

PATENT SPECIFICATION

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- (21) Application No. 16712/77 (22) Filed 21 April 1977
(31) Convention Application No. 692 083
(32) Filed 2 June 1976 in
(33) United States of America (US)
(44) Complete Specification published 24 Jan. 1979
(51) INT CL² F02C 3/00 7/22 7/26
(52) Index at acceptance F1G 10B 10G 18 5CX

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(54) EMERGENCY HYDRAULIC POWER SYSTEMS

(71) We SUNDSTRAND CORPORATION, a corporation organised and existing under the laws of the State of Delaware, United States of America, of 4751 Harrison Avenue, Rockford, Illinois 61101; United States of America, 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:—

The invention relates to emergency hydraulic power systems for aircraft, operable on engine failure of the aircraft main engines, and to start-up fuel supply systems for such power systems.

Modern aircraft include hydraulic power systems for delivering fluid under pressure to operate such components as rudder, slats, flaps and ailerons. The pump for the hydraulic system is driven from the aircraft engine; so it is essential that there be an auxiliary power system which permits safe operation and landing of the aircraft in the event of engine failure. Some such systems are disclosed in our United States Letters Patent 3,660,977, 3,722,217 and 3,800,534. The systems disclosed in those three patents all use a start grain to provide energy to the turbine until turbine speed is high enough to cause the fuel pump to deliver fuel under pressure from the main fuel tank to the decomposition chamber.

Use of a start grain for initiating operation of the system involves an inherent difficulty which derives from the fact that the rate of energy release from the grain may not match the requirements of the system over the wide range of temperatures encountered in use. The rapid burning and rapid energy delivery from a warm grain could result in turbine overspeed which can be damaging to the system. While this need has been met by secondary speed controls in accordance with US Patent No. 3,800,534, it is still desirable to have a start system which does not require the use of a start grain.

In the event the tank must be located a considerable distance from the fuel pump, it

may be desirable to provide a boost pump at the tank outlet to minimize the required tank pressurization and line sizes.

The present invention provides a start-up fuel supply system for an emergency hydraulic power system operable upon aircraft engine failure, which emergency system comprises a system controller, a monofuel tank, a fuel decomposition chamber, and a turbine drivable by gaseous decomposition products from the chamber to drive a pump for supplying fuel from the tank to the decomposition chamber; wherein the start-up fuel supply system comprises a start bottle which includes a cell for containing monofuel, a start fuel conduit for connecting the cell with the decomposition chamber, a gas pressure source, means including a normally closed start valve for delivering, when opened, gas from the source to the start bottle for expelling monofuel from the cell, and means associated with the start fuel conduit for normally blocking fuel flow from the cell to the decomposition chamber but openable upon starting of the system to permit flow of monofuel under pressure through or past the fuel pump and to the decomposition chamber. The present invention also provides an emergency hydraulic power system for an aircraft incorporating such a start-up fuel supply system.

The start-up fuel supply system of the present invention does not require the use of a start grain, and does not require high pressure in the fuel tank.

Preferably high pressure gas from the gas pressure source, such as a gas cylinder, expels starting fuel from the cell in the start bottle and drives the starting fuel to the decomposition chamber, while at the same time a branch line which is provided with a regulating valve set for a relatively low pressure permits gas from the high pressure cylinder to exert a relatively low pressure upon the fuel in the tank.

In one embodiment of the invention there is provided a jet pump operatively associated with a conduit from the monofuel

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tank to the pump, and a jet conduit connecting the jet pump to an outlet conduit from the pump, and a normally closed solenoid valve is provided in the conduit from the fuel tank to the pump. When the turbine reaches a predetermined speed following start-up, speed sensing means act through the system controller to open the normally closed solenoid valve so that part of the start fuel supplied by the fuel pump goes to the jet pump which assists in delivery of fuel from the fuel tank to the decomposition chamber.

