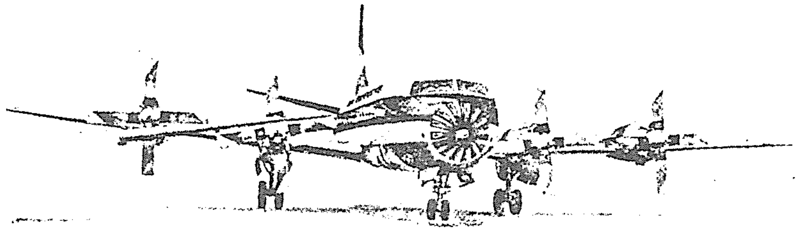
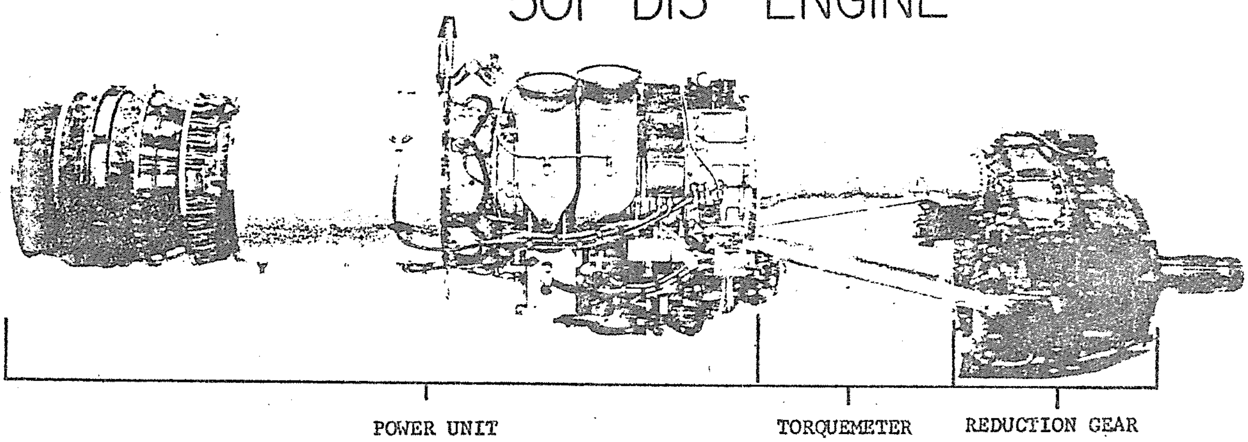


AIR CALIFORNIA

POWER PLANT

ENGINE COMPONENTS

501-D13 ENGINE



ENGINES

GENERAL

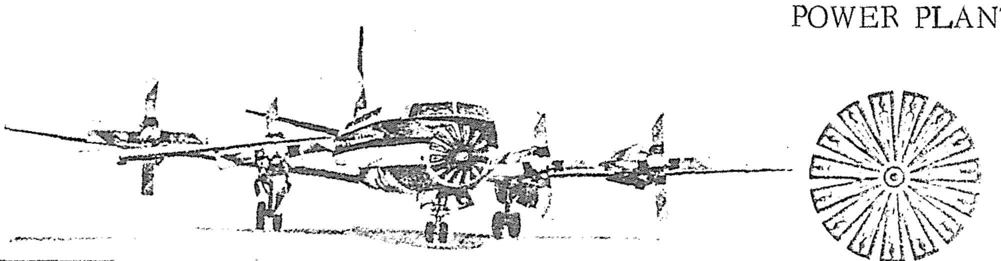
The Allison model 501-D13 engine is an internal combustion, gas turbine power unit connected by a torquemeter assembly and struts to a reduction gear having a single propeller shaft.

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.

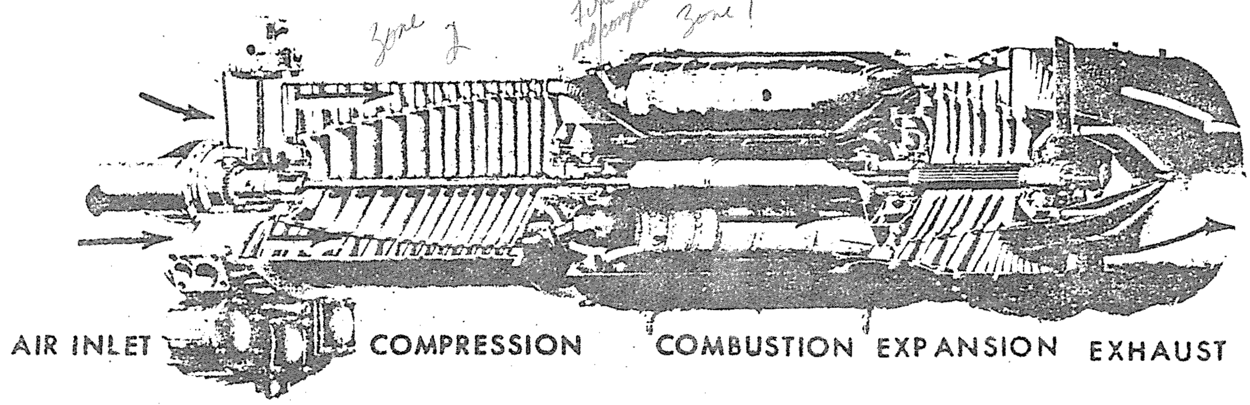
The torquemeter assembly transmits power from the power unit to the reduction gear. The twist of the torquemeter drive shaft under load is measured electronically and registered as shaft horsepower on a cockpit indicator.

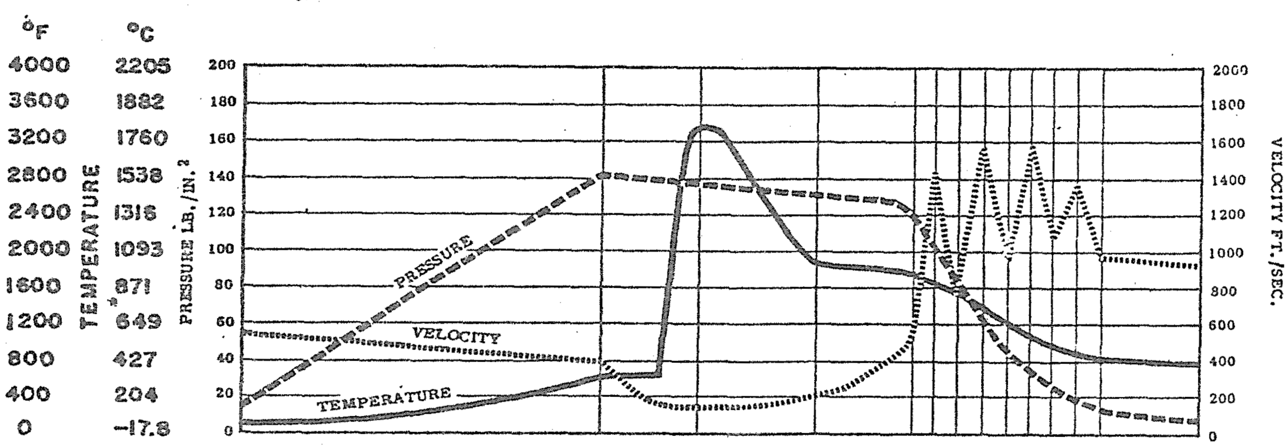
The two tie-struts assist in carrying the overhang moments and forces produced by the propeller and the reduction gear.



POWER PLANT

ENGINE COMPONENTS





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.

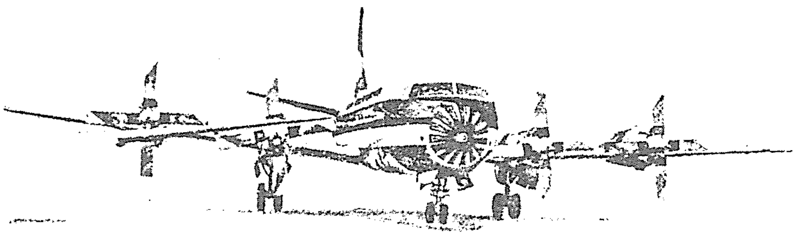
Engine specifications, based on sea level standard day static conditions, guarantee the engine will develop at take-off power a minimum of 3460 Shaft Horsepower (SHP) through the reduction gear box to the propeller. The jet thrust developed will be equivalent to 290 horsepower. The total guaranteed power,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

Curves in Section 4, PERFORMANCE, show expected torquemeter shaft horsepower under various conditions of ambient temperature, altitude, airspeed, and T.I.T.

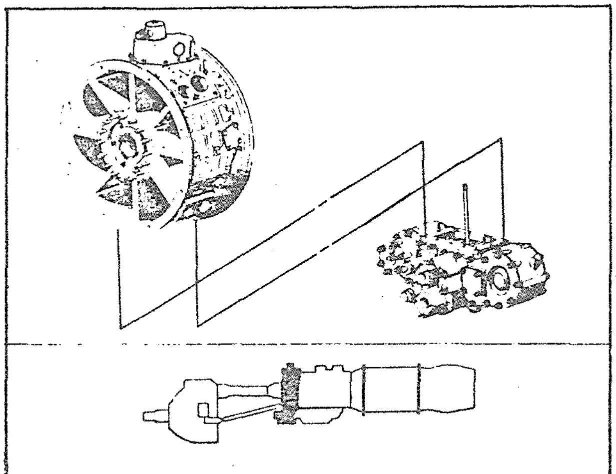
POWER SECTION

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:

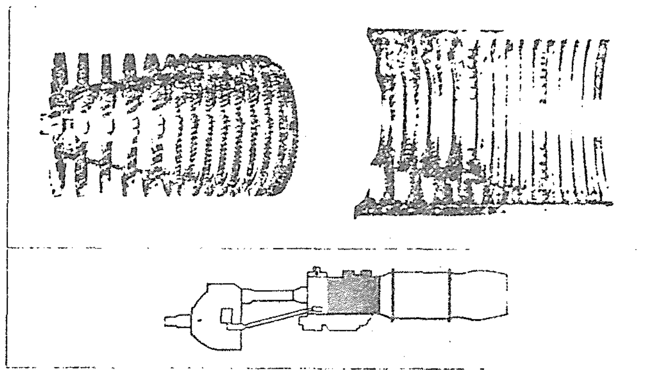
1. Air Inlet Section
2. Compressor Section
3. Diffuser Section
4. Combustion Section
5. Turbine and Exhaust Section



ENGINE COMPONENTS



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 power section 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.

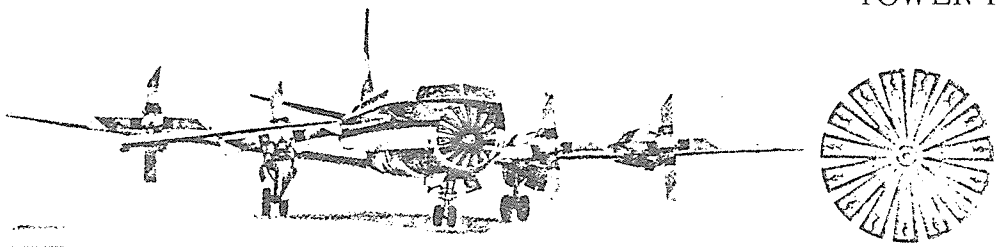
COMPRESSOR SECTION

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

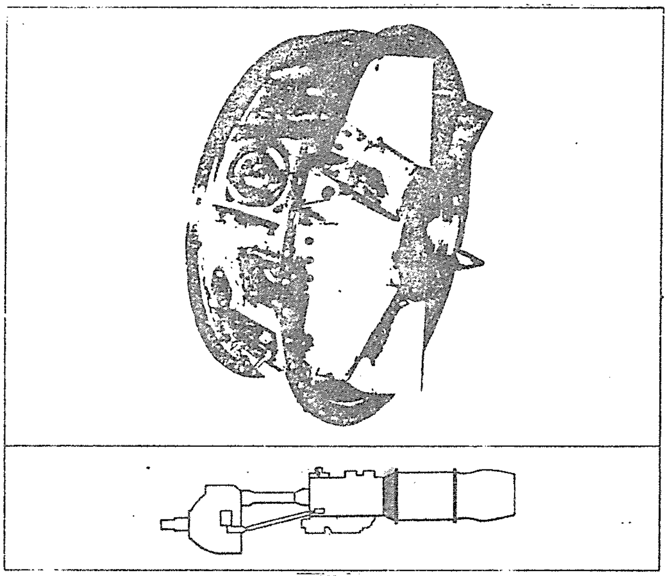
Four acceleration bleed valves are mounted around the outside of the compressor case at the 5th stage and four at the 10th stage. Those at the 5th stage are manifolded together, and those at the 10th stage are manifolded together. They are used to unload the compressor to prevent engine stall and surge 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, and their operation is controlled by the speed sensitive valve.



