ENGINES - DESCRIPTION

BENDIX DIRECT FUEL INJECTION

GENERAL

The Bendix direct fuel injection consists of three major sections; namely, the master control, two fuel injection pumps, and 18 individual cylinder head discharge nozzles.

The master control is very similar to the Stromberg "PR" series injection carburetors; the important difference being that the metered fuel from the fuel control unit is piped directly to the injection pumps instead of to the usual single discharge nozzle or discharge bar.

The injection pumps, which may be considered merely as distributors, accurately divide the total quantity of fuel delivered by the master control into equal parts, and deliver the equally divided parts to the engine cylinders at high pressure, through discharge nozzles screwed into the cylinder heads.

The discharge nozzles, one in each cylinder head, are connected to the injection pumps through high-pressure, stainless steel injection lines. The path of the 18 injection lines to each of the cylinders is primarily inside the engine, except in the vicinity of the nozzles, and for a relatively short distance from the front of the supercharger rear housing to the rear of the supercharger front housing, where the lines are external. The nozzles open when the pressure in the injection lines is great enough to overcome the force of the nozzle spring (500 PSI), and spray fuel into the engine cylinders during the intake strokes.

The driving mechanism of each pump is lubricated by engine oil, at engine oil pump pressure, fed through a channel in the mounting flange. The oil flows through the lower driving mechanism and drains back through the bearings into the engine oil sump.

Vapor is eliminated from each pump through a vent float and valve system in a housing in the top of the pump. The float is held in place within a cage, which allows the float to move up and down as the fuel level in the pump rises and falls.

Inasmuch as this system is a dual pump installation, it is very important that the two pumps be synchronized as to the position of the by-pass control plates which control the output position of the by-passes. For this reason, there is an external lever on each pump which, in conjunction with the pump control diaphragm, controls the position of the by-pass control plates. These two levers are connected through a link rod which, when properly adjusted, synchronizes these two external levers and, in turn, the position of the by-pass control plates.

MASTER CONTROL, description and principles of operation

The Stromberg PR-58S2 master control is attached to the regular engine carburetor mounting flange. The master control incorporates a fuel head power enrichment valve, constant head idle spring, rotary idle valve, a manual mixture control providing for "IDLE CUT-OFF", and an automatic mixture control unit combining a temperature compensator and an altitude control.

The main venturi forms a restriction in the air passage and is so shaped that when the air speed is increased there is a drop of pressure at the venturi throat. The more the throttle is opened the lower this pressure becomes, thus providing an accurate measure of incoming air.

The boost venturi is placed in the airstream so that the tail comes at the smallest restriction in the main venturi, or at the throat. By using the double venturi system in this manner the measure of entering air becomes more accurate. A boost venturi has two purposes: to increase the air metering differential and to measure the amount of air flowing to the engine.

Eight impact tubes are spaced around the main venturi and direct a sampling of impact air through the automatic mixture control and altitude compensator needles to "A" chamber. These tubes are large enough and so spaced that they will give an adequate and accurate sampling of the incoming scoop air pressure. At set altitude this pressure varies but slightly with changing air speeds.

The regulator is one means of setting up or changing fuel pressure in the carburetor. The Stromberg injection has a differential regulator which is diaphragm operated.

"A" chamber is impact pressure, which remains practically constant, at one altitude, regardless of RPM.

"B" chamber is boost venturi throat pressure which decreases as the throttle valves are opened and the air speeds up through the throttle body.

Air metering force - the two pressures "A" and "B" are separated by a diaphragm. In opposing one another they cause this diaphragm to move, thus forming the first section of pressure regulator.

OPERATION

Air entering the carburetor at the air intake passes downward through the main venturi plates and boost venturi tubes, past the controlling throttle valves into the supercharger. The boost venturi tubes, in conjunction with the main venturi plates, create a suction, which is transmitted from the throat of the boost venturi tubes to chamber B in the regulator. A portion of the air entering the air intake flows into the impact tubes and then through an internal channel, past the automatic mixture control needles and temperature compensator, where its flow is restricted. The flow, thus restricted, is termed "regulated impact pressure." The regulated impact pressure is transmitted to chamber A in the regulator and is greater than the venturi suction in chamber B. This pressure differential between chambers A and B, acting on the air disphragm between these 2 chambers, produces a force to the right, tending to open the poppet valve. This force, termed the "air metering force," increases or decreases as the throttle valves are opened or closed to permit more or less air to flow through the throttle unit.