The invention is hereinafter particularly described, by way of example only, with reference to the drawings of which:

Figure 1 is a diagrammatic illustration of a first embodiment of an emergency hydraulic power system incorporating a start-up fuel supply system according to the present invention; and

Figure 2 is a diagrammatic illustration of a second embodiment of such a power supply system.

Referring first to Figure 1, the emergency hydraulic power supply system includes a decomposition chamber 10 such as a thermal or a catalytic decomposition chamber which produces hot gases to drive a turbine 11 having an output shaft 12 driving a gear box, indicated generally at 13. A fuel pump 14 is driven by the turbine 11 through the gear box to supply monopropellant fuel to the decomposition chamber from a fuel tank 15 which may be located remotely from the turbine. One fuel tank of this general type is disclosed in our US patent 3,903,924.

An inlet conduit 16 connects the fuel tank 15 to the inlet side of the fuel pump 14, and an outlet conduit 17 connects the outlet side of the fuel pump with the decomposition chamber 10. A normally closed solenoid run/overspeed valve 18 is in the inlet conduit 16, and a normally open solenoid primary speed valve 19 is in the outlet conduit 17. A jet conduit 20 connects the outlet conduit 17 with a jet pump 21 which is operatively associated with the fuel tank 15 and the inlet conduit 16. A normally closed solenoid run valve 22 controls flow through the jet conduit 20.

Conventional magnetic pickups 23 provides means for sensing the speed of the turbine 11 by detecting the passing of a projection 9 attached to the output shaft 12 as the latter is rotated. The pickups provide input to a system controller such as the electronic controller 24 which controls operation of the normally closed valves 18 and 22 and the normally open valve 19.

In normal aircraft operation, the gear box 13 is driven by any suitable means from a main aircraft engine (not shown) and a hydraulic pump (not shown) is mechanically

driven from the gear box 13 to supply the power for the aircraft hydraulic system. In case of failure of the main aircraft engine, the emergency hydraulic power system is started, as described below.

A start fuel bottle, indicated generally at 25, includes a cell 26 which is filled with the same fuel as that in the tank 15, and the cell 26 has a movable wall 27 and a collapsible sidewall 28. A start fuel conduit 29 connects the cell 26 with the inlet conduit 16 downstream from the normally closed valve 18; and a pressure-rupturable disc 30 provides means normally blocking communication between the cell 26 and the inlet to the fuel pump 14.

A cylinder 31 contains gas at a pressure of, for example, 3,000 psig; and a first gas conduit 32 connects the cylinder 31 with the start bottle 25 through a normally closed start valve 33 and a pressure regulator 34 which is set for a relatively high pressure such as 800 psig. Connected to the first conduit 32 between the pressure regulator 34 and the start fuel bottle 25 is a branch conduit 35 which is connected with the fuel tank 15 through a pressure regulator 36 which is set to a relatively low pressure such as 35 to 39 psig.

In the event of main aircraft engine failure, a command signal produced automatically by the electronic controller 24 causes the start valve 33 to be opened. Alternatively, the command signal may be produced by manually throwing a switch (not shown). Once the start valve is opened, gas from the cylinder 31 flows through both the branch conduit 35, to pressurize the fuel tank, and the conduit 32, leading to the start bottle 25. Because of the pressure regulator 36, the fuel tank is pressurized at the low pressure of 35 to 39 psig. On the other hand, the gas flowing into the conduit 32 and the regulator 34 applies a pressure of about 800 psig to the movable wall 27 of the cell 26, causing the disc 30 to rupture and forcing fuel from the cell to the decomposition chamber 10. In this embodiment, the fuel pump 14 is a dynamic pump so that the fuel from the cell flows into the start fuel conduit 29 to the downstream end portion of the inlet conduit 16 and then through the fuel pump 14 to the outlet conduit 17. Should it be desirable to use a different type of fuel pump, such as a gear pump, which would not allow the through-flow of fuel during start-up, a suitable by pass and check valve arrangement (not shown) may be employed to connect the start fuel conduit 29 directly to the outlet conduit 17 upstream of the normally open solenoid primary speed valve 19.