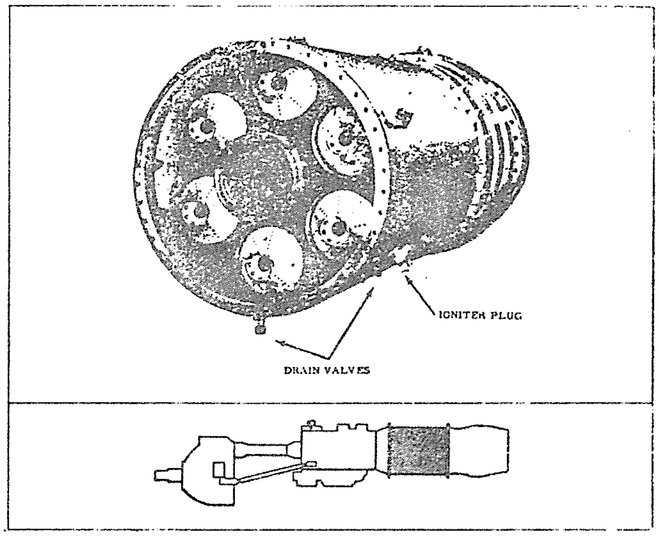
POWER PLANT

ENGINE COMPONENTS

POWER SECTION



Diffuser



Combustion Chamber Assembly

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 and de-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 (burner cans) 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.

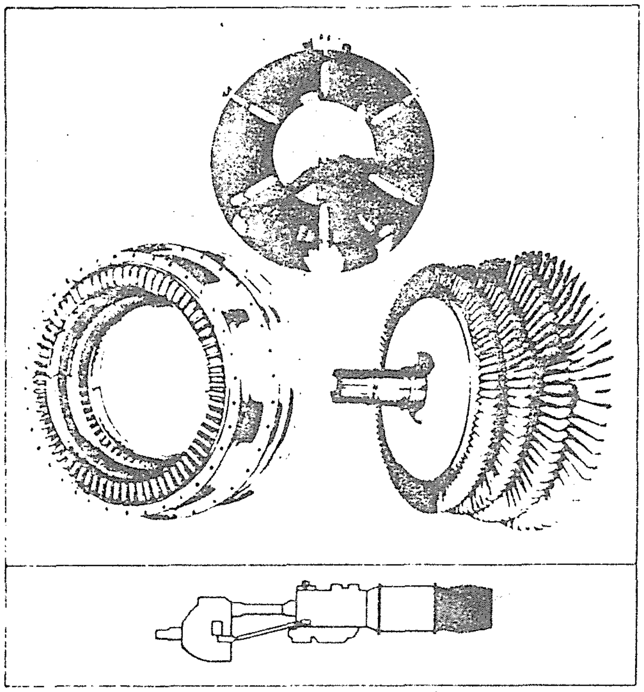
The outer casing provides the supporting structure between the diffuser and the turbine section. Mounted on the bottom of the outer casing are two combustion chamber drain valves to drain fuel after a false start or at engine shut down.

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 temperature of the gases entering the turbine.

AIR CALIFORNIA

POWER PLANT

ENGINE COMPONENTS


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. indication be accurate.

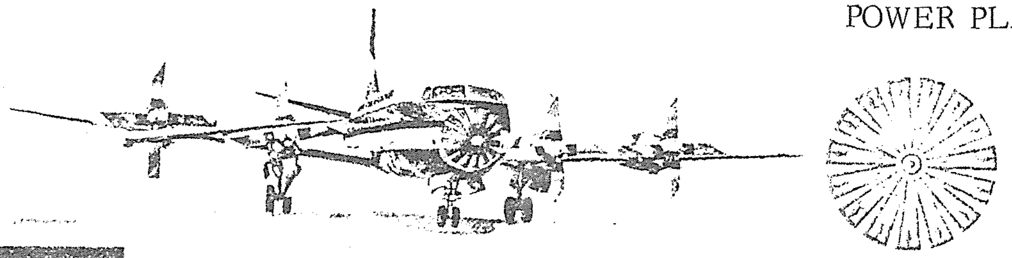
The turbine rotor assembly consists of four turbine wheels which are splined to a turbine shaft. The entire assembly is supported by roller bearings at each end.

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.

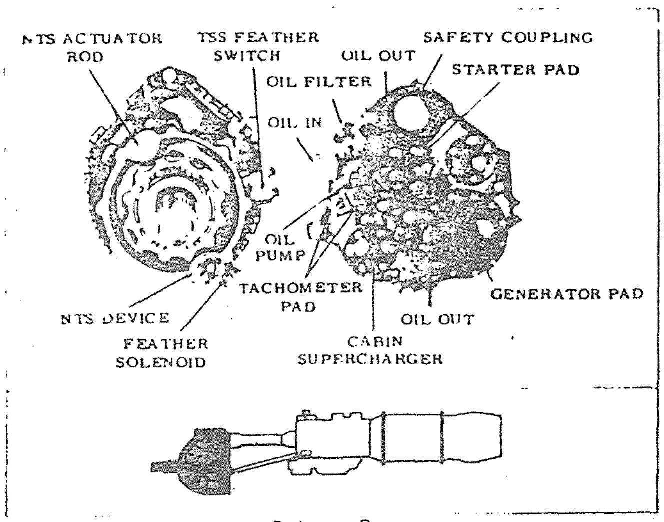
The turbine vane casing encases the turbine rotor assembly, and retains the four stages of turbine vane (stator) assemblies. It is the structural member for supporting the turbine rear bearing support. The vanes are airfoil design, and serve two basic functions. These increase the gas velocity prior 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.



POWER PLANT

ENGINE COMPONENTS



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:

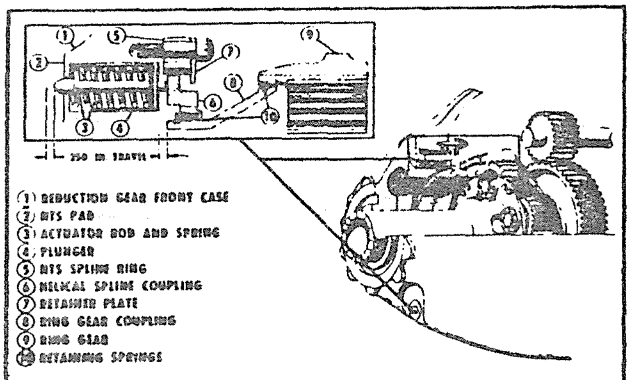
- Propeller Brake (prevents windmilling of a feathered propeller and reduces time for propeller to come to rest after engine shut down).
- Negative Torque System (NTS) (prevents excessive drag due to engine failure or excessive power loss in flight).
- Thrust Sensitive Signal (TSS) (will provide for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

PROPELLER BRAKE

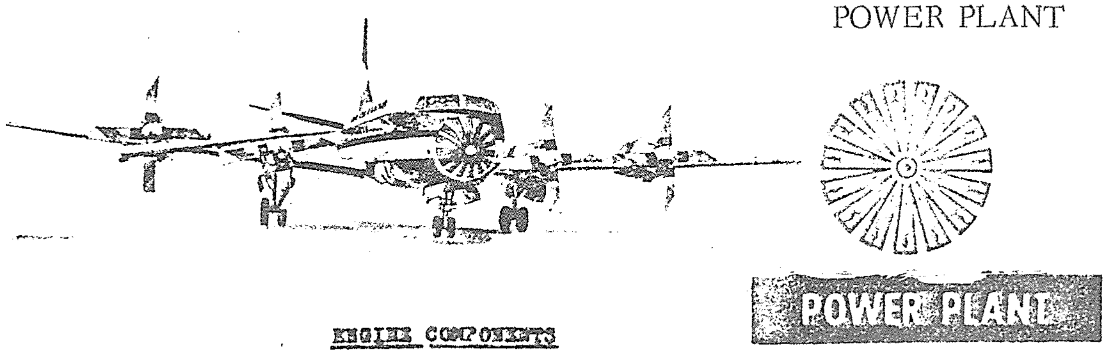
The propeller brake is designed so that it will prevent the propeller from windmilling when it is feathered in flight (may windmill slowly at airspeeds above 225 knots), and also to decrease the time for the propeller to come to a complete stop after ground shut-down, in which case brake engagement begins 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.

There is no conclusive ground check of the propeller brake. Manual, backward rotation of the propeller may be possible due to several variables which can prevent friction brake (no mechanical lock) engagement in the static condition; however, this is not indicative of unsatisfactory brake operation in flight. Also, the elapsed time for propeller to cease rotation on a normal engine shut-down does not reflect on brake operation. When a propeller is feathered, a good check of brake operation is to maintain airspeed below 225 KIAS and observe the propeller. If it rotates backward at airspeeds below 220 KIAS, possible improper brake operation is indicated; however, the feathered blade angle must be considered. If this angle is too great, a normal brake will be incapable of stopping backward rotation; likewise, if the angle is too small, forward rotation will result. Because of feather angle tolerances, the propeller may still rotate forward when the blades are set within limits, in which case the brake has very little effect. Slow rotation of a feathered propeller, in either direction, has negligible effect on performance.

NEGATIVE TORQUE SYSTEM (NTS)



Negative Torque Signal Components

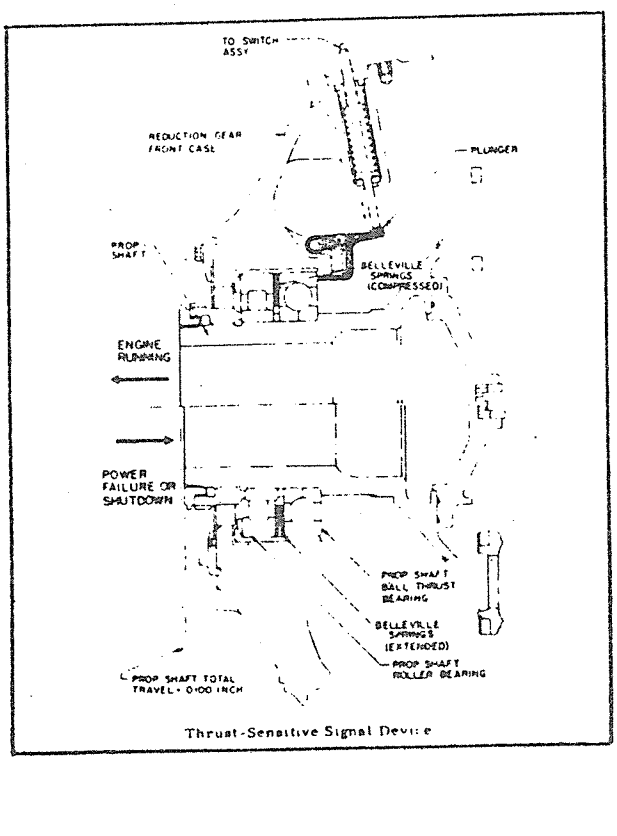


ENGINE COMPONENTS

NEGATIVE TORQUE SYSTEM (NTS)

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 drag.

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 300 to 420 horsepower 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, a plunger is moved forward through an opening in the reduction gear front case. This 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, thus making normal propeller governor functioning inoperative. 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 300-420 horsepower. As the negative torque is relieved, the propeller returns to normal governing.

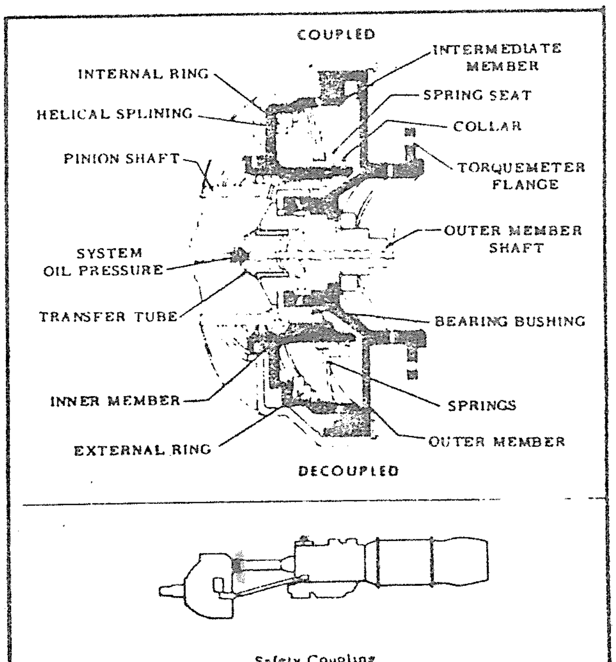


Thrust-Sensitive Signal Device

THRUST SENSITIVE SIGNAL (TSS)

The thrust sensitive signal provides the means for initiating auto-feathering at take-off. 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 loss occurs.