Fuel enters the regulator at the fuel inlet and passes through the fuel strainer into chamber E of the regulator. The pressure of the fuel in this chamber is delivered by the fuel pump and is the highest pressure in the carburetor. Fuel vapor or air is eliminated from chamber E by the action of the vapor separator. The valve of the separator opens when vapor or air accumulates in chamber E and allows the vapor or air to escape through a line to the fuel tank. An identical system is used to vent the unmetered fuel chamber D. These 2 venting systems are connected by an internal channel.

From chamber E, the liquid fuel flows past the poppet valve into chamber D of the regulator. The pressure of the fuel in chamber D is lowered pressure because of the restriction of the poppet valve. The fuel at this reduced pressure is termed "unmetered fuel."

As the fuel flows from chamber D of the regulator, it passes through an internal channel into the fuel control unit, flows past the idle valve, and then through the metering jets. After passing through the jets, the fuel pressure is further reduced. Fuel at this pressure is termed "metered fuel." A portion of the metered fuel flows through another internal channel to chamber C in the regulator. This results in a pressure differential between chambers C and D acting on the fuel diaphragm to create a force to the left, tending to close the poppet valve. This force is termed the "fuel metering force."

The air metering force (pressure in chamber A minus pressure in chamber B) acting upon the large air diaphragm together with the assistance of the constant head idle spring creates a force which shifts the diaphragm to the right and opens the poppet valve. As the opening of the poppet valve increases, the pressure of the unmetered fuel in chamber D increases, permitting more fuel to flow through the jets of the fuel control unit. This results in an increased fuel metering force (pressure in chamber D minus pressure in chamber C). The fuel metering force is regulated by and is equal to the air metering force except in the idle range.

The constant head idle spring, located in the poppet valve shaft in the regulator, holds the poppet valve open in the idle range (the air metering force in the idling range is not great enough to open the poppet valve sufficiently). This causes the fuel metering force to be slightly higher than the air metering force, thereby furnishing the desired mixture enrichment in the idle range.

The metered fuel in the fuel control unit flows upward through the manual mixture control plates and through external fuel transfer lines to the fuel injection pumps.

When the airplane is cruising and the mixture control in the flight compartment is in the AUTO-LEAN position, the fuel flow is limited by the size of the auto-lean jet, which is selected to give maximum fuel economy. Additional fuel for "higher power" can be added by moving the manual mixture control to the AUTO RICH position, whereupon fuel also flows through the auto-rich jet.

A diaphragm-operated power enrichment valve is incorporated in the fuel control unit for take-off and all high power operation. When the force of the unmetered fuel pressure on the enrichment valve diaphragm is sufficient to overcome the combined force of the metered fuel pressure and the enrichment valve spring, the valve opens and allows additional fuel to flow through the open valve. The power enrichment jet is larger than the auto-rich jet; therefore, a richer mixture will be obtained whenever the enrichment valve is open. When the power enrichment valve is wide open, the metering of the fuel is accomplished by the AUTO LEAN, AUTO RICH, and POWER ENRICHMENT jets.

Power enrichment usually starts at about 70% of full power. Though an engine would develop more power if the fuel and air mixture were kept at a lean cruising ratio, in the power range it would overheat and soon start detonating. To prevent damaging the engine in this manner a rich mixture is introduced into the combustion chamber. The enrichment valve automatically opens to compensate for the added fuel needed in the higher power range. This valve is operated by pressure differential.

The power enrichment delay restriction functions as the mixture control is being moved from the auto rich to the auto lean setting. A drilled passage in the clover leaf mates with the auto rich channel as the clover leaf is rotated towards auto lean, thereby allowing restricted unmetered fuel to enter the metered fuel side. This additional fuel aids in evading operation at Best Power and/or Chemically Correct Power.

