SECTION 6

POWER PLANT

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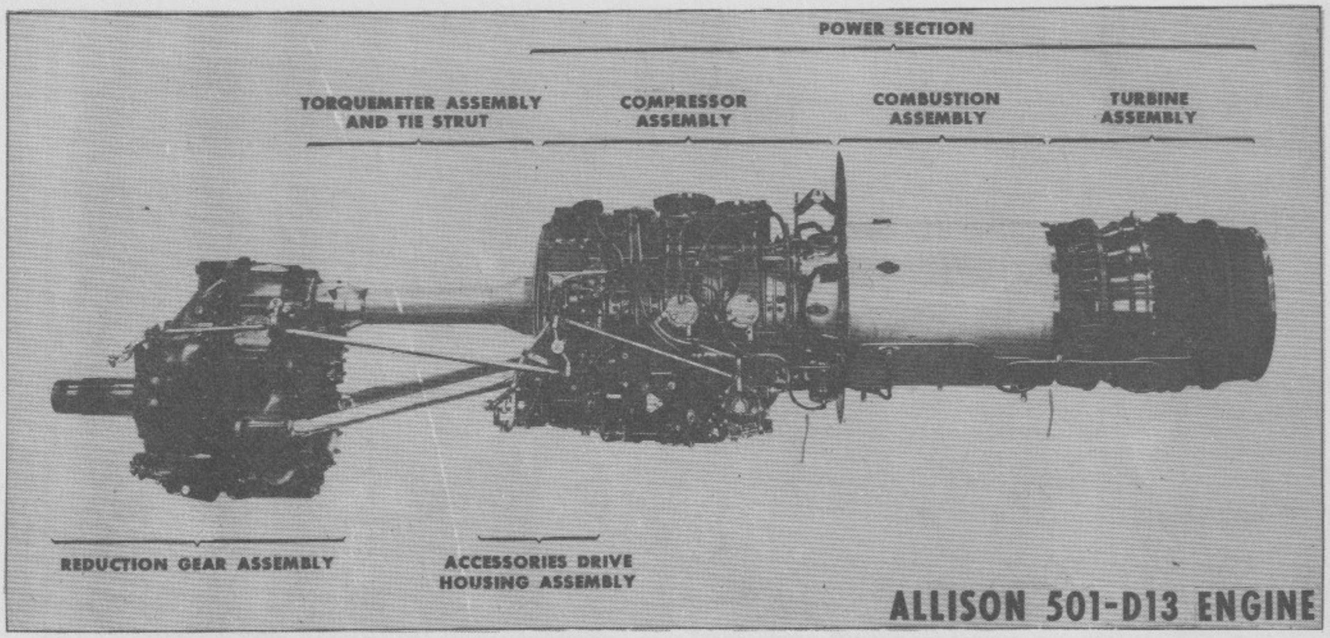
ENGINE COMPONENTS



ENGINES

GENERAL

The Allison model 501-D13 engine is an internal combustion, gas turbine power unit connected by a torquemeter assembly and struts to a reduction gear having a single propeller shaft.

The power section consists of a single-spool fourteen stage axial flow compressor, a diffuser section containing six fuel nozzles, and a set of six combustion liners of the cylindrical through-flow type, a four-stage turbine, and exhaust (jet) nozzle. An engine accessory drive housing is mounted on the bottom of the forward end of the compressor.

The reduction gear assembly contains two stages of reduction driving a propeller shaft. It provides a 13.54 to 1 reduction in power section-to-propeller shaft speed. Necessary gears and their drive pads are provided on the reduction gear case for accessories. The reduction gear assembly also incorporates an automatic propeller brake, a negative torque signal system, a thrust sensitive signal system used for auto-feathering at Take-Off, and a safety coupling.

The torquemeter assembly transmits power from the power unit to the reduction gear. The twist of the torquemeter drive shaft under load is measured electronically and registered as shaft horsepower on a cockpit indicator.

The two tie-struts assist in carrying the overhang moments and forces produced by the propeller and the reduction gear.

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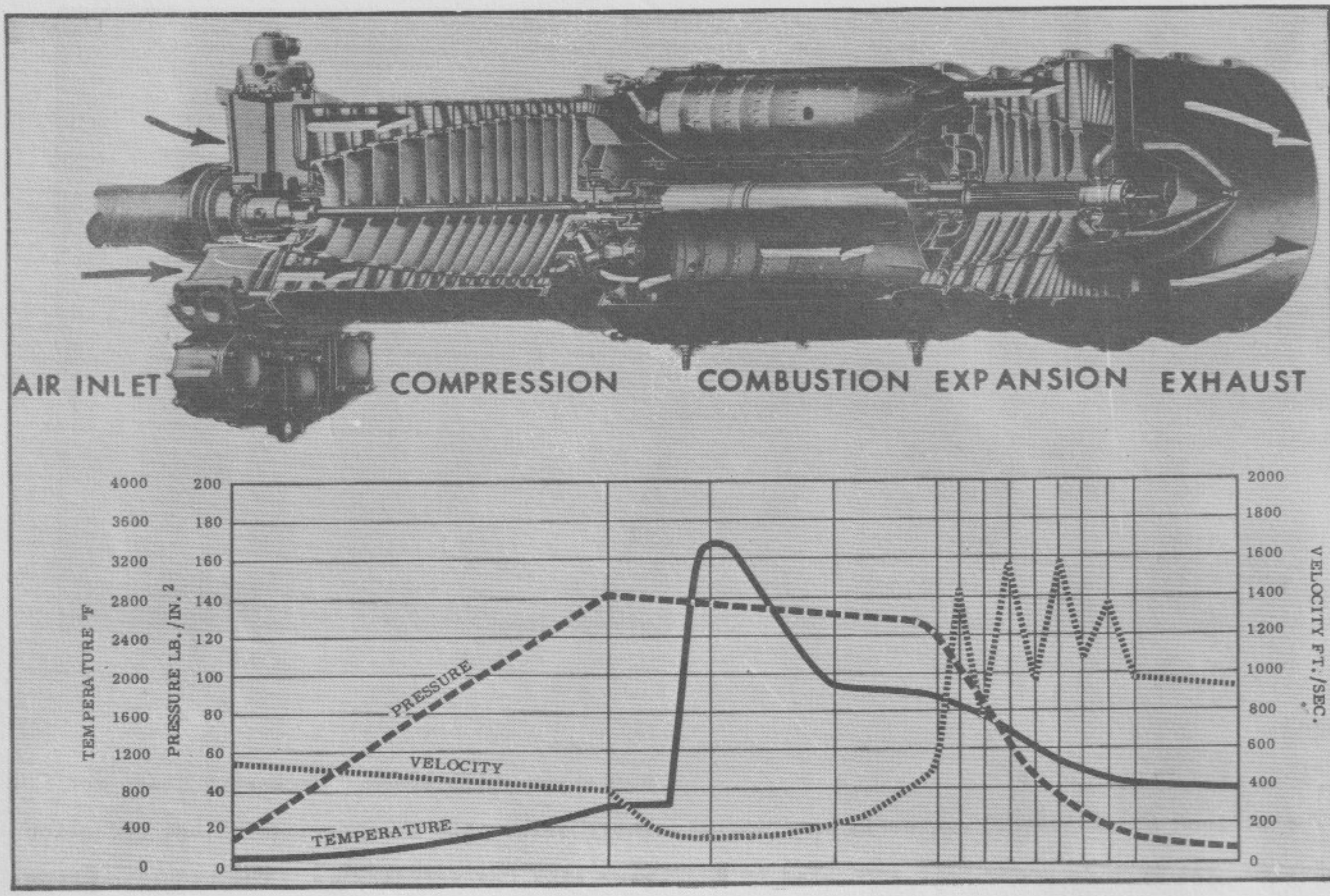

AIR FLOW AND COMBUSTION

Through aircraft ducting, air enters the opening at the front of the power section and is compressed as it passes through the compressor. From the compressor, the air enters the diffuser section which serves to distribute it equally to the combustion liners of the combustion section.

