

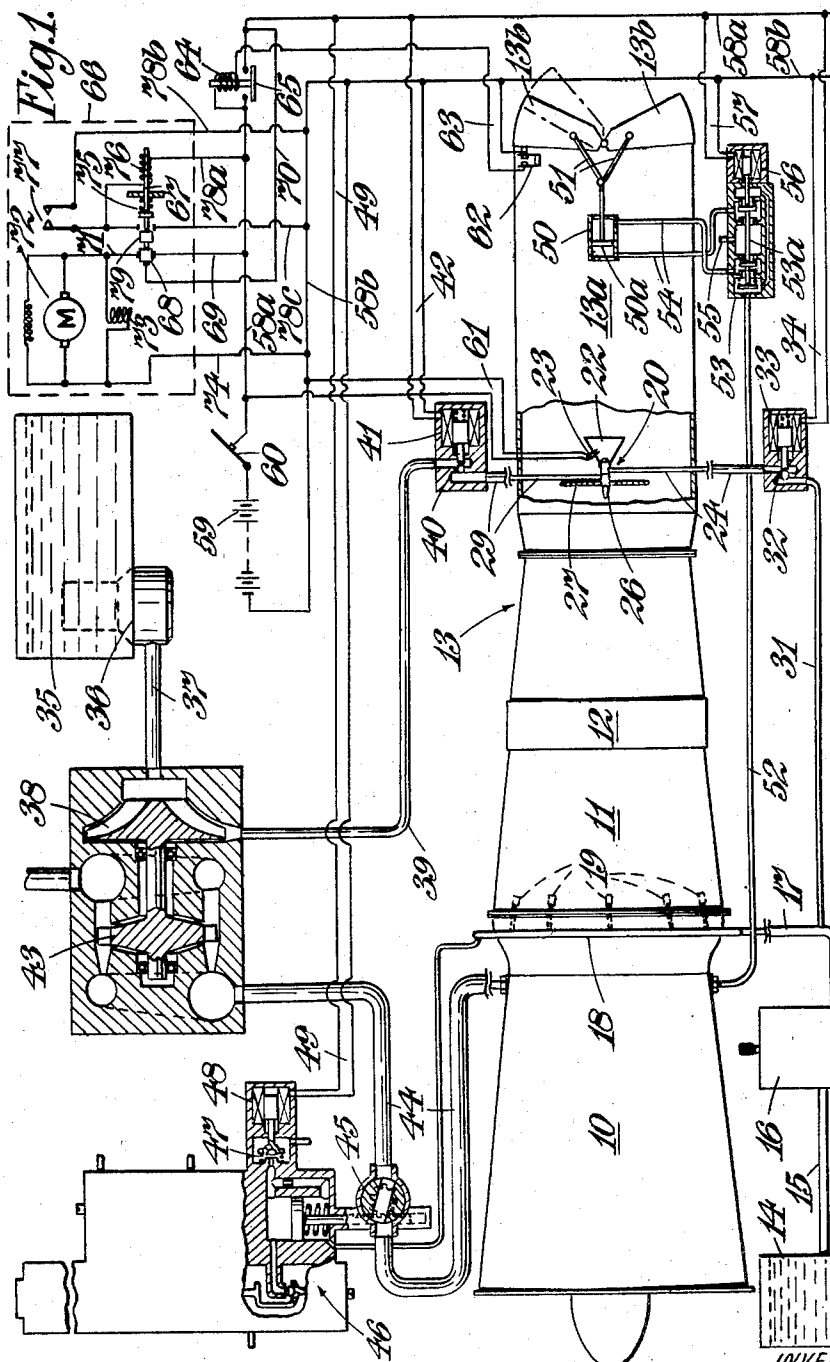
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GAS-TURBINE ENGINE WITH REHEAT COMBUSTION
EQUIPMENT AND VARIABLE AREA NOZZLE