SUMMARIZATION OF PRINCIPLES OF OPERATION OF MASTER CONTROL

Opening the throttle allows more air to enter the master control, and since the venturi is fixed size the only way more air can enter is for it to speed up. The design and position of the boost venturi causes the air to pass more rapidly through the main venturi. This causes a distinct low pressure at the throat of the boost venturi. This area is connected to chamber "B" so that when the pressure is decreased the diaphragm will move to the right causing the poppet valve to open more. This allows a larger supply of fuel to enter the injection pumps which distribute it evenly to the cylinders where fuel is mixed with the air to maintain a constant and desirable mixture. Closing the throttle valves restricts the flow of air to

ENGINES - DESCRIPTION

the engine. This slower air speed passing through the venturi increases the throat pressure of the boost venturi which in turn slightly increases the pressure in chamber "B". With this greater pressure in chamber "B" the poppet valve closes slightly - chamber "A" pressure remains unchanged, so "A" -"B" is less than before. Due to the fuel injection pumps regulation, chamber "C" remains constant, but due to the poppet valve partially closing, chamber "D" pressure drops off slightly. Chamber "D" pressure decreases as much as "B" pressure increases. The entire carburetor operation is based on the formula A -B = D -C. Since A -B = D -C the balance would be upset. Basically:

a. A, C and E remain constant pressure.
b. B rises slightly in pressure as the airflow decreases.
c. D pressure lowers as much as B rises.

FUEL INJECTION PUMPS; principles of operation.

Metered fuel from the fuel control unit of the master control is piped directly to each of the two direct fuel injection pumps.

A bypass control sleeve and nine individual bypass control plates, hold and position the nine individual bypass sleeves. Each one of the nine pump plungers operates inside of one of these bypass sleeves. The amount of fuel delivered by the plungers is, therefore, controlled by the position of the sleeves as a unit, which varies the effective length of plunger strokes. The plungers have a constant length stroke, as controlled by the wobble plate contour, while the "effective length" of plunger stroke is controlled by the position of the bypass sleeves. The "End of Injection" of the plungers is a constant factor predetermined in the design of the injection pump.

Fuel in the low pressure chamber of the injection pump enters into the open ports of the plungers when these plungers are in the retracted position. As the plungers are moved on their individual compression strokes by the action of the wobble plate, the left hand port in a plunger is closed by the bypass sleeve, at which time the actual pumping operation begins. It should be noted that the bypasses are held stationary in relation to the movement of the plungers except when their position is changed by the action of the bypass control sleeve and plates for a change in throttle setting.

As the plunger moves to the right, sufficient pressure is built up to overcome the force of the check valve spring (210 PSI), the check valve opens, allowing fuel to flow into the injection lines. Further upward movement of the plunger creates a fuel pressure in the injection lines to produce the 500 PSI hydraulic pressure required to open the cylinder head discharge nozzle and spray fuel into the engine combustion chamber during the intake stroke.

The pumping action continues until the right-hand port in the plunger is opened by the annulus and port in the bushing. The high pressure fuel then escapes back into the low pressure area in the pump body. This relieves the pressure on the check valve, and the valve closes, stopping the flow of fuel to the engine. Fuel is thus trapped in the injection line, preventing the line from being evacuated at the next stroke of the plunger. The point at which the right hand port in the plunger is opened by the annulus and port in the plunger bushing is termed the "End of Injection" and is a fixed, predetermined position.

The position of the bypasses on the plungers determines the length of the effective plunger stroke, the length of the effective stroke increasing as the bypass sleeves are moved farther to the left on the plungers toward the pump wobble plate. The position of the bypasses is controlled by means of the bypass control sleeve and plates which hold them in the same relative position on the plungers. The bypass control sleeve is connected by the control stem to the pump control diaphragm. Metered fuel pressure is applied to one side of this control diaphragm, and boost venturi suction is applied to the other side. The resulting force (metered fuel pressure minus boost venturi suction) overcomes the force of the bypass control spring, which tends to move the bypass sleeves into the "Idle Cut-Off" position, and properly locates the bypasses so that the plungers will pump the total volume of fuel delivered by the master control.

As the air-flow and fuel-flow through the master control increases (throttle opened wider), the metered fuel pressure in the pump becomes greater and the pressure differential between the two chambers in the pump control housing increases. This increased pressure differential on the pump control diaphragm compresses the bypass control spring, causing the bypass control sleeve and plates to move the bypasses to the left, thereby increasing the length of the effective plunger pumping stroke.

