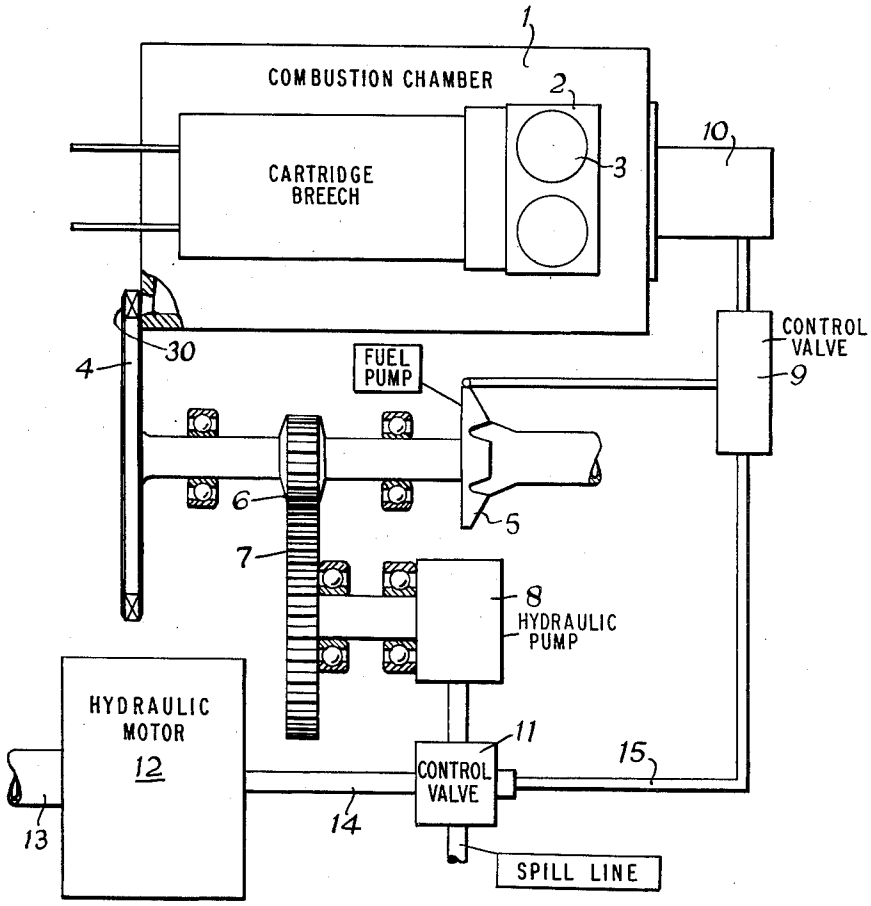
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LIQUID-FUEL OPERATED ENGINE STARTERS

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Fig. 1.



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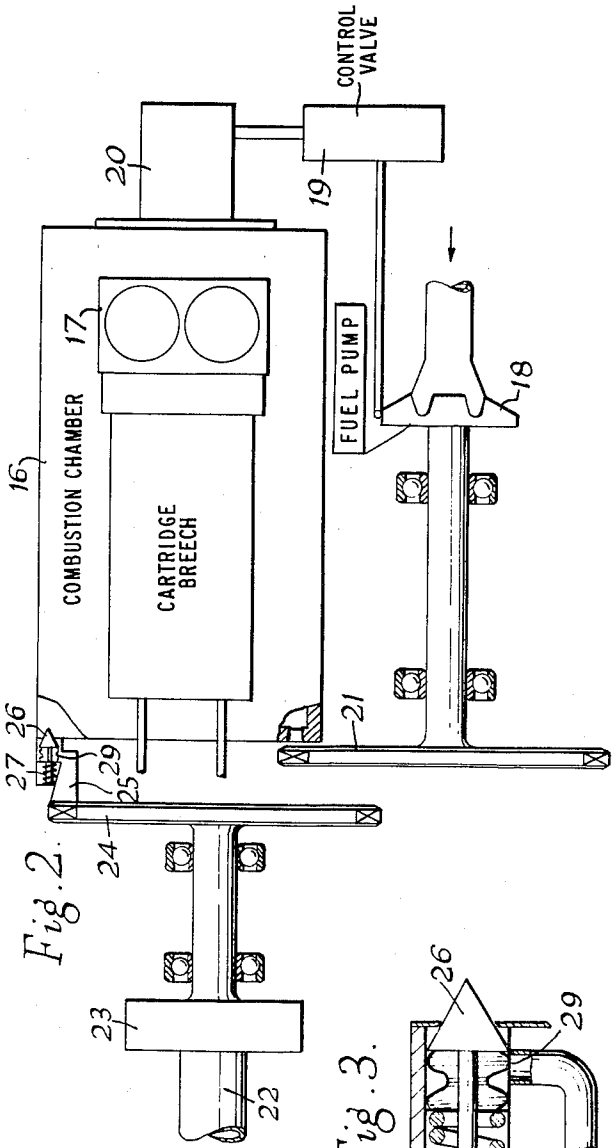