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2 Sheets-Sheet 1



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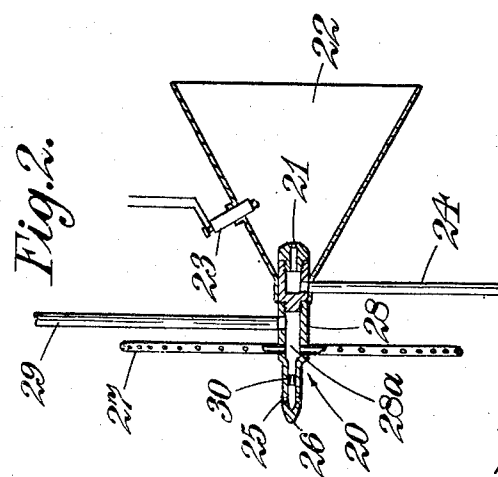
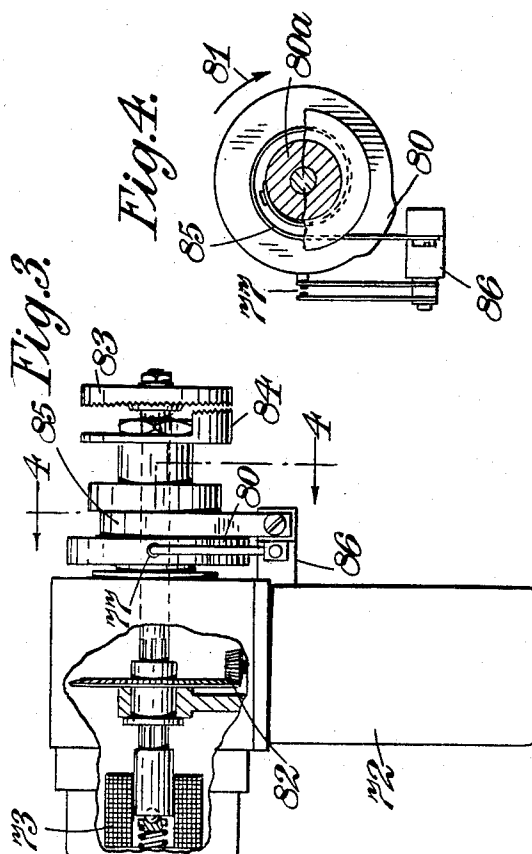
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2 Sheets-Sheet 2



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GAS-TURBINE ENGINE WITH REHEAT COMBUSTION EQUIPMENT AND VARIABLE AREA NOZZLE

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Claims priority, application Great Britain June 18, 1951

9 Claims. (Cl. 60—35.6)

This invention relates to jet-propulsion gas-turbine engines.

A jet-propulsion gas-turbine engine normally comprises a compressor to compress air for delivery to combustion equipment, a turbine receiving hot gas from the combustion equipment and driving the compressor, and an exhaust unit receiving the exhaust gases from the turbine and delivering them to atmosphere through a propelling nozzle to develop a propulsive thrust.

It is often required that the thrust developed by the engine should be temporarily in excess of the maximum that can be obtained from the exhaust gases from the turbine, and to achieve the temporary increase in thrust the exhaust gases are heated by having fuel burnt in them in the exhaust unit. It is common in engines having provision for the burning of fuel in the exhaust unit to make the propelling nozzle at the outlet from the exhaust unit adjustable in effective area, and when fuel is being burnt in the exhaust the propelling nozzle is adjusted to increase its effective area from the value of this area employed when no fuel is being burnt in the exhaust unit.

This invention relates to jet-propulsion gas-turbine engines of the kind (hereinafter referred to as the kind specified) having means to supply fuel to be burnt in an engine exhaust unit and also having an adjustable area propelling nozzle at the outlet to atmosphere from the exhaust unit, and this invention has for an object to avoid certain disadvantages of prior proposed control arrangements for the supply of fuel to the exhaust unit and for the control of the adjustable propelling nozzle.

According to this invention, there is provided a control system for use with a jet-propulsion gas-turbine engine of the kind specified, which control system comprises means to initiate a main supply of fuel to the exhaust unit, means to initiate combustion of said main fuel supply, means to initiate an opening adjustment of the adjustable-area propelling nozzle simultaneously with the initiation of the main supply of fuel, and time-operated means arranged to operate to cut off said main supply of fuel on failure of the nozzle to open to a selected area within a selected time from the moment of the simultaneous initiation of the main fuel supply and of the opening adjustment of the nozzle.

