ABSTRACT: A rotary fuel pump for supplying liquid fuel of the kind including a centrifugally operable spill valve operable to spill fuel back to pump inlet at a predetermined speed. When a pump of this kind is used to supply fuel to a gas turbine engine there may be a tendency for surging to occur when the pump and the engine are being accelerated prior to said spill valve opening. To reduce the tendency to surge, a second centrifugally operable spill valve is provided to open temporarily to reduce fuel delivery by the pump during acceleration prior to said spill valve opening.
FIG. 1.

FIG. 3.

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ROTARY FUEL PUMP

The invention is concerned with a rotary fuel pump of the kind (hereinafter called the "kind described") employed for supplying liquid fuel to a burner of a gas turbine engine and comprising a rotor having a plurality of axially extending bores circumferentially spaced around the axis of the rotor and each containing a piston urged by a spring into abutment with a cam plate inclined to the axis of rotation of the rotor, the bores having open ports communicating with the ends therefore remote from the cam plate, whereby, during rotation of the rotor, the open port of each bore passes successively a fuel inlet and a fuel outlet in the form of circumferentially spaced arcuate apertures, coaxial with the rotor and positioned in a stationary thrust face in a housing containing the rotor, the thrust face coating with the end face of the rotor containing the open ports of the bores, the inlet aperture communicating with the interior of the housing which forms a reservoir for fuel and the outlet aperture leading to a delivery pipe.

U.S. Pat. No. 3,085,619 is concerned with an engine-driven fuel pump of the kind described in which the outlet aperture also communicates through a spill passage in the rotor, via a centrifugally operable valve member carried by the rotor, with the interior of the housing. When a predetermined rotational speed is reached the centrifugally operable valve member operated permits fuel being delivered by the pistons to flow through the spill passage in the rotor to the interior of the housing and hence back to the inlet aperture. During acceleration of the pump to the speed at which the centrifugally operable valve will open to spill fuel to the interior of the housing, the normal acceleration line of the pump obtained by plotting fuel delivery against rotor speed, will pass through a region where the compressor supplying air to the combustion chamber of the gas turbine engine is likely to surge, especially during rapid acceleration of the engine and the pump.

An object of the invention is to provide in a rotary fuel pump of the kind described a centrifugally operable spill valve which is arranged to open to spill a predetermined quantity of fuel being delivered by the pistons back to the pump housing when the engine and the pump are being accelerated through the aforesaid surge region and thereby to reduce the fuel delivery temporarily to prevent or to reduce the possibility of surge occurring.

According to the invention, a fuel pump of the kind described includes a first centrifugally operable valve comprising means carried on the rotor and defining a first valve seat communicating with a spill passage in the rotor leading from the open ports of the bores, the valve seat when open permitting flow of fuel from the spill passage to the interior of the housing, and a first valve member carried by the rotor and urged by first spring means to close said first valve seat and operable by centrifugal force in opposition to the force of said first spring means when the rotor reaches a predetermined speed, the fuel pump also including a second centrifugally operable valve comprising means carried on the rotor and defining a second valve seat communicating with the or another similar spill passage in the rotor, a second valve member carried by the rotor and urged by second spring means to close said second valve seat and operable by centrifugal force in opposition to the force of said second spring means when the rotor reaches a predetermined speed lower than that at which said first valve member will open, a plunger slideable within the means defining said second valve seat and carrying a third valve member engageable with a third valve seat formed radially inwardly of said second valve seat, the end of the plunger remote from said third valve member being engageable with said second valve member, and there being a leak path around the plunger and through said second valve seat when said second and third valve members are open, the axial length of the plunger being such that said third valve member is held open when said second valve member is closed and will remain open while the latter is opening to its fully open position, thereby permitting a restricted flow of fuel through said second valve seat until said second valve member has opened fully, when said third valve member will close under centrifugal force, thereby stopping the flow of fuel through the spill passage until the rotor speed has increased to a value at which said first valve member will open.

