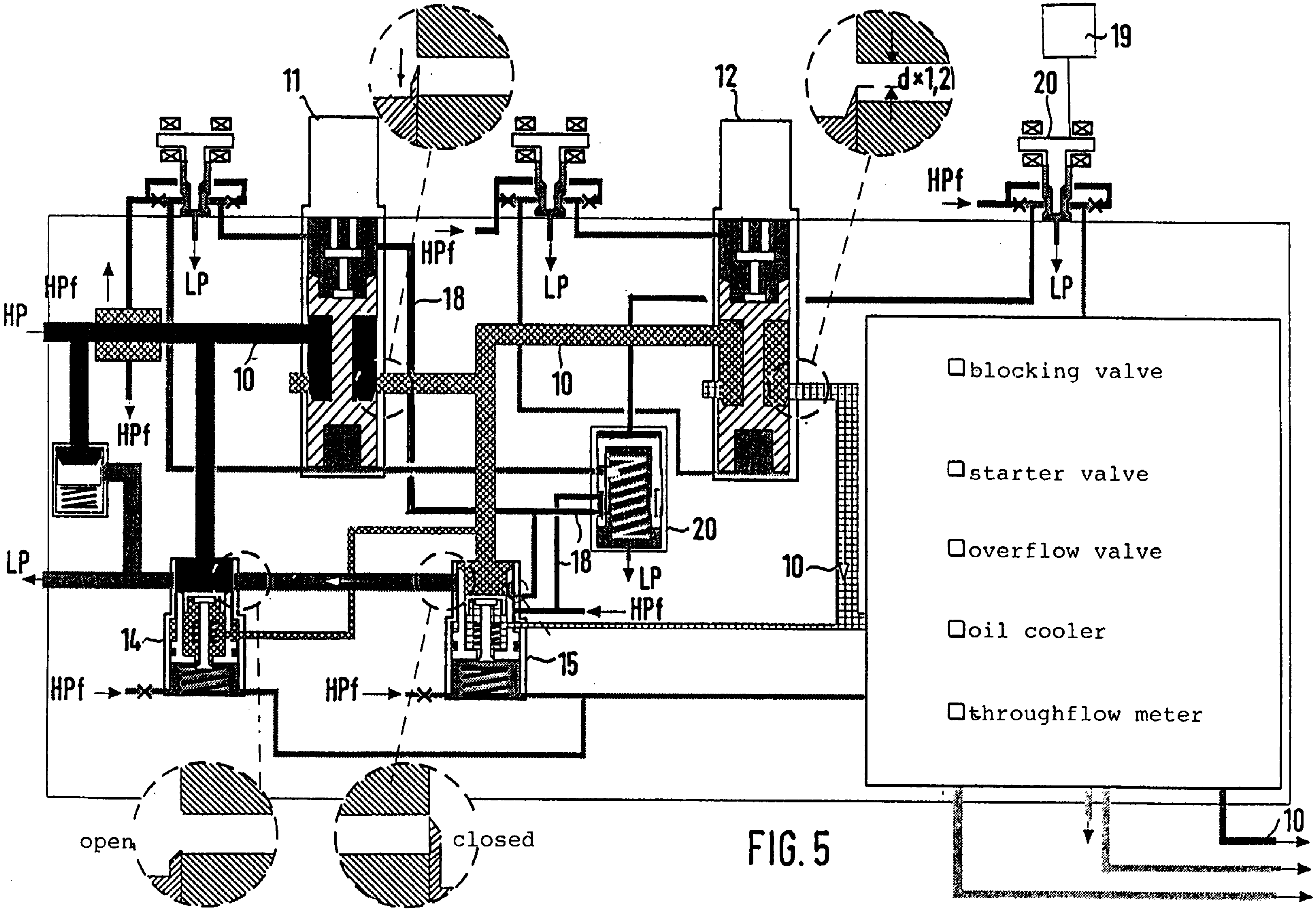
11
12
19
20
HP
HPf
LP
10
18
14
15
d×1,2
open
closed
blocking valve
starter valve
overflow valve
oil cooler
throughflow meter

FIG. 5

Fuel regulator for turbojet engines

The invention relates to a device for regulating a turbojet engine parameter, in particular a rotor speed (n), having a fuel-metering device connected between a fuel pump and a jet burner, to be acted on by an engine regulator which, depending on the engine parameter (n), supplies to the metering device a control variable (Y_S,Y_M) representing the fuel throughflow (m_T). Such a device is described in Patent Application DE - A - 195 45 987.