The hot gases produced by the decomposition chamber 10 drive the turbine 11 to start up the fuel pump 14 through the gear

box 13 and also to drive a hydraulic pump (not shown) for the aircraft emergency hydraulic system. When turbine speed has reached a predetermined level, such as 90% of normal operating speed, as sensed by the magnetic pickups 23, the electronic controller 24 functions to open the normally closed valves 18 and 22. Then, there is an immediate rush of fuel from the outlet-conduit 17 through the jet conduit 20 to the jet pump 21 which co-operates with the fuel pump 14 in supplying fuel from the tank 15.

In operation, the supply of fuel to the decomposition chamber 10 is controlled by the primary speed valve 19 and the run/overspeed valve 18 in known manner.

As indicated in the drawing, the system includes a fuel fill port 37 and an air vent 38 for refilling the system; and the fuel tank is provided with a relief valve 39 and vent pipe 40 in the usual way.

Referring now to Figure 2, the second embodiment is similar to the first in including a decomposition chamber 10, a turbine 11, a turbine output shaft 12 with projection 9, a gear box 13, a fuel pump 14, and a fuel tank 15. There is also an inlet conduit 16 between the fuel tank 15 and the fuel pump 14, and an outlet conduit 17 between the fuel pump and the decomposition chamber 10. There is also a solenoid primary speed control valve 19 in the outlet conduit 17 as there is in the embodiment of Figure 1.

The embodiment of Figure 2 differs from that of Figure 1 principally in eliminating the jet pump 21 and the jet pump conduit 20; and substituting for the solenoid run/overspeed valve 18 and the solenoid run valve 22 a normally closed solenoid run valve 51 and an overspeed control valve 52, both of which are in the inlet conduit 16 down stream from a start fuel conduit 53. With the solenoid run valve 51 downstream from the start fuel conduit 53 the pressure-rupturable disc 30 of the first embodiment may be eliminated; and in order to prevent start fuel from passing from a start fuel bottle, indicated generally at 54, to the fuel tank 15, a check valve 55 is located in the feed conduit 16 between the start fuel conduit 53 and the fuel tank.

As in the first embodiment of the invention, the start fuel bottle 54 contains a cell 56 that has a movable wall 57 and a collapsible wall 58. The cell 56 is filled with the same fuel that is in the fuel tank 15.

A gas cylinder 31 is connected through a conduit 32 to the start bottle, and in the conduit 32 are a start valve 33 and a pressure regulator 34. A branch conduit 35 is in communication with the conduit 32 through the rear of the start bottle 54, and there is a pressure regulator 36 in the branch conduit 35. The pressure of gas in the cylinder 31,

and the pressures to which gas is regulated by the regulators 34 and 36, are the same as in the embodiment of Figure 1.

Also as in the embodiment of Figure 1, there are magnetic pickups 23 to sense turbine speed and feed the sensed information to an electronic controller 59. The electronic controller controls operation of the start valve 33, the primary speed control valve 19, the solenoid run valve 51 and the overspeed control valve 52.

Upon main aircraft engine failure, the start valve 33 is opened and at the same time the normally closed solenoid run valve 51 is opened. The higher regulated pressure of gas from the cylinder 31 immediately expels start fuel from the cell 56 which passes through the start fuel conduit 53, the inlet conduit 16, the outlet conduit 17 and to the decomposition chamber 10 in order to begin operation of the turbine 11. At the same time, the lower regulated gas pressure is applied to the fuel in the fuel tank 15, and as soon as turbine speed causes the operation of the fuel pump 14 to reach a high enough speed, fuel from the tank 15 passes through the check valve 55 with the assistance of the low pressure gas in the branch conduit 35.

The principal advantage of the embodiment of Figure 2 over that of Figure 1 is that recharging of the fuel tank 15 through a fuel fill port 37 also serves to recharge the start bottle cell 56 through the check valve 55 as soon as the fuel tank is full, whereas in the first embodiment it is necessary to replace the start fuel bottle 25 and pressure-rupturable disc 30, or else have separate means for recharging the start fuel bottle after the burst disc has been replaced.