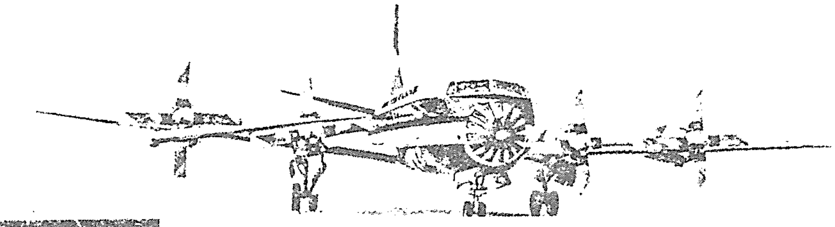
The system is designed to operate (when armed) when the propeller is delivering less than 500 lbs. of positive thrust. The propeller shaft tends to move in a forward axial direction as the propeller produces thrust. This axial travel is limited by mechanical stops. Forward movement of the shaft compresses 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.

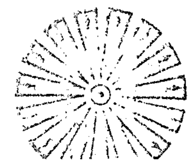


Safety Coupling

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 1630 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





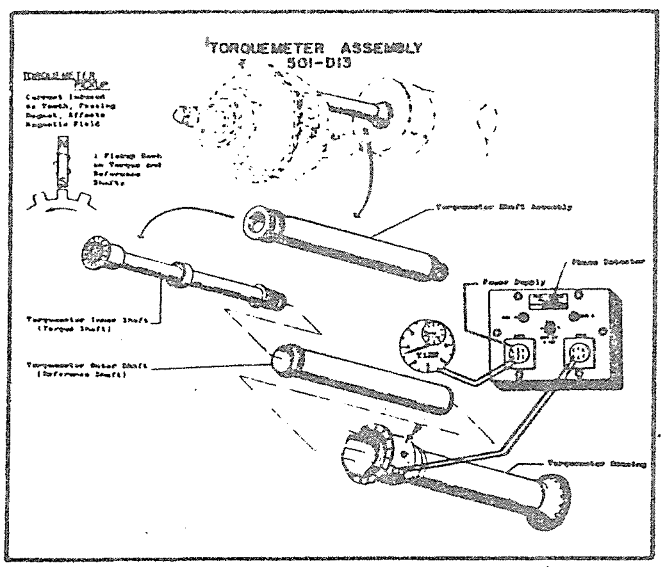
POWER PLANT

ENGINE COMPONENTS

SAFETY COUPLING (Continued)

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 1630 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 1630 SHP will cause it to de-couple 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

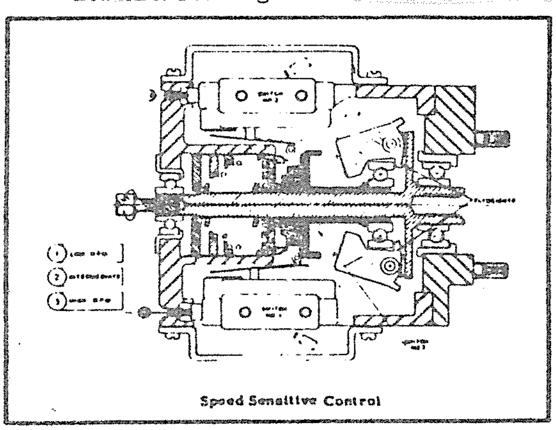
The torquemeter housing and two tie struts secure and provide alignment between power section and reduction gear assembly. The torquemeter shaft assembly, within the housing, provides the means of both transmitting torque from the engine to the gear box and of measuring that torque.

The torquemeter shaft assembly consists essentially of a solid shaft and a hollow shaft 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 distrubed, 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.

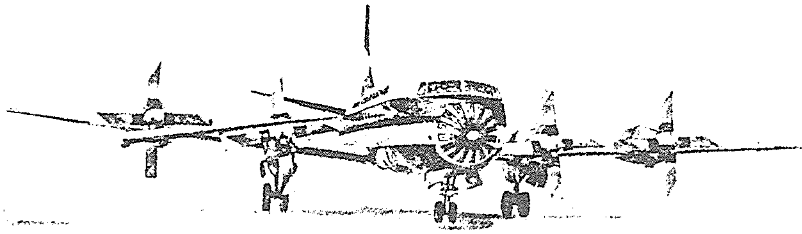
NOTE: Torquemeter is calibrated for 13,820 RPM. Low RPM readings will not be accurate.



Speed Sensitive Control

SPEED SENSITIVE CONTROL

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



AIR CALIFORNIA

POWER PLANT

ENGINE COMPONENTS

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:

NOTE: Fuel and Ignition Switch must be armed - ON

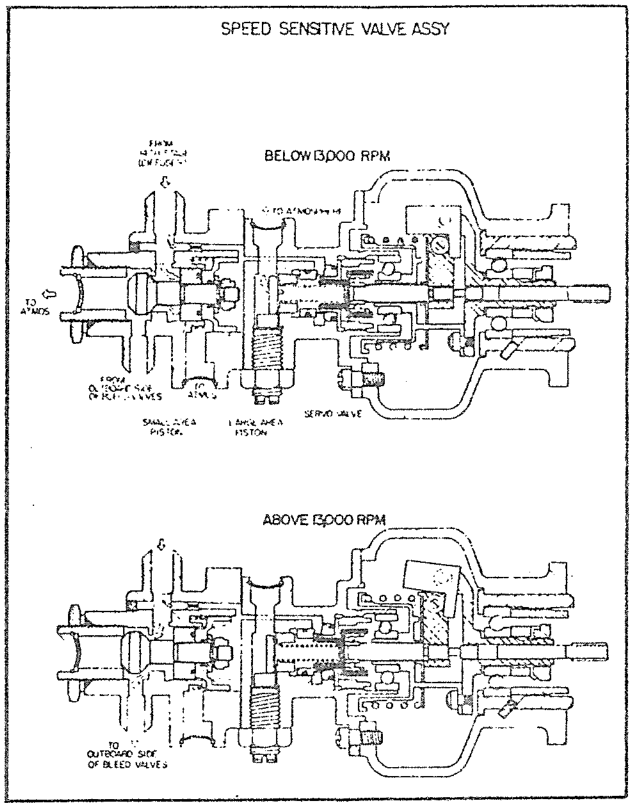
- The fuel control cut-off valve is opened at the outlet of the fuel control.
- Ignition System - ON
- Drip Valve - Closed (Energized)
- Fuel Pump Paralleling Valve - Closed - Fuel pumps placed in parallel, and fuel pump light comes on, indicating operation of secondary pump.
- Primer Valve - Opens - If Primer Switch held to ON position, will automatically close when fuel manifold pressure reaches 50 PSI.

AT 9000 RPM, THE FOLLOWING OCCURS:

- Ignition System - Off
- Drip Valve - De-energized (remains closed due to fuel pressure)
- Paralleling Valve - Open - Fuel pumps placed in series and fuel pump light goes out, indicating operation of the primary pump.
- Primer Valve - Disarms circuit (already de-energized by pressure switch).

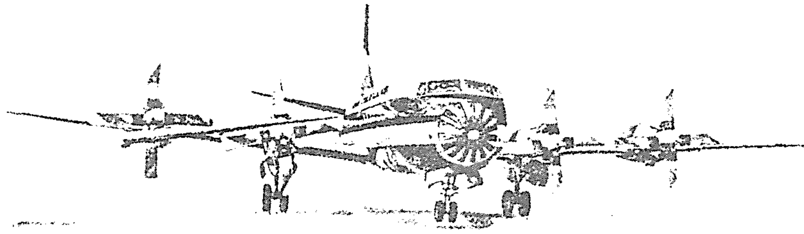
AT 13,000 RPM, THE FOLLOWING OCCURS:

- The electronic temperature trim system maximum T.I.T. limit is changed from 830°C to 977°C.
- Resets maximum possible take of fuel by the temperature datum valve to 20% rather than previous 50%.



SPEED SENSITIVE VALVE

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 acceleration 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.



AIR CALIFORNIA

POWER PLANT

ENGINE COMPONENTS

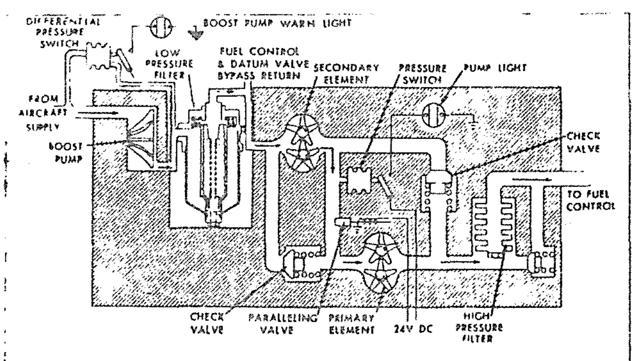
IGNITION SYSTEM

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, the ignition circuits are de-energized through the action of the speed sensitive control.

The ignition system has a maximum continuous rating of three minutes. However, to prevent overheating of the exciter, the operating cycle should not be more than two (2) minutes ON, three (3) minutes OFF, two (2) minutes ON and twenty-three (23) minutes OFF.



Fuel Pump and Filter Assembly Series Operation

This assembly includes a centrifugal boost pump, 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.

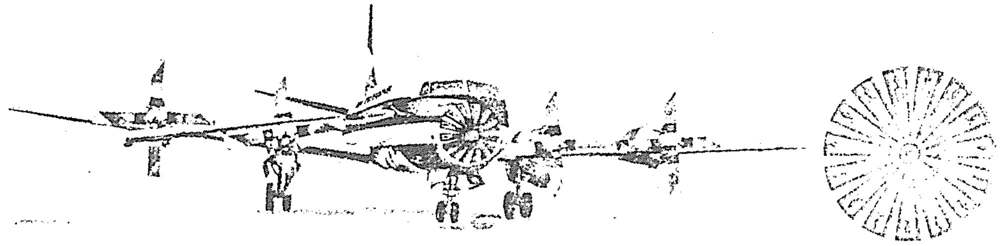
A differential pressure switch, sensing engine driven boost pump inlet and outlet pressures, is actuated and illuminates a light on the fuel control panel on the pedestal, when the differential between the two sensing pressures falls below a set value. Before starting, the light will be illuminated, 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.

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.



POWER PLANT

ENGINE COMPONENTS

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, engine RPM, 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.