By way of example, a liquid fuel pump in accordance with the invention is now described with reference to the accompanying drawings, in which:

FIG. 1 is a graph of fuel delivery plotted against pump rotor speed for a fuel pump of the kind described in the aforesaid specification;

FIG. 2 is a similar graph for the fuel pump in accordance with the present invention;

FIG. 3 is an end view of the rotor of the pump in accordance with the present invention;

FIG. 4 is a section of the line IV-IV of FIG. 3;

FIG. 5 is a section on the line V-V in FIG. 3;

FIG. 6 is an elevation to a larger scale of a plunger shown in FIG. 5;

FIG. 7 is an end view of the plunger in the direction of the arrow VII in FIG. 6;

FIGS. 8, 9 and 10 are three successive different positions of valve members appearing in FIG. 5, and FIG. 11 is a side elevation and part axial section of the pump.

The known fuel pump and also the pump in accordance with the present invention are each arranged to supply liquid fuel to a combustor chamber of a gas turbine engine and have a rotor arranged to be driven by the engine.

Referring firstly to FIGS. 3, 4 and 11 the fuel pump in accordance with the present invention has a rotor 1 having a plurality, e.g., three, axially extending bores 2, each containing a piston (30 in FIG. 11) of which one end extends from the bore and is urged by a spring (31 in FIG. 11) into abutment with a cam plate (32 in FIG. 11) inclined to the axis of rotation of the rotor and positioned adjacent the end 3 thereof (see FIGS. 4 and 11). The bores 2 have open ports at their ends remote from the cam plate, the said ports being circumferentially spaced around the axis of the rotor, whereby during rotation of the rotor and an integral shaft 5 thereof, the open port of each bore passes successively a fuel inlet and a fuel outlet in the form of circumferentially spaced arcuate apertures (33, 34 in FIG. 11) in a housing support (35 in FIG. 11) containing the rotor, the arcuate apertures being coaxial with the rotor and positioned in a stationary thrust face 38 in the housing support and coating with the end face of the rotor containing the said fuel inlet aperture communicates with the interior 36 of a tubular housing 37 carried by the housing support 35 and which forms a fuel reservoir and the outlet aperture leads to a delivery pipe. The outlet aperture also communicates with a spill passage 6 in the rotor 1 leading to the interior of the housing via a first centrifugally operable valve comprising a seating 7 in screw-threaded engagement with a socket 8 in the rotor 1 communicating with the spill passage 6 and a half-ball valve 9 carried on a leaf spring 10 extending parallel with the axis of the rotor and mounted thereon in cantilever fashion on a bracket 11 secured to the rotor 1 by means of screws 12. The fuel pump has another similar centrifugally operable valve arranged to open at a lower speed of rotation. The higher speed valve shown in FIG. 4 is indicated in FIG. 3 by arrow 9. The similar lower speed valve is indicated in FIG. 3 by arrow 9'. The two valves 9 and 9' are arranged at positions spaced apart by an angle of 120° with respect to the axis of rotation and in a known pump they are balanced by a balancing weight mounted on the rotor 1 in the position of a valve shown by arrow 9" in FIG. 3 and described hereinafter.

Referring now to FIG. 1, when the known pump rotor is accelerated, the fuel delivery will follow a line as indicated by A until the lower speed valve 9' opens under centrifugal force against the resistance of the relevant leaf spring 10 to spill fuel from the spill passage 6 through the seat 7 into the interior of the pump housing and hence back to the pump inlet. This oc-
curs at the point B shown in FIG. 1. In FIG. 1, the fuel flow which may cause the compressor supplying air to the combustion chamber of the gas turbine engine to surge is indicated by broken line C. When the engine, and hence the pump, is accelerated rapidly through the portion D, there is a possibility that the compressor will surge. The rotor of the pump in accordance with the present invention carries another centrifugally operable valve 9" instead of the aforementioned balancing weight. This valve is arranged to open centrifugally for a short period during operation along the line A in the region of surge C so that the acceleration line will follow a line of the general shape shown in chain lines at D in FIG. 1, instead of following the line A between points E and F on either side of the surge region C. In this way the possibility of the compressor surging will be avoided or reduced.