By arranging that the main fuel supply and opening of the nozzle are initiated simultaneously the advantage is obtained that there will be no loss of thrust due to opening of the nozzle before commencement of burning of fuel in the exhaust unit, and by arranging that the fuel supply is only continued provided the nozzle opens to a preselected area within a given time, damage to the nozzle parts and other parts of the exhaust unit and engine due to overheating in the event of failure of the nozzle to open, is avoided.

Conveniently it is arranged that the fuel supply is only permitted to continue if the nozzle, in the case of a nozzle which moves between minimum and maximum area positions, opens fully within a short time, for instance, within three seconds.

Preferably the time-operated means also causes the operation of the main fuel combustion initiating means to be stopped simultaneously. Preferably also the time-operated means is operative to initiate a closing adjustment of the adjustable-area propelling nozzle. In this way, if the nozzle does not open to the selected area

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within the selected time, not only is the likelihood of damage to the propelling nozzle elements greatly reduced, due to the cutting off of the main fuel supply, but also due to the nozzle being caused to return to the original position which it occupied prior to the selection of reheat combustion, normally the minimum area position, the thrust of the engine is restored to the normal value which is greater than would be obtained if the nozzle were allowed to remain in a position intermediate between the normal position and the reheat position.

According to a feature of this invention, the control may comprise an electrical time-controlled switch which is normally closed to pass electrical current for operating the means to initiate the main fuel supply and the means to initiate opening adjustment of the adjustable-area propelling nozzle and which is opened at the end of the selected interval of time, and includes also a nozzle-controlled switch arranged to be actuated when the nozzle has opened to the selected area and on actuation to render opening of the time-controlled switch ineffective to interrupt the fuel supply or nozzle opening.

The nozzle-controlled switch is conveniently in parallel with the time-controlled switch and is closed when the nozzle opens to the preselected area and may be afforded by a contactor of a relay whereof the coil is energized by closure of primary contacts by the propelling nozzle on reaching the selected effective area.

A jet-propulsion gas-turbine engine of the kind specified and its fuel systems and fuel supply control systems will now be described with reference to the accompanying drawings in which—

Figure 1 shows diagrammatically the jet-propulsion gas-turbine engine, its fuel systems and control systems,

Figure 2 is a detail of part of Figure 1 to a larger scale, Figure 3 illustrates a component suitable for use in the arrangement of Figure 1, and

Figure 4 is a section on the line 4—4 of Figure 3.

Referring to Figure 1, the jet-propulsion gas-turbine engine comprises a compressor 10 which is shown in outside view and as an axial-flow compressor, main combustion equipment 11 which may be of any convenient kind and which is connected to receive compressed air from the compressor 10, a turbine 12 which is also shown in outside view only and which is connected to receive hot gases from the main combustion equipment 11 and which is connected in a well-known manner to drive the compressor 10. The engine also comprises an exhaust unit 13 including a jet pipe 13a having at its outlet end an adjustable propelling nozzle afforded by a pair of nozzle segments 13b pivoted on the end of the jet pipe and adjustable between a maximum area position (as indicated in full lines in Figure 1) and a minimum area position (as indicated in chain lines in Figure 1).

In normal operation of the gas-turbine engine, fuel is burnt in the main combustion equipment 11 only, the fuel being conveniently drawn from a storage tank 14 through a pipe 15 by an engine-driven pump 16 and delivered by the pump through a delivery pipe 17 to a fuel manifold 18 supplying a ring of fuel injectors 19 which deliver the fuel into the combustion equipment. Any convenient control system may be adopted for the main fuel system.

In operation of a gas-turbine engine as just described it is often required that the thrust developed by the engine should be temporarily in excess of the maximum that can be obtained from the exhaust gases from the turbine 12, and to achieve this temporary increase in thrust the exhaust gases are heated by having fuel burnt in them in the exhaust unit 13.

One hitherto proposed form of fuel injection means for delivering fuel into the jet pipe 13a is indicated at 20 in Figure 1 and illustrated to a larger scale in Figure 2.