WHAT WE CLAIM IS:—

1. A start-up fuel supply system for an emergency hydraulic power system operable upon aircraft engine failure, which emergency system comprises a system controller, a monofuel tank, a fuel decomposition chamber, and a turbine drivable by gaseous decomposition products from the chamber to drive a pump for supplying fuel from the tank to the decomposition chamber; wherein the start-up fuel supply system comprises a start bottle which includes a cell for containing monofuel, a start fuel conduit for connecting the cell with the decomposition chamber, a gas pressure source, means including a normally closed start valve for delivering, when opened, gas from the source to the start bottle for expelling monofuel from the cell and means associated with the start fuel conduit for normally blocking fuel flow from the cell to the decomposition chamber but openable upon starting of the system to permit flow of monofuel under pressure through or past

box 13 and also to drive a hydraulic pump (not shown) for the aircraft emergency hydraulic system. When turbine speed has reached a predetermined level, such as 90% of normal operating speed, as sensed by the magnetic pickups 23, the electronic controller 24 functions to open the normally closed valves 18 and 22. Then, there is an immediate rush of fuel from the outlet conduit 17 through the jet conduit 20 to the jet pump 21 which co-operates with the fuel pump 14 in supplying fuel from the tank 15.

In operation, the supply of fuel to the decomposition chamber 10 is controlled by the primary speed valve 19 and the run/overspeed valve 18 in known manner.

As indicated in the drawing, the system includes a fuel fill port 37 and an air vent 38 for refilling the system; and the fuel tank is provided with a relief valve 39 and vent pipe 40 in the usual way.

Referring now to Figure 2, the second embodiment is similar to the first in including a decomposition chamber 10, a turbine 11, a turbine output shaft 12 with projection 9, a gear box 13, a fuel pump 14, and a fuel tank 15. There is also an inlet conduit 16 between the fuel tank 15 and the fuel pump 14, and an outlet conduit 17 between the fuel pump and the decomposition chamber 10. There is also a solenoid primary speed control valve 19 in the outlet conduit 17 as there is in the embodiment of Figure 1.

The embodiment of Figure 2 differs from that of Figure 1 principally in eliminating the jet pump 21 and the jet pump conduit 20; and substituting for the solenoid run/overspeed valve 18 and the solenoid run valve 22 a normally closed solenoid run valve 51 and an overspeed control valve 52, both of which are in the inlet conduit 16 down stream from a start fuel conduit 53. With the solenoid run valve 51 downstream from the start fuel conduit 53 the pressure-rupturable disc 30 of the first embodiment may be eliminated; and in order to prevent start fuel from passing from a start fuel bottle, indicated generally at 54, to the fuel tank 15, a check valve 55 is located in the feed conduit 16 between the start fuel conduit 53 and the fuel tank.

As in the first embodiment of the invention, the start fuel bottle 54 contains a cell 56 that has a movable wall 57 and a collapsible wall 58. The cell 56 is filled with the same fuel that is in the fuel tank 15.

A gas cylinder 31 is connected through a conduit 32 to the start bottle, and in the conduit 32 are a start valve 33 and a pressure regulator 34. A branch conduit 35 is in communication with the conduit 32 through the rear of the start bottle 54, and there is a pressure regulator 36 in the branch conduit 35. The pressure of gas in the cylinder 31,

and the pressures to which gas is regulated by the regulators 34 and 36, are the same as in the embodiment of Figure 1.

Also as in the embodiment of Figure 1, there are magnetic pickups 23 to sense turbine speed and feed the sensed information to an electronic controller 59. The electronic controller controls operation of the start valve 33, the primary speed control valve 19, the solenoid run valve 51 and the overspeed control valve 52.