Fuel is introduced through a nozzle in each liner dome and is combined with the air to maintain constant combustion. The combustion forms an expanding hot gas which is directed to the power turbine.

The turbine converts the major portion of the gas energy into shaft horsepower which is utilized to drive the compressor and accessories as required, with the balance of the shaft horsepower transmitted to the reduction gear box to drive the propeller. A small percentage of the gas energy passes out the exhaust cone as jet thrust.

Engine specifications, based on sea level standard day static conditions, guarantee the engine will develop at take-off power a minimum of 3460 Shaft Horsepower (SHP) through the reduction gear box to the propeller. The jet thrust developed will be equivalent to 290 horsepower. The total guaranteed power, therefore, is 3750, which is known as Equivalent Shaft Horsepower (ESHP).

Curves in Section 3-2, PERFORMANCE, show expected torquemeter shaft horsepower under various conditions of ambient temperature, altitude, airspeed, and T.I.T.

POWER SECTION

From front to rear, the power section can be broken down into the general sub-sections enumerated below, in which order they will be briefly discussed:

1. Air Inlet Section
2. Compressor Section
3. Diffuser Section
4. Combustion Section
5. Turbine and Exhaust Section.

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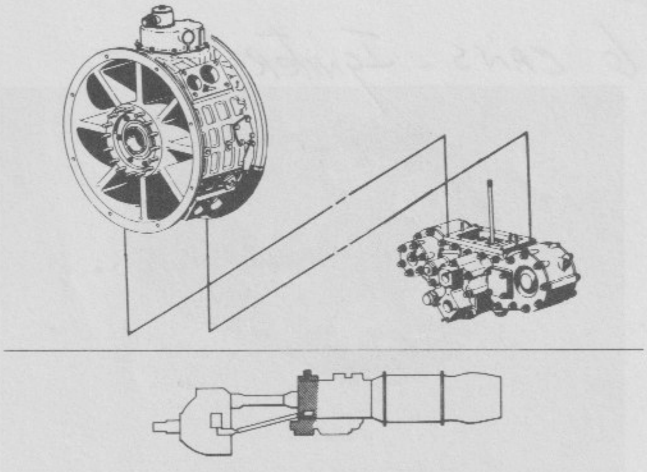
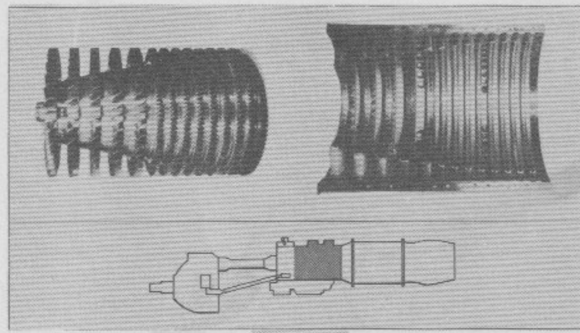


Air Inlet Housing



Compressor

AIR INLET HOUSING

The air inlet housing directs and distributes air into the compressor rotor. It also provides the mounting location for the front compressor bearing, the engine breather, the accessory (engine) drive assembly, the torquemeter assembly, anti-icing air valves and the inlet vane assembly. The inlet air temperature (Tt2) and inlet air pressure (pt2) sensing probes are installed at the front of this section.

The inlet vane assembly is mounted on the aft side of the air inlet housing struts and imparts the proper direction and velocity to the airflow as it enters the first stage of the compressor rotor.

As the eight supporting struts and the inlet vanes between the center hub and the outer ring of the casting are subject to icing under certain atmospheric conditions, this section incorporates anti-icing valves and passages for directing hot compressor discharge anti-icing air to the strut leading edges, air inlet pressure probe, defrosting shield around the inlet air temperature probe, and the inlet guide vanes. After accomplishing this purpose, the air is returned to the first stage of the compressor.

ACCESSORY DRIVE ASSEMBLY

An accessory drive assembly is incorporated on the bottom of the air inlet housing. Mounting pads for the speed sensitive control, speed sensitive valve and oil pump (combination pressure and scavenge) are on the front face housing. On the rear face of the housing are mounting pads for the fuel control and fuel pump. All of these accessories are for operation of the power section only. Other accessories are mounted on the aft face of the reduction gear case.

COMPRESSOR SECTION

The compressor section is that portion of the power unit which produces an air pressure rise. It has a fourteen-stage axial flow compressor. There is a pressure rise at each stage. The first stage rotor blades accelerate the air rearward into the first stage vane assembly. This decreases the velocity of the air to increase the static pressure and directs it at the proper angle into the second stage compressor rotor blades. The second stage rotor blades accelerate the air rearward into the second stage vane assembly; and so on through the compressor rotor blades and stator vanes until the air exits into the diffuser aft of the 14th stage of compression.

Air temperature and pressure increase as the air passes from the inlet housing through the compressor to the diffuser. The highest air total pressure is at the inlet of the diffuser. As the air passes rearward through the diffuser, the velocity of the air slows down, causing an increase in static pressure. The highest static air pressure is at the inlet of the combustion section.

Compressor Acceleration Bleed Valves

Four acceleration bleed valves are mounted around the outside of the compressor case at the 5th stage and four at the 10th stage. Those at the 5th stage are manifolded together, and those at the 10th stage are manifolded together. They are used to unload the compressor to prevent engine stall and surge between 0 and 13,000 RPM and to make it easier to accelerate the engine during starting. These bleeds are open during low speed taxi operation.

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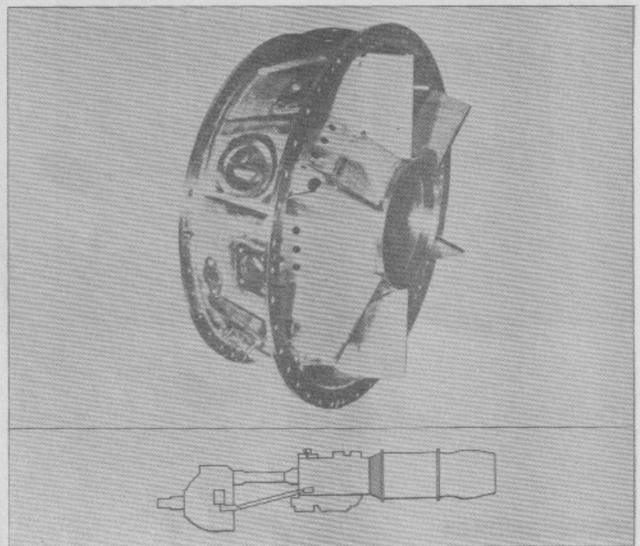
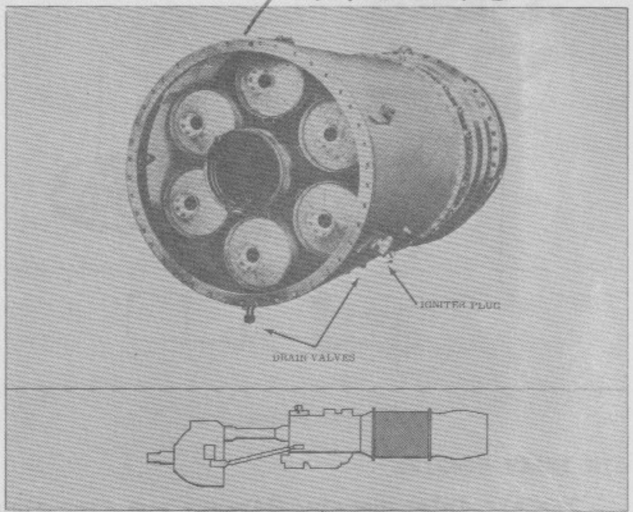
6 CANS - Igniters # 2&5