The fuel injection means comprises three separate injection means, the first injection means comprising an atomiser having a single orifice 21, being accommodated on the downstream side of and within a conical baffle 22 and having associated with it an electrical igniter device 23 which is conveniently mounted in the wall of the conical baffle 22. The atomiser orifice is supplied with fuel through a supply pipe 24.

The second injection means comprises a number of

orifices 25 in a nozzle member 26 arranged coaxially with the orifice 21 but upstream of the conical baffle 22. The orifices 25 form a pilot fuel supply injector.

The third injection means comprises a series of perforated radial arms 27 which extend outwardly from a boss 28 forming a central portion of the mounting of the fuel injection means 20 and the radial arms have central bores feeding the perforations therein from a chamber 28a in the boss 28. The perforated arms 27 constitute the main fuel supply means for supplying fuel into the jet pipe.

The pilot fuel supply means afforded by orifices 25 and the main fuel supply means afforded by the perforated radial arms 27 are both fed with fuel through a pipeline 29 leading to the chamber 28a in the boss 28. The orifices 25 in the nozzle 26 communicate with the chamber 28a through a restrictor 30.

The atomiser 21 is fed with fuel from the main fuel system of the engine through a pipeline 31 branching from the delivery pipe 17 and leading to the atomiser fuel supply pipe 24. The flow of fuel from the branch pipeline 31 to the atomiser fuel pipe 24 is controlled by an atomiser shut-off cock 32 the operation of which is controlled by a solenoid device 33 the coil of which is fed with energising current through leads 34. The arrangement is such that when the coil 33 is energised the atomiser shut-off cock 32 is open thus allowing fuel to flow from the main fuel system of the engine to the atomiser.

The fuel supply system to the pilot fuel orifices 25 and the main injectors 27 of the jet pipe fuel injection means, is separate from the main fuel supply system of the gas-turbine engine and will be referred to hereafter as the auxiliary fuel system.

The auxiliary fuel system comprises a storage tank 35 from which fuel is drawn by a booster pump 36 and the fuel is delivered through a pipe 37 to the eye of a main centrifugal pump 38. The delivery of the centrifugal pump 38 is connected with the pipeline 29 by a pipeline 39 and the flow of fuel from the pipeline 39 into the pipeline 29 is controlled by an auxiliary fuel supply shut-off cock 40. The auxiliary fuel supply shut-off cock 40 is controlled by a solenoid device 41 the coil of which is fed with energising current through leads 42. It is arranged that when the solenoid device 41 is energised, the shut-off cock 40 is open permitting a flow of fuel to the pilot orifices 25 and to the main injectors 27.

The centrifugal pump 38 of the auxiliary fuel system may be driven in any convenient manner and is illustrated as being driven by an air motor 43 which is supplied through a duct 44 with compressed air tapped off from the delivery of the compressor 10. The speed of operation of the air motor 43, and thus the delivery of pump 38, is controlled by a throttle 45 the position of which is controlled by a hydraulic mechanism indicated at 46, which mechanism includes a valve 47. The valve 47 is operated by a solenoid device 48 the coil of which is fed with energising current through leads 49. It is arranged that when the solenoid device 48 is de-energised, the throttle 45 is closed and that when the solenoid device 48 is energised the valve 47 closes and permits operation of the hydraulic mechanism 46 to adjust the throttle 45. The details of construction and operation of this form of drive for the pump 38 are fully set out in copending application Serial No. 237,628, filed July 19, 1951, in the names of D. O. Davies et al.

The nozzle segments 13b are moved between the two positions indicated in Figure 1 by means of a pneumatic ram 50, the piston 50a of which is connected by links 51 with the nozzle segments. Compressed air for the operation of the ram 50 is tapped off from the delivery of the compressor 10 through a duct 52 and is fed to the ram from the duct 52 under control of a reversing valve 53 inter-connecting the duct 52 with ducts 54 leading one to each end of the cylinder of the ram 50. The reversing valve 53 comprises a piston valve element 53a which in one position (the position shown) permits compressed air to flow from the duct 52 into the duct 54 leading to the right-hand end of the ram 50, and connects the other duct 54 with an exhaust duct 55; in this position of the valve the nozzle segments are moved to and held in the full line position illustrated in Figure 1. In the other position of the valve 53a the left-hand end of the cylinder of ram 50 is connected with the pressure air duct 52 and the right-hand end is connected

with the exhaust duct 55, and in this position of the valve 53a the nozzle segments are moved to the chain line position.

