

[54] **COMPACT HIGH SPEED FUEL PUMP ASSEMBLY**

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[58] Field of Search 418/40, 176, 177, 266, 418/267, 268, 284, 293; 417/201, 202, 283, 294

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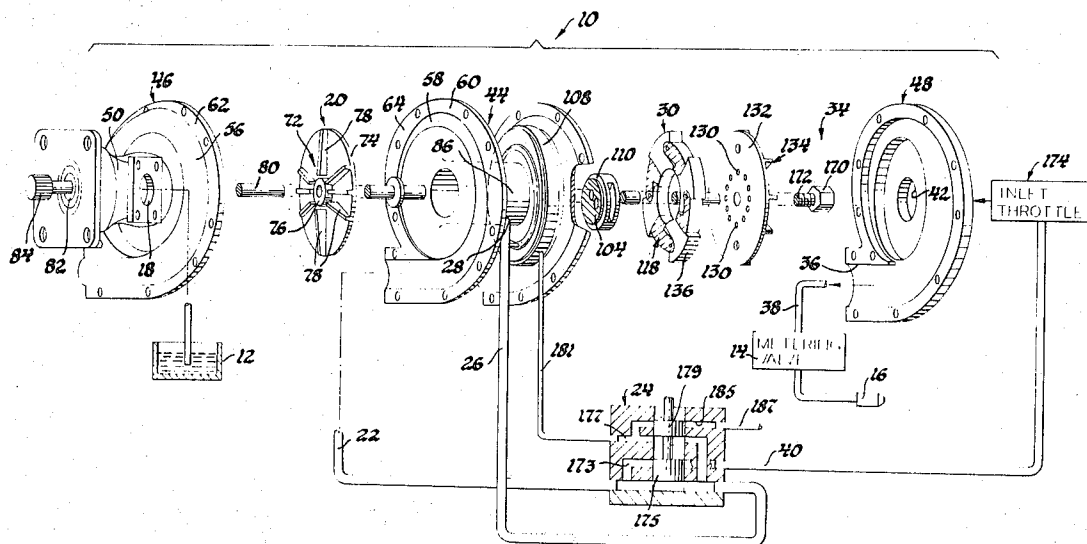
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[57] **ABSTRACT**

A high speed combination fuel pump for supplying fuel to a turbine engine including a centrifugal pump that develops a pressure required for turbine engine fuel systems by the use of a small diameter impeller running at turbine speed or higher RPM; fuel flow for starting and acceleration to idle turbine speed is furnished by a small positive displacement vane pump built physically into the backside of or otherwise in series or parallel arrangement with the centrifugal pump impeller. Following the start up phase of operation and at some speed below idle RPM the vanes of the impeller respond to centrifugal forces to unload the positive displacement pump whereby the centrifugal pump furnishes all the fuel.

