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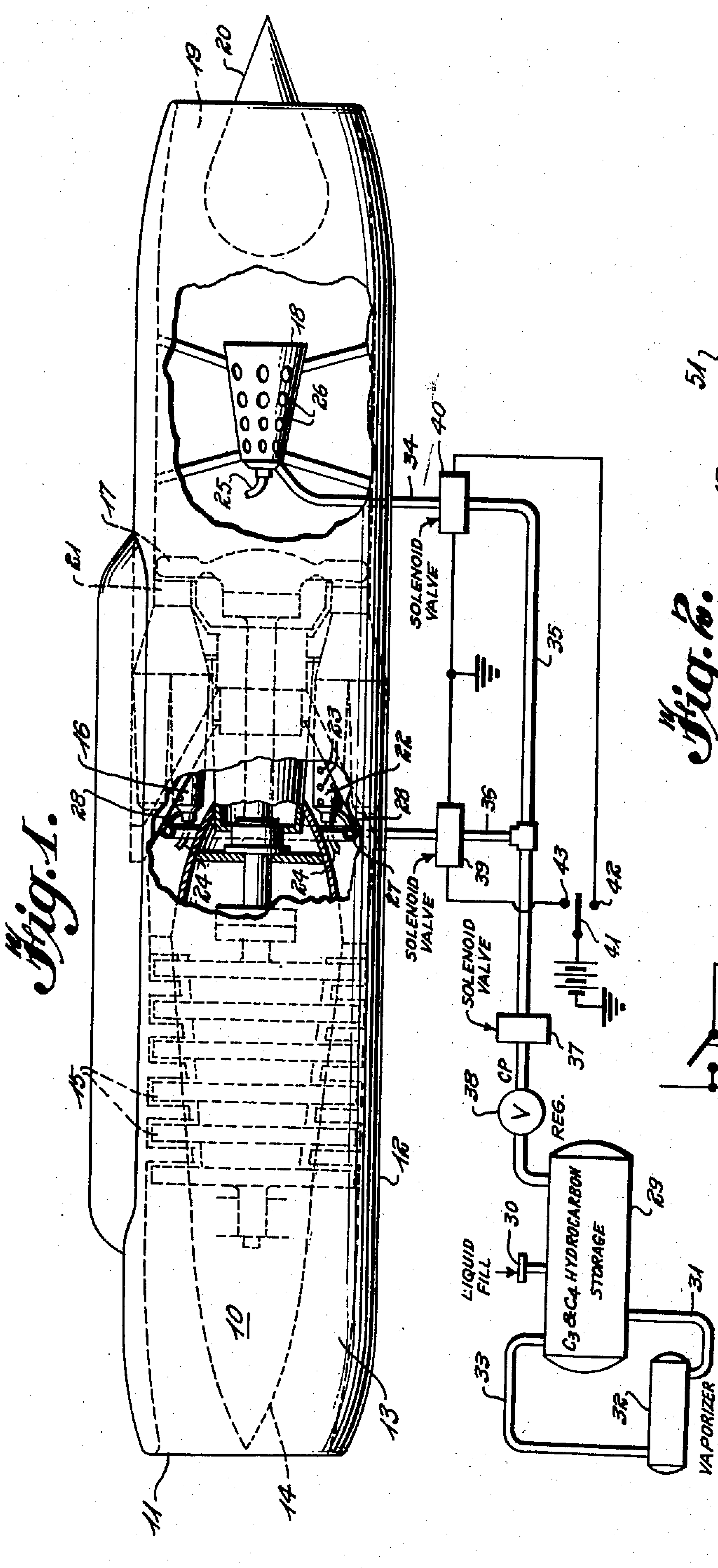