Diffuser



Combustion Chamber Assembly

Speed sense valve ports 14 stage air to 5 & 10th valves @ 13000 RPM

DIFFUSER

The diffuser assembly is bolted to the aft end of the compressor housing. It is the mid-structural member of the engine, and one of the three engine-to-aircraft mountings is located at this point. Six struts form passages which conduct compressed air from the outlet of the 14th stage of the compressor to the forward end of the combustion liners. These struts also support the inner cone which provides the mounting for the rear compressor bearing, the seals, the rear compressor bearing oil nozzle, the diffuser scavenge oil pump, and the forward end of the combustion inner casing.

Bleed Air

Bleed air is extracted from ports around the diffuser for engine air inlet scoop, wing and tail anti-icing. Bleed air is also extracted from this section for cross-feeding from one engine to another for engine starter operation.

The 14th Stage Start Bleed Valve

The 14th stage start bleed valve is mounted on the diffuser case and between 0 to 5,000 RPM bleeds off air to facilitate the ignition of the fuel-air mixture during the starting cycle and to aid in initial acceleration after"light-off".

Six Fuel Nozzles

Six fuel nozzles are mounted at the aft end of the diffuser. A fire shield is provided at the rear split line.

COMBUSTION SECTION

This assembly consists of an outer and an inner casing which form an annular chamber in which six combustion liners are located. Fuel is sprayed continuously during operation into the forward end of each liner. During starting, two igniter plugs, located in combustion liners numbers 2 and 5, ignite the fuel-air mixture. All six liners are interconnected near their forward ends by cross-over tubes. Thus, during the starting cycle after ignition takes place in numbers 2 and 5 combustion liners, the flame propagates to the remaining liners.

The outer casing provides the supporting structure between the diffuser and the turbine section. Mounted on the bottom of the outer casing are two combustion chamber drain valves to drain fuel after a false start or at engine shut down.

Approximately 25% of the air which enters the combustion section is required to burn the fuel. This air known as "Primary Air" enters the forward section of the combustion liner and normally reaches a temperature in excess of 3000°F in the combustion process. The remaining air enters the rear section of the combustion liner and is known as "Secondary Air". The secondary air surrounds the liner walls to prevent the flame front from impinging on it and also mixes with the combustion gases to lower the average gas temperature entering the turbine.

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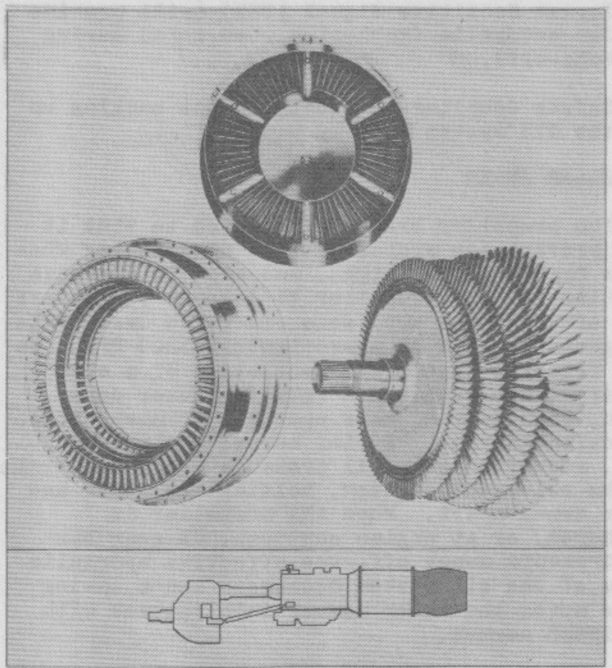
Turbine and Exhaust Assembly

TURBINE AND EXHAUST SECTION

The turbine inlet casing is attached at its forward end to the outer and inner combustion casings. It houses the forward turbine bearing and seal assembly, front turbine bearing oil jet, and the turbine front scavenge oil pump. The casing is divided into six equal passages by six airfoil struts. Each of these passages provides the means of locating and supporting the aft end of a combustion liner.

Located around the outer casing are eighteen openings, each fitted with one thermocouple assembly. Three of these thermocouple assemblies are positioned into each of the six combustion liners at the outlet of the liners. They provide a temperature indication at the turbine inlet (referred to as Turbine Inlet Temperature - T.I.T.). The thermocouple assemblies are dual; viz., each contain two separate thermocouples, and thus provides for two separate circuits in parallel. Each circuit measures the average temperature of a set of eighteen thermocouples and provides a very accurate indication of the gas temperature entering the turbine inlet section at all times. One circuit is used as a signal to the electronic temperature trim system (part of the fuel system). The other circuit is used to provide a temperature indication (T.I.T. gage) to the flight deck.

As the power being produced under any given set of conditions is dependent upon turbine inlet temperature, it is important that T.I.T. be accurate.

The turbine rotor assembly consists of four turbine wheels which are splined to a turbine shaft. The entire assembly is supported by roller bearings at each end.

A turbine coupling shaft assembly connects the turbine rotor to the compressor rotor, and thus power extracted by the four stages of the turbine is transmitted to the compressor rotor, driven accessories, reduction gear assembly, and the propeller.

The impact and expansion of the gases of combustion through the turbine section enables the rotor to develop shaft horsepower. As the temperature of the gases at the turbine inlet increase, the work of the gases through the turbine increase which results in increased horsepower, developed by the turbine rotor. The shaft horsepower, developed by the turbine rotor over and above the requirements for driving the compressor rotor and accessories, is delivered to the propeller through the torquemeter, safety coupling, and the reduction gear assembly. The turbine does not absorb all of the gas energy which passes through it. The remaining energy in the gases is recovered through the exhaust (jet) nozzle as jet thrust.

The turbine vane casing encases the turbine rotor assembly, and retains the four stages of turbine vane (stator) assemblies. It is the structural member for supporting the turbine rear bearing support. The vanes are airfoil design, and serve two basic functions. These increase the gas velocity prior to each turbine wheel stage, and also direct the flow of gases so that they will impinge upon the turbine blades at the most efficient angle.

The turbine rear bearing support attaches to the aft end of the turbine rear vane casing. It houses and locates the turbine rear bearing, the turbine rear scavenge pump, and the inner exhaust cone and insulation. It also forms the exhaust (jet) nozzle for the engine.