7 Claims, 5 Drawing Figures



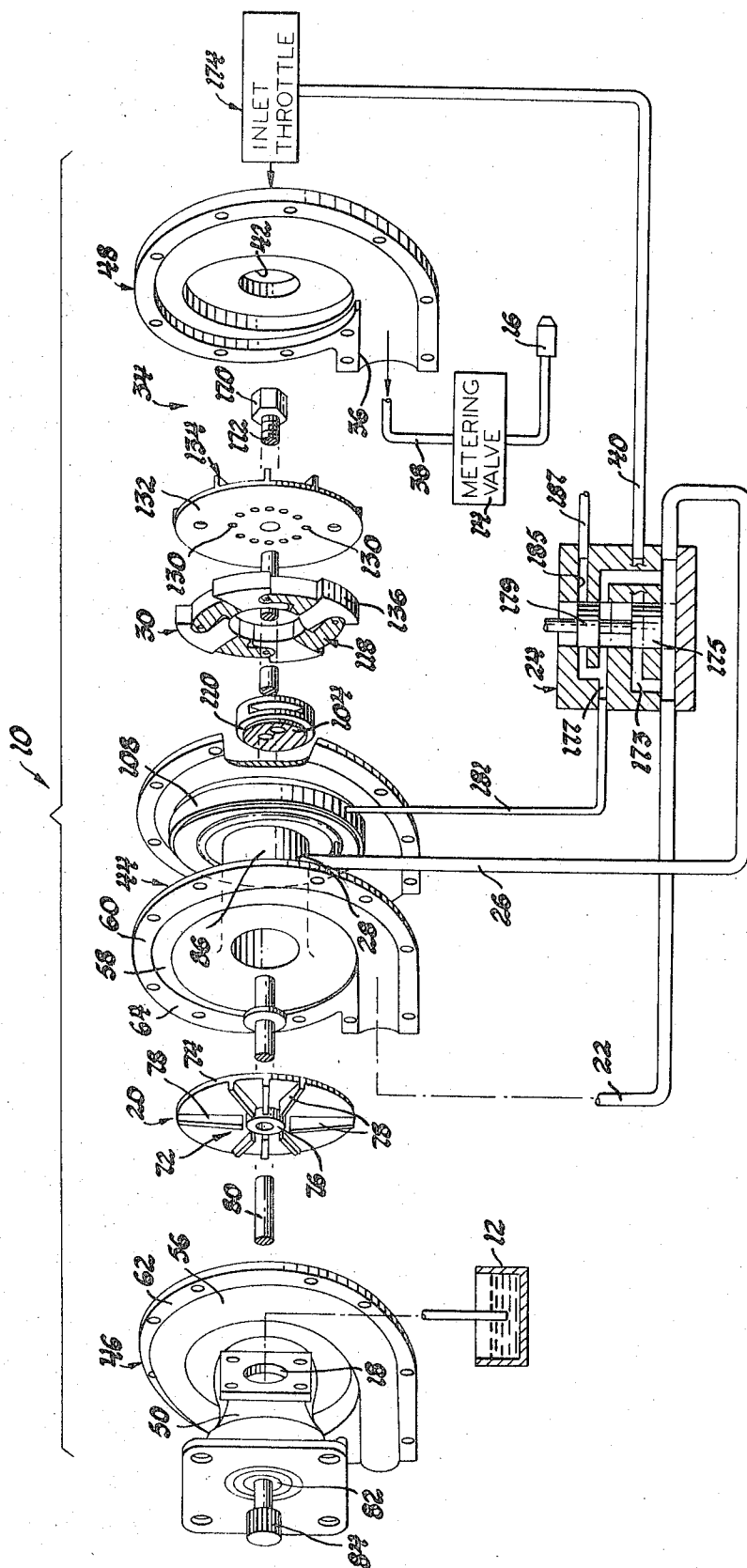
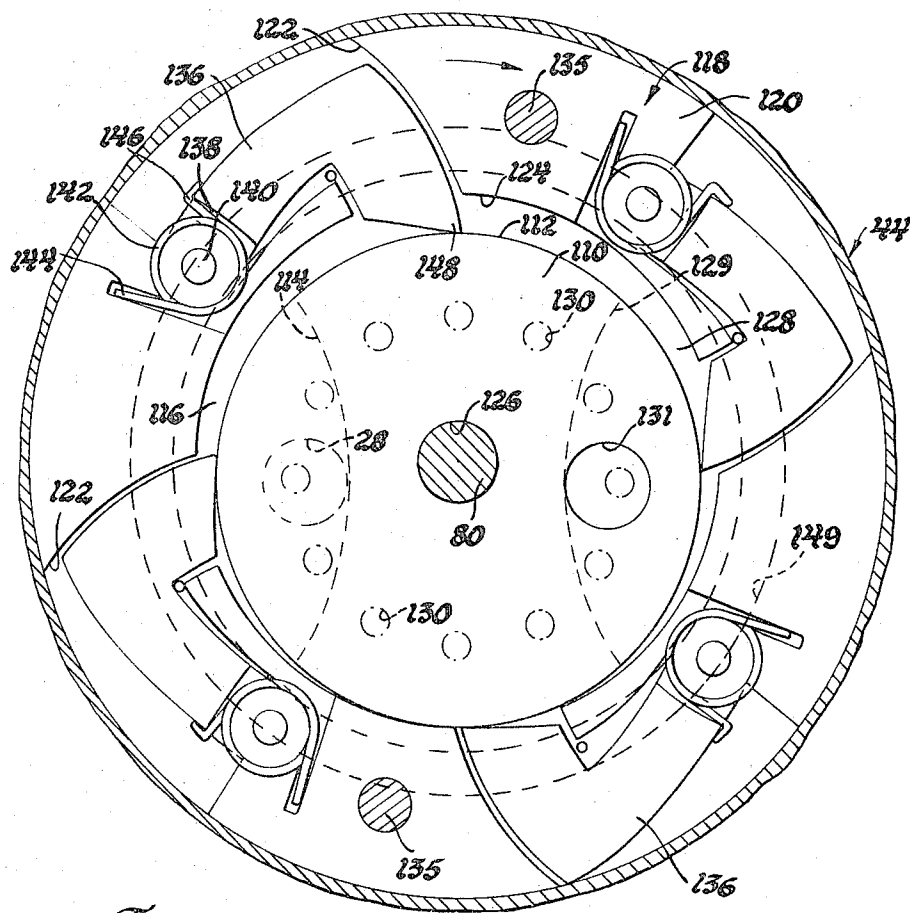
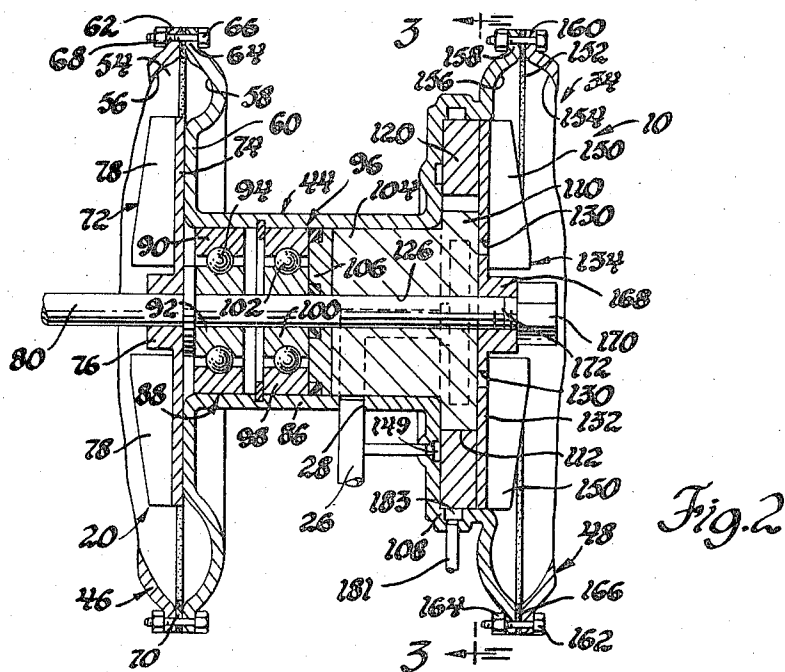