The essential purpose of the fuel regulation installation of a turbojet or gas turbine engine is to bring the engine to the appropriate thrust or power output according to the throttle position selected by the operator. This is effected by a regulated fuel supply to the burners of the engine. The regulating device has to take into account the operating limits of the engine such as, for instance, the highest permissible rotor speed or turbine temperature.

To protect the engine from excessive speeds in one of the rotors, the system disclosed in DE-PS 38 30 805 acts on a main metering valve by means of regulating circuits and control units so as to reduce excessive speed by reducing or stopping the fuel supply. As described in the above-mentioned patent application 195 45 987 also, a fuel metering device comprising a metering valve and a pressure-regulating valve connected in parallel with the metering valve is used for this purpose, the fuel- metering device being arranged in the fuel line between the fuel pump and the burners of the engine. By means of a mechanical or electronic regulator, a control variable representing the fuel throughflow is supplied to the metering device in dependence on an engine parameter such as the rotor speed and the throttle position. The metering valve opens or closes the fuel supply in dependence on this control variable, or moves into an intermediate position corresponding to the degree of throttle opening.

The pressure-regulating valve connected in parallel with the metering valve ensures a constant drop in pressure between the upstream and downstream connections of the metering valve so that the fuel throughflow corresponds in a predetermined way to the position of the metering valve.

It is a pre-requisite for a correcting action of the fuel-regulating device during malfunctions such as speed overshoots that faults of this type are detected by means of appropriate sensors on the engine side and are supplied to the regulating device so that it counteracts the faulty performance by the use of an appropriate control variable. In the known regulating devices, however, the time which elapses until malfunctions of this type are recognised and until the regulating device triggers counteracting actions leads to a continuing exceeding of the operating limit. Possible malfunctions are, for instance, the damage to engine components by excessive speeds due to an excess of fuel, or shutting off of the engine or its combustion chamber. However, the essential feature of the known regulating devices is the recognition of critical operating states by means of sensors.

Proceeding from this background, it is the aim of the invention to provide a device for regulating the supply of fuel which, with little needed in the way of sensors, on the one hand prevents the engine operating limits from being exceeded, and on the other hand prevents the engine from being unintentionally switched off.

The aim is achieved according to embodiments of the invention by having two metering valves connected in series in the fuel supply line, each with its own regulating valve for setting a constant pressure drop, the downstream metering valve being controlled in the same manner as the first but with an intermediate multiplier somewhat greater than unity.

The advantage of the invention is that, through the arrangement of two metering valves connected in series, the downstream metering valve can be operated in the normal case with a slightly larger opening position so that in the case of the open setting of the upstream metering valve erroneously being too large the possible throughflow of fuel through the fuel metering device as a whole is positively limited. Speed overshoots can thus be kept within tolerable limits and the engine can also be moved nearer to the disc fracture speed. Performance reserves can thus be better utilised.

The larger open setting of the downstream metering valve is produced by the imposition of a control variable Y_S that is, say, 20% larger than the control variable Y_M of the upstream metering valve. The resultant difference in the opening position of the metering valves leads to a positive limitation of the amount of throughflow to the higher value, without the necessity of action by the regulator, which in turn would have to react to the signal of a sensor. Prevention of overshoots is therefore not dependent in the first place on fault recognition times and activation times. During a malfunction, for instance when the metering valve is jammed in the open position, the limited overdosing of fuel resulting from the slightly larger control variable Y_S is noted by the regulator after the normal fault reaction time; the regulator then counteracts this increased fuel throughflow by a correspondingly reduced control variable Y so that the downstream metering valve now sets the necessary fuel throughflow.

A further advantage is that the increased open position of the downstream metering valve in the normal operating case means that regulation of the drop in pressure at the downstream metering valve by its regulating valve does not take place, so that the regulating action of the upstream regulating valve is not disturbed any regulating procedures of the downstream regulating valve. However, the primary advantage is that the excess of fuel and hence possible overshoots or exceeding of operating limits can be unambiguously determined by the position of the downstream metering valve.

Further preferred exemplary embodiments of the invention can be seen in the dependent claims.