The centrifugally operated valve 9" in FIG. 3 is shown in section in FIG. 5 and comprises a seating 17, similar to the seating 7, inserted in a socket in the rotor 1. The seating 17 communicates with the spill passage 6 and, when open, with the interior of the housing. The seating 17 is arranged to be closed by a half-ball valve 19, similar to the half-ball valve 9 in FIG. 4, and mounted in a similar fashion on a leaf spring 20. The seating 17 has a central throughway in which a plunger 21 is freely slideable. The plunger has at its radially inner end an integral valve member 22 engageable with the radially inner end face 23 of the seating 17. The plunger 21 is longer than the seating 17 and so when the radially outer end of the plunger 21 is engaging the half-ball valve 19, when the latter is in its closed position as shown in FIG. 5, the valve member 22 is held in its open position in which it is clear of the end face 23. The plunger 21 is shown to a larger scale in FIGS. 6 and 7 and the radially outer end, that is the end remote from the valve member 22, has a flat side face 24 formed thereon. The plunger 21 is a fairly close sliding fit in the radially outer portion of the throughway in the seating 17 and so there is a controlled leakage path there through determined by the radial depth of the flat side face 24.

When the valve member 19 is closed and the valve member 22 is open, as shown in FIGS. 5 and 8, there will be no spill flow through the centrifugally operable valve 9" from the spill passage 6. However, as the speed of rotation increases, the half-ball valve 19 will lift from engagement with the seating 17 against the resistance of the spring 20 into an intermediate position shown in FIG. 9 in which the plunger will remain in engagement with the half-ball valve 19 and thus in which the latter is engageable by member 22 with a full stop. In this position a restricted spill flow will occur past the flat side face 24 into the spill passage 6. As the speed of rotation of the rotor increases still further, the half-ball valve 19 will lift to its fullest extent and it will become separated from the radially outer end of the plunger 21. Thus the latter will be permitted to enter into the position shown in FIG. 10 in which the valve member 22 will close the end face 23 of the seating 17 and spill flow through the valve 9" will cease.

This operation may be followed with reference to FIG. 2, which shows the fuel delivery line followed by the pump. As the speed of rotation of the rotor increases, the fuel delivery will follow the line A, the valves 9, 9' and 9" all remaining closed until a point E' is reached, when the half-ball valve 19 of the valve 9" will open to the position illustrated in FIG. 9, the half-ball valve 19 being set to open at a lower speed than the half-ball valve 19 of the low speed centrifugally operable valve 9'. When point E' is reached, there will be a restricted spill flow, as determined by the flat side face 24 of the plunger 21 until a speed has been reached at which the half-ball valve 19 will have opened sufficiently for the valve member 22 to close, as illustrated in FIG. 10. In that position spill flow will cease and the point E' will be reached. The speed of the rotor will then increase still further along an upper part of the line A to the end face remote from said head portion and engageable with said second valve member, said plunger being slideable within a throughway in a block defining at opposite ends of said.
throughway said second and third valve seats respectively and said plunger having a side face thereon cooperable with a wall of said throughway said to define said leak path

3. A fuel pump as claimed in claim 2 in which each of said first and second valve members is a half-ball valve and said first and second spring means are each a leaf spring carried by said rotor and on which the respective half-ball valve is carried.

4. A fuel pump as claimed in claim 3 in which said leaf springs extend substantially parallel with the axis of rotation of said rotor and are spaced apart circumferentially of said rotor.

5. A fuel pump as claimed in claim 1 in which said rotor carries a further centrifugally operable valve controlling flow through a spill passage in said rotor leading from said bores to the interior of said housing, said further valve being openable independently of said first and second valve members and at a rotational speed greater than that at which said first valve member opens.

6. A fuel pump as claimed in claim 5 in which said further valve comprises a half-ball valve and a leaf spring carried by said rotor and on which said half-ball valve is mounted.

7. A fuel pump as claimed in claim 5 in which each of said first and second valve members is also a half-ball valve and said first and second spring means are each also a leaf spring carried by said rotor and on which the respective half-ball valve is carried, said three leaf springs extending substantially parallel with the axis of rotation of said rotor and spaced apart circumferentially of said rotor at substantially equiangular positions around the rotor axis.