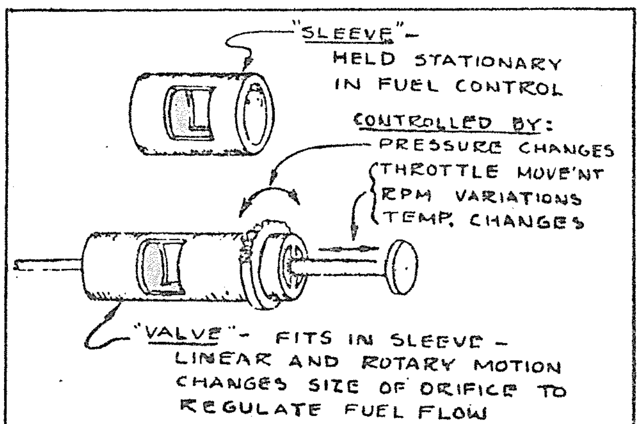
The volume of fuel metered by the fuel control is actually 120% of the engine requirements. This excess amount of fuel permits the electronic fuel trim system, located between the fuel control and the engine, to "trim" the amount of fuel the fuel control sends to the engine so a specified turbine inlet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

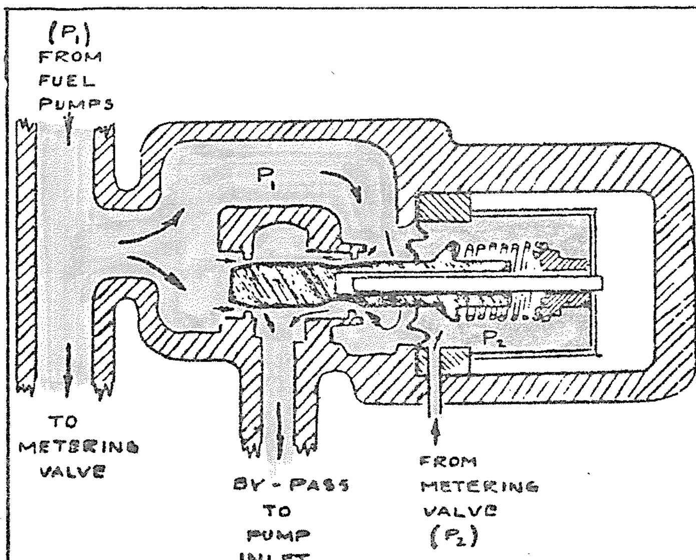
The metering valve itself consists of two concentric cylinders, each having two window cut-outs on either side of equal size. The larger cylinder is fixed or stationary in the fuel control body and is called the "sleeve"; the smaller cylinder, called the "valve", fits inside the sleeve and may be moved 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



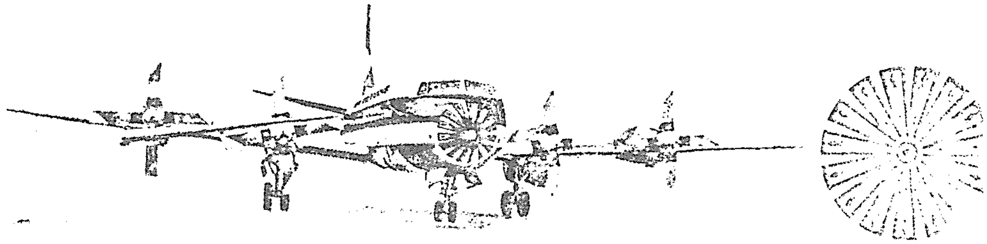
BY-PASS VALVE SCHEMATIC

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



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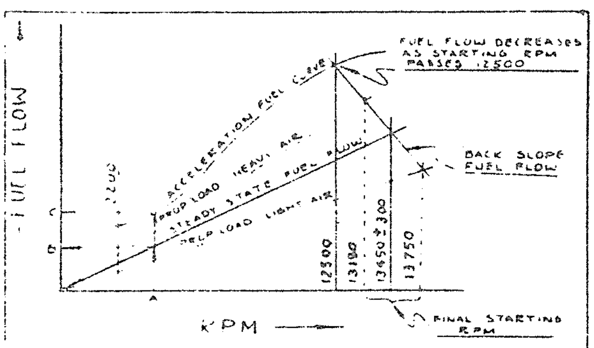
POWER PLANT

ENGINE COMPONENTS

BY-PASS VALVE (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 bypassed 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.



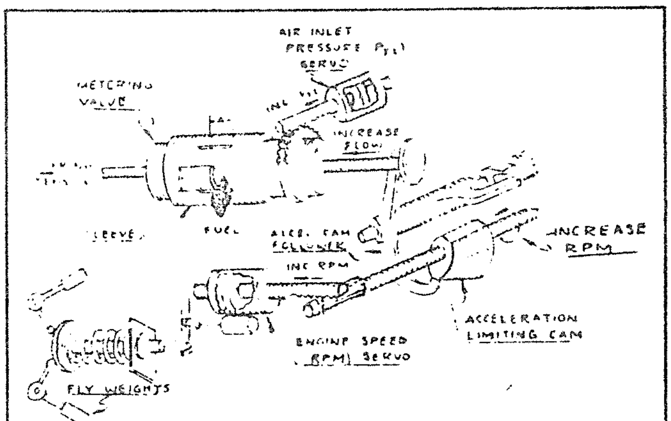
STARTING FUEL FLOW

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.

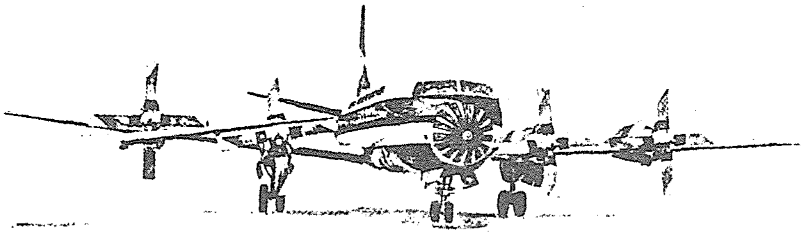
As the engine approaches operating speed, it is necessary to shut off this extra fuel at such a rate that when the engine is on speed, 13,450 ±300 RPM, fuel flow will coincide very closely with the steady state fuel flow line. For this reason, at 12,500 rpm a weaning action starts which withdraws the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



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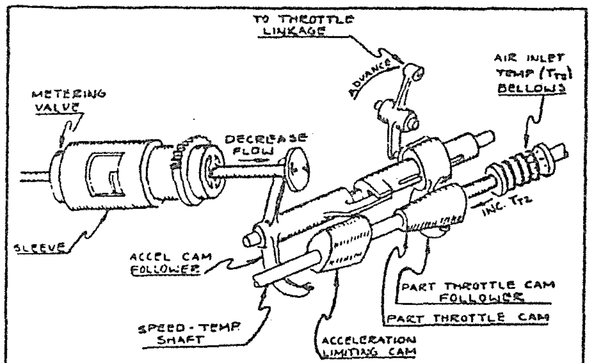
POWER PLANT

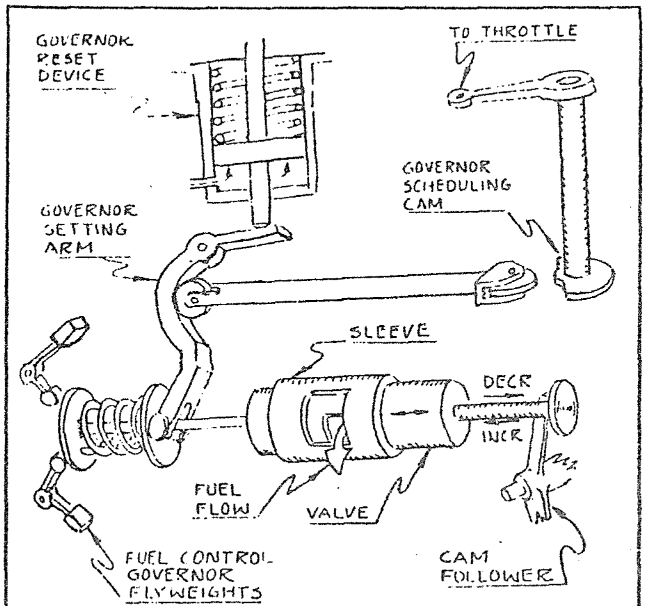
ENGINE COMPONENTS

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



FUEL CONTROL GOVERNOR
schematic

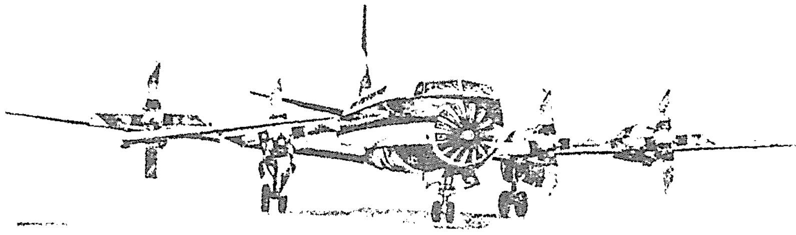
The Part Throttle Cam is contoured circumferentially to provide the "back slope" fuel flow curve. At engine speeds of 12,500 rpm and above this cam, through its follower and appropriate linkage, unseats the acceleration limiting cam and causes opposite linear motion of the metering valve in its sleeve (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 temperature variables, and to throttle movement in High Speed Taxi and all flight regimes, as shown in the 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.



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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.

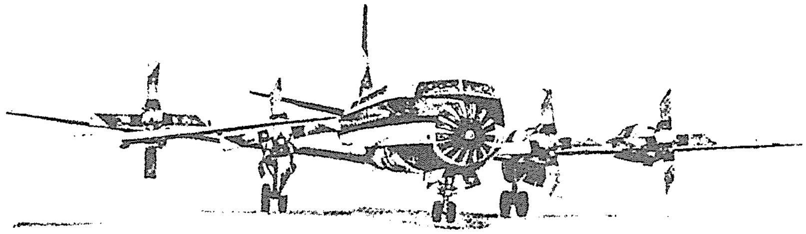
FUEL CUT OFF VALVE

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.



ENGINE COMPONENTS

ELECTRONIC TEMPERATURE TRIM SYSTEM

INTRODUCTION

As a measure of the power developed by a piston engine we speak in terms of manifold pressure and RPM. The amount of power developed by a gas turbine engine depends on the heat energy released by the fuel being used, and we speak of that power in terms of temperature and RPM; as the 501-D13 is a constant speed engine, we can refer to power in terms of temperature alone. Some manufacturers measure this temperature after the exhaust gases have passed through the turbine wheels, and refer to it as "EGT" which stands for Exhaust Gas Temperature. On this engine the temperature is measured at the inlet to the turbine and is called "TIT", an abbreviation for Turbine Inlet Temperature.

The engine is a commercial outgrowth of a gas turbine model that was originally developed for the military. One of the military specifications--in very general terms--was that the engine be capable of developing its full rated power whether using kerosene at an extremely low temperature or Avgas at an extremely high temperature for fuel without readjustment of fuel system components. It can be seen that a given volume of fuel could vary widely in heat energy potential because of the extremes in fuel density and BTU content imposed by this specification. This engineering problem was answered by the development of the electronic temperature trim system.

A thumbnail sketch of this system will help to understand it. Let's say the Pilot has moved the throttles forward to the take-off position. Through linkage this sets a potentiometer in the coordinator to the 971°C setting which is 100% Maximum Rated Temperature (MRT). Remember, we refer to power in terms of temperature. This sends a signal to a little black box, called the Temperature Datum Control, which tells it the Pilot wants maximum power. The little black box is also receiving a signal from the thermocouples around the inlet to the turbine (TIT). It compares the TIT signal to the signal sent down by the Pilot, and tells a valve in the fuel system to "PUT" more fuel to the engine until 971°C is reached, then adjusts the trim to hold it there. After becoming airborne and obtaining proper airspeed, the Pilot will reduce throttle to obtain climb power. This action readjusts the potentiometer in the coordinator to a lesser value; the new power reference (temperature) is sent on to the little black box which compares actual TIT with that desired by the Pilot, "takes" fuel until the desired temperature is reached, then trims fuel to maintain temperature regardless of altitude changes. Thus it can be seen that it is not necessary, as with a piston engine, to continually readjust throttle position during climbs and descents.

Many of us are sometimes confused by terminology when introduced to new equipment. This may be because words are used which are strange to us, or because words with which we are familiar are used in a different sense. DATUM is a word used frequently in connection with fuel system of the 501-D13 engine; and to allay possible confusion when it crops up, it means a reference, or the point, from which a reckoning starts. To illustrate, sea level is a datum or reference from which surveyors run levels to determine the height of terrain; it is also the datum from which altitude of flight is measured; a vertical line through the nose of an airplane is frequently used as a datum from which fuselage locations known as "stations" are measured.

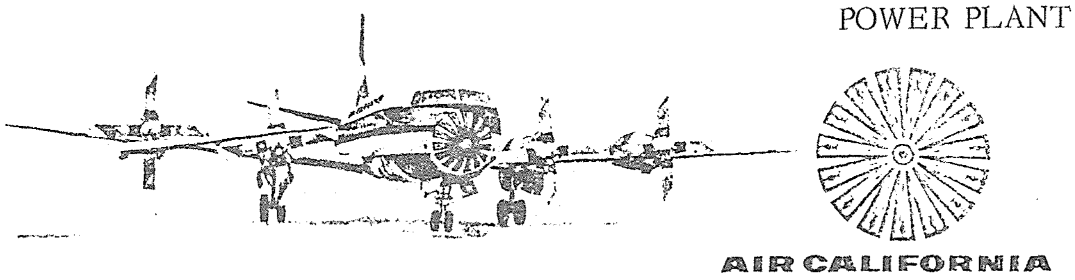
A separate datum, or reference, is used by the electronic temperature trim system for each of three separate circumstances.