The piston valve element 53a is controlled as to its position by a solenoid device 56, the coil of which is fed with energising current through leads 57. It is arranged that when the solenoid device 56 is energised the piston valve element 53a is in a position in which the nozzle segments 13b are opened (full line position of Figure 1), and that when the solenoid device 56 is de-energised the piston valve element 53a is in a position in which the nozzle segments 13b are closed (the chain line position of Figure 1).

The solenoid devices 33, 41, 48 and 56 are required to be energised simultaneously and they are connected in parallel to the main current supply leads 58a and 58b which are connected with a suitable power source 59, and the lead 58a contains a main pilot-controlled switch 60 which must be closed before reheating of the exhaust gases can be effected.

The electrical igniter device 23 is connected by leads 61 to the main supply leads 58a and 58b and depends for its operation solely upon closure of the main pilot-controlled switch 60.

In order to avoid overheating and consequent damage to the jet pipe 13a and nozzle segments 13b should the nozzle segments 13b fail to open fully on initiation of combustion in the jet pipe, it is arranged according to the present embodiment of the invention that if the nozzle segments 13b have not reached the full line position within a selected time after closure of the switch 60, then the solenoid devices 33, 41, 48 and 56 are de-energised so rendering the jet pipe reheating system inoperative and closing off the nozzle segments to their chain line position.

In the embodiment illustrated, the following arrangement is adopted for this purpose. The nozzle segments 13b are arranged when they reach the full line position to close a pair of primary contacts 62 which contacts are in a circuit comprising leads 63 and a relay coil 64 and which circuit is connected across the main supply leads 58a and 58b so that when the switch 60 is closed and the primary contacts 62 are closed, the relay coil 64 is energised. The relay coil 64 operates a contactor 65 in main supply line 58a, and the contactor 65 is between the main pilot-controlled switch 60 and the connections to the main supply line 58a of the leads 34, 42, 49 and 57. Thus, when the contactor 65 is closed, the solenoids 33, 41, 48 and 56 are all energised.

Since, however, the primary contacts 62 are not closed until the nozzle segments 13b are fully open, means is provided to supply the solenoid devices with energising current during initiation of exhaust gas reheating, and there is provided for this purpose a time controlled switch mechanism indicated at 66.

The time controlled switch mechanism includes a contact-carrying bar 67 having on it a number of contact pieces including a contact piece 68 through which a lead 69 branching from the main supply line 58a at a point between the switch 60 and the contactor 65 is connected to a lead 70 branching from the main supply line 58a at a point therein on the side of the contactor 65 away from the point of connection of lead 69. The contact piece 68 also makes connection between the lead 69 and a supply lead 71 leading to an electric motor 72 and a clutch coil 73 the purpose of which will appear below, the other terminals of the motor 72 and clutch coil 73 being connected by a lead 74 to the main supply line 58b.

The contact-carrying bar 67 is controlled as to its position by a spring 75 urging the contact-carrying bar 67 into a position in which the contact piece 68 joins lead 69 with the leads 70 and 71, and by a solenoid 76 energisation of which is controlled by switch contacts 77. The solenoid 76 is connected by a lead 78a to the main supply line 58a at a point between the main pilot-operated switch 60 and the contactor 65 and by a lead 78b to the other main supply line 58b. It is arranged that when the solenoid 76 is energised by closure of the switch 77, the contact-carrying bar 67 moves to the right against the action of spring 75 immediately disconnecting lead 69 from lead 70, then by contact piece 79 connecting the solenoid 76 to the main supply line 58b through a lead 78c which is in parallel with the switch 77 and lead 78b, and finally moving the contact piece 68 so far to the right that the lead 69 is disconnected from the lead 71 so

cutting off the supply of current to the motor 72 and the clutch coil 73.