A preferred embodiment of the invention is explained below with reference to the attached drawings in which:

Fig. 1 is a diagrammatic sketch of a jet engine with a device for regulating the fuel supply,

Fig. 2 is a diagrammatic sketch of a fuel metering arrangement in accordance with the invention in normal operating state,

Fig. 3.1 is a diagrammatic sketch of the fuel metering arrangement according to Fig. 2 in the "upstream metering valve open" fault mode at the start of the fault,

Fig. 3.2 is a diagrammatic sketch of the fuel metering arrangement according to Fig. 2 in the "upstream metering valve open" fault mode after correction of the fault,

Fig. 4 is a diagrammatic sketch of the fuel-metering arrangement according to Fig. 2 in the "upstream pressure regulating valve closed" fault operating mode, and

Fig. 5 is a diagrammatic sketch of the fuel metering arrangement according to Fig. 2 in the "upstream metering valve blocked" fault mode with controlled positive opening.

The jet engine 1 shown in Fig. 1 has a compressor 2 which is driven by way of a common rotor 3 by a turbine 4 and supplies the compressed air to the combustion chamber 5. The air heated in this expands in the turbine 4 and provides the thrust force for the jet engine 1 on exiting from the discharge nozzle 6. In a jet engine 1 of this type, the requirement is to set the engine parameters, such as the compressor pressure ratio, the nozzle pressure, the turbine inlet temperature and in particular the speed of the rotor 3, in dependence on the throttle position and the atmospheric values, and to control them within the operating limits. This control is carried out by means of a control system comprising a regulator 19 and a fuel-metering device 8. This system conveys the amount of fuel supplied by a fuel pump 21 from the tank to the combustion chamber 5 in a metered manner so that the engine parameters, here the desired speed n_{Soll} of the rotor 3, are attained. Provided in the fuel line 10 between the fuel metering unit 8 and the combustion chamber 5 are further units which can be assigned to the fuel system of the engine 1 and are referenced symbolically by the numeral 25 (Fig. 2). The units are, amongst others, Tw start valves, overflow valves, oil coolers and throughflow meters.

As can be seen in Fig. 2, which shows the fuel-metering device 8 provided in the fuel line 10 between the fuel pump 21 and the combustion chamber 5, the device includes two metering valves 11 and 12 connected in series, which can each adjust the amount of throughflow to the combustion chamber 5 by means of a respective control member 13 actuated by differential pressure. The positioning of the control members 13 is effected by means of a differential pressure transmitter or generator 22, 23 assigned to the respective metering valves 11, 12, and this converts the electrical control variable Y_M, Y_S, relating to the upstream or downstream metering valve 11, 12 respectively, into fuel pressure which in turn moves the control members 13 into the position corresponding to the variable Y_S or Y_M. Connected in parallel to each of the two metering valves 11 and 12 is a respective pressure-regulating valve 14, 15, which ensures a constant drop in pressure at the respective metering valve 11, 12 to ensure a well-defined correspondence of the throughflow at the respective metering valve 11, 12 to the position of its control member 13. The regulating valves 14 and 15, connected respectively upstream and downstream of the respective metering valve 11 or 12 to the main fuel line 10, ensure a drop in pressure, constant over the entire operating area, between the inlet and outlet of the metering valves 11, 12, by drawing off fuel upstream of the metering valve 11 or 12 into a return line 16 via the pressure-regulating valve 14 or 15. In the undisturbed operational mode, however, the downstream metering valve 12 does not undergo adjustment processes, since a larger control variable Y_S is applied to it in any event.

When regulating the rotor speed **n** the electronic regulator 19 compares the desired speed with the actual speed n_{IST} measured by means of the sensor 17, and supplies a corresponding control variable Y to the fuel-metering device 8 to preserve the desired speed n_{Soll}. The positioning of the control members 13 is carried out by means of the respective differential pressure transmitters 22, 23 assigned to the metering valves 11, 12, which converts the control variable Y_M, Y_S assigned to the upstream or downstream metering valve 11, 12 into fuel pressure, which in turn moves the control members 13 into the position corresponding to the control variable Y_S or Y_M. The control variable Y_M supplied to the upstream metering valve 11 causes a corresponding opening or closing of the upstream metering valve 11, and because of the constant drop in pressure at the metering valve 11 the control variable Y_M thus directly, i.e. proportionally, represents the fuel throughflow m_T at the upstream metering valve 11. The control variable Y_S supplied via a multiplier 18 to the downstream metering valve 12 is greater by a factor X, which in this example is 1.2, than the control variable Y_M which is supplied to the upstream metering valve 11.