Fig. 2



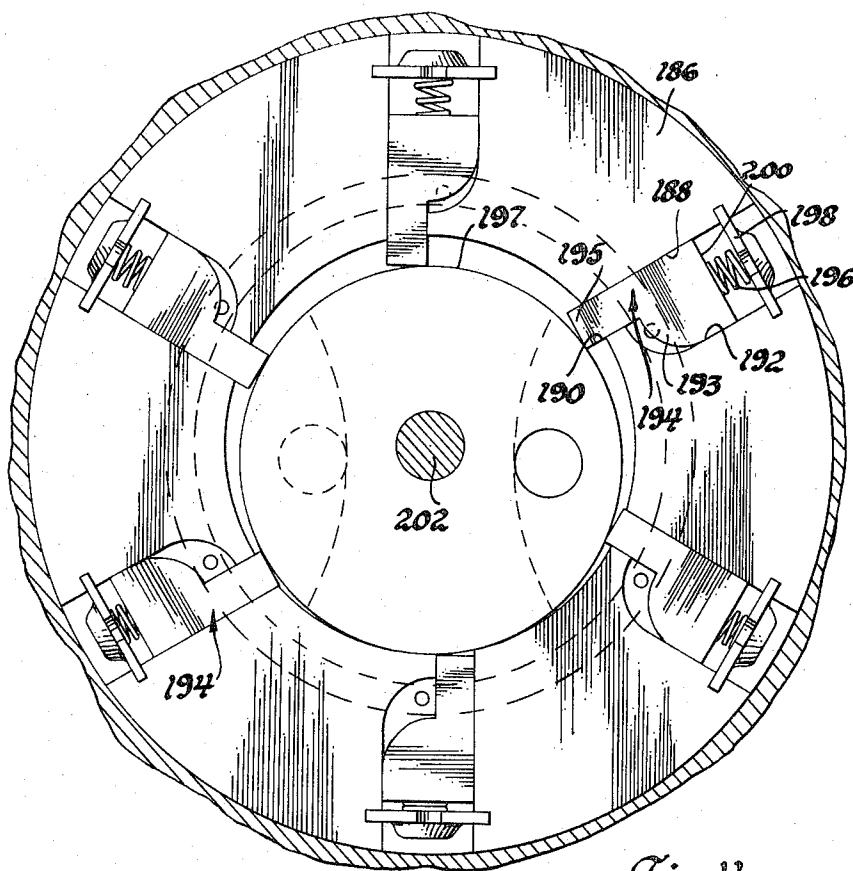


Fig. 4

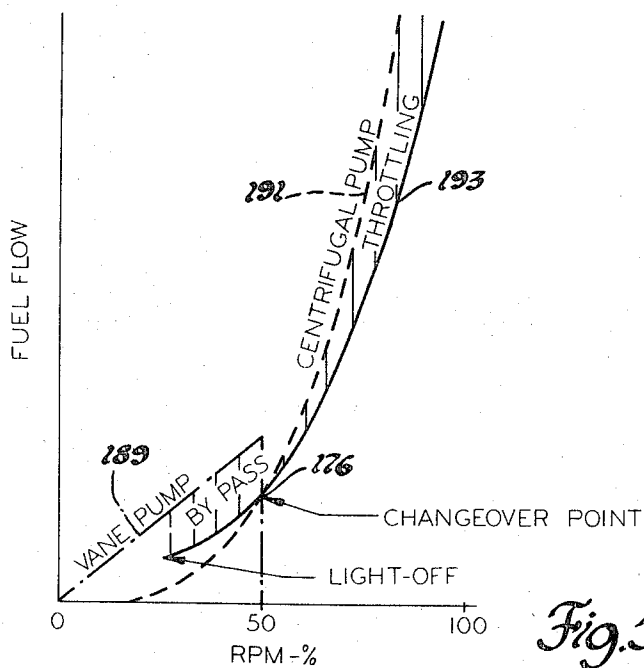


Fig. 5

COMPACT HIGH SPEED FUEL PUMP ASSEMBLY

This invention relates to multiple pump systems and more particularly to multiple pump systems for supplying the fuel requirement for gas turbine engines.

Gas turbine fuel and control systems for aircraft have evolved as a result of rigorous performance requirements of high performance vehicles. One approach to such systems is to utilize a centrifugal pump for supplying high volume fuel requirements to turbine engines at and above idle speeds of operation. In order to supply a positive head of fuel under start and acceleration to idle conditions prior systems have utilized a separate positive displacement pump such as a gear type pump. In such systems, as the turbine is accelerated through idle speeds of operation, the output pressure of the positive displacement pump exceeds that required for operation of the engine. Accordingly, such systems include means for bypassing fluid from the outlet of the positive displacement pump back to the inlet of the centrifugal pump which serves to supply a lower pressure greater flow requirement of the engine at idle and greater speeds of operation.

The use of small turbine engines in varied applications both for air borne vehicles and ground vehicles requires simpler systems with a lesser need for close temperature and speed control or fast acceleration and deceleration performance requirements.

Accordingly, an object of the present invention is to simplify fuel pump supply systems for turbine driven engines having compact configurations and capable of running at determined speeds and having a simplified design for bypassing fluid from a positive displacement pump operative to provide a high pressure supply of fluid from start through acceleration to idle speed.

Yet another object of the present invention is to provide an improved low cost compact high speed combination fuel pump assembly having a first pump means therein that develops a high fuel flow and required fuel pressures at and above idle speeds of turbine engine operation and further including a second pump means operative from start through acceleration to idle speed to produce a high pressure required volume of flow through this phase of operation and wherein the pump design is highly insensitive to wear by contaminants in the fuel and includes means for operating the centrifugal pump independently of the start pump means once the turbine has attained idle and greater speeds of operation.

Still another object of the present invention is to provide a compact, low cost, high speed fuel pump assembly for supplying fuel to a turbine driven engine wherein a small positive displacement vane pump is operative from start through acceleration to idle speeds for supplying fuel to the turbine at a reduced flow and a high pressure; the positive displacement vane pump including a radially outer rotor ring mounted on a turbine shaft support plate; suitable vanes in the ring being responsive to a predetermined speed of rotation to unload the positive displacement vane pump and to place the vanes out of operative engagement with a cam surface to reduce pump wear where the rotor of the vane pump is continuously operated in response to turbine operation.

Still another object of the present invention is to provide a low cost, compact, high speed pump assembly for supplying a gas turbine engine wherein the assembly includes a centrifugal pump with one rotating part that

is operated with or without gear reduction from the drive shaft of the turbine and wherein a centrifugal vane pump element is formed on the backside of the centrifugal pump or located as previously described and operative to produce a high pressure output from start through acceleration to idle speed and including means responsive to idle speed of operation to reduce the fluid flow from the positive displacement pump and thereby maintain a fluid flow from the pump dependent upon the pumping characteristics of the centrifugal pump; the centrifugal pump and positive displacement pump being structurally related so as to be highly insensitive to wear by contaminants in the fuel.