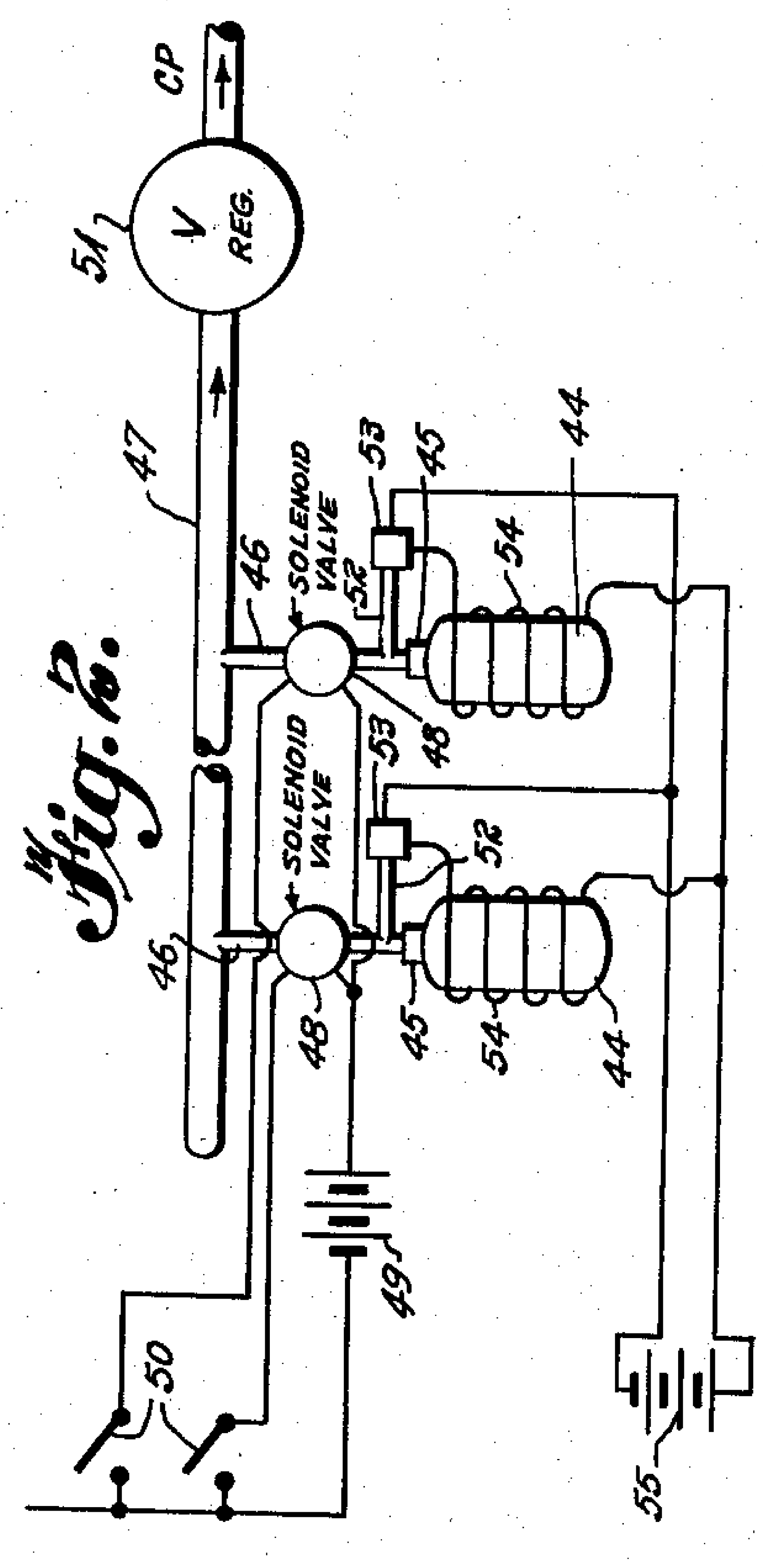

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APPARATUS FOR AVOIDING HOT STARTS IN TURBOJET ENGINE OPERATION AND FOR IGNITING FUEL IN THE AFTERBURNER

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1 Claim. (Cl. 60—35.6)

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The present invention relates to apparatus for avoiding hot starts in turbojet engine operation and for igniting fuel in an after burner thereof. In the operation of turbojet engines there is a considerable delay in the ignition of the fuel charge with the result that the combustion chamber and the propulsion nozzle are all completely filled with a combustible mixture before ignition occurs. When ignition occurs, it is frequently accompanied by a rather violent explosion and is evidenced by a tremendous burst of smoke and incompletely combusted material from the nozzle. This is very hazardous, both from the standpoint of the explosive force within the turbojet engine itself and because of fire hazards.

Another and somewhat related problem in the operation of turbojet engines, particularly those embodying an after burner, i. e., mechanism for introducing and burning additional fuel in the propulsion nozzle portion of the jet engine to the rear of the turbine, resides in insuring ready and immediate ignition of the auxiliary fuel supplied to the after burner.