Referring now to Figures 3 and 4, the switch contacts 77 are arranged to be closed at a short interval, say three seconds, after closure of the pilot-operated switch 60, the closure of the switch contact 77 being effected by a cam 80, rotation of which in the direction of arrow 81 is started on closure of the pilot-operated switch 60. The cam 80 is rotated against the action of spring 85 one end of which is secured to fixed structure 86 and the other end of which is anchored to a boss 80a of the cam 80, the rotation being effected by the motor 72 through a reduction gear 82 which drives directly a toothed clutch plate 83, which clutch plate 83 is drawn into engagement with a toothed sector 84, against a resilient load, by energisation of the clutch coils 73 which, as shown, form part of a unit comprising the motor 72, reduction gear 82, clutch 83, 84 and switch mechanism 77, 80. The toothed sector 84 and cam 80 are secured together in any convenient manner.

The operation of the control system as above described is as follows.

When it is desired to burn fuel in the jet pipe 13 to heat the exhaust gases therein, the pilot closes the pilot-operated switch 60, so that current is supplied through leads 69 and 71 to drive the motor 72 and to energise the clutch coil 73 thereby to engage the clutch 83, 84, whereby the cam 80 starts to rotate.

At the same time current is supplied through leads 69, 70 (by-passing contactor 65) to the four solenoid devices 33, 41, 48 and 56 so that simultaneously

- (a) A fuel supply is started to the atomiser nozzle 21,
- (b) The air throttle 45 is opened allowing the air to be fed to air motor 43 thereby to drive the fuel pump 38,
- (c) The auxiliary fuel system shut-off cock 40 is opened allowing the fuel from pump 38 to be fed to the pilot orifices 25 and to the fuel injectors 27, and
- (d) Compressed air is supplied to the ram 50 so commencing opening of the nozzle segments 13b.

Simultaneously also current is supplied to the electrical igniter device 23 through lead 61.

The fuel fed to the jet pipe by atomiser orifice 21 is ignited by the device 23, and the fuel from the pilot orifices 25 and main injectors 27 is ignited by the flame produced by burning of the atomiser fuel. Combustion normally commences before the nozzle segments 13b are fully open.

If the nozzle segments 13b open normally and reach their full line position in less than the time required for the cam 80 to close switch contacts 77, the primary contacts 62 are closed and the relay coil 64 is energised so closing the contactor switch 65 and ensuring the continued energisation of the four solenoid devices 33, 41, 48 and 56 irrespective of the operation of the time controlled switch mechanism 66.

At the end of an appropriate interval, say three seconds, the cam 80 closes the switch contacts 77 thus energising the solenoid 76 which moves the contact-carrying bar 67 to the right immediately breaking the connection between contact piece 68 and the end of lead 70 and thereby disconnecting the lead 70 from the lead 69. This, however, has no effect since the contactor 65 has already been closed. The contact-carrying bar 67 continues to move to the right and when the contact piece 79 joins lead 78c to the solenoid 76 a holding circuit is set up to hold the contact-carrying bar 67 in its extreme right-hand position until the pilot-operated switch 60 is again opened. Just prior to the time at which the contact-carrying bar 67 reaches its extreme right-hand position the contact piece 68 moves clear of the leads 69 and 71 so de-energising the clutch coil 73 and stopping the motor 72. On de-energising the clutch coil 73 the clutch plate 83 disengages from the toothed sector 84 and the cam 80 is returned by the spring 85 to the position in which it started.

If at the end of the selected interval of time at which the switch contact 77 closes, the contactor 65 is still open due to the nozzle segments 13b not having opened fully and closed the primary switch 62, then as soon as the contact-carrying bar 67 commences to move to the right the four solenoids 33, 41, 48 and 56 will be de-energised since the supply of current to them through the leads 69, 70 is stopped. Thus, the supply of fuel to the atomising

orifice 21, the pilot orifices 26 and main fuel injection devices 27 will be stopped, the throttle 45 will be closed and the piston valve 53a controlling ram 50 will be moved to a position causing the ram piston 50a to move to the right, closing the nozzle segments 13b. The contact-carrying bar 67 will, however, continue to move to its right-hand position, first completing the holding circuit through lead 78c, coil 76 and lead 78a and then disconnecting the motor 72 and clutch coil 73 from the current supply, and the parts will remain in this position until the pilot-operated switch 60 is opened de-energising the solenoid 76 and allowing the contact-carrying bar 67 to return to its left-hand position.