(1) A potentiometer set to 830°C provides over-temperature protection during engine starts and whenever engine speed is below 13,000 rpm, which includes low speed taxi. Should TIT rise above 830°C, under these circumstances, the system would "TAKE" fuel from the engine until the TIT is reduced.

(2) Another potentiometer set to 977°C provides the datum when engine speed is above 13,000 rpm as long as the throttle is less than 65° toward its advanced position. It provides over-temperature protection in the same manner as just decribed.

(3) A variable potentiometer, set by throttle movement and located in the coordinator, provides the datum during normal flight when the throttle is advanced beyond the 65° position. The electronic trim system will regulate flow of fuel to the engine during this phase of flight to keep the TIT at the temperature reference set by the throttle. At take-off, with the coordinator in the 90° position (full throttle), the potentiometer is set at 971°C. However, the normal EAL throttle settings for take-off, climb and cruise result in potentiometer settings of 950°C, 885°C and 837°C respectively.

The system trims the 120% fuel flow from the fuel control as required for any condition of engine operation. There are two general ranges of operation; namely, Temperature Limiting and Temperature Controlling.



ENGINE COMPONENTS

ELECTRONIC TEMPERATURE TRIM SYSTEM (Continued)

Temperature Limiting

Temperature limiting serves to prevent the possibility of exceeding critical turbine inlet temperatures during those phases of engine operation when the throttle is less than 65° advanced. 830°C is used for a datum when the engine speed is below 13,000 rpm; 977°C is the datum at engine speeds above 13,000 rpm. Temperature limiting also occurs when operating with a "locked in" fuel correction above 65° throttle setting.

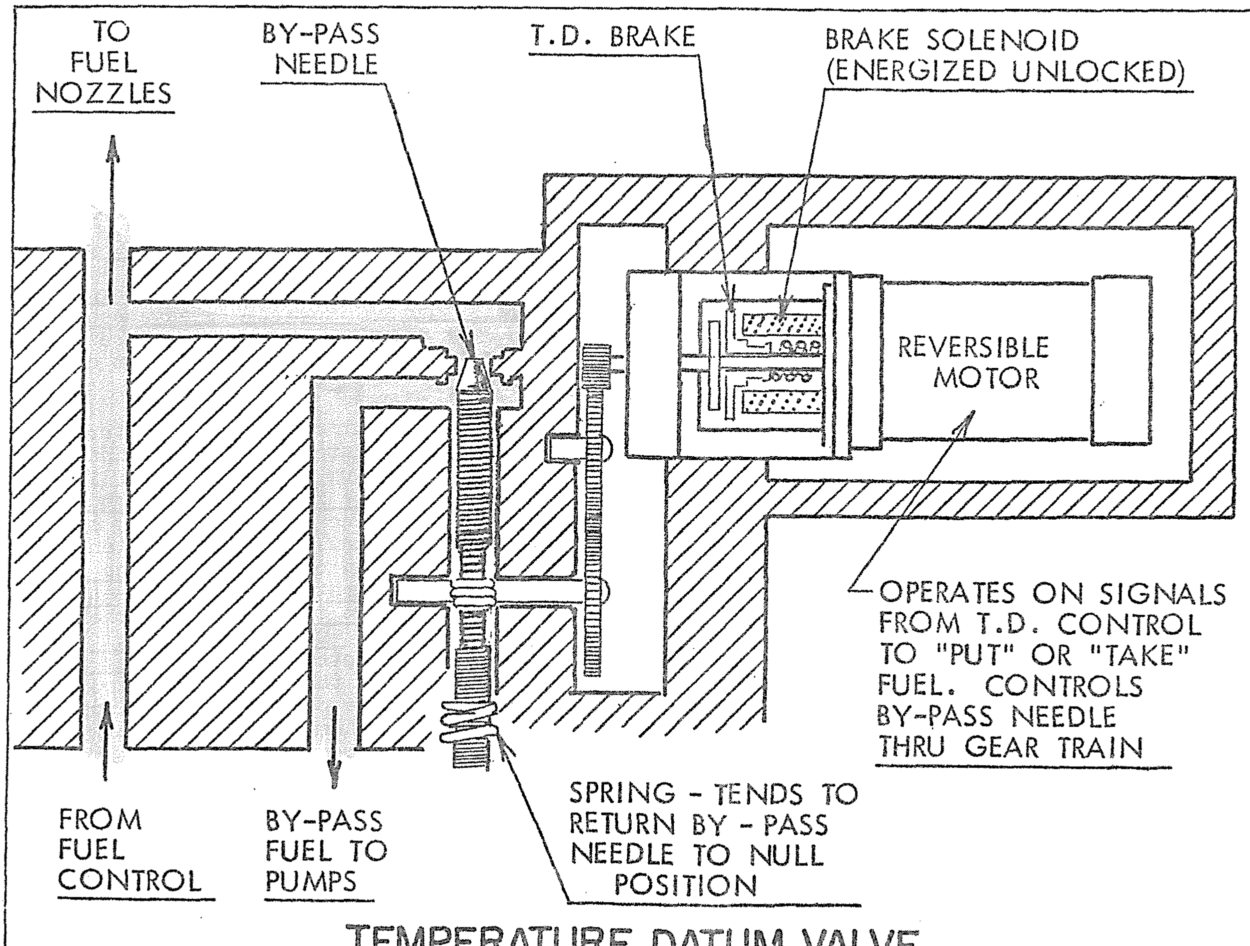
Temperature Controlling

Temperature controlling permits the use of the throttle to select a desired Turbine Inlet Temperature (power setting) when operating above 65° throttle position. That power setting will be automatically maintained without further adjustment of the throttle regardless of changes in outside temperature, pressure, or altitude. Temperature controlling requires RPM in excess of 13,000 without a "locked in" fuel correction, and throttle setting above 65°.

TEMPERATURE DATUM CONTROL

The temperature datum control is the "brain" of the fuel trimming system. It is our "little black box". Actually, it is an electronic amplifier which uses 115V, 400 cycle alternating current. Its operation requires having the engine temperature datum control switch, located in the upper right corner of the overhead switch panel, in the NORMAL position. There is one switch for each engine.

The temperature datum control is furnished actual turbine inlet temperature data from a set of thermocouples, and a reference temperature value or datum.



TEMPERATURE DATUM VALVE

take only { Below 13,000 = 830° (Starts & Gnd Taxi) 50% Take } 0-65° coordinator
Limiting Lights on { above 13,000 = 977 (throttle below 65°) 20% Take }

Put & Take Controlling Lights out { Temp Set to Power Lever Position } above 65 coord.

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ENGINE COMPONENTS

ELECTRONIC TEMPERATURE TRIM SYSTEM (Continued)

TEMPERATURE DATUM CONTROL (Continued)

It compares the temperatures and signals necessary corrective action to the temperature datum valve which trims fuel flow accordingly. In the temperature limiting range (0°-65°) the temperature datum control acts only when the limiting temperature is exceeded, at which time it signals the temperature datum valve to decrease fuel flow. In the temperature controlling range (65°-90°), the T.I.T. is compared to the reference temperature set by the throttle in the coordinator potentiometer; if there is a difference, the temperature datum control signals the temperature datum valve to increase or decrease fuel flow to bring the temperature back on schedule.

TEMPERATURE DATUM VALVE

The temperature datum valve is located between the fuel control and the fuel nozzles. It is a motor-operated by-pass valve which responds to signals received from the temperature datum control. In throttle positions between 0° and 65° the valve remains in a 20% by-pass or "null" position, and the engine operates on the fuel flow scheduled by the fuel control. The valve remains in the null position unless it is signaled by the temperature datum control to limit the turbine inlet temperature. The valve then reduces the fuel flow (up to 50% during starting, 20% above 13,000 rpm) to the nozzles by-passing the excess fuel to the inlet of the fuel pump. When the turbine inlet temperature lowers to the desired level, the temperature datum control signals the valve to return to the null position. In throttle positions between 0° and 65° the control system is in the temperature limiting range.

"limit" take only 15%

In throttle positions between 65° and 90° the temperature datum valve acts to control turbine inlet temperature to a pre-selected schedule corresponding to throttle position; this is known as the temperature controlling range. In this range the valve may be signaled by the temperature datum control to allow more (high temperature desired) or less (lower temperature desired) of the fuel to flow to the fuel nozzles.

"control" put & take 15% - 20%

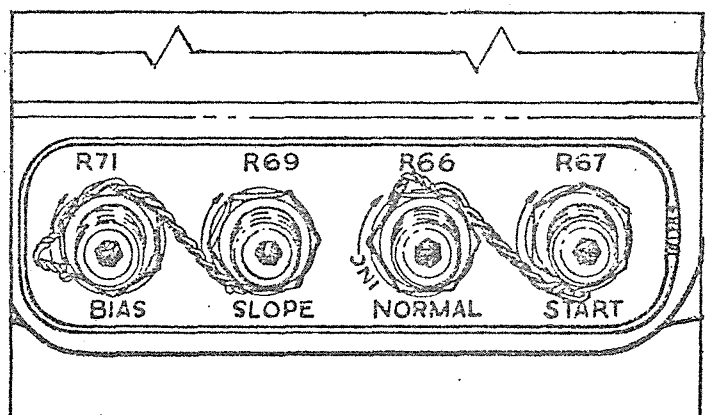
Any specific fuel flow trim correction applied in the 65°-90° throttle range can be "locked in" to the temperature datum valve while above 65°, and it will be maintained in the 0°-65° throttle range by placing the Temperature Trim Switch, located in the lower left corner of the throttle pedestal, in the LOCKED position.

The fuel trimming system can also be completely removed operationally from the fuel system at any time by placing the Temperature Datum Control Switch, located on the Engine Test Overhead Panel, in the NULL position. When the fuel trimming system is thus deactivated, automatic temperature limiting circuits are inoperative, the temperature datum valve remains in the NULL position (20% bypass), and all fuel metering is then accomplished by the fuel control. Temperature limiting must be accomplished by throttle adjustment under this circumstance, and the TIT gage must be monitored very closely.

NOTE: Modifications to original installation have been made which results in NULL configuration being obtained if TDC switch is in either NULL or OFF position.

TEMPERATURE DATUM CONTROL - TRANSISTORIZED

Temperature adjustments on the transistorized Temperature Datum Control are made by means of four potentiometers mounted on the control. These potentiometers provide for the adjustment of the start limit and normal limit temperatures, and the bias and slope settings of the controlling temperature range.



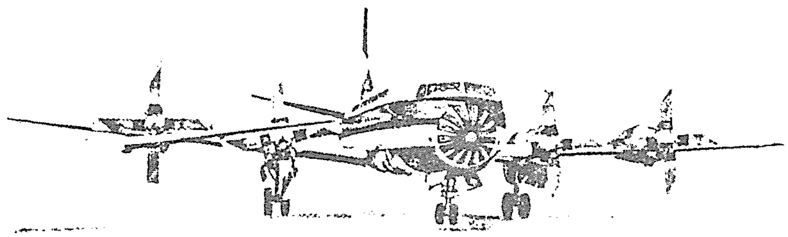
Temperature Datum Control— Transistorized = 2 position Switch
~~w/3 position switch~~
could still be off with guard down so open to be sure

RELAY BOX

The relay box is mounted in the engine nacelle and contains the relays necessary for sequencing all automatic and manual control components.

THERMOCOUPLES

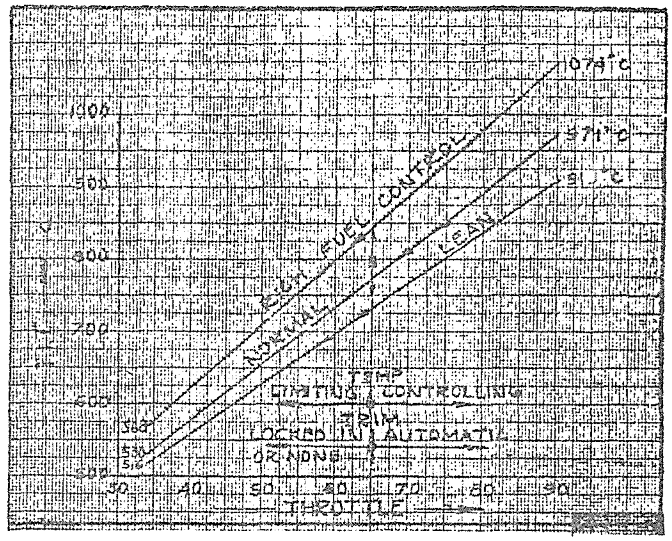
There is a total of eighteen dual thermocouples, forming two individual parallel circuits. One provides turbine inlet temperature to the cockpit instrument, and the other provides an actual temperature indication to the temperature datum control.