These and other objects of the present invention are attained in one working embodiment which includes a pump assembly having a drive shaft directly coupled to the drive shaft of a gas turbine driven engine to be operated at the turbine or higher speed of operation and wherein a centrifugal impeller is coupled to the shaft and operative within a centrifugal pump casing to supply a high volume reduced pressure flow of fuel to the turbine during a first phase of operation above turbine idle speed and wherein a positive displacement pump rotor is coupled to the centrifugal impeller to be driven within a cylindrical positive displacement pump chamber with respect to the outer periphery of a stationary cam plate to produce a high pressure fuel flow from the positive displacement pump chamber to the outlet of the centrifugal pump to produce a high pressure fuel low to meet the engine requirements from start through acceleration to idle speeds of operation.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred embodiment of the present invention is clearly shown.

IN THE DRAWINGS

FIG. 1 is a perspective view showing the operative components of the present invention in exploded relationship;

FIG. 2 is an enlarged cross sectional view of a single housing member in the present invention;

FIG. 3 is an enlarged vertical sectional view taken along the line 3—3 of FIG. 1;

FIG. 4 is a vertical sectional view of another embodiment of a positive displacement pump suitable for use in the present invention; and

FIG. 5 is a chart showing the fuel flow relationship to speed of operation of the gas turbine engine from the vane pump and centrifugal pump components of the high speed fuel pump assembly of the present invention.

Referring now to FIG. 1, a combined pump assembly 10 is illustrated which is operative to supply fuel from a fuel supply 12 through a metering valve 14 to a fuel nozzle 16 of a gas turbine engine.

As is best illustrated in FIG. 1, the fuel flow is from an inlet 18 through a vapor liquid inlet inducer 20. From the vapor liquid inlet inducer 20, flow passes through a starting circuit conduit 22 thence into the inlet of a changeover valve 24 from whence it passes through an outlet conduit 26 of the starting circuit which in turn is in communication with an inlet port 28 to a speed responsive positive displacement pump assembly 30. The flow passes from the pump 30 axially of the assembly through ports 32 leading to a centrifugal

gal pump assembly 34 having its outlet 36 connected by a conduit 38 through the metering valve 14 thence to the nozzle 16. The fluid circuit further includes a conduit 40 that connects the inlet conduit 22 of the starting circuit directly with an inlet 42 of the centrifugal pump assembly 34 during certain phases of operation.

More particularly, the pump assembly 10 includes a single housing member 44 that defines part of the vapor liquid inlet inducer as well as part of the positive displacement pump assembly 30. The single housing member is associated with a first closure plate 46 and a second closure plate 48 to seal the unit together as a compact assembly suitable for association with small gas turbine engines.

More particularly, the closure plate includes a tubular extension 50 thereon having the inlet 18 formed in the side thereof. The inlet 18 thence directs fuel through the tubular extension 50 into the eye of a volute chamber 54 formed by a volute shaped surface 56 on the closure plate 46 and a like volute shaped concave surface 58 formed on a housing portion 60 of the single housing member 44.

An outer peripheral portion 62 of the closure plate 46 is connected to an outer peripheral portion 64 of the pump housing portion 60 by suitable fastening means such as bolts 66 and nuts 68 and are sealed with respect to one another by means of an annular gasket member 70.

The vapor liquid inlet inducer 20 includes an impeller 72 having a back plate 74 thereon located closely adjacent the inner surface of the centrifugal pump housing portion 60 and with its outer periphery located closely adjacent the inboard edge of the volute chamber 54. The impeller further includes a central hub 76 and a plurality of radial vanes 78 extending from the central hub 76 to the outer periphery of the impeller 72. Each of the radial vanes extend between the central hub 76 and the outer periphery of the impeller 72 and decrease in height from the central hub to the outer periphery of the impeller.

A drive shaft 80 located within the volute chamber 54 extends therefrom through the tubular extension 50 to a point outboard of the end closure plate 46. Shaft seal means 82 are located within the tubular extension 50 at the end thereof and the outboard end of the drive shaft 80 has a pinion 84 secured thereto for direct coupling to a turbine drive shaft whereby the compact pump assembly 10 is operated at maximum speeds in the order of 40,000 - 60,000 revolutions per minute.

The drive shaft 80 extends axially through a tubular segment 86 of the single housing member 44. The tubular portion 86 defines a bearing housing for the shaft 80. More particularly, a first bearing assembly 88 is located at one end of the tubular extension 86 including an outer race 90 connected to the tubular portion 86 adjacent the impeller 72 and an inner race 92 connected to the shaft 80. Suitable anti-friction means such as balls 94 are located between the inner and outer races 90, 92 for rotatably supporting the shaft 80 at this location for relative rotation with respect to the fixed housing members.

A second bearing assembly 96 is located at the opposite end of the portion 86. It includes an outer race 98 secured to the opposite end of the tubular extension and an inner race 100 connected to the shaft. Suitable ball bearing means 102 are located between the inner and outer races 100, 98 respectively to rotatably sup-

port the shaft at this location. A cylindrical plate member 104 is inserted in the end of the portion 86 to hold a shaft seal assembly 106 against one face of the bearing assembly 96 thereby to seal against leakage of fluid along the shaft 80 into a cylindrical pump housing 108 formed on the single housing member 44 opposite to the centrifugal pump housing 60 thereon.

The cylinder plate member 104 has an extension 110 thereon located within the cylindrical housing 108. It includes an eccentrically formed cam surface 112 on the outer periphery thereof.