Fig. 2.

Fig. 3.

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LIQUID-FUEL OPERATED ENGINE STARTERS

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This invention relates to liquid-fuel operated engine starters and has for an object to provide an improved starter device for operation by liquid fuel, which does not require the use of an electric motor for the initial supply of the liquid fuel.

According to the invention the starter device comprises a fuel pump driven by a gas turbine the speed of which is independent of the output speed of the starter, for supplying the liquid fuel to the combustion chamber of the starter system, the combustion chamber being adapted to be initially raised to operative pressure and supplied with gas, for example by means of a cartridge, and the use of gas from the combustion chamber being substantially confined to the use for accelerating and driving the fuel pump, until the fuel pump delivers fuel to the combustion chamber. As a result of this the starter cartridge need only be of moderate size.

In one form of the invention the turbine driving the fuel pump also drives a hydraulic pump which serves as a source of power for a hydraulic starter motor, the arrangement being such as to allow the hydraulic pump to operate at full speed irrespective of the speed of the hydraulic motor. In the case of a positive-displacement pump this may be achieved by the use of a variable-displacement pump or by the addition of a relief valve which allows hydraulic liquid to spill back to a sump or the like when the delivery pressure exceeds a predetermined value. Preferably, however, the relief valve is arranged to be unloaded until the pressure of the fuel supplied by the fuel pump reaches a predetermined value, thereby shortening the time required for raising the turbine speed to that requisite for operation of the combustion chamber by fuel supplied by the pump.

In an alternative form of the invention the fuel pump is driven by an auxiliary turbine fed from the combustion chamber, so as to be independent of the speed of the main starter turbine. Preferably the supply of gas from the combustion chamber to the main starter turbine is controlled by a toppling valve which remains closed until, due to the supply of liquid fuel, the pressure in the combustion chamber rises beyond a predetermined value, and which is arranged once opened to move immediately to the fully open position so as thereafter to offer little resistance to the flow of gas from the combustion chamber to the main turbine.

Two embodiments respectively corresponding to the two systems are illustrated in the drawing accompanying the specification, in which

FIGURE 1 is a somewhat diagrammatic plan view illustrating an embodiment of the invention involving a hydraulic drive, while

FIGURE 2 similarly illustrates an embodiment utilising an auxiliary turbine for the drive of the fuel pump,

FIGURE 3 of the accompanying drawing is a sectional elevation of the toppling valve.

Referring to FIGURE 1, a combustion chamber **1** is equipped with a cartridge breech **2** adapted to accommodate one or more cartridges **3**, for example of cordite, and adapted to fire the cartridges individually by any convenient or conventional means not shown. Gases from the combustion chamber **1** are admitted through a suitable nozzle arrangement **30** to a turbine **4** the shaft of which carries a centrifugal fuel pump **5** and in addition drives, through reduction gearing **6**, **7**, a hydraulic

pump **8**. Fuel supplied by the pump **5** is conducted under the control of a control valve **9**, for example a non-return valve, to an atomiser **10** by which, once its pressure exceeds the pressure prevailing in the combustion chamber **1**, injects the fuel, for example a monofuel such as iso-propyl nitrate into the combustion chamber, the conditions in which now ensure reliable ignition of the monofuel. The hydraulic liquid delivered by the pump **8** is supplied through a hydraulic control valve **11** to the hydraulic motor **12**, the output shaft **13** of which serves as a starter shaft for the engine to be started. The control valve **11** may be a relief valve maintaining a constant pressure in the line **14** leading to the motor **12**, or may be controlled by the output torque of the motor **12** so as to maintain this torque constant. In any case the valve **11** is preferably so arranged as to be unloaded while the turbine **4** is accelerated and until the fuel pressure supplied by the pump **5** reaches a predetermined value, for which purpose a connection **15** is provided between the fuel line and the valve **11**.