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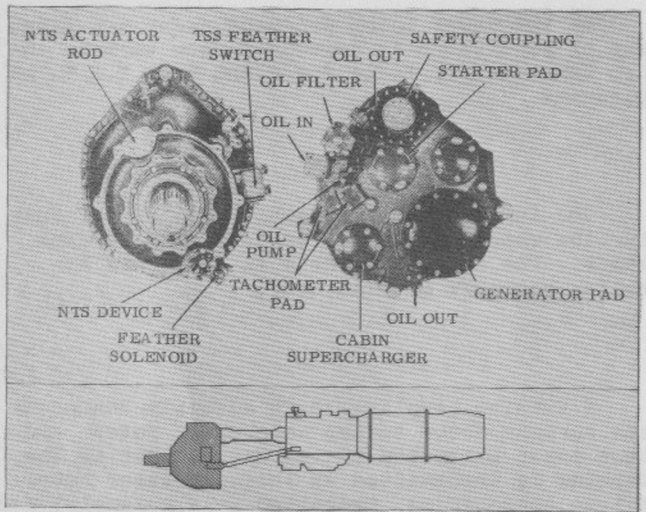


Reduction Gear

REDUCTION GEAR ASSEMBLY

The prime function of the reduction gear assembly is that of providing the means of reducing power section RPM (13,820) to the range of efficient propeller RPM (1020). It also provides pads on the rear face for mounting and driving the accessories illustrated. EAL hydraulic pumps, however, will be electrically driven, and will be in the hydraulic service center in the belly of the airplane.

The reduction gear assembly has an independent lubrication system which includes a pressure pump and two scavenge pumps. The oil supply is furnished from a common oil tank which also supplies the power section.

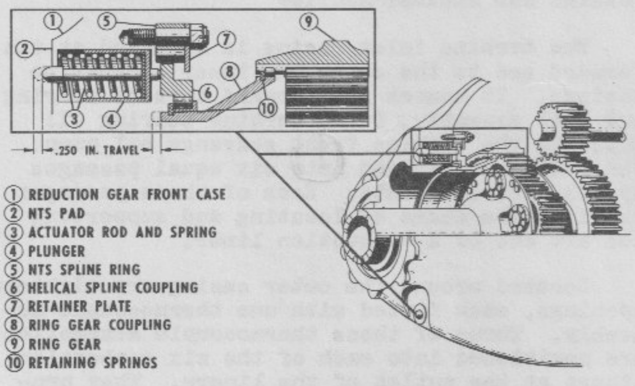
The reduction gear assembly is remotely located from the power section, and is attached by a torquemeter assembly and two tie struts.

It has an overall reduction gear ratio of 13.54 to 1. This is accomplished through a two-stage step-down. The primary stepdown is accomplished by a spur gear train having a ratio of 3.125 to 1, and the secondary step-down is by a planetary gear train with a ratio of 4.33 to 1. In addition to the reduction gears and accessory drives, the reduction gear assembly includes the following major units:

- Propeller Brake (prevents windmilling of a feathered propeller and reduces time for propeller to come to rest after engine shut down).
- Negative Torque System (NTS) (prevents excessive drag due to engine failure in flight).
- Thrust Sensitive Signal (TSS) (will provide for automatic feathering when armed during take-off). @ +500 lbs thrust
- Safety Coupling (a safety device backing up the NTS system). @ -1500 # torque

PROPELLER BRAKE

The propeller brake is designed so that it will prevent the propeller from windmilling when it is feathered in flight, and also to decrease the time for the propeller to come to a complete stop after ground shut-down, in which case brake engagement begins at approximately 3200 RPM. It is a friction type brake consisting of a stationary inner cone and a rotating outer cone which, when locked, acts upon the primary stage reduction gearing. During normal engine operation, reduction gear oil pressure keeps the brake in the released position, holding the outer and inner cones apart. When the propeller is feathered. or at engine shutdown, as gear box oil pressure drops off, the effective hydraulic force of the oil system decreases and a spring force moves the outer member into contact with the inner member.



Negative Torque Signal Components

NEGATIVE TORQUE SYSTEM (NTS) - 250 to 370

Offset propeller drag of a failed turbo-prop engine far exceeds that of a piston engine because the compressor of the turbo-prop absorbs a great deal more energy than the frictional forces in the piston engine. A plane powered by turbo-prop engines would therefore encounter serious control problems, if an engine failed in flight, unless some means were provided to reduce the offset thrust.

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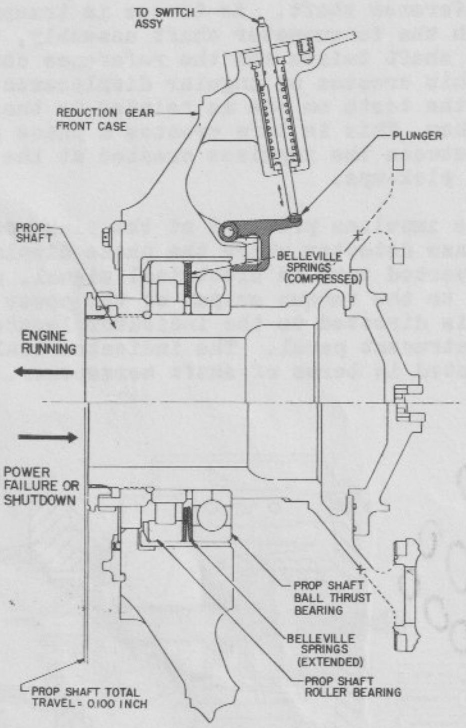
300 # Neg Torque

The negative torque system (NTS) is designed to prevent the aircraft from encountering excessive propeller drag. This system is part of the reduction gear, and is completely mechanical in design and automatic in operation. A negative torque value in the range of 250 to 370 horsepower (Neg) transmitted from propeller into the reduction gear causes the planetary ring gear to move forward, overcoming a calibrated spring force. As the ring gear moves forward, it will actuate two plungers which move forward through openings in the reduction gear front case. Only one plunger is used to actuate the propeller mechanism, signaling the propeller to increase blade angle (toward feather) until the abnormal propeller drag and resultant excessive negative torque are relieved. The propeller will not go to the feather position, but will continue to move through a small blade angle such that it will not absorb more than approximately 250-370 (Neg) horsepower. As the negative torque is relieved, the propeller returns to normal governing.

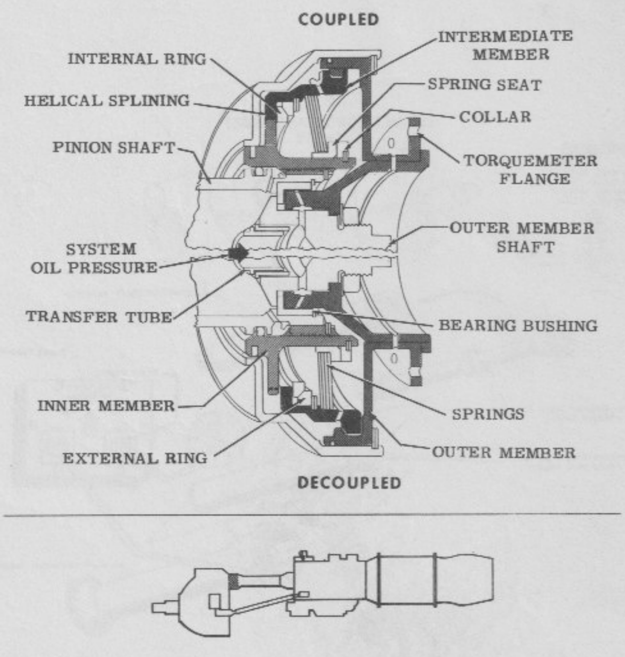


Thrust-Sensitive Signal Device

THRUST SENSITIVE SIGNAL (TSS) Auto-Feather +500

The thrust sensitive signal provides the means for initiating auto-feathering at takeoff. The system must be armed if it is to function, and a blocking relay is provided to prevent feathering of more than one propeller. The system is armed by a cockpit switch and a power lever actuated switch. The setting of the power lever switch is such that if operation is normal, the propeller will be developing in excess of 500 lbs. positive thrust. This prevents auto-feather except when a power failure occurs.