It will thus be seen that the invention provides means whereby overheating of the nozzle segments 13b due to failure of the nozzle segments to open properly on commencement of burning of fuel in the jet pipe 13a can be avoided. Overheating of the turbine 13 due to the rise in pressure in jet pipe 13a and the consequent increased turbine inlet temperature is also avoided. Furthermore, it will be seen that, when the time-operated switch mechanism 66 has operated to cut off the fuel supply the nozzle segments 13b return to their minimum area position and thus the engine thrust will return to its normal value and there will be no continued loss of thrust due to the nozzle segments 13b remaining open. It will also be seen that once the time-operated switch mechanism 66 has operated to prevent burning of fuel in the jet pipe 13a the fuel supply mechanism cannot operate until the pilot has first opened his control switch 60 and closed it again.

As has been said the air throttle 45 may be controlled in the manner described in said co-pending Patent Application Serial No. 237,628 and if so controlled the throttle 45 is operated so that the ratio of the compressor delivery pressure to the pressure in the jet pipe is maintained at a constant value. For any given atmospheric conditions and engine speed, the compressor delivery pressure will be constant, and thus for given atmospheric conditions and engine speed the control operates to maintain the pressure in the jet pipe constant. For any given final nozzle area of the jet pipe, an increased supply of reheat fuel to the reheat combustion equipment will cause the pressure in the jet pipe to rise and vice versa; thus if the pressure in the jet pipe is reduced, for example, by an increase in the size of the final nozzle area, the control operates to restore the pressure to the controlled value by allowing more fuel to be supplied to the reheat combustion system.

Thus, when the control system of the present invention is used in conjunction with a control as described in said co-pending application Serial No. 237,628, an additional safeguard is provided against failure of the final nozzle to open to the selected effective area. If the nozzle does not open, the pressure in the jet pipe will not be reduced to the value to which it would be reduced if it did open, and accordingly the control will only permit a correspondingly reduced amount of fuel to be supplied to the reheat combustion equipment. Conveniently, the pressure in the jet pipe, which is maintained constant by the control system controlling the supply of fuel to the reheat combustion equipment when the reheat is in operation (which normally will correspond with the final nozzle being in its maximum open position), is selected to be the same as the pressure in the jet pipe without reheat combustion and with the final nozzle in the closed position.

In this way, if no opening movement of the final nozzle occurs on selection of reheat, the pressure in the jet pipe will remain the same and thus the control will operate to reduce the fuel supply to the reheat combustion equipment to a negligible quantity.

If, however, the nozzle opens to an intermediate position on the selection of reheat, the pressure in the jet pipe will fall by a corresponding amount and thus the control system will allow a certain quantity of reheat fuel to be supplied to the reheat combustion equipment; for example, if the final nozzle opens to a position half-way between the minimum and maximum areas, the control may allow approximately half the quantity of fuel to be supplied which would normally be supplied with the nozzle in the fully open position. In this case, there would be a serious risk of the final

nozzle parts being damaged by the reheat combustion, and this risk is overcome by the use of the control system in accordance with the present invention.

We claim:

1. For a gas-turbine engine including a compressor, combustion equipment receiving air compressed by said compressor, a turbine receiving hot gas from the combustion equipment and driving the compressor, an exhaust unit receiving the exhaust gases from the turbine, an adjustable-area propelling nozzle at the outlet of the exhaust unit through which the exhaust gases are delivered to atmosphere, and reheat combustion equipment in said exhaust unit; a control system comprising controllable means to deliver fuel to be burnt in said reheat combustion equipment, ignition means to initiate combustion of said fuel, motor means to adjust said adjustable-area propelling nozzle to vary the effective area thereof, actuating means to actuate said controllable means to effect initiation of the delivery of fuel to said reheat combustion equipment and simultaneously to actuate said motor means to initiate opening adjustment of said adjustable-area nozzle, a time-controlled switch mechanism connected to said controllable means and adapted to be set in operation on actuation of said controllable means and adapted after a preset time delay to cause cutting off of fuel delivery to said reheat combustion equipment, and means adapted to be actuated when within said preset time said adjustable-area nozzle has been adjusted to a selected area in the sense of opening to render said time-controlled switch mechanism ineffective to cut off said fuel delivery.