In the embodiment of FIGURE 2 a combustion chamber **16** is equipped with a starter breech **17** and with a fuel supply system including a fuel pump **18**, a fuel control **19** and an atomiser **20**, similarly as the combustion chamber **1** in the embodiment described with reference to FIGURE 1, and, also similarly to the said embodiment, the fuel pump **18** is driven by a turbine **21** operated by combustion gas from the chamber **16** admitted through a suitable nozzle. In contrast, however, to the arrangement described with reference to FIGURE 1, the turbine **21** is an auxiliary turbine which only drives the fuel pump **18**, and which is not utilised for the transmission of torque to the output shaft **22**. The latter is driven, through a gear box or reducing gear **23**, by a separate starter turbine **24**, the nozzle unit **25** of which is supplied with gas from the combustion chamber **16** through a gas toppling valve **26** which, until a predetermined pressure is reached in the combustion chamber, is held closed by a loading spring **27**, against the action of combustion chamber pressure upon the front of the valve **26** and the back of which is sealed from the pressure prevailing in the nozzle unit **25** by a bellows **29** so that, once the valve **26** has been raised from its seat, the pressure of the combustion gas will act on the whole, and no longer on part only, of the front surface of the valve **26**, thereby rapidly forcing valve **26** into the fully open position.

To start the unit, a cordite cartridge is fired in the breech **17**. This raises the pressure in the combustion chamber sufficiently to ignite the iso-propyl nitrate and at the same time serves to accelerate the auxiliary turbine to a speed at which the fuel pressure supplied by the pump **18** is sufficient to effect injection of fuel against the pressure prevailing in the chamber **16**. Up to this point the toppling valve **26** is closed, so that the whole power developed by the cartridge is utilised for accelerating the auxiliary turbine **21**.

As soon as the liquid fuel, which may be iso-propyl nitrate, enters the combustion chamber, the pressure in the combustion chamber rises and causes the toppling valve to open, thereby admitting gas from the combustion chamber to the main starter turbine. The fuel valve **19** then maintains the pressure in the combustion chamber constant by regulating the flow of fuel from the pump **18** to the atomiser **20**. The output shaft **22**, similarly to the output shaft **13** in the example described with reference to FIGURE 1, may be coupled in the conventional manner to an engine to be started, for example to an aircraft gas turbine.

What I claim is:

1. In a liquid-fuel operated engine starter device the combination of a combustion chamber, means for initial-

ly raising the combustion chamber to operative pressure, a first pump connected to act as a fuel pump for supplying liquid fuel to the combustion chamber to maintain the same under operative pressure, a gas turbine operated by gas from the combustion chamber said turbine being drivingly connected to said fuel pump, and a hydraulic drive including a second pump also driven by said turbine to provide a supply of liquid under pressure, a starter output shaft, a hydraulic motor connected to the starter output shaft and fed with liquid from said second pump in such manner as to permit the second pump to run at a speed independent of the speed of the output shaft, and including automatic control means preventing the transmission of substantial power to the output shaft until the fuel pump delivers fuel to the combustion chamber.

2. A device as claimed in claim 1, wherein the second pump is a hydrodynamic pump.

3. A device as claimed in claim 1, wherein the second pump is a positive-displacement pump, the device including an excess-pressure relief valve interposed in the line from the hydraulic pump to said second motor to limit the delivery pressure of the pump.

4. A device as claimed in claim 1, wherein the second pump is a positive-displacement pump, the device including automatic unloading means unloading the connection from the second pump to the hydraulic motor until the pressure supplied by the fuel pump reaches a predetermined value.

5. A device as claimed in claim 1, including means automatically limiting the pressure loading of the second pump.

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