The system is designed to operate (when armed) when the propeller is delivering less than 500 lbs. of positive thrust. The propeller shaft tends to move in a forward axial direction as the propeller produces thrust. This axial travel is limited by mechanical stops. Forward movement of the shaft compresses two belleville springs. As power decreases to 500 lbs. of thrust, the spring force moves the shaft axially in a rearward direction. This movement is multiplied through mechanical linkage and transmitted mechanically to a pad on the left side of the reduction gear front case. An electrical switch, mounted on the case, when actuated energizes the feathering circuit.



Safety Coupling

SAFETY COUPLING

The safety coupling could readily be classified as a "Back-Stop" for the negative torque signal system (NTS). It has a negative torque setting of approximately 1500 horsepower, and in the event the NTS system would not function properly, this system would uncouple the reduction gear from the power section. A double

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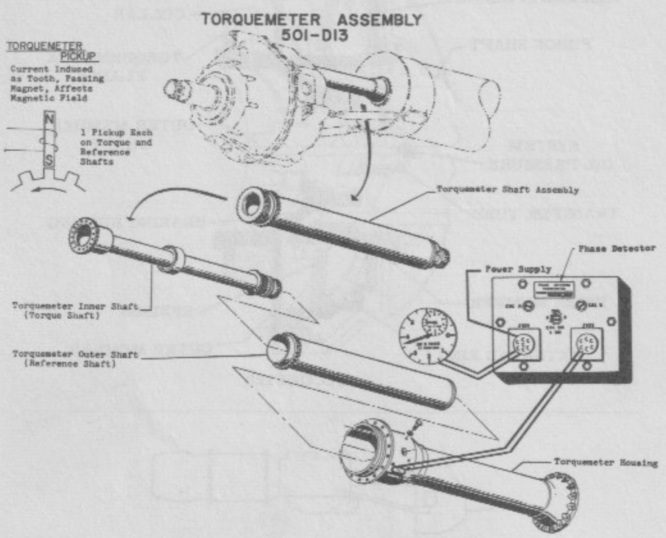
failure would have to occur before it is put to use; failure of the engine to develop power after it has been running, and failure of the NTS system. When the safety coupling disengages, the resulting windmilling drag horsepower is approximately 35 to 75 horsepower after passing through a drag horsepower transient of approximately 1500 horsepower for a fraction of a second.

The safety coupling is bolted to the forward end of the torquemeter shaft and connects to the gear box by mating splines to the shaft of the input pinion gear. Thus, it becomes part of the shaft transmitting power from the engine to the reduction gear assembly. Helical splines inside the coupling, aided by springs, tend to screw the coupling into tight contact when engine power is applied to the torquemeter shaft. When negative torque is applied to the propeller so that it starts motoring the engine, the helical splines tend to unscrew, and negative torque in excess of 1500 ± 200 SHP will cause it to decouple automatically. The safety coupling is designed to re-engage when power section and reduction gear RPM are approximately the same. Whenever it is known that the coupling has disengaged, inspection by Maintenance is required.



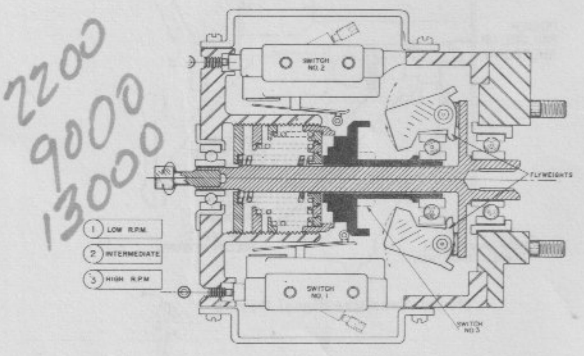
TORQUEMETER ASSEMBLY

The torquemeter housing and two tie struts secure and provide alignment between power section and reduction gear assembly. The torquemeter shaft assembly, within the housing, provides the means of both transmitting torque from the engine to the gear box and of measuring that torque.

The torquemeter shaft assembly consists essentially of two hollow shafts mounted concentrically. They are firmly fastened together at the end which mates with the power unit, thus they rotate as one. Their outer, or gear box ends are fitted with flanges upon which teeth are machined after assembly, hence the teeth on one shaft are accurately aligned with the teeth on the other. At this end the shafts are not fastened to each other. The inner (torque) shaft is bolted to the safety coupling, which in turn drives the reduction gear and propeller. This shaft is subject to twist as it transmits torque; the greater the torque, the greater the twist. The outer (reference) shaft provides no driving force and is therefore not subject to twist.

The torquemeter pick-up, reduced to its simplest form, consists of two small permanent magnets, about each of which are several turns of wire. It follows that whenever the magnetic fields are disturbed, an electrical current will be induced in the windings. The magnets are accurately aligned and mounted on the torquemeter housing so that they protrude into the housing, one directly above the teeth of the torque shaft, the other directly above the teeth of the reference shaft. As torque is transmitted through the torquemeter shaft assembly, the torque shaft twists and the reference shaft does not; this creates an angular displacement between the teeth on one as related to those on the other. This in turn creates a phase difference between the impulses created at the individual pick-ups.

The impulses produced at the pick-ups enter the phase detector where the phase displacement is converted into an electrical signal, proportional to the torque output of the power unit, which is directed to the indicator located on the instrument panel. The indicator scale is calibrated in terms of shaft horsepower.



Speed Sensitive Control

SPEED SENSITIVE CONTROL switch

The Speed Sensitive Control is mounted on the forward side of the accessories housing.

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The control is a flyweight type which incorporates 3 microswitches that are actuated in sequence at 2200, 9000 and 13,000 engine RPM. As each microswitch is actuated, electrical circuits are opened or closed, which makes the engine starting procedure an automatic one.

AT 2200 RPM, THE FOLLOWING OCCURS:

- The fuel control cut-off valve is opened at the outlet of the fuel control.

  NOTE: Fuel and Ignition Switch must be armed - ON.

- Ignition System - ON.
- ~~Drip Valve - Closed (Energized).~~
- Fuel Pump Paralleling Valve - Closed - Fuel pumps placed in parallel, and fuel pump light should come on, indicating operation of secondary pump.
- Primer Valve - Opens - If Primer Switch held to ON position. Will automatically close when fuel manifold pressure reaches 50 PSI.

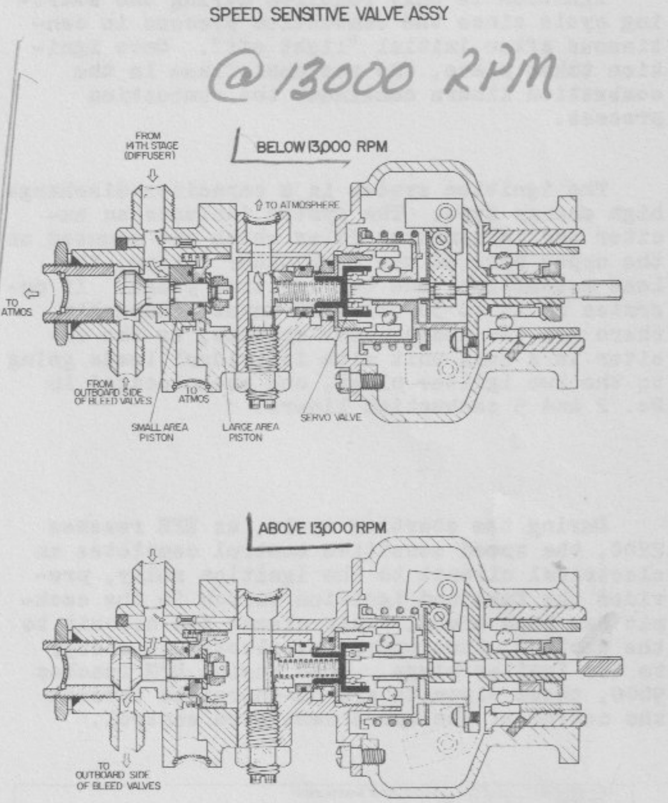
AT 9,000 RPM, THE FOLLOWING OCCURS:

- Ignition System - Off.
- ~~Drip Valve - De-energized (already closed by fuel pressure).~~
- Paralleling Valve - Open - Fuel pumps placed in series and fuel pump light should go out, indicating operation of the primary pump.