Upon main aircraft engine failure, the start valve 33 is opened and at the same time the normally closed solenoid run valve 51 is opened. The higher regulated pressure of gas from the cylinder 31 immediately expels start fuel from the cell 56 which passes through the start fuel conduit 53, the inlet conduit 16, the outlet conduit 17 and to the decomposition chamber 10 in order to begin operation of the turbine 11. At the same time, the lower regulated gas pressure is applied to the fuel in the fuel tank 15, and as soon as turbine speed causes the operation of the fuel pump 14 to reach a high enough speed, fuel from the tank 15 passes through the check valve 55 with the assistance of the low pressure gas in the branch conduit 35.

The principal advantage of the embodiment of Figure 2 over that of Figure 1 is that recharging of the fuel tank 15 through a fuel fill port 37 also serves to recharge the start bottle cell 56 through the check valve 55 as soon as the fuel tank is full, whereas in the first embodiment it is necessary to replace the start fuel bottle 25 and pressure-rupturable disc 30, or else have separate means for recharging the start fuel bottle after the burst disc has been replaced.

WHAT WE CLAIM IS:—

1. A start-up fuel supply system for an emergency hydraulic power system operable upon aircraft engine failure, which emergency system comprises a system controller, a monofuel tank, a fuel decomposition chamber, and a turbine drivable by gaseous decomposition products from the chamber to drive a pump for supplying fuel from the tank to the decomposition chamber; wherein the start-up fuel supply system comprises a start bottle which includes a cell for containing monofuel, a start fuel conduit for connecting the cell with the decomposition chamber, a gas pressure source, means including a normally closed start valve for delivering, when opened, gas from the source to the start bottle for expelling monofuel from the cell and means associated with the start fuel conduit for normally blocking fuel flow from the cell to the decomposition chamber but openable upon starting of the system to permit flow of monofuel under pressure through or past

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- the fuel pump and to the decomposition chamber.
2. A system according to claim 1, including a conduit downstream of the start valve for delivering gas from the gas pressure source to the monofuel tank when the gas is applied to the start bottle.
3. A system according to claim 2, wherein the means for delivering gas from the source to the start bottle includes a first pressure regulating valve; the conduit downstream of the start valve for delivering gas from the gas pressure source to the monofuel tank includes a second pressure regulating valve for establishing a pressure lower than that established by the first pressure regulating valve; and valve means are provided for normally preventing the flow of fuel from the cell into the monofuel tank.
4. A system according to claim 3, in which the valve means for normally preventing the flow of fuel from the cell into the monofuel tank comprise a check valve between the tank and the start fuel conduit.
5. A system according to any of claims 1 to 3, in which the valve means for normally preventing the flow of fuel from the cell into the monofuel tank comprises a normally closed solenoid valve between the tank and the start fuel conduit; sensing means are provided for sensing turbine speed; and means in the system controller are operatively connected to the sensing means for opening the normally closed solenoid valve when the turbine speed reaches a predetermined value.
6. A system according to claim 5, in which the start fuel conduit is connected to the decomposition chamber via an inlet to the pump.
7. A system according to claim 5 or claim 6, including a jet pump operatively associated with a conduit from the monofuel tank to the pump, and a jet conduit connecting the jet pump to an outlet conduit from the pump.
8. A system according to any preceding claim wherein the means for normally blocking the flow of fuel from the cell to the decomposition chamber comprise a pressure-rupturable disc between the cell and the start fuel conduit, rupturable by the pressure applied to the fuel by gas under pressure.
9. A system according to any of claims 1 to 7, in which the means for normally blocking fuel flow from the cell comprises a normally closed valve in the start fuel conduit, and in which the system controller opens both the start valve and the normally closed valve upon start of the system.
10. A system according to any preceding claim, in which the cell includes a movable wall.
11. A start-up fuel supply system for an emergency hydraulic power system of an aircraft, substantially as particularly described herein with reference to the drawings.
12. An emergency hydraulic power system for an aircraft, incorporating a start-up fuel supply system according to any preceding claim.
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