ELEC'RONIC TEMPERATURE TRIM SYSTEM (Continued)

SPEED SENSITIVE CONTROL (13,000 RPM switch)

At 13,000 RPM it de-energizes the solenoid operated valve in the temperature datum valve, thus switching from a maximum "take" of 50% to one of 20%. It also switches the temperature limiting reference or datum of the temperature datum control from the 830°C potentiometer to the 977°C potentiometer.



TEMPERATURE TRIM SWITCH

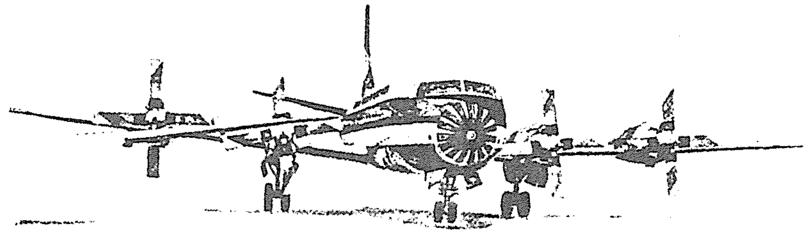
The Temperature Trim switch, when placed in the LOCKED position, causes the datum valve to lock. This occurs only with the throttle in a position greater than 66° throttle setting. When the switch is moved to the CONTROLLED position, it releases the brake.

Due to variables such as manufacturing tolerances, burner and fuel nozzle dirt accumulations, fuel density variations with temperature, and instrument inaccuracies in bench settings, the output of one fuel control assembly may vary quite widely from that of another. Suppose that all the plus tolerances were concentrated in one fuel control and all the minus variables were concentrated in another. The first would deliver 23% more fuel than desired, while the second would deliver 21% less. In other words, the first would be extremely rich, the second extremely lean. Remember that the gas turbine compressor delivers about 75% more air than is normally needed for combustion, which means that all the fuel passing through the nozzles is completely consumed. Therefore, if a turbine engine has a rich fuel control, one that is delivering more fuel than it should, the engine will deliver more power than it should; conversely a lean engine will deliver less.

Above the 65° throttle position, the electronic fuel trim system trims the output of the fuel control so that the fuel flow through the nozzles is neither rich nor lean, but on the schedule set up by throttle position.

Referring to the graph of throttle position plotted against T.I.T., we can see that without fuel trim, in the flight range of throttle setting (34°-90°), a rich fuel control would give T.I.T.'s ranging from 568°C to 1074°C, while a lean one would range from 516°C to 919°C. Remembering that T.I.T. is an indication of power on a constant speed gas turbine, it can be seen, even though the above illustrations are extreme, that we can expect some variation in the power output of one engine as compared to another when the electronic fuel trim system is not in operation; remember it is not operating at throttle setting less than 65° (unless locked in).

The 530-971°C. T.I.T. line on the graph is the norm, or desired, power line. Assuming the electronic fuel trim system to be working, the arrows indicate what T.I.T.s might be expected on reducing the throttles to two engines, one having a fuel control extremely rich, the other lean. On retarding through the 65° position, the rich engine would increase its power output, the lean one would fall off and possibly cause an offset thrust.



ENGINE COMPONENTS

ELECTRONIC TEMPERATURE TRIM SYSTEM (Continued)

If the fuel controls of all four engines of an Electra were rich, with the throttles in the flight idle position during an approach for landing, sufficient excess power might exist to cause a faster than desired approach speed which would cause a tendency to use an excessive length of runway.

On the other hand, with four lean engines, the tendency would be toward undershooting and the propellers might even do a little NTS-ing during a landing approach.

To eliminate these undesirable characteristics it is possible to "lock in" the electronic fuel trim by setting the Temperature Trim Switch when the throttles are above the 65° position. Then as throttles are retarded for a landing approach, fuel flow should be neither rich nor lean, but trimmed properly so that all T.I.T.'s will reduce in a straight line relation with throttle position.

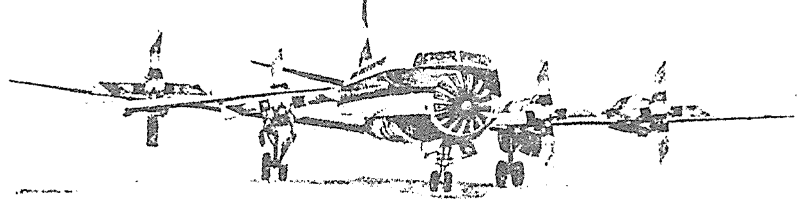
Whenever the temperature datum brake is locked, the 977°C potentiometer is switched in as the reference for the temperature datum control and the electronic temperature trim system will provide over-temperature protection at this figure. Should an over-temperature occur, the electronic system will automatically unlock the T.D. valve brake and send a "take" signal to the T.D. valve until the over-temperature condition is corrected. The brake remains unlocked unless reset.

TEMPERATURE TRIM LIGHT

The temperature trim light will be ON in the throttle range 0°-65°, indicating operation in the temperature limiting range. In the throttle range 65°-90° it will be OFF, indicating operation in the temperature control range. It will also be OFF in the 0°-65° throttle range when the Temperature Trim Switch is in the LOCKED position. However, if an over-temperature occurs with the brake locked the light will come ON. When the temperature trim light is OFF, it indicates that the electronic temperature trim system is making a fuel flow correction (put or take) and when the light is ON, it indicates that no correction is being made, or there is, or has been, an over-temperature condition.

ENGINE TEMPERATURE DATUM CONTROL SWITCH

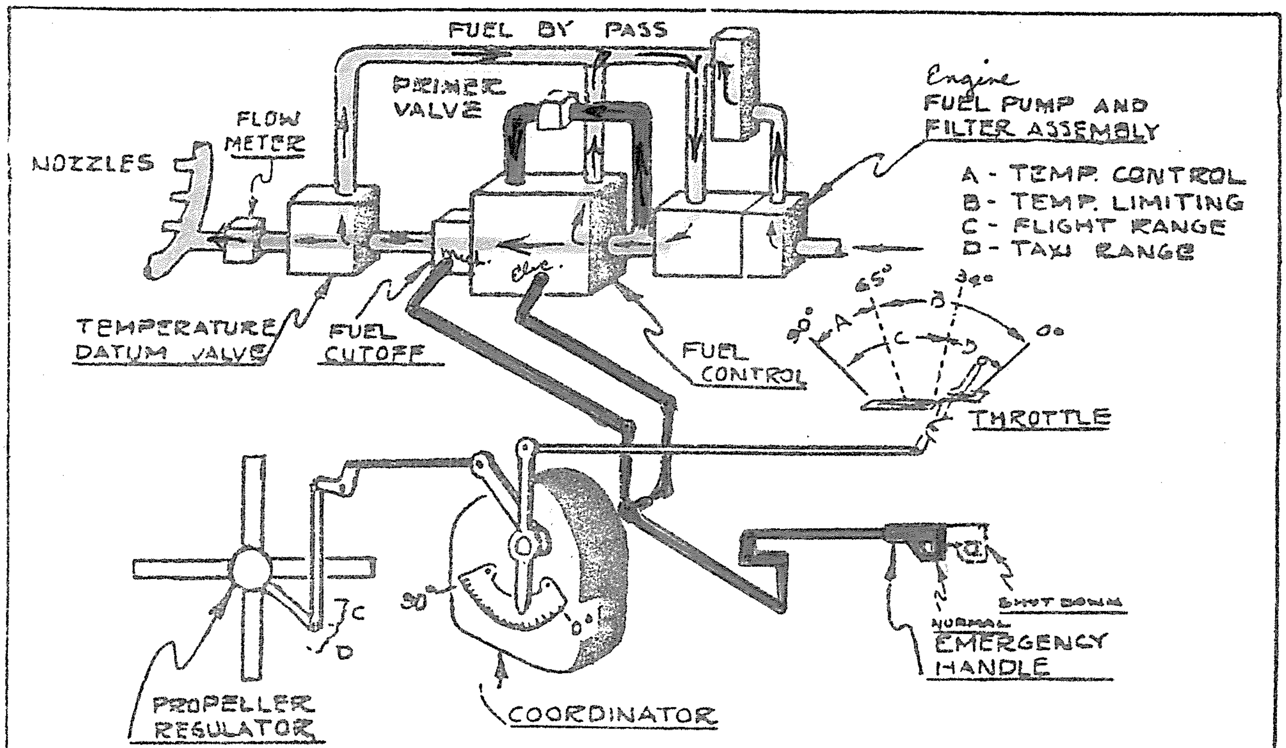
The engine Temperature Datum Control Switch must be placed in the NORMAL position for the electronic temperature trim system to function. When placed in NULL, the system is inoperative and the temperature datum valve returns to the null position, bypassing 20% of the 120% of fuel furnished by the fuel control. The metering of fuel is now accomplished solely by the fuel control. Closer monitoring of turbine inlet temperature is required, and it should be remembered that over-temperature protection is lost. The switch has a third position--OFF. When in this position, the same conditions apply as in the NULL position.



AIR CALIFORNIA

POWER PLANT

ENGINE COMPONENTS



CO-ORDINATOR MECHANICAL LINKAGE

COORDINATOR

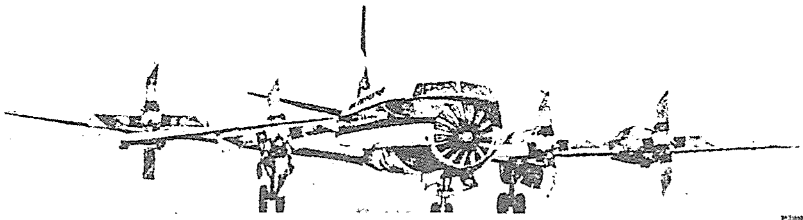
The coordinator is mounted on the rear of the fuel control. It is a mechanical device which coordinates the throttle, the Emergency Handle, the propeller, the fuel control and the electronic trimming system. Movements of the throttle are transmitted to the coordinator and, in turn, to the fuel control and the propeller by a series of levers and rods.

No matter what the throttle position may be, when the Emergency Handle is pulled out it moves the propeller linkage toward feather, energizes the feather solenoid, and closes the fuel cut-off valve both mechanically and electrically.

A scale, calibrated from 0° to 90° is fastened to the outside of the coordinator case, and a pointer is secured to the coordinator main shaft where the throttle linkage is tied in. When making reference to throttle position in degrees, it is actually the position of the pointer on the coordinator scale that is meant. For instance, 0° throttle setting (full reverse position) means that the pointer is at 0° on the coordinator scale, which is usually referred to as a quadrant as it covers 90°.

A variable potentiometer in the coordinator is actuated by a sector gear mounted on the coordinator main shaft. Movement of the throttle changes the resistance of the potentiometer, and thus changes the reference signal sent to the temperature datum control when the electronic fuel trimming system is in operation (65°-90° throttle position), thus making T.I.T. a function of throttle position.

Propeller blade angle is scheduled by the throttle in the taxi (0°-34°) range of throttle position. In the flight range (34°-90°), the propeller is governing and blade angle will vary to keep the engine on speed at 13,820 RPM. Throttle movement in this range serves primarily to change fuel flow and also to change propeller hydraulic pitch stop settings.



ENGINE COMPONENTS

COORDINATOR (Continued)

Cams on one of the internal shafts of the potentiometer operate two microswitches. One is operated at the 65° quadrant position, which transfers the reference signal source of the electronic fuel trim system from the 977°C limiting potentiometer in the temperature adjustment box to the controlling potentiometer in the coordinator which is varied by throttle setting. The condition changes from one which protects T.I.T. against over-temperatures to one which provides T.I.T. selection (power setting) by throttle position. The other microswitch is actuated at 66° and affects the temperature datum valve brake. It permits electronic fuel trim to be "locked in", when the throttle is past 66° by placing the Temperature Trim Switch to the LOCKED position.

ENGINE STARTER

The engine starter is an air-operated unit consisting of an air turbine, reduction gearing, engaging mechanism, spline drive to mate with the engine starter drive shaft and automatic controls. Air is ducted into the starter inlet, through the turbine section to the outlet and overboard through the outlet duct. Two integral centrifugally operated, speed sensitive switches are used to terminate starter operation and to give overspeed indication.