AT 13,000 RPM, THE FOLLOWING OCCURS:

- The electronic temperature trim system is changed from temperature limiting with a maximum temperature of 871°C. to a maximum of 977°C.

- Resets maximum possible take of fuel by the temperature trim valve to 20% rather than previous 50%.



SPEED SENSITIVE VALVE To close 5th + 10th stage

The Speed Sensitive Valve is mounted on the forward side of the accessories housing. This valve is a flyweight type, which responds to engine RPM. When running at less than 13,000 RPM, this valve is positioned so that all the 5th and 10th stage air bleed valve piston heads are vented to atmosphere and the bleed valves (5th & 10th stage) are open. Above 13,000 RPM, 14th stage air is directed by the Speed Sensitive Valve to the bleed valve piston heads, causing the valves to close.

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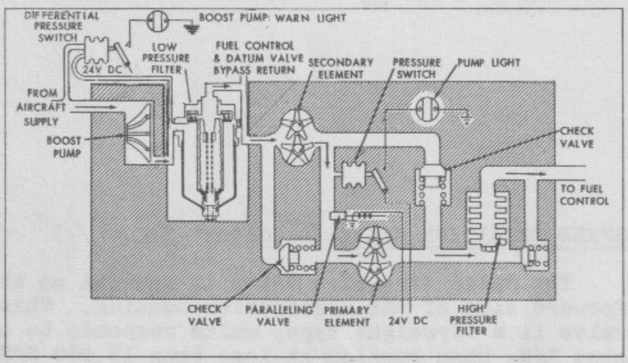
IGNITION SYSTEM

Ignition is only required during the starting cycle since the combustion process is continuous after initial "light off". Once ignition takes place, the residual flame in the combustion liners continues the combustion process.

The ignition system is a capacitor-discharge high energy type. The system includes an exciter and an ignition relay which are mounted on the upper part of the compressor casing, the lead assemblies, and two ignition plugs. It operates on 14 to 30 volts DC input. Actually, there are two independent systems, as the exciter is a dual unit with individual leads going to the two igniter plugs, one each located in No. 2 and 5 combustion liners.

During the starting cycle, as RPM reaches 2200, the speed sensitive control completes an electrical circuit to the ignition relay, provided the fuel and ignition switch in the cockpit has been armed. This closes the circuit to the exciter, thus providing electrical energy to the igniter plugs. When engine RPM reaches 9000, these circuits are de-energized through the action of the speed sensitive control.



Fuel Pump and Filter Assembly - Series Operation

FUEL PUMP AND FILTER ASSEMBLY

This assembly includes a centrifugal boost pump element, two spur gear type high pressure pumps (primary and secondary), two check valves, a paralleling valve, a pressure switch, a high pressure fuel filter and bypass valve.

During normal operation, fuel from the aircraft fuel system enters the engine driven boost pump and is directed external of the pump assembly to a low pressure replaceable paper cartridge type filter. From the filter the fuel goes back into the pump assembly to the secondary pump and thence to the primary pump, then passes through the high pressure filter and exits to the fuel control.

A differential pressure switch, sensing engine driven boost pump inlet and outlet pressures, is actuated and illuminates a light on the fuel control panel on the pedestal, when the differential between the two sensing pressures falls below a set value. Before starting, the light will be illuminated, but should go out during the engine start and remain out for all normal engine operation, indicating proper operation of the engine driven boost pump.

During engine starts (2200-9000 RPM), the paralleling valve is actuated by the speed sensitive control, causing the pumps to operate in parallel. In this speed range (low pumping capacity) during engine starting, the pumps in parallel provide the necessary fuel flow required for the start.

By means of the check valves, if either the secondary or primary pump fails while the engine is operating, the output of the other will automatically "take over" and supply adequate fuel for all engine operation, including takeoff.

The engine fuel pump light is actuated by a pressure switch sensitive to secondary pump pressure. During starts when this pump is in parallel with the primary pump, the light comes on, indicating proper operation of the secondary pump. When the pumps go to series operation, the light goes off, as the pressure of the secondary pump output is decreased by the primary pump requirements. Therefore, during starts, the operation of both the secondary and primary pumps can be ascertained by observing that the fuel pump light is out up to 2200 RPM, then comes on (indicating proper operation of primary pump). If the light is not on between 2200 and 9000 RPM, secondary pump failure is indicated. If the light remains on, or comes on above 9000 RPM (during start or other operation) primary pump failure is indicated.

Bypass valves are provided for both the high pressure filter and the low pressure filter to allow flow of fuel should the filters become clogged.

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FUEL CONTROL

The fuel control is a volume metering device which accepts the output of the engine fuel pumps, determines the amount of fuel needed by the engine from throttle position and by sensing air inlet temperature and pressure and meters that volume of fuel to the engine. The surplus output of the pumps is by-passed back to their inlet.

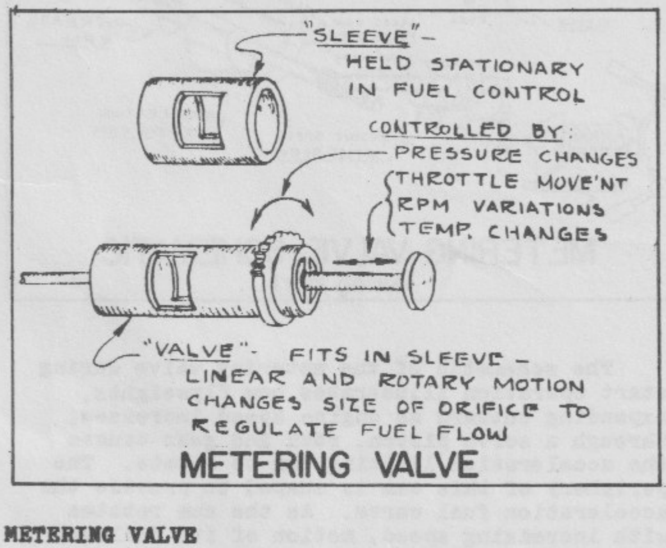
The volume of fuel metered by the fuel control is actually 120% of the engine requirements. This excess amount of fuel permits the electronic fuel trim system, located between the fuel control and the engine, to "trim" the amount of fuel the fuel control sends to the engine so a specified turbine inlet temperature is maintained as pre-selected by throttle position.