As the air-flow and fuel-flow decreases (throttle moved towards the closed position) the pressure differential decreases; the bypass control spring then moves the bypasses upward, shortening the length of the effective plunger pumping stroke.

When the manual mixture control lever is placed in the "IDLE CUT-OFF" position, the fuel flow to the injection pump ceases, reducing the fuel pressure on the pump control diaphragm. The bypass control spring then moves bypasses to a position such that, even though the plungers are traveling their full stroke, the left hand ports in the plungers will never be covered until the right hand ports are uncovered. Therefore, fuel pressure will not be increased sufficiently to open the check valves, and no fuel will be delivered to the engine.

A similar action will occur if the fuel supply is exhausted from the fuel tanks while the airplane is in flight; that is, the bypasses will be moved to the "IDLE CUT-OFF" position, stop the fuel flow to the engine, and leave the pump bodies full of fuel. Then, if the pumps are

ENGINES - DESCRIPTION

rotated by the "windmilling" of the engine, no damage will be done to the pumping mechanisms through lack of lubrication, as the fuel in the pumps will provide the necessary lubrication.

THE FUEL ENRICHMENT SWITCHES, on the aft overhead switch panel, provide a means of opening the poppet valve in the master control, supplying a fixed amount of fuel enrichment in pounds independent of altitude, airspeed and temperature, whenever the air metering control will not any longer meter correctly due to impact tube icing.