Normal termination of starter operation is by a switch which opens at an engine speed of 8240-8650 RPM at which time the starter button should "pop out". (Button should be manually pulled out if it does not "pop out".) Failure of the clutch to disengage will result in the starter being driven by the engine to an overspeed condition. When the engine speed reaches 9300 ±500 RPM, the second switch closes, and the overspeed light is illuminated. Immediate termination of engine operation is necessary to prevent serious damage to the engine starter.

NOTE: To prevent overheating of starters, the following recommendation should be observed:

- After making three consecutive start attempts, not more than two being with high idle bleed air, the engine start system should be examined and at least 31 minutes should elapse before repeating starting attempts.
- After making four consecutive start attempts, none being made with high idle bleed air, the start system should be examined and at least 22 minutes should elapse before repeating starting attempts.
- Maximum of 2 minutes motoring in any 22 minute period.

STARTER OVERSPEED LIGHT

The starter overspeed light is located adjacent to the Start Switch. The starter overspeed light will come on during an engine start if the starter clutch failed to disengage and the engine drives the starter turbine to the 9300 ±500 rpm speed range.

NOTE: Modifications have been made to the starter and starter overspeed warning system, so that it is not now normal for the overspeed light to blink at the time of normal starter disengagement, as has been the case previously.

ENGINE STARTER AIR SYSTEM

Air pressure is used to turn the starter turbine which is coupled to the engine. The air pressure is obtained from either of two sources, the external gas turbine compressor or the bleed air from an operating engine. The starting system consists of the aircraft ducting, bleed air valves, low pressure regulating valves, and turbine starter.

Ducting from the bleed ports on each engine and the ground starting source in the aft portion of the fuselage (also underside of right inboard wing fillet) interconnect to form an air manifold, and make air available to the starter of each engine.

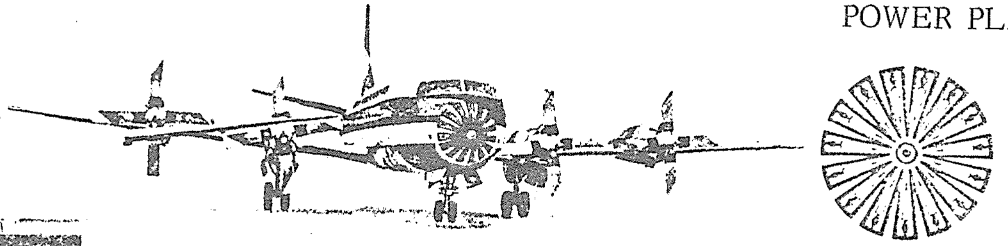
When using the aft ground air connection the FUSELAGE switches on the Airfoil Ice Panel must be OPEN, and other switches on the panel in the OFF or NORM positions.

The Bleed Air Valve Switch for each engine is opened or closed by a switch on the Engine Starting Panel. There is a low pressure regulating valve for each engine combined with a starter valve which is actuated by the Starter Button and which is selected by the Engine Start Selector on the Engine Starting Panel.

To start the engines the Bleed Air Valve switches, for all the engines, are placed in the OPEN position to route air pressure to the low pressure regulating valves. When the Start Button is pressed to START, the starter valve opens and the regulator regulates air flow to the selected turbine starter. The start cycle is terminated by an internal switch within the starter, or by manually pulling out the Start Button.

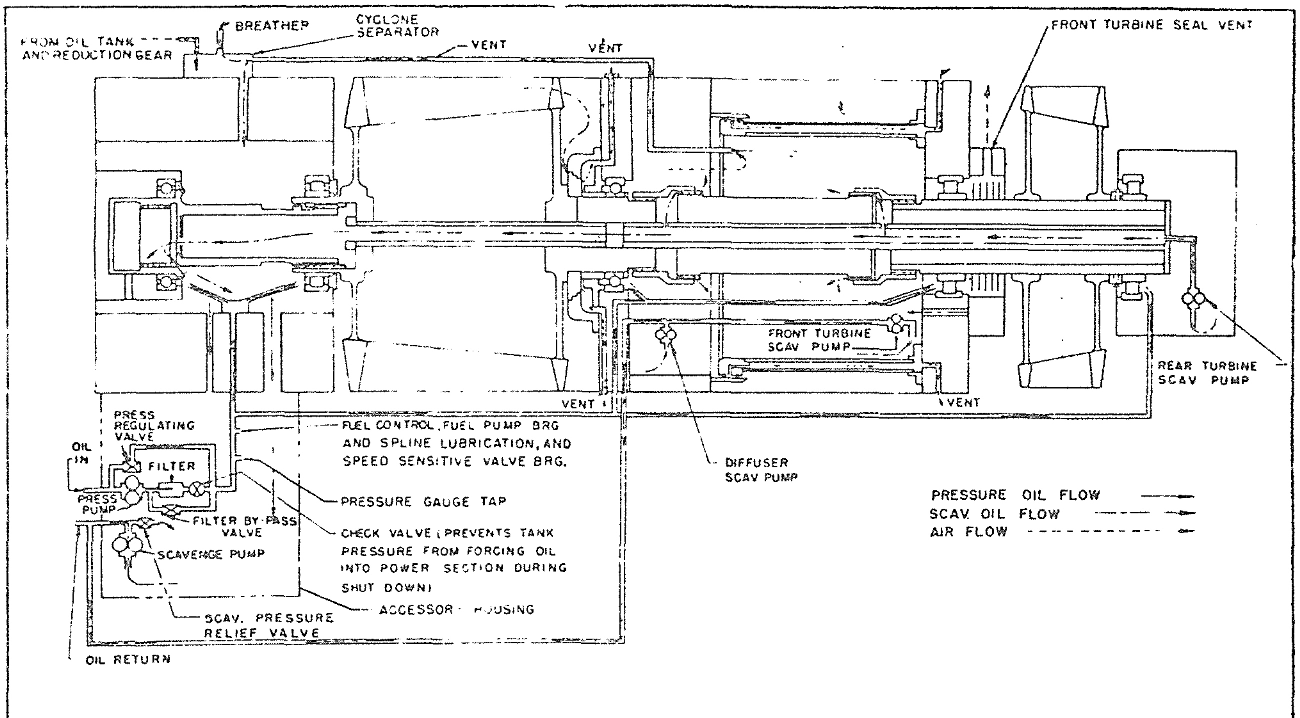
To start the remaining engines, the Engine Start Selector switch is repositioned for the respective engine to be started, and the Start Button pressed. In this condition, bleed air from the running engine or engines and ground supply air, if still connected, is used to start the engine. After all of the engines are started, the Bleed Air Valve switches should be returned to the CLOSED position.

NOTE: Normally ground supply air is used only to start the first engine in High RPM. All other engines are started in Low RPM using cross bleed air from previously started engines.



POWER PLANT

ENGINE COMPONENTS



Power Unit Oil System

LUBRICATION SYSTEM

Independent lubrication systems are provided for each the power section and the reduction gear unit. Each receive their supply from, and scavenge back to, a common oil tank.

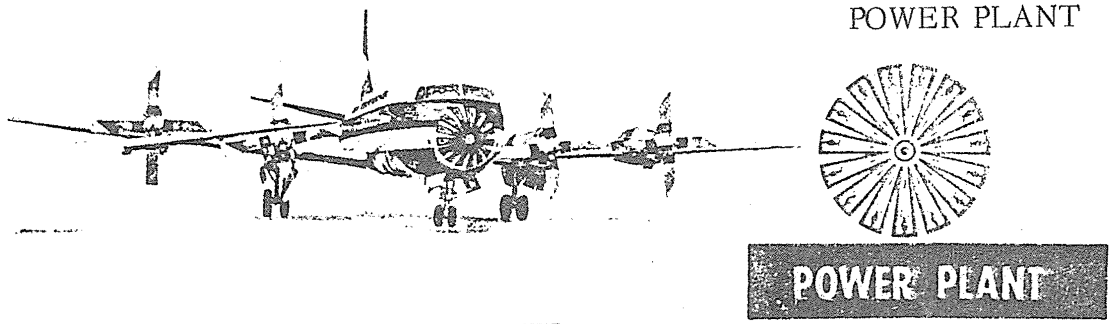
POWER SECTION SYSTEM

The oil pressure pump (which also is combined with the main scavenge pump unit) contains a pressure regulating valve (50-75 PSI) and furnishes pressure oil to jets at the four main engine bearings and compressor extension shaft bearing, and for internal shaft spline lubrication. Pressure lubrication is also supplied to bearings of the engine accessories.

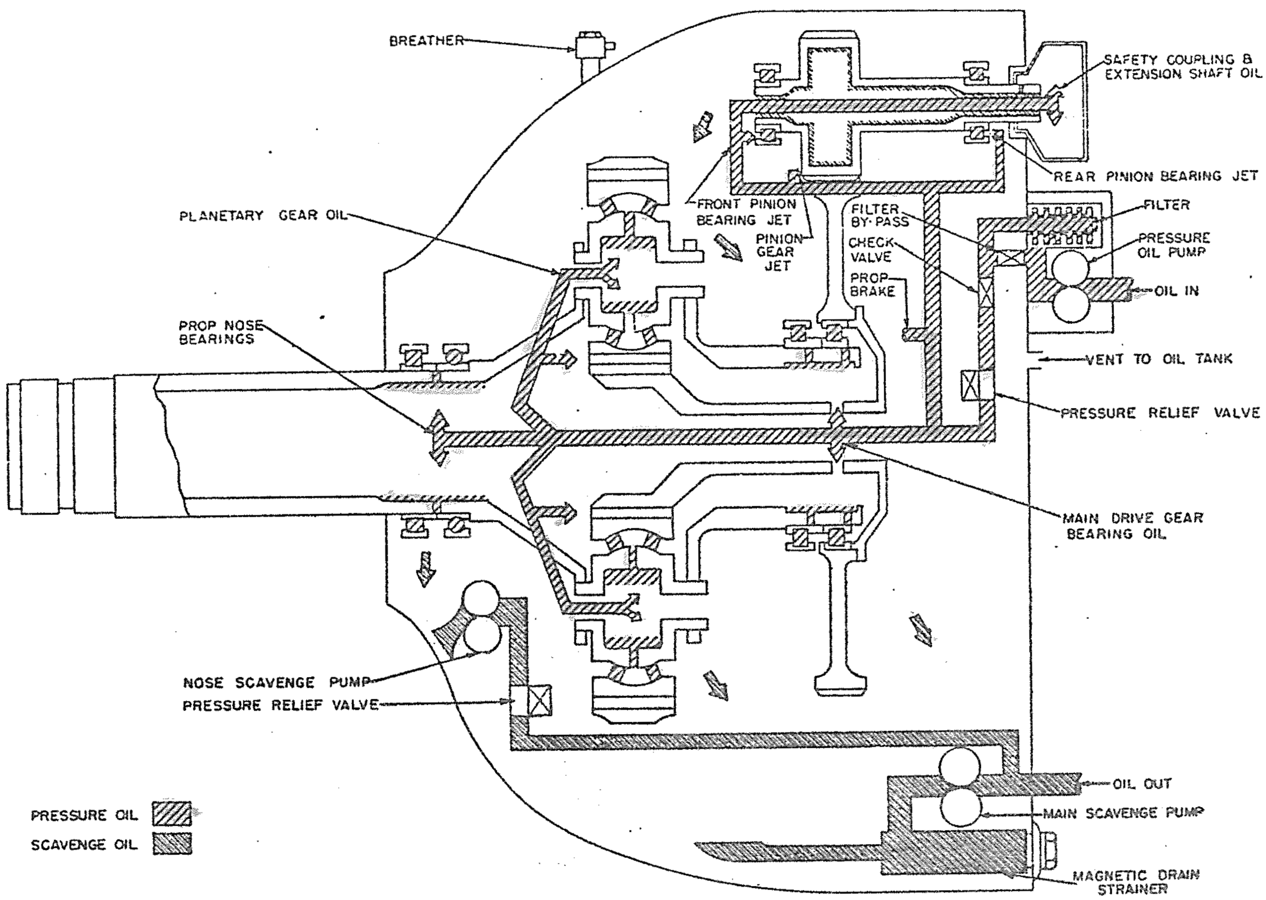
Before the oil flows to any parts requiring lubrication, it flows through a 117 micron filter. A bypass valve is incorporated in the system in the event that the filter becomes clogged. The bypass valve is not located in the filter as is sometimes common, and therefore, if it should open, contaminated oil will not flow into the system. A check valve prevents oil from seeping into the power section whenever the engine is not running.