Should the Electronic Trim Control malfunction, it can be "locked out". In this condition it by-passes 20% of the fuel passing through it, thus the 120% metered by the Fuel Control less the 20% by-passed gives 100% of the fuel needed by the engine for any operating condition. In other words, the engine can be operated by the fuel control alone without use of the electronic fuel trim system, BUT it will be necessary to continually monitor Turbine Inlet Temperatures and make necessary changes with the throttle to prevent over-temperatures and to accommodate power variations.

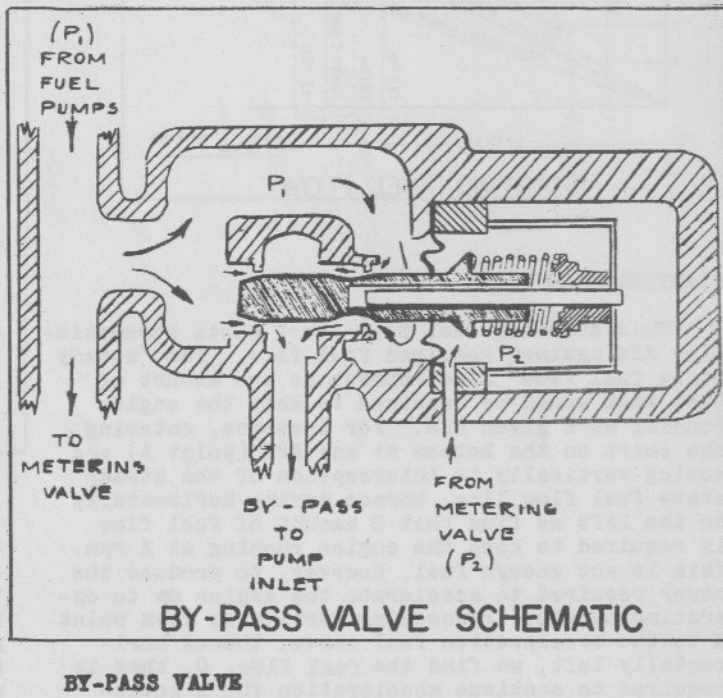
The metering valve itself consists of two concentric cylinders, each having two window cut-outs on either side of equal size. The larger cylinder is fixed or stationary in the fuel control body and is called the "sleeve"; the smaller cylinder, called the "valve", fits inside the sleeve and may be moved linearly or rotationally. When the window cut-outs of the sleeve and the valve coincide, a maximum of fuel may flow through; as the valve is moved linearly or rotationally, or both, the size of the orifice is reduced and fuel flow is restricted.

Rotational movement of the valve is accomplished automatically by the Inlet Pressure Actuator, connected to the pressure sensing probe in the compressor air inlet housing, to compensate for metering changes required due to variations in atmospheric and ram pressures. Linear movement of the valve is accomplished by throttle movement (manual), RPM variations and temperature changes (both automatic).

For precise control of the power output of the engine, it is necessary to assure that the volume of fuel flow through the metering valve is directly proportional to the size of the orifice; to do this, the pressure drop across the orifice must be regulated. This function is accomplished by the by-pass valve.



METERING VALVE



BY-PASS VALVE SCHEMATIC

METERING VALVE

The volume of fuel flowing to the engine depends on the opening of the variable orifice of the metering valve and the pressure differential across that opening.

BY-PASS VALVE

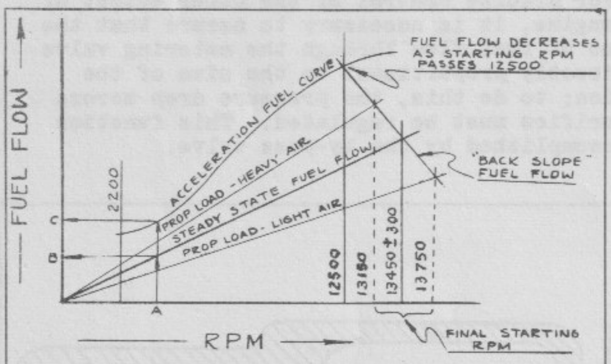
Entry of fuel to the metering valve from the pumps is through ports in the by-pass valve. Thus, fuel pump pressure (called P_1) is exerted both at the entry to the metering valve and on a

POWER PLANT

ENGINE COMPONENTS

FUEL CONTROL (Continued)
diaphragm in the by-pass valve. Metering valve outlet pressure (called P_2) is ported by a static line to a chamber in the by-pass valve on the opposite side of the same diaphragm. It can be seen that the diaphragm senses pressure differential across the metering valve. P_1 minus P_2 equals the pressure drop. Any time there is a constant fuel flow through the fuel control, P_1 equals P_2 plus spring pressure, and fuel by-passed back to the pump inlet will be constant.

Power changes will change values of P_1 and P_2. This causes movement of the diaphragm which readjusts the quantity of fuel being by-passed. After power changes, P_1 equals P_2 plus spring pressure again, and stabilizes the diaphragm in a new position to adjust by-pass fuel quantity to the new stabilized condition.



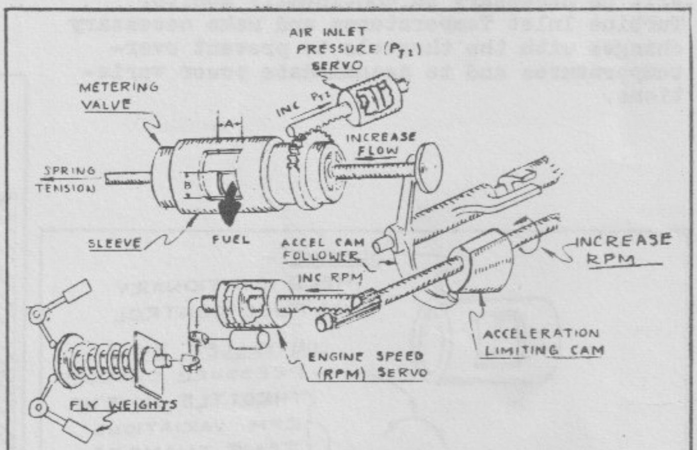
STARTING FUEL FLOW

STARTING FUEL FLOW

This starting fuel flow chart plots schematically RPM against required fuel flow. The "steady state fuel flow" line represents the amount of fuel that would be required to keep the engine running at a given RPM. For instance, entering the chart on the bottom at any RPM (point A) and moving vertically to interception of the steady state fuel flow line, thence moving horizontally to the left we find that B amount of fuel flow is required to keep the engine running at A rpm. This is not enough fuel, however, to produce the power required to accelerate the engine up to operating speeds. Proceeding vertically from point A to the acceleration fuel curve, thence horizontally left, we find the fuel flow, C, that is required to continue acceleration for a satisfactory start. The difference between C and B being the amount of fuel required to provide the energy for acceleration alone.

As the engine approaches operating speed, it is necessary to shut off this extra fuel at such a rate that when the engine is on speed, 13,450 ± 300 RPM, fuel flow will coincide very closely with the steady state fuel flow line. For this reason, at 12,500 rpm a weaning action starts which withdraws the extra fuel, and fuel flow drops off along the "back slope" fuel flow line.

So far, the discussion of starting fuel flow might be described as elementary or ideal. Variations in air density and their effects on combustion and prop loading must also be considered. Prop load lines, one for heavy and one for light air, may be seen on either side of the steady state fuel flow line. These represent the departures from the ideal situation which will more than likely be encountered in day in, day out operation. Their intercepts with the back slope line indicate where RPM may finally stabilize under varying atmospheric conditions. It is interesting to note that under atmospheric conditions which make for dense heavy air, the RPM will be less and THE FUEL FLOW GREATER than under conditions which tend to make the air less dense or lighter. Ordinarily, we would expect a higher fuel flow for the higher RPM.