A fuel enrichment solenoid valve, installed on the accelerating pump mounting boss, is connected by flexible lines to the balance chamber front body and the fuel pressure indicator outlet. Two restrictions are installed in the balance chamber, one between D chamber and the fuel pressure indicator outlet, and one between the balance chamber and D chamber.

EXHAUST SYSTEM

Each nacelle has three groups of exhaust stack and ball joints; each group of six cylinders exhausts into one of three power recovery turbines. Viewing the engine from the aft end, #1 turbine is located at 3 o'clock, #2 at 7 o'clock and #3 at 11 o'clock. The exhaust stacks, support clamps and flexible joints are interchangeable between any of the three turbine positions. Cylinders #4, 5, 6, 7, 8 and 9 exhaust into #1 turbine. Cylinders #10, 11, 12, 13, 14 and 15 exhaust into #2 turbine, and cylinders #16, 17, 18, 1, 2, and 3 exhaust into #3 turbine.

> NOTE: The turbine flight hood clamp bolts (two for each hood) should be only finger tight.

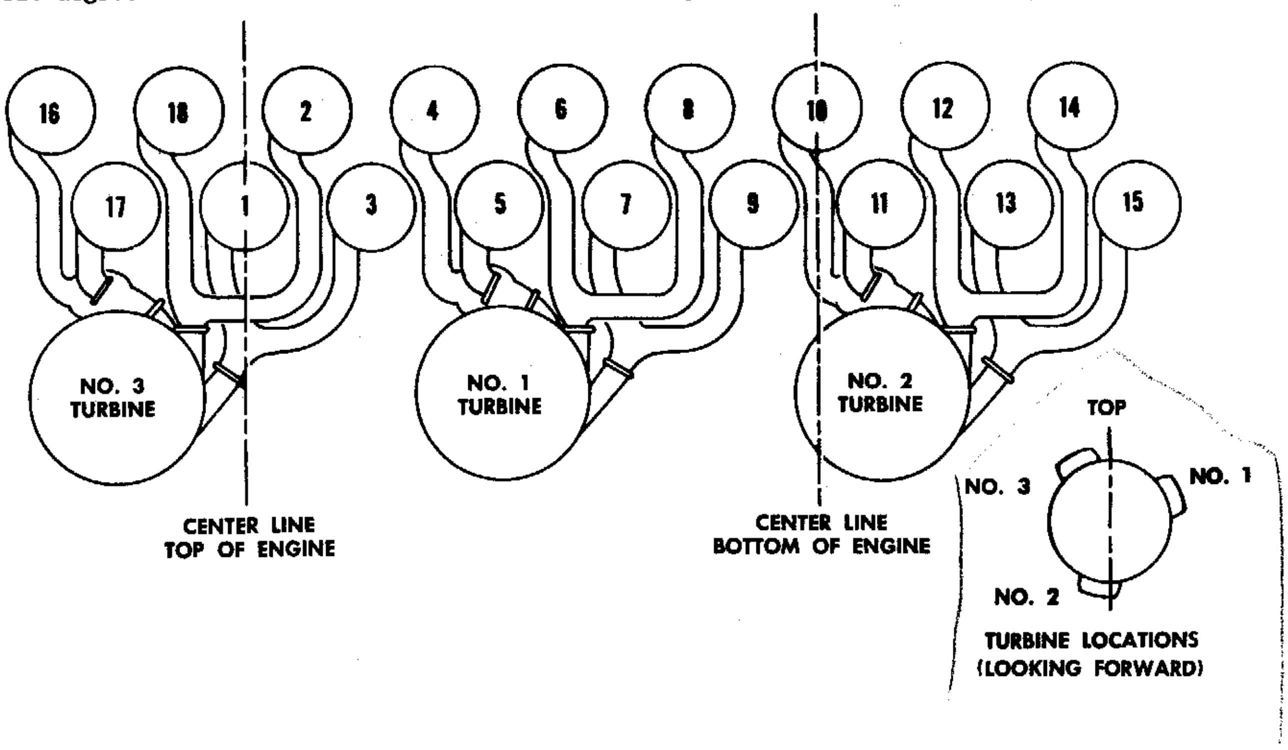
Each turbine is supplied exhaust gases from six cylinders, three front and three rear. The gases are directed into the turbine wheel by a fixed nozzle having 15 stator vanes divided into three 120-degree inlet sectors. Thus, there is one inlet sector or discharge area for each siamesed pipe. The stator vanes direct the gas into the turbine wheel at the optimum angle, and all three turbines turn clockwise when viewed from their outer end. Their speed is proportional to engine crankshaft RPM, and the turbine drive gear train has an overall ratio of 6.52:1. Consequently, the turbine maximum RPM is only 19,000, during take-off.