Furthermore, the inlet port 28 to the speed responsive positive displacement pump assembly 30 is in communication with a slot 114 formed on one side of the cylindrical member 104 and radially outwardly of the extension 110 through the periphery 112 thereon. The slot 114 communicates with a low pressure side 116 of a pumping chamber formed between the stationary cam surface 112 and a rotor assembly 118. The rotor assembly 118 more particularly includes an annular rotor member 120 having a plurality of circumferentially located slots 122 thereon that extend through the annular member 120 from the outer periphery thereof to a central bore 124 therein located concentrically of the shaft 80 which extends axially through a bore 126 through the cylindrical member 104.

The annular rotor member 120 is spaced with respect to the outer cam periphery surface 112 to form in addition to the low pressure side of the pumping chamber, a high pressure side 128 that is in communication with a plurality of ports 130 formed in the base plate 132 of a centrifugal impeller 134 that forms part of the centrifugal pump assembly 34. The rotor 120 is connected by bolts 135 to plate 132 whereby both impeller 134 and rotor 120 are driven as a unit.

In order to produce a high pressure discharge during operation of the assembly from start to idle speeds of operation, the rotor 120 includes a plurality of centrifugally responsive elements shown in the embodiment of FIGS. 1 through 4 as vane elements 136 each including a base portion 138 located in one of the slots 122 and pivotally secured by means of a pin 140 to the rotor 120. A biasing spring 142 is wound around the pin 140 and includes one end portion 144 thereon fastened to the rotor 120 and an opposite end portion 146 located on the vane 136 so as to bias a radially inwardly directed tip portion 148 thereon against the cam periphery 112. The vanes 136 are further biased by pressure differential thereacross produced by low pressure annulus 149 and high pressure annulus 183 in housing 108. The vanes will draw fluid through the inlet 28 and the cylinder slot 114 into the low pressure side 116 of the pumping chamber thence to be physically displaced through the high pressure side 128 of the pumping chamber and thence through the ports 130.

The ports 130 lead to a plurality of passages formed between radial vanes 150 on the impeller 134 from whence the liquid will flow through an annular passage 152 formed by a volute casing 154 that leads to the outlet 36. The remainder of the volute passage 152 is formed by a concave volute casing portion 156 on the outer periphery of the cylindrical housing 108. Outer peripheral lips 158, 160 on the volute portion 156 and the housing portion 154 are joined by suitable fastening means such as screws 162 and nuts 164 and are sealed with respect to one another by means of a sealing gasket 166 located therebetween.

The shaft 80 is connected to a central hub 168 on the impeller 134 by means of a nut 170 secured to the threaded end 172 of the shaft 80 which is located within the inlet eye 42 formed in the casing member 154 in alignment with an inlet throttle valve mechanism 174 which is connected by means of conduit 40 to the outlet of changeover valve 24.

The inlet throttle valve assembly 174 is of the type well known to those skilled in the art including a valve member located in the center eye inlet of the centrifugal pump assembly 34. It is controlled by flow control means to vary the flow of fuel from the conduit 40 into the eye of the impeller 34 thence to the delivery conduit connected to the outlet 36.

Under start and acceleration to idle speeds of operation, the illustrated pump assembly 10 will draw liquid from the fuel supply 12 through the inlet 18 thence through the vapor liquid inlet inducer 20 and through the conduit 22 to the changeover valve 24 that is conditioned as shown in solid line in FIG. 1 to have a spool 175 thereon located to complete a start circuit to the conduit 26 thence into the inlet 28 of the positive displacement pump means 30. Under these conditions, the speed of operation is such that the centrifugally biased vane elements 136 will be held by the spring so as to locate the vane tips 148 against the cam surface 112 thereby to displace liquid from the positive displacement pumping chamber through the ports 130. Output pressure in conduit 22 is directed through passage 177 in valve 24 which is opened by spool 179 through conduit 181 to an annulus 183 in housing 108 to pressure load the vanes 136 during start.

At start and acceleration to idle speeds, the vane pump will increase from approximately zero to near idle, 10,000 RPM. Under such circumstances, in one working embodiment, the pump fuel flow increases at a linear rate as shown by curve 189 in FIG. 5 to 6 gallons per minute at 10,000 RPM. At this speed of operation, the vane elements 136 are subjected to centrifugal action to overcome the force of the springs thereby to reduce sealing engagement between the vane tips 148 and the cam surfaces 112. This transition is shown in FIG. 5 at point 176.

Once an idle speed of operation has been reached, the changeover valve 24 is conditioned by suitable means (not shown) to shift spools 175, 179 downwardly into the dotted line position seen in FIG. 1 to block communication between conduits 22, 26 and to directly communicate the outlet conduit 22 with conduit 40 to the inlet throttle valve 174 through valve passage 183. The back pressure on vanes 136 is relieved through valve passage 185 and conduit 187 to the inducer inlet 18.

Following attainment of idle speed of operation and conditioning of the changeover valve to communicate the conduit 22 with the inlet throttle valve 174 and the volute passage 152 the further increase in speed of operation of the turbine will drive the shaft 80, which is directly coupled to the turbine, to speeds in the order of 40,000 - 60,000 RPM thus causing the centrifugal impeller 134 to supply ever increasing quantities of fuel to the turbine to maintain efficient operation thereof.

During this phase of operation, the positive displacement start pump 30 is unloaded thereby to reduce heat generated and the power required to operate the pump assembly.

Another advantage of the arrangement is that once the vanes 136 are retracted by centrifugal action thereon so that the tips 148 are spaced from the cam periphery 112, the wear of the vanes will be reduced to make possible the use of lower cost materials in their construction. Further, the vane pump does not operate continuously with displacement from the outlet thereof having to be controlled by bypass valve means back to the fuel supply to avoid conditions wherein the output capacity of the pump exceeds the requirement of the engine following the start phase of operation and acceleration through idle phase operation.

In the illustrated arrangement, the centrifugal pump 34 along with the positive displacement impeller 120 formed integrally on the back thereof constitutes one rotating part having long life. This results in a dependable unit of simple design that requires no gear reduction from the turbine shaft speed of operation. Moreover, the pump design is highly insensitive to wear by contaminants in the fuel since the flow passages throughout the system are relatively unrestricted to allow free flow of fluid from inlet 12 to nozzle 16.