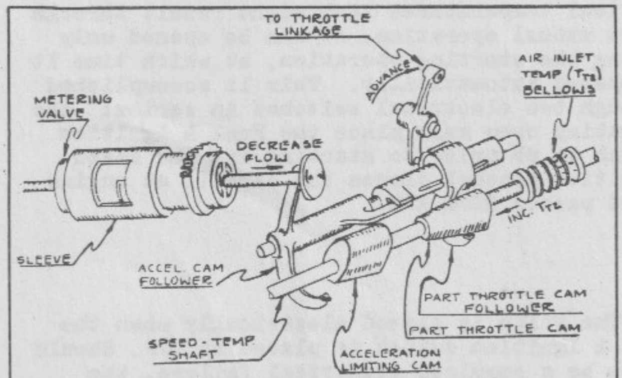
METERING VALVE SCHEMATIC
during start

The schematic of the metering valve during start operation illustrates how flyweights, expanding outward as engine speed increases, through a servo piston, rack and gear causes the acceleration limiting cam to rotate. The periphery of this cam is shaped to provide the acceleration fuel curve. As the cam rotates with increasing speed, motion of its follower permits the metering valve to move linearly (to the left in the illustration), increasing dimension A to provide greater fuel flow.

ENGINE COMPONENTS

FUEL CONTROL (Continued)

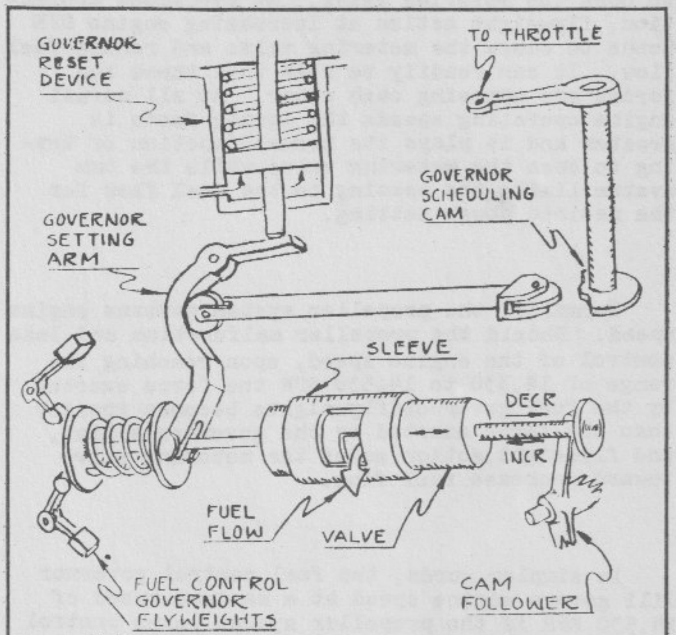
Shown also is a schematic presentation of the manner in which the air inlet pressure probe, through action of a servo piston, rack and pinion, alters dimension B to increase or decrease fuel flow as barometric pressure or altitude changes.



METERING VALVE SCHEMATIC
12500 RPM OR MORE

The Part Throttle Cam is contoured circumferentially to provide the "back slope" fuel flow curve. At engine speeds of 12,500 rpm and above this cam, through its follower and appropriate linkage, unseats the acceleration limiting cam and causes opposite linear motion of the metering valve in its sleeve (to the right in the illustration) to reduce fuel flow.

The linear contour of the Part Throttle Cam provides for fuel flow changes due to throttle movement and temperature variables, as shown in the schematic .



FUEL CONTROL GOVERNOR
schematic

FUEL CONTROL GOVERNOR

It can be seen by studying the fuel control governor schematic that the force exerted by the governor spring tends to OPEN the metering valve to permit maximum fuel flow. Cam action, relayed through the cam follower, opposes the spring force and tends to limit the size of the opening in the metering valve and thereby limit the amount of fuel flow. Should more power be called for from the flight deck, the cam follower would be moved toward increase fuel flow, establishing a new limit to which the governor spring could open the orifice of the metering valve.

Ordinarily, as the governor spring expands to increase fuel flow, it might be thought that the spring force would decrease as it is no longer under the same compression. However, in order to keep the spring force as constant as possible with varying fuel flow demands, spring compression is adjusted through the governor setting arm by action of the high lobe of the governor scheduling cam which is hooked up with the throttle.

POWER PLANT

ENGINE COMPONENTS

FUEL CONTROL (Continued)
Metering Valve Overspeed Protection

It was said that governor spring force tends to open the metering valve. As overspeed protection, flyweight action at increasing engine RPM tends to close the metering valve and reduce fuel flow. It can readily be seen that these two forces are opposing each other. At all normal engine operating speeds the spring force is greater and it plays its normal function of trying to open the metering valve while the cam system limits the opening to the fuel flow for the desired power setting.

Normally, the propeller system governs engine speed. Should the propeller malfunction and lose control of the engine speed, upon reaching the range of 14,330 to 14,530 RPM the force exerted by the fuel governor flyweights becomes greater than the force exerted by the governor spring, and flyweight action moves the metering valve toward decrease fuel flow.

In simpler words, the fuel control governor will govern engine speed at a maximum speed of 14,530 RPM if the propeller system loses control at 13,820 RPM.

Low Speed Taxi Setting

It is desirable to govern the engine at 10,000 RPM during some phases of ground operation to keep noise and prop blast at the lowest possible levels. This is accomplished by reducing the compression of the fuel control governor spring so that spring-flyweight forces will balance out at 10,000 RPM.

One switch for each engine is located on the forward left corner of the throttle pedestal. The switch actuates a solenoid mounted on the fuel control body. When actuated, the solenoid opens a port introducing fuel pressure into the governor reset device in such a manner that it removes a stop from the governor setting arm, permitting compression to be relieved from the governor spring.

This will be done, of course, with the throttle in the taxi range of operation, in which range, the governor scheduling cam will regulate the amount of movement of the setting arm - hence regulating spring pressure for the 10,000 RPM setting.

Act. by 'E' Handle - Feather button.

FUEL CUT OFF VALVE

or Fuel + ign sw.

The fuel cut off valve is situated at the outlet of the fuel control. Because of the critical temperatures that might result through inept manual operation, it can be opened only during the starting operation, at which time it is opened automatically. This is accomplished through two electrical switches in series: the operating crew must place the Fuel & Ignition switch to ON prior to starting and the speed sensitive control closes the circuit as engine speed passes 2200 RPM.

The valve is closed electrically when the Fuel & Ignition switch is placed to OFF. Should there be a complete electrical failure, the cut-off valve may be closed manually by pulling out the emergency handle. In closing the valve manually, electrical switching is also completed which will call for the electric actuator to go to the closed position whenever electric current is restored.

FUEL PRIMING SYSTEM

The fuel priming system may be used during the starting cycle if an increased initial fuel flow is required. It is placed in operation by a spring loaded primer switch on the flight deck. Fuel is drawn from the pumps upstream of the fuel control, passes through the primer valve and is introduced into the fuel control at a point ahead of the cut-off valve which bypasses the metering section of the fuel control. This fuel flows through the cut-off valve, through the electronic fuel trim valve, then to the fuel manifold and fuel nozzles. Priming fuel does not start flowing until the cut-off valve opens at 2200 RPM. A pressure switch, which senses the fuel manifold pressure, breaks the electrical circuit to the primer valve solenoid when the fuel pressure reaches 50 PSI. An electrical interlock prevents energizing the primer system after the engine is once started.