2. A gas-turbine engine as claimed in claim 1, having said time-controlled switch mechanism comprising an electrical switch which is normally closed to pass electrical current for operating said controllable means to initiate the main fuel supply and the means to initiate opening adjustment of the adjustable-area propelling nozzle and which is opened at the end of the preset time delay, and a nozzle-controlled switch arranged to be actuated when the nozzle has opened to the selected area and on actuation to render opening of the time-controlled switch ineffective to interrupt the fuel supply or nozzle opening.

3. A gas-turbine engine as claimed in claim 2, wherein said nozzle-controlled switch is arranged in parallel with the time-controlled switch and is closed when the nozzle opens to the selected area.

4. A gas-turbine engine as claimed in claim 3, wherein the nozzle-controlled switch is afforded by a contactor of a relay whereof the coil is energized by closure of primary contacts by the propelling nozzle on opening to the selected effective area.

5. A gas-turbine engine as claimed in claim 1, wherein said time-controlled switch mechanism comprises an electrical current source, a contact carrier movable between a first position in which electrical current flows from said source through a contact piece on said carrier to operate the controllable means to initiate the main fuel supply and said motor means to initiate opening movement of the propelling nozzle, and a second position in which said current flow is broken, resilient means to urge said contact carrier in said first position, and means to hold said contact carrier in the second position after the expiry of the preset time delay.

6. A gas-turbine engine as claimed in claim 5, wherein said means to hold the contact carrier in the second position comprises a solenoid device and parallel circuits for energizing the solenoid device, one of which parallel circuits includes first switch contacts to be closed at the end of the preset time delay and the sec-

ond of which parallel circuits includes second switch contacts which are adapted to be closed in said second position of the contact carrier.

7. A gas-turbine engine as claimed in claim 6, comprising also electrical motor means, said contact carrier being adapted also to control the supply of current thereto, a cam driven by said electrical motor means and adapted for closing said first switch contacts at the end of said preset time delay, said contact carrier being adapted on movement to said second position to break the supply of current to said electrical motor means subsequent to closure of the second switch contacts.

8. A gas-turbine engine as claimed in claim 1, having said controllable means to initiate the main fuel supply comprising a solenoid-operated fuel-cock; having the ignition means to initiate combustion of said main fuel supply comprising a solenoid-operated atomiser fuel-cock; having said motor means to initiate opening adjustment of the adjustable-area propelling nozzle comprising a solenoid-operated pressure fluid control valve; having said means adapted to be actuated by said adjustable-area nozzle comprising a nozzle-controlled switch which is adapted to be closed when said nozzle opens to said selected area; and having a source of electrical current, said operating solenoids of said fuel-cocks and said valve being connected in parallel to be supplied with energizing current from said source under control of said time-controlled switch mechanism and said nozzle-controlled switch.

9. For a gas-turbine engine including a compressor, combustion equipment receiving air compressed by said compressor, a turbine receiving hot gas from the combustion equipment and driving the compressor, an exhaust unit receiving the exhaust gases from the turbine, an adjustable-area propelling nozzle at the outlet of the exhaust unit through which the exhaust gases are delivered to atmosphere, and reheat combustion equipment in said exhaust unit; a control system comprising controllable means to deliver fuel to be burnt in said reheat combustion equipment, ignition means to initiate combustion of said fuel, reversible motor means to adjust said adjustable-area propelling nozzle to vary the effective area thereof, actuating means to actuate said controllable means to effect initiation of the delivery of fuel to said reheat combustion equipment and simultaneously to actuate said motor means to initiate opening adjustment of said adjustable-area nozzle, a time controlled switch mechanism connected to said controllable means and adapted to be set in operation on actuation of said controllable means and adapted after a preset time delay to cause cutting off of fuel delivery to said reheat combustion equipment and simultaneously to actuate said motor means to initiate closing adjustment of said adjustable-area nozzle, and means adapted to be actuated when within said preset time said adjustable-area nozzle has been adjusted to a selected area in the sense of opening to render said time-controlled switch mechanism ineffective to cut off said fuel delivery and ineffective to initiate said closing adjustment of said nozzle.

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