When the regulating device is operating normally, the downstream metering valve 12 always has a larger open position than the upstream metering valve 11, and so in the end the maximum possible throughflow is set at the downstream metering valve, and the metering is carried out by the upstream one. This means that the fuel throughflow m_T through the downstream metering valve 12 is less than the position of the control member 13 of the downstream metering valve 12 would allow, because of the greater control variable Y_S. This also means too slight a drop in pressure at the downstream metering valve 12 and so the associated downstream pressure-regulating valve 15 tries to counteract this state by blocking the discharge of fuel into the return line 16. This operating mode also ensures that the regulating action of the upstream pressure-regulating valve 14 is not disturbed by the second downstream pressure-regulating valve 15 since the latter is in the closed position.

Now the case will be described where there is a fault condition in the fuel-metering device 8, for instance if the control member 13 of the upstream metering valve 11 remains suspended in its open position or sticks - Fig. 3.1 shows this operating mode. With regulating devices according to the prior art, this fault could lead to damaging speed overshoots of the jet engine 1 because of the system-intrinsic reaction times. With the regulating device of the present embodiment, however, the possible fuel throughflow m_T at any instant is limited by the still operational downstream metering valve 12, and so the level of the speed overshoot can be directly affected by the size of the multiplication factor X. As this multiplication factor X is only slightly greater than 1, excess speeds that occur will be considerably less than in the prior art, so that the jet engine 1 can also be moved closer to its limits as no systematic fault reaction times have to be taken into account either.

Eventually, the slight overrun of the speed, limited by the factor X, is registered by the regulator 19, which regulates the control variable Y down in order to set the desired speed n_{soll}. In this operating state the too large open position of the upstream metering valve 11 leads to closure of the upstream pressure- regulating valve 14 as a result of the inadequate drop in pressure, and now, since the downstream metering valve 12 becomes crucial for the fuel throughflow m_T, the downstream pressure-regulating valve 15 will take over the regulating procedure for the correct pressure conditions at the downstream metering valve 12 by controlling fuel into the return line 16. Finally, as can be seen in Fig. 3.2, the control member 13 of the downstream metering valve 12 is in the appropriate position for metering. The over-large open position determined by the factor X has been corrected by appropriate down-regulation of the control variable Y. The fuel supply can therefore be regulated independently of the erroneous position of the upstream metering valve 11 without loss of the regulating characteristics of the regulating device.

A third operating mode (second error mode) is shown in Fig. 4, wherein the upstream pressure-regulating valve 14 is shown in a faulty setting. The valve is blocked in the closed position so that it is no longer possible to control fuel into the return line 16. This means that the inlet of the upstream metering valve 11 is acted on by too high a fuel pressure, and this leads to an increased fuel throughflow m_T for a given position of the control member 13 of the upstream metering valve 11. These malfunctions mean, therefore, that there is no longer a clear correspondence of the position of the control member 13 to the fuel throughflow m_T. Now the downstream pressure-regulating valve 15 connected to the fuel line 10 between the two metering valves 11 and 12 comes into play and, in reaction to the increased fuel pressure between the two metering valves 11 and 12, draws the excess fuel stream into the return line 16 so as to maintain the specific drop in pressure at the downstream metering valve 12. Nevertheless, because of the calculatedly larger downstream control variable Y_S according to the factor X a slightly increased amount of fuel is supplied to the combustion chamber 5; this continues until the regulator 19 ascertains a deviation of the desired variables from the measured engine characteristics and correspondingly reduces the control variable Y until the downstream metering valve 12 meters the correct fuel throughflow m_T. The downstream valves 12, 15, which otherwise remain passive, in normal operating states, thus carry out the sole measurement of the fuel throughflow m_T.

Finally, Fig. 5 shows a fourth operating mode in which the control member 13 of the upstream metering valve 11 is locked in the closed position. The excess fuel coming from the fuel pump is drawn via the upstream pressure-regulating valve 14 into the return line 16. Since the downstream metering valve 12 also cannot operate in a case like this because of the series connection, a controlled opening of the blocked metering valve 11 or 12 is provided.

To this end the engine control unit 19 fed by engine variables recognises an insufficient supply of fuel and by means of an additional valve arrangement 20 analogous to the pressure converters 22, 23 puts a high-pressure connection line 18 under pressure via a valve 24, forcing the blocking control member 13 downwards into the open position.