To prevent damaging effects from the high temperatures of the exhaust gases, cooling air is drawn from a duct on top of cylinders #3, 9 and 15 and conducted into the turbine assemblies. A tube and duct assembly delivers the air between the nozzle support and the cooling air shield. An impeller is provided to force the cool air through the assembly and discharge it, together with the exhaust gases, from the outer shield outlet. The cooling air is sealed under the turbine wheel by a labyrinth type seal facing the underside of the impeller. The seal prevents exhaust gases and cooling air from mixing until they are discharged from the outer shield. Oil from the turbine drive shaft is kept from entering the cooling air stream by the bellows-loaded seal which is a tight fit in the nozzle support.

A vibration damper assembly, consisting of spring-loaded plates and discs, assists in dampening lateral vibrations within the turbine system.

A hollow shaft, splined to the turbine wheel, passes thru a support clamped to an adapter on the supercharger front housing. A coupling, splined at each end, connects this hollow turbine shaft to the transmission system inside the supercharger front housing, the main component of which is the fluid coupling.

The coupling shaft, located inside the supercharger front housing adapter, has a bevel gear at its lower end which meshes with a larger bevel gear connected by a drive shaft to the fluid coupling impeller. The fluid coupling rear half (runner) is



ENGINES - DESCRIPTION

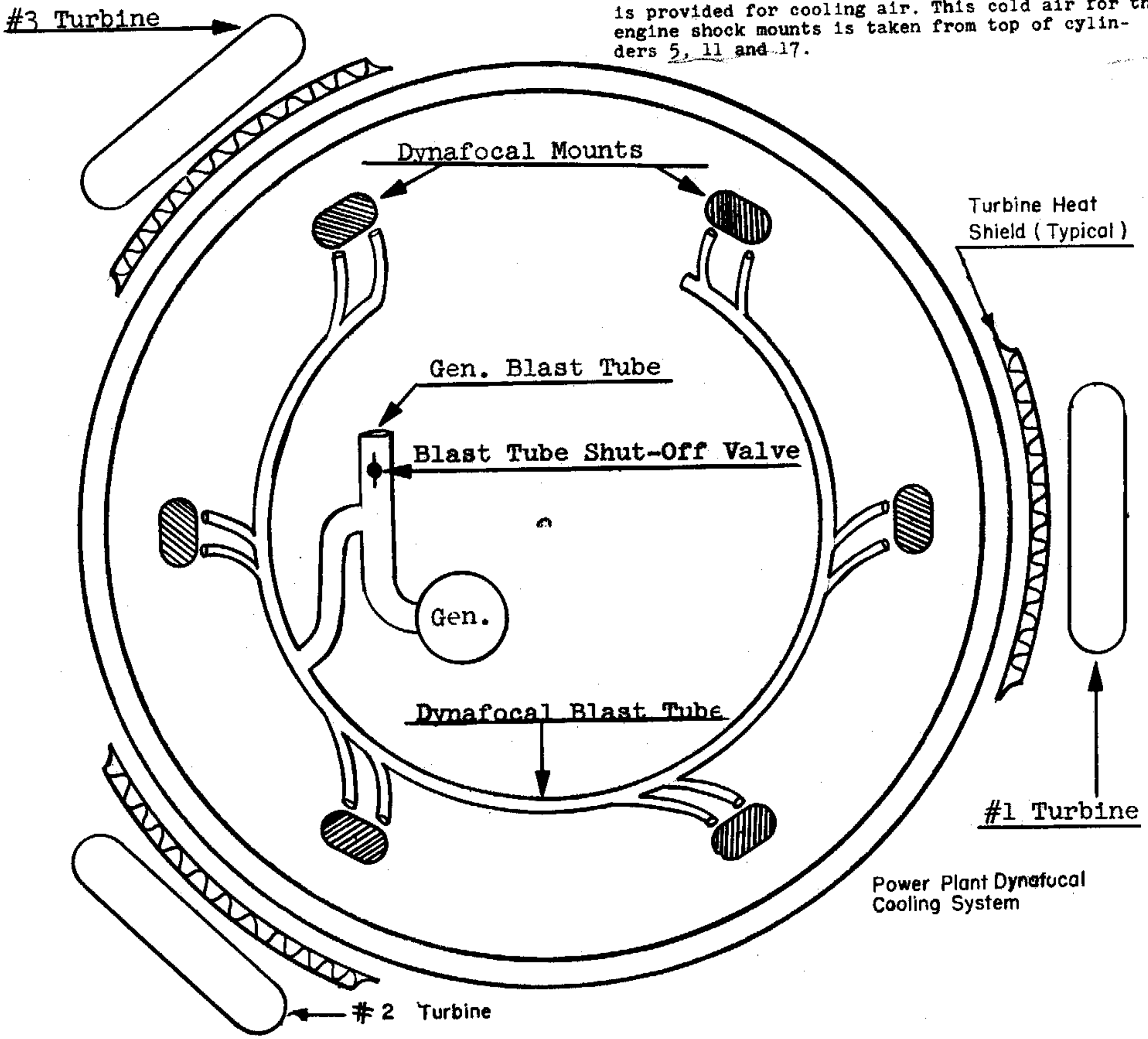
connected by a splined shaft to a pinion which meshes with the crankshaft drive gear coupled to the engine crankshaft. Since oil fills the fluid coupling, the power developed by the turbine is transmitted to the crankshaft thru the fluid drive as the runner follows the impeller, with a normal slippage of one to two per cent.

Slippage is advantageous in that the intermittent exhaust pulses impinging on the turbine buckets tend to set up torsional (twisting) vibrations in the turbine drive system. The fluid couplings tend to absorb this vibration and prevent it from being transmitted to the crankshaft. At the same time, couplings prevent crankshaft vibrations from being transmitted to the turbines, and help absorb the inertia loads during changes in speed.