It is among the purposes and objects of the present invention to provide apparatus for insuring immediate ignition of the primary fuel supply to the main combustion chamber of the turbojet engine, i. e. that combustion chamber positioned in advance of the turbine, and also for insuring immediate direct and positive ignition of auxiliary fuel when supplied to the after burner of the turbojet engine.

It has been heretofore proposed to employ an after burner in association with a turbojet engine. However, great difficulty has been encountered in the practical application of this principle because of the great difficulty in maintaining continuous ignition of the auxiliary supply of fuel admitted to the after burner. The velocity of the exhaust gases from the turbine including, of course, great quantities of excess air, is such that it tends to blow the flame completely out of the propulsion jet and preclude continuous combustion in the after burner. Obviously, if the after burner is to be effective, the fuel supplied thereto must be immediately consumed therein and this must take place despite the high velocity of the exhaust gases and excess air being delivered to the after burner from the turbine.

In its more specific aspects, the present invention contemplates the ignition of the fuel charge supplied either to the primary combustion chamber or to the after burner of the turbojet or the simultaneous ignition of both the main fuel supply admitted to the primary combustion chamber and

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the auxiliary fuel supply admitted to the after burner by providing a pilot flame supported by a highly volatile, normally gaseous hydrocarbon in the form of propane or butane or mixtures thereof. The pilot flame supported by such normally gaseous auxiliary hydrocarbon fuel is exceedingly effective in insuring immediate ignition of the main jet fuel supplied either to the primary combustion chamber of the turbojet engine or to the after burner thereof.

It is a further purpose and object of the invention to introduce the pilot flame supporting fuel in vaporous condition to either the primary combustion chamber or the after burner of the turbojet engine at a pressure at least equal to the pressure prevailing in such combustion zones of the turbojet engine.

More specific purposes and advantages of the invention will become apparent as the description proceeds, which will be given by reference to the accompanying drawing wherein

Figure 1 is a diagrammatic view in side elevation illustrating one embodiment of an apparatus appropriate for practicing the invention.

Figure 2 is a fragmentary diagrammatic view of an alternative embodiment conforming to the invention.

Referring to Figure 1, the power plant or turbojet engine is indicated generally at **10**, with the intake end **11** at the left of this figure. The power plant comprises an outer shell or casing structure **12** having an air duct **13** extending fore and aft with respect to the aircraft. The casing **12** has mounted therein along its longitudinal axis a nose portion **14** in which fuel lubricating oil pumps and appropriate igniting apparatus may be housed. There is provided an axial flow multi-stage compressor **15**, a primary combustion apparatus **16**, a turbine **17**, an after burner **18** and a propulsion jet **19** defined by the casing **12**, and a tail piece **20** mounted concentrically therein. Air enters at the intake end **11**, and flows back through the compressor **15** wherein it is compressed, and thence into the primary combustion apparatus **16**, wherein it is heated. The heated compressed air, on leaving the combustion apparatus **16**, is directed by appropriate guide vanes or nozzles **21** against the blades of the turbine rotor **17**, and thence passes around the after burner **18** to and through the propulsion jet **19**. The combustion apparatus **16** may be of any suitable construction, and is here shown as comprising a plurality of flared burner tubes **22** provided with openings **23** in the walls thereof through which the compressed air enters the tubes **22** and mixes with the jet fuel in the form of kerosene or other relatively high boiling fuel supplied to the burner tubes **22** by means of pipes **24** which lead to a source of jet fuel not shown. A suitable igniter in the form of a spark plug is mounted in the fuel receiving end of each of the burner tubes **22**.

The excess air discharged with the products of combustion through the turbine **17** is adequate to support combustion of additional jet fuel which is supplied to the after burner **18** through the line **25** which may lead to appropriate controls also associated with the fuel supply lines **24** for appropriately controlling the supply of jet fuel selectively to the primary combustion zone represented by the burner tubes **22** or to the after burner **18**, or as is more frequently the case simultaneously to both the primary combustion zone embracing tubes **22**, and to the after burner **18**. The after burner **18** is provided with openings **26** through which the excess air enters to be mixed with the auxiliary fuel supply entering through the lines **25**. A suitable spark plug is mounted in the fuel oil receiving end of the after burner **18**.