In one working embodiment, preliminary calculations showed that the pump assembly 10 produces a maximum fluid flow requirement of 20,000 lbs. per hour of kerosene type fuel at 25,000 RPM of pump speed. In the illustrated arrangement, the maximum pressure output of the centrifugal impeller 34 is in the order of 1,000 psi at 25,000 RPM.

Referring now more particularly to FIG. 5, the pump operation sequence is graphically illustrated including the start and acceleration phase of operation wherein the vane pump curve 189 will supply the fuel flow requirements until approximately 40-50 percent of the speed of operation is attained at which point, the centrifugal pump will take over to produce a greater fuel flow requirement at higher speeds of operation. This is shown by a centrifugal fuel flow curve 191. A third curve 193 is shown on the graph which represents the fuel flow required to run the turbine. Necessary throttling is provided by the inlet throttle valve 174 to closely match the fuel flow output of the pump assembly to the fuel requirements of the engine.

In the illustrated arrangement, the vane pump discharge pressure is admitted to the top of each of the vane elements to assist the spring 142 to urge the vane tip 148 into its operative relationship with respect to the cam periphery 112. The combined force of the vane pump discharge pressure and the spring is in opposition to centrifugal force and the inlet pressure through the port 28 and slot 114. At idle speed, the changeover valve 24, which is sensitive to pressure rise from inlet to outlet of assembly 10 and to pressure rise from vane pump inlet to outlet is closed by spring force. As the pressures equalize between vane pump inlet and outlet, the vane pump inlet is blocked and the area behind the vanes is vented to low pressure thereby permitting centrifugal force to overcome the spring load on the vanes and to retract them to the inoperative position. As shown in the graph, the centrifugal element alone supplies the fuel to the engine from this point on.

In another embodiment of the present invention, the positive displacement pump assembly 30 includes a rotor assembly as shown in FIG. 4 which has an annular rotor 186 with a plurality of circumferentially located slots 188 therein each including a rectangularly config-

ured radially inner portion 190 and an enlarged upper portion 192 with a curved wall portion thereon that supports a like configured offset surface 193 of a retractable vane 194 having a radially inner tip portion 195 biased by means of a spring 196 radially inwardly against the outer periphery of a cam surface 197 like the cam surface 112 in the first embodiment of the invention. Springs 196 are each retained by a perforated lock washer 198. In this embodiment, the enlarged head portion of each of the vanes will be maintained by the spring force and a high pressure output from the vane pump acting on surface 200 on vane 192 so as to maintain the vanes in pumping contact with the cam surface 197 from start through idle speeds of operation. Thereafter, centrifugal forces acting on each of the vanes along with the inlet pressure will act to raise each of the vane tips radially outwardly in the slots to unload the pump thereby reducing the power requirements for the start pump from a drive shaft 202 corresponding to the shaft 80. Concurrently, internal valving, part of the changeover valve (not shown) will close the vane pump inlet and will vent the high pressure areas behind the vanes to a low pressure region thereby quickly permitting the centrifugal force to overcome the spring load on the vanes causing them to be retracted to an inoperative position. As in the first case, this embodiment of a positive displacement centrifugal responsive vane pump will serve to direct liquid flow through a primary centrifugal impeller. Furthermore, the rotor 186 is formed as an integral part of the centrifugal pump to maintain a reduced compactness in the pump assembly and to enable the pump assembly components to be operated at turbine speed or higher RPM and to supply required fuel flow requirements to the pump within a desired output pressure range all by the means of a single drive shaft directly coupled to the turbine power shaft.

While the embodiments of the present invention, as herein disclosed, constitute a preferred form, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. A pump assembly for producing a high pressure output during a start phase of operation, housing means forming a chamber having an inlet and an outlet thereto, a rotatable shaft directed through said housing driven between first and second speeds, a rotor located within said chamber radially outwardly of said rotatable shaft including a radially inwardly located central bore therein concentric of said rotatable shaft, coupling means connecting said rotor to said shaft for concurrent rotation therewith, means forming a stationary cam member within said rotor bore having an outer periphery eccentric to said shaft for forming a pump chamber with said rotor in communication with said inlet and outlet, said rotor having a plurality of radial slots therein each opening into said central bore therethrough, a vane located in each of said slots including a radially inner located tip thereon located in sliding engagement with the outer periphery of said cam member for displacing fluid from said chamber between said inlet and outlet, spring means having a predetermined rate for biasing said vanes into sealed engagement with said cam periphery during a start phase of operation between first and second predetermined speeds wherein said vanes positively displace fluid to cause a high lift flow of fluid from the inlet to the outlet of said pump chamber to produce a high pressure fluid dis-

charge during the start phase of operation, said vanes being responsive to centrifugal action at said second predetermined speed to compress said spring means and to move radially outwardly within said slots to disengage the inner tips thereof from the outer periphery of said stationary cam thereby to terminate the positive displacement of fluid from said inlet to said outlet at said second predetermined speed and to reduce frictional wear between said vanes and said cam when said shaft is driven at said second predetermined speed.

2. A pump assembly for producing a high pressure output during a start phase of operation, housing means forming a chamber having an inlet and an outlet thereto, a rotatable shaft directed through said housing driven between first and second speeds, a rotor located within said chamber radially outwardly of said rotatable shaft including a radially inwardly located central bore therein concentric to said rotatable shaft, means forming a stationary cam within said rotor having an inner bore therethrough and an outer periphery eccentric to said shaft for forming a pump chamber with said rotor in communication with said inlet and outlet, said shaft being directed through said eccentric cam bore and including a driven end located exteriorly of said chamber and a drive end, coupling means connecting said shaft to said rotor for concurrent rotation, said coupling means including a plate extending circumferentially of said shaft and directed radially therefrom to define an end wall of said pump chamber rotatable with respect to said housing during rotation of said rotor within said housing chamber, said rotor having a plurality of radial slots therein each opening into said central bore therethrough, a vane located in each of said slots including a radially inner located tip thereon located in sliding engagement with the outer periphery of said cam for displacing fluid from said chamber between said inlet and outlet, spring means having a predetermined rate for biasing said vanes into sealed engagement with said cam periphery during a start phase of operation between first and second predetermined speeds wherein said vanes positively displace fluid to cause a high lift flow of fluid from the inlet to the outlet of said pump chamber to produce a high pressure fluid discharge from said pump assembly during the startup phase of operation, said vanes being responsive to centrifugal action at said second speed to compress said spring means and to move radially outwardly within said slots to disengage the inner tips thereof from the outer periphery of said stationary cam thereby to terminate the positive displacement of fluid from said inlet to said outlet at said second speed and to reduce frictional wear between said vanes and said cam when said shaft is driven at said second speed.