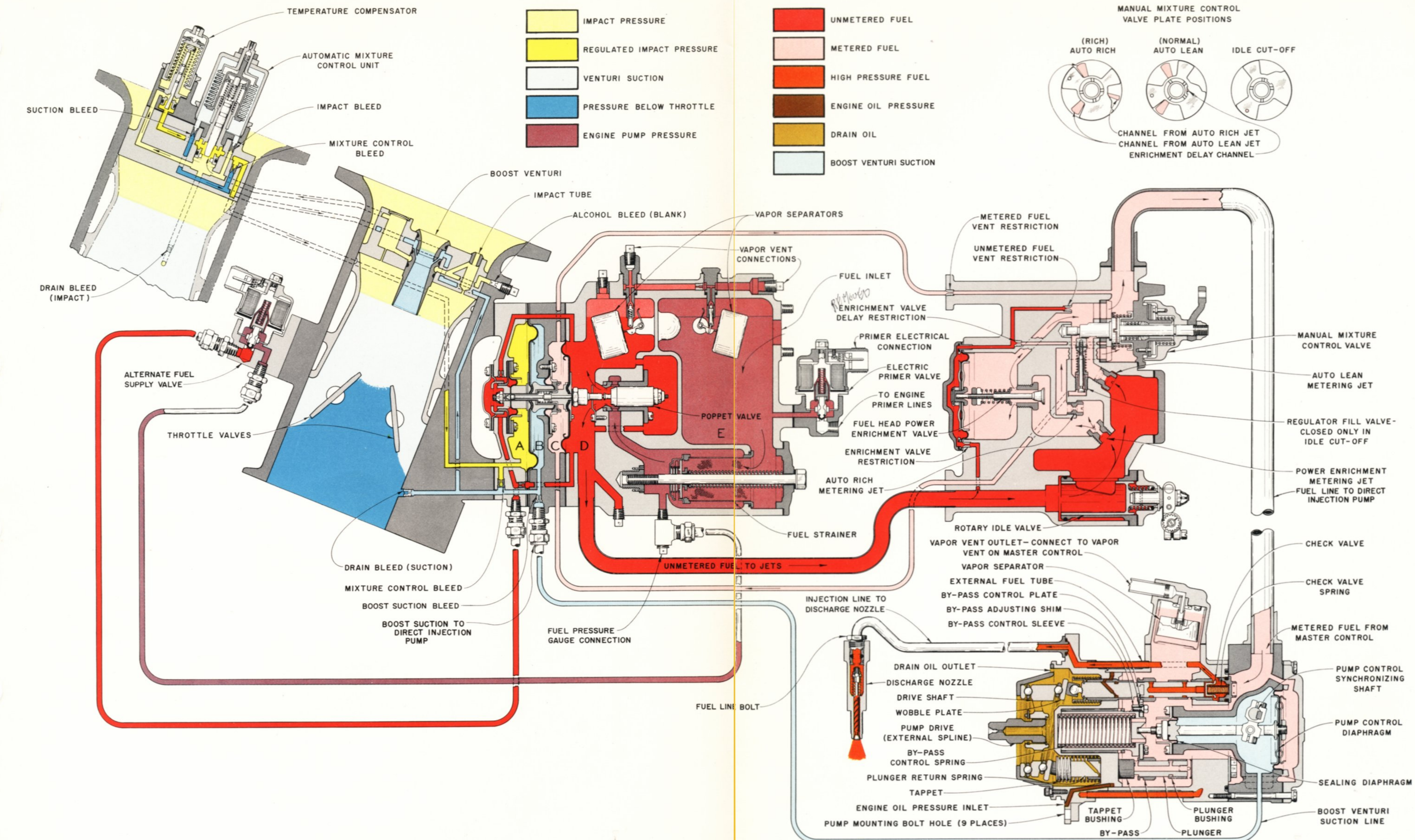
All three turbines operate thru identical fluid drive mechanisms, on the same crankshaft drive gear. When engine is shut down, oil gradually drains from couplings, and they are momentarily disconnected on a cold engine start until engine oil pressure is obtained.

GENERATOR AND ENGINE SHOCK MOUNT COOLING

Cold air for cooling the generator and the aft side of engine mounts is obtained thru a small air scoop which extends thru the top of oil cooler forward fairing into the air passage for oil cooler. Air is delivered thru a blast tube to generator. There is a shut-off valve installed in this blast tube; it is operated in conjunction with other emergency firewall shut-off valves. The cooling jets for aft side of engine mounts are supplied with air from generator blast tube taken downstream from the shut-off valve. Closing the shut-off valve will therefore stop this airflow. The engine shock mount cooling system for the forward side of mounts is an independent system, and since it is forward of the inner ring in Zone I, no shut-off is provided for cooling air. This cold air for the engine shock mounts is taken from top of cylinders 5, 11 and 17.



Power Plant Dynafocal Cooling System



Schematic Diagram of Bendix Direct Fuel Injection System, With The D9H3 Direct Fuel Injection Pump.

Form No. 15-2071
12-15-55

Printed in U.S.A.