As hereinbefore indicated, it is the purpose of the present invention to insure against "hot starts" in the operation of the turbojet engine and also to provide for the continuous, uninterrupted combustion of auxiliary fuel in the after burner during those periods when the after burner is not being used. For these purposes, there is disclosed in the embodiment of Figure 1 an annular header **27** from which a plurality of pilot fuel supply conduits **28** extend to the burners **22**. The pilot fuel conduits **28** preferably discharge the pilot fuel conveyed thereby into the chambers **22** closely adjacent to the associated igniter which preferably takes the form of a suitable spark plug. The pilot fuel is supplied to the burners at a point spaced a short distance from the point of introduction of the normal relatively high boiling jet fuel being supplied to the burners **22**.

It will be observed that the annular header **27** is common to all of the burners **22**. The annular header **27** receives its supply of normally gaseous hydrocarbons, for example propane, from the auxiliary pilot fuel supply chamber **29** having a liquid fill **30**. The liquified propane or other liquifiable normally gaseous hydrocarbon is maintained in the chamber **29** under the appropriate predetermined pressure, which at all times will be maintained greater than the operating pressure prevailing in the burners **22** of the turbojet engine. Liquefied gaseous hydrocarbons pass from the bottom of the chamber **29** through the line **31** to the vaporizer **32** supplied with any suitable source of heat to effect requisite vaporization at the prevailing pressure of the liquified gaseous hydrocarbon. Vapors from the vaporizer **32** pass through line **33** and re-enter the tank **29** to thereby maintain a constant supply of high pressure vaporous, gaseous hydrocarbons directly available for delivery to the primary combustion zone represented by the burners **22** of the turbojet engine.

Before describing the details by which high pressure vaporous, normally gaseous hydrocarbons are supplied from the tank **29** to the burners **22** to initiate and support a pilot flame therein, it is desired to refer briefly to the provision of means for also supplying vaporous, normally gaseous hydrocarbons to the after burner **18** to initiate and support a pilot flame therein to insure continuous combustion of fuel during periods when it is supplied to the after burner **18** through the line **25**. Line **34** leading from header **35** is adapted to convey high pressure vaporous hydrocarbons into the after burner **18** at a point adjacent a spark plug igniter for initiating and supporting a pilot flame in the after burner **18**. A second branch line **36** extends from the header **35** for conveying high pressure vaporous hydrocarbons to the annular header **27** to be supplied therefrom by branch lines **28** to the burners **22**. The header **35** upstream of the branch lines **34** and **36** is provided with a master solenoid valve **37** downstream from the pressure regulator **38**. The circuit for the master solenoid valve **37** is, of course, under control of the turbine engine operator, usually the pilot of the jet propelled aircraft, and when the master valve **37** is closed, there is no supply of high pressure vaporous hydrocarbons to either the primary combustion zone of the turbine engine embracing the burners **22**, or to the after burner **18**. A further solenoid valve **39** is disposed in the branch line **36** leading from the header **35** to the annular header **27** in the primary combustion chamber, and there is still a further solenoid valve **40** disposed in the branch line **34** leading from the header **35** to the after burner **18**. The solenoid valves **39** and **40** are in a common circuit controlled by the toggle switch **41**. The solenoid valves **39** and **40** are normally biased to open position, so that when the toggle switch is open or in the position shown in Figure 1, valves **39** and **40** are open. Under these conditions, actuation of the master solenoid valve **37** which is normally biased to closed position will effect an open communication from the storage tank **29** through header **35** and branch lines **34** and **36** for the simultaneous combustion of high pressure vaporous hydrocarbons to both the annular header **27** in the primary combustion chamber of the turbojet engine and to the after burner **18** to thereby initiate and support a pilot flame in each of these zones effective to immediately ignite and maintain continuous combustion of jet fuel supplied thereto. There will be occasions in the operation of the turbojet engine when it is desirable to initiate and support a pilot flame in both the primary combustion chamber and the after burner. This is particularly true during take-off of the jet propelled plane, and sometimes on occasions during flight thereof. Quite frequently, however, it will be desirable to initiate and support a pilot flame in the primary combustion chamber of the turbojet engine represented in the exemplified embodiment between burners **22** during a period when the after burner **18** is not in use. To effect this result, it is only necessary to move the toggle switch **41** into contact with terminal **42** to close a circuit through the solenoid and close that valve which will then preclude the passage of high pressure vaporous hydrocarbons to the after burner **18**. Alternatively, there may be occasions when it is desired to initiate and support a pilot flame in the after burner **18**, when no pilot flame is required in the primary combustion chamber of the turbojet engine. To accomplish this result, it is only necessary to move the toggle switch **41** into contact with the terminal **43** to thereby effect actuation of the solenoid valve **39** to close the same, and thus cut off possibility of supply high pressure vaporous hydrocarbon via branch line **36** to the annular header **27**.