3. A pump assembly for producing a high pressure output during a start phase of operation, housing means forming a chamber having an inlet and an outlet thereto, a rotatable shaft directed through said housing driven between first and second speeds, a rotor located within said chamber radially outwardly of said rotatable shaft including a radially inwardly located bore therein concentric of said rotatable shaft, means connecting said rotor to said shaft for concurrent rotation therewith, means forming a stationary cam within said rotor bore having an inner bore therethrough and an outer periphery eccentric to said shaft for forming a pump chamber with said rotor in communication with said inlet and outlet, said rotor having a plurality of ra-

dial slots therein each opening into said central bore therethrough, a vane located in each of said slots including radial inner and outer surfaces and a radially inner located tip thereon located in sliding engagement with the outer periphery of said cam for displacing fluid from said chamber between said inlet and outlet, spring means having a predetermined rate for biasing said vanes into sealed engagement with said cam periphery during a start phase of operation between first and second predetermined speeds wherein said vanes positively displace fluid to cause a high lift flow of fluid from the inlet to the outlet of said pump chamber to produce a high pressure fluid discharge from said pump assembly during the startup phase of operation, said vanes being responsive to centrifugal action at said second speed to compress said spring means and to move radially outwardly within said slots to disengage the inner tips thereof from the outer periphery of said stationary cam thereby to terminate the positive displacement of fluid from said inlet to said outlet at said second speed and to reduce frictional wear between said vanes and said cam when said shaft is driven at said second speed, means defining a first annulus in said housing means radially outwardly of said rotor to apply a first fluid pressure on said radial outer surface on each of said vanes, means defining a second annulus in said housing means radially inwardly of said first annulus to apply a second lesser fluid pressure on said radial inner surface on each of said vanes to produce a pressure differential on said vanes to supplement the bias of said spring means during the start phase of operation between said first and second speeds of operation.

4. A multiple pump assembly for producing a high pressure output during start operation and a higher volume output during a high speed operation comprising: a pump housing including a centrifugal pump chamber having an inlet and an outlet thereto and a positive displacement pump chamber having an inlet and an outlet thereto, an impeller located within said housing including a first portion thereon operative within said centrifugal pump chamber to draw fluid from said centrifugal inlet for discharge through the centrifugal outlet, a shaft directed through said housing connected to said impeller, said impeller having a rotor thereon located within said positive displacement pump chamber radially outwardly of said shaft including a radially inwardly located bore therein concentric of said shaft, means forming a stationary cam member within said rotor bore having an outer periphery eccentric to said shaft for forming a low pressure inlet region therebetween and a high pressure outlet region therebetween, said rotor portion having a plurality of radial slots therein each opening into said central bore therethrough, a vane located in each of said slots including a radially inner located tip thereon located in sealing engagement with the outer periphery of said cam member, spring means for biasing said vanes into sealed engagement with said cam periphery during a startup phase of operation wherein said vanes serve to positively displace fluid from the low pressure region to the high pressure region thereby causing a high lift flow of fluid from the inlet to the outlet of said positive displacement pump chamber to produce a high pressure fluid discharge from said pump assembly during a startup phase of operation, said impeller being rotated by said shaft to produce a second high speed operation wherein fluid is supplied from the centrifugal pump

chamber from the inlet to the outlet thereof at a high flow rate during a high speed phase of operation, said vanes in said second impeller portion being responsive to the higher speed of operation to move radially outwardly within said slots to disengage the inner tips thereof from the outer periphery of said stationary cam thereby to terminate the positive displacement of fluid from the low to the high pressure region of said positive displacement pump chamber and to reduce frictional wear between said vanes and said cam during said high speed phases of operation.

5. A multiple pump assembly for producing a high pressure output during start operation and a higher volume output during a high speed operation comprising: a pump housing including a centrifugal pump chamber having an inlet and an outlet thereto and a positive displacement pump chamber having an inlet and an outlet thereto, an impeller located within said housing, shaft means for rotating said impeller, said impeller including a first portion thereon operative within said centrifugal pump chamber to draw fluid from said centrifugal inlet for discharge through the centrifugal outlet, said impeller having a rotor thereon located within said positive displacement pump chamber radially outwardly of said shaft including a radially inwardly located central bore therein concentric of said shaft, means forming a stationary cam member within said radially inwardly located bore including an outer periphery eccentric to said shaft for forming a low pressure inlet region therebetween and a high pressure outlet region therebetween, said second impeller portion having a plurality of radial slots therein each opening into said central bore therethrough, a vane located in each of said slots including a radially inner located tip thereon located in sealing engagement with the outer periphery of said cam member, spring means for biasing said vanes into sealed engagement with said cam periphery during a startup phase of operation wherein said vanes serve to positively displace fluid from the low pressure region to the high pressure region thereby causing a high lift flow of fluid from the inlet to the outlet of said positive displacement pump chamber to produce a high pressure fluid discharge from said pump assembly during a startup phase of operation, said impeller being rotated by said shaft to produce a second high speed operation wherein fluid is supplied from the centrifugal pump chamber from the inlet to the outlet thereof at a high flow rate during a high speed phase of operation, said vanes in said rotor being responsive to the higher speed of operation to move radially outwardly within said slots to disengage the inner tips thereof from the outer periphery of said stationary cam thereby to terminate the positive displacement of fluid from the low to the high pressure region and to reduce frictional wear between said vanes and said cam during said high speed phases of operation, an inducer pump coupled to said shaft to be rotated with said impeller, said inducer pump having an inlet and an outlet, fluid circuit switching means selectively connecting said last mentioned outlet to said positive displacement pump inlet when said vanes engage said cam and to said centrifugal pump inlet when said vanes are disengaged thereby to direct flow from said inducer pump to said centrifugal pump in bypassed relation to said positive displacement pump during high speed operation.