An automatic forced opening of the upstream metering valve 11 is effected by means of the downstream regulating valve 15 and the high-pressure connection 18 as soon as the regulating valve 15 begins the pressure-regulating process for the downstream metering valve 12. Because the open position of the valve 12 is larger in normal operation than that of the upstream valve, the pressure regulation procedure is only effected in the case of a malfunction, as described previously. In order to ensure a satisfactory, undisturbed substitute function of the downstream metering valve, it is advisable to force the malfunctioning upstream metering valve 11 into the open position.

The operating modes with the various fault possibilities have been shown by way of example for the upstream valves 11, 14 and also apply for malfunctions of the downstream valves 12, 15. It would also be conceivable to have the upstream valve as the limiting valve and the downstream valve as the normally-controlling valve.

Claims

1. A system for regulating the fuel supply of a turbojet engine (1) in dependence on at least one engine parameter, having a fuel-metering device (8) to be connected between a fuel pump (21) and a jet burner (5), to be acted on by an engine regulator (19) which, depending on the engine parameter, supplies to the metering device (8) a control variable (Y_S, Y_M) representing the fuel throughflow (m_T), characterised in that the metering device (8) has two metering valves (11, 12) connected in series so that the fuel supplied to the burner (5) flows through both metering valves (11, 12) one after the other, a respective regulating valve (14, 15) is associated with each metering valve (11, 12) for setting a constant drop in pressure at the respective metering valve (11, 12) and a multiplier (18) is incorporated into the control of the downstream valve in such a way that the control variable (Y_S) connected to the downstream metering valve (12) is greater by a factor X>1 than the control variable (Y_M) applied to the upstream metering valve (11).

2. A system according to claim 1, in which the drop in pressure at one or both metering values is kept constant by diverting fuel upstream of the respective metering valve (11, 12).

3. A system according to claim 1 or 2, in which each metering valve (11, 12) has a control member (13) actuated by differential pressure for setting the amount of pressure throughflow, and the differential pressure is set by a differential pressure transmitter (22, 23).

4. A system according to any preceding claim, in which at least the upstream metering valve is arranged so that it can be acted on by high pressure for forced opening.

5. A system according to claim 4, in which the forced opening is effected by the engine regulator (19).

6. A system according to claim 4 or 5, in which the forced opening of the upstream metering valve (11) is effected by the downstream regulating valve (15) as soon as it begins feeding fuel back during the pressure equalisation process.

7. A system according to one of the preceding claims, in which the regulator (19) is a PID regulator.

8. A system according to one of the preceding claims, in which the factor X is 1.2.

9. A system substantially as described herein with reference to any of the accompanying drawings.

10. A jet engine incorporating a fuel regulation system according to any preceding claim.

11. A method for regulating the fuel supply of a jet engine in dependence on at least one engine parameter, in particular a rotor speed (n), by way of a fuel-metering device connected between a fuel pump and a jet burner, acted on by an engine regulator which, depending on the engine parameter (n), supplies to the metering device a control variable (Y_S, Y_M) representing the fuel throughflow (m_T), characterised in that the metering device has two metering valves connected in series that the fuel supplied to the burner flows through both metering valves one after the other, one control variable (Y_M) is supplied to one of the metering valves in order to regulate the total flow, and the other control variable (Y_S) is supplied to the other metering valve and is greater than the control variable (Y_M) connected to the first metering valve.

Application No: GB 9714471.1
Claims searched: 1-10
Examiner: C B VOSPER
Date of search: 13 October 1997

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.O): F1G(GNB,GND)

Int Cl (Ed.6): F02C 9/00,9/26,9/32,9/38,9/46

Other: ONLINE WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X:P	GB 2300451 A	LUCAS (whole document)	1-3 at least
A	GB 1226942	LUCAS (fig. , and page 2, lines 22-25, noting series valves 19,20 controlled by different variables)	
X	GB 1141113	HOBSON (whole document but page 3, claim 1, in particular)	1
A	GB 1058927	BENDIX (page 8, claim 1)	
A	EP 0436513 A1	LUCAS (col. 7, lines 27-48; col. 8, line 53 - col. 9, line 21)	
A	EP 0399437 A2	COLT (whole document, noting fuel control devices 16,24 in fig., in particular)	

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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E Patent document published on or after, but with priority date earlier than, the filing date of this application.