It will thus be observed that in the embodiments of Figure 1 of the invention high pressure vaporous hydrocarbons, preferably propane, may be continuously supplied to support a pilot flame in both the primary combustion chamber and the burner of the turbojet engine. Likewise, the supply to both of these zones may be intermittent and instantaneous. Additionally, the high pressure vaporous hydrocarbon may be selectively supplied to either the primary combustion zone or to the after burner of the turbojet engine. When starting the turbojet engine, it will be commonly found desirable to close the solenoid vailve **40** and to open the solenoid valve **37**. In this way, a pilot flame will be initiated and maintained in the primary combustion zone to insure the instantaneous ignition of the jet fuel supplied thereto, and to avoid commonly termed "hot starts" which flow from delayed ignition in the initial starting of the engine.

In Figure 2 an alternative embodiment which provides for controlled intermittent supply of high pressure gaseous hydrocarbon to the primary combustion zone, and the after burner of the turbojet engine is disclosed. In this embodiment, a bank of any desired number of precharged cartridges **44** containing liquified gaseous hydrocarbon such as propane, are provided. The cartridges **44** are replaceable, so that when one or more of them have been emptied, they may be removed from the permanent parts of the installation, and charged cartridges substituted therefor. To facilitate this replacement, an appropriate screw-type connection **45** is provided for each cartridge **44**. It will be understood that the arrangement is such that when a charged cartridge **44** is placed in the system, it will be vented into the system through the action of the screw-type connection collar **45**. From each chamber **44** an individual conduit **46** connects to a common header **47**. In each conduit **46** there is disposed a suitable solenoid valve **48**, each of which is disposed in a circuit individual thereto. The battery supply **49** operates the electrical source for these parallel circuits, which are individually closeable through the medium of switches **50** which may take the form of hold-type push buttons mounted on a panel. The arrangement is such that when any given switch **50** is closed, the push button thereof remains in depressed position, indicating that the cartridge **44** associated with that particular push button, has been discharged.

The header **47** leads to a pressure regulator **51** comparable to the pressure regulator **38** in Figure 1, and it acts to reduce the pressure on the high pressure vaporous hydrocarbons from that pressure maintained in the header **47** to a constant lower pressure equal to or exceeding the pressure prevailing in the primary combustion chamber and the after burner of the turbojet engine. The header **47**, when employing the alternating embodiment of Figure 2, may be substituted for the header **35** in Figure 1. In other words, when the alternating embodiment of Figure 2 is being employed, the branch lines **34** and

36 of the embodiment of Figure 1 will be connected into the header **47** of Figure 2 on the downstream side of the pressure regulator **51**.

Vaporous hydrocarbons are maintained under the requisite predetermined high pressure in the respective cartridges **44** through the controlled supply of heat to the individual cartridges. To this end, the outlet of each cartridge **44** on the upstream side of the associated solenoid valve **48** leads through a line **52** to a pressure actuated electrical switch **53**. The switch **53**, associated with any given cartridge **44**, is adapted to automatically close when the pressure in that cartridge falls below the predetermined minimum. The closing of any given switch **53** will establish the flow of current through the associated heater coil **54** with resulting limited vaporization of liquified gaseous hydrocarbons in that particular cartridge. When the required predetermined pressure has been restored in the cartridge, the associated switch **53** will open. The source of current for the heater coils **54** in this embodiment is the battery **55**.

The embodiment of Figure 2 has certain advantages, particularly in aircraft operation, in that each cartridge carries a predetermined quantity of liquified gaseous hydrocarbon, and can be readily replaced when discharged. The replacing of completely charged cartridges for discharged cartridges avoids the necessity for high pressure charging of large supply tanks carried on the aircraft. The foregoing description has been given by way of exemplification, and not in limitation thereof.

What I claim is:

An apparatus comprising a turbojet engine mounted in an aircraft, a primary combustion chamber in said engine, an afterburner in said engine, means for supplying normally liquid fuel to each of said primary combustion chamber and said afterburner, a pressure vessel for containing a normally gaseous hydrocarbon in liquid form, selective means for supplying a normally gaseous hydrocarbon in vapor form from said pressure vessel to either of said primary combustion chamber and said afterburner, and means for igniting and maintaining independent combustion of said normally gaseous hydrocarbon in either of said primary and secondary combustion chambers.

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