6. A multiple pump assembly for supplying a positive head of liquid fuel to a turbine through a wide range of

turbine speeds comprising a housing member having a volute chamber portion formed on one end thereof and a positive displacement pump chamber formed on the opposite end thereof, first closure means with a volute chamber connected to said one end for forming an inducer pump chamber, said first closure means having an inlet therein for supplying vapor and liquid fuel to the inducer pump chamber, second closure means including an outlet for closing said positive displacement chamber, a drive shaft having one end outboard of said first closure means to be directly coupled to a turbine shaft, said drive shaft having an opposite end thereof directed through said first closure means and said housing member into said positive displacement pump chamber, a vapor liquid inlet inducer impeller located within said inducer pump chamber and connected to said shaft for rotation therewith and operative to draw liquid and vapor from said first closure means inlet and discharge it radially outwardly of said inducer pump chamber, an outlet from said inducer pump chamber, means forming an inlet to said positive displacement pump chamber, a stationary cam located within said positive displacement pump chamber having a peripheral slot therein in part defining the inlet to said positive displacement pump chamber, a rotor connected to the opposite end of said shaft located within said positive displacement pump chamber including an inner periphery thereon located in spaced relationship with the outer periphery of said stationary cam to form a low pressure inlet and a high pressure outlet region therebetween, means including a second slot in said cam to communicate said high pressure outlet region with said second closure means outlet, a plurality of slots located within said rotor from the inner to the outer periphery thereof, vane elements located within said slots having an inner tip portion thereon located within the low and high pressure regions in engagement with the outer periphery of said stationary cam, spring means for biasing said vane tips against said cam for positively displacing liquid from the low and high pressure regions of the positive displacement pump chamber during rotation of said shaft and said rotor with respect to said stationary cam plate thereby to produce a high pressure discharge of fluid from said multiple pump at start through idle speeds of operation, said vanes responding to a predetermined centrifugal force produced by a predetermined speed of rotation of said shaft to shift radially outwardly within said slots to cause said vane tips to move away from said cam periphery thereby to reduce wear between said vane tips and said cam periphery during high speed rotation of said shaft, and changeover valve means for directing fuel from the outlet of said inducer chamber to the inlet of said positive displacement chamber following pump startup and up to idle speed of rotation, said changeover valve means being responsive to speeds of rotation above idle to divert fluid from the outlet of said inducer chamber to the outlet from said second closure means to bypass the operative components of the positive displacement pump during high speed operation.

7. A multiple pump assembly comprising a housing member having a volute chamber portion on one end thereof and a positive displacement pump casing on the opposite end thereof including a radially outwardly located volute portion on the outer periphery thereof, a first closure member having a volute chamber portion on the outer periphery thereof and a side fuel inlet

thereto, said first closure member closing said volute casing portion on said single housing member and defining therewith an inducer pump chamber having an axial inlet in communication with the fuel inlet and a radial outlet, a vapor liquid inlet inducer impeller located within said inducer pump chamber, a drive shaft directed through said first closure member having a portion thereon fixedly secured to said inducer impeller for rotating said inducer impeller within said inducer pump chamber, said housing member having a central bearing bore therein, bearing means within said bore supportingly receiving an extension on said shaft, said shaft having an opposite end thereon located at the opposite end of said housing member outboard thereof, said positive displacement casing forming a positive displacement pump chamber, a radially outwardly located volute portion on said positive displacement casing, a second closure member for said housing member having an inlet opening therein and a volute casing formed thereon connected to said housing to define a centrifugal pump chamber with an outlet, a centrifugal impeller located within said centrifugal pump chamber for drawing fluid from the inlet in said second closure member for discharge through the outlet from said centrifugal pump chamber, means for connecting said centrifugal impeller to said shaft for rotation within said centrifugal pump chamber, said centrifugal impeller having a rear plate thereon, a positive displacement rotor connected to said rear plate of said centrifugal impeller, said positive displacement rotor located within said positive displacement chamber radially outwardly of said shaft and including a plurality of circumferentially located radial slots therein communicating with a central bore therein formed concentrically of said shaft, a cam located within said central bore and having the outer periphery thereof eccentric of said shaft and located in spaced relationship with the inner periphery of said positive displacement rotor to define a low pressure and a high pressure region therebetween, an inlet in said cam for supplying fluid into said low pressure region, an outlet in said cam for directing fluid from said high pressure region, a plurality of openings in said plate of said centrifugal impeller for diverting fluid discharged from said high pressure region radially outwardly of said centrifugal impeller through the outlet of said centrifugal pump chamber, a vane element in each of said slots including a radially inner tip portion thereon located within the bore of said rotor, spring means for biasing said vane tip into sliding sealed engagement with the outer periphery of said cam to cause fluid to be positively displaced from the low pressure region to the high pressure region during rotation of said shaft to produce a high pressure discharge of fluid through said centrifugal impeller and outwardly of the outlet of said centrifugal chamber during a startup phase of operation, means for communicating the outlet from said inducer pump chamber with the inlet to said positive displacement pump during the start phase of operation, said means including means responsive to a predetermined speed of rotation of said shaft to divert liquid from the outlet of said inducer pump chamber to the inlet of the centrifugal pump chamber, said vanes being responsive to said predetermined speed of operation to move radially outwardly of said slots thereby to reduce wear between said vane elements and the outer periphery of said cam during high speed operation following a start phase of operation.

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