The four scavenge pumps are so located that they will scavenge oil from the power section in any normal attitude of flight. The scavenge pump, which is located with the pressure pump, scavenges oil from the accessories drive housing. The other three scavenge oil from the diffuser, and from the front and rear of the turbine. The output of the rear turbine scavenge pump is re-scavenged by the main scavenge pump.

A scavenge relief valve is located so that it will prevent excessive pressure build-up in the power section scavenge system. The combined flows of scavenge oil from the power section (and reduction gear scavenge systems) are cooled and returned to the supply tank. There are two magnetic plugs on the accessories drive housing, one on the bottom, and another at the scavenge oil outlet on the front side.



ENGINE COMPONENTS



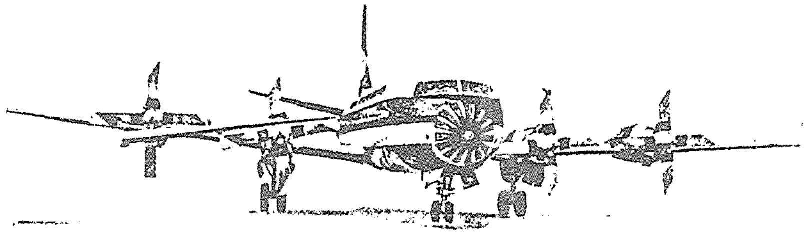
Reduction Gear Oil System Diagram

LUBRICATION SYSTEM (Continued)

REDUCTION GEAR SYSTEM

The reduction gear oil pressure pump is located on the left rear side of the reduction gear case, and included in the assembly is a filter (117 micron), filter bypass valve and check valve. Oil flows through the filter and to all parts within the gear reduction case which require lubrication. In addition, oil pressure is used as hydraulic pressure in the propeller brake assembly. The filter bypass valve provides for continued oil flow in the event that the filter becomes clogged. A check valve prevents oil flow in the reduction gear after engine shut down. A relief valve which is set to begin opening at 180 PSI, and is fully opened at 240 PSI, prevents excessive system pressure. This valve is not a pressure regulating valve, but functions strictly to limit pressure.

The two scavenge pumps are located to provide scavenging in any normal attitude of flight. The output of the scavenge pumps returns the oil by a common outlet to the supply tank. A scavenge relief valve limits the maximum scavenge pressure. A magnetic plug is located at the bottom rear of the reduction gear casing, and when removed provides a means of draining the reduction gear assembly.



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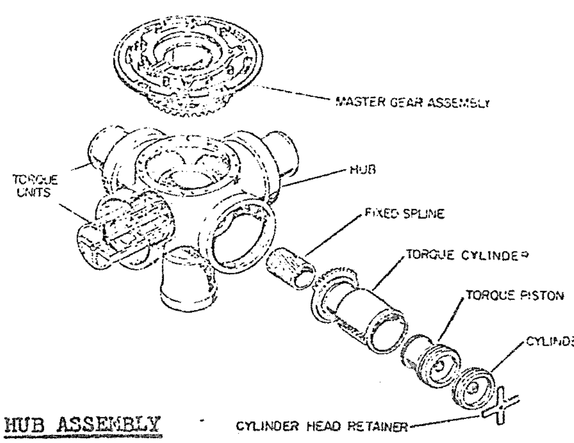
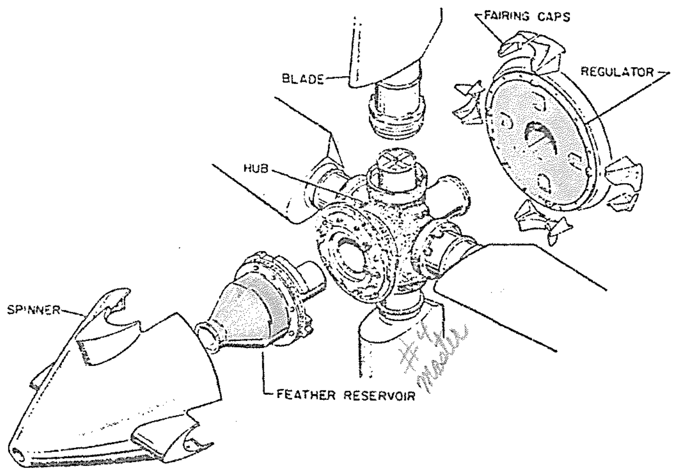
POWER PLANT

PROPELLER COMPONENTS





PROPELLERS

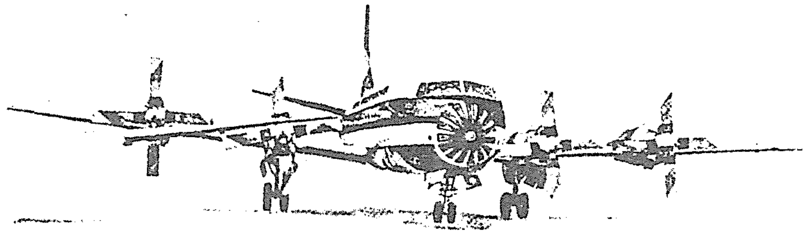
GENERAL

The Aeroproducts No. A6441FN-606 propeller is a single rotation, hydraulically controlled, constant speed type, incorporating an integral hydraulic governing system operating independently to maintain precise control during all operating conditions. The diameter is 13 ft. 6 in. and total installed weight is approximately 1030 lbs. The complete assembly is provided with spinner, feathering and reversing features, selective pitch control, negative torque control, synchronizing, phase-synchronizing, and electrical icing control.

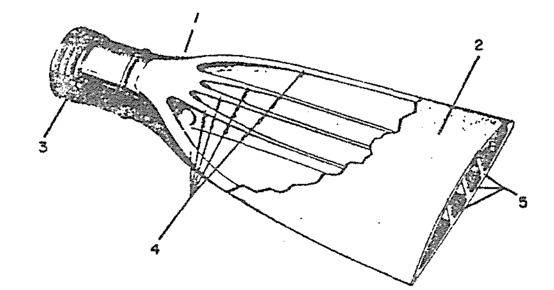
The propeller has four blades. The propeller converts engine torque to thrust and regulates this torque to absorb engine power under varying conditions. The integral hydraulic system of the propeller supplies the power required to change propeller blade angle, or pitch to compensate for variations in blade loading and maintain a constant RPM. The hydraulic system is controlled by a mechanical linkage from the cockpit, with an electronic system providing a vernier or trimmer to hydraulic governing for synchronizing and phase-synchronizing with a master propeller.

HUB ASSEMBLY

The hub assembly consists of four torque units, one mounted in each hub socket. The conversion of hydraulic energy to mechanical turning action is the purpose of these units. This is accomplished by having two oil passages, one to the outboard side of the torque piston and the other to inboard side of the torque piston. The helical spline machined on the torque unit components convert linear piston movement to blade rotation movement. A master gear meshes with the blade gear, which is a machined part of the torque cylinder, to coordinate blade angle change and is located on the face of the hub body. The master gear assembly includes the mechanical pitch lock and low pitch stop. The pitch lock is a ring with ratchet type teeth spring loaded into engagement with teeth on the master gear to prevent rotation of the master gear in a decrease pitch direction. This will occur with a loss of hydraulic pressure as CTM (Centrifugal Twisting Moment) will tend to decrease blade angle without assistance from hydraulic pressure. The lock will also engage if an overspeed beyond a pre-determined setting occurs and will hold the existing blade angle. The pitch lock will operate in the governing range only. The mechanical low pitch stop consists of two members, one splined to the hub and the other to the master gear. Each has four lugs equally spaced circumferentially on engaging faces. The two members are spring loaded into engagement, and the lugs are so designed that the member splined to the master gear is prevented from further rotation in the decrease pitch direction. When reverse pitch is desired, the member splined to the hub is hydraulically positioned to permit scheduled blade angle changes. Through the feedback drive gear machined on the pitch stop member, which rotates with the master gear blade angle, intelligence is relayed through a shaft which in turn positions a part of the regulator mechanical control linkage. By scheduling blade angle with fuel flow, a blade angle can be selected by the power setting in the beta ranges, and a variable minimum blade angle can be established in the governing range.



PROPELLER COMPONENTS

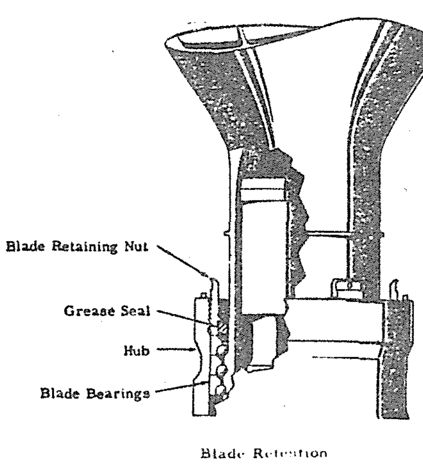


Blade Structure

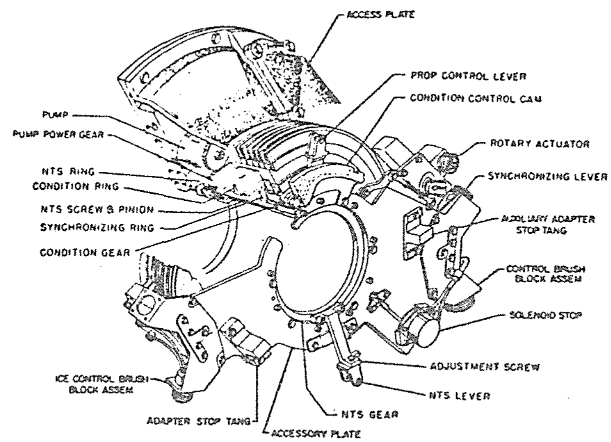
BLADE AND RETENTION ASSEMBLY

The blades are of hollow steel construction incorporating three longitudinal strengthening ribs and are composed of a thrust member and a camber sheet which are joined together by a brazing process and roll welded from the 54" station on lead and trail edge outboard to blade tip. The blade is equipped with a de-iced plastic cuff. The internal parts of the blades are treated with an iron oxide rust preventive paint and the cavities are purged with nitrogen at atmospheric pressure to prevent corrosion of the internal surfaces. The nitrogen is sealed in the blade cavities by a cup seal. This cup also has a stud located in the center for placing of balance washers to obtain horizontal propeller balance. The blades are retained in the hub by a blade retaining nut and an integral race retention assembly. The three inner races of the retention assembly are machined on the blade root and flame hardened. The retention assembly consists of three sets of balls, a nylon cage, ground matched set of three outer races, a metal seal spacer, seal back-up snap ring, a grease seal and blade retaining nut.

The blade root is hollow to receive the torque unit cylinders. Splines are machined on the inside diameter of the blade root which mate with the indexing ring on the torque cylinder. This provides a torque drive to turn the blades and a means of indexing blade angle.



Blade Retention

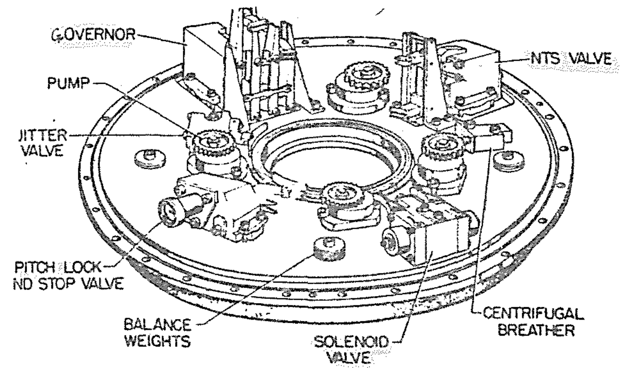


[REGU]LATOR ASSEMBLY

THE REGULATOR ASSEMBLY

The regulator provides selective propeller pitch from full reverse to the flight idle range. It schedules blade angle in accordance with throttle position. In the flight range it provides speed governing along with protective and emergency features, such as pitch lock, increase pitch for NTS, feathering, and auto-feathering. It is the brains and heart of the propeller in that it normally governs engine speeds and also senses abnormalities of operation, reacts accordingly, and controls the system as required for the compensation of error.

The regulator assembly is doughnut-shaped, mounted on the rear of the hub and consists of a housing and cover, adapter assembly, accessory mounting plate, pumps and hydraulic components.



Regulator Housing and Components

The Housing and Cover, when combined, make up the hollow doughnut-shaped reservoir that stores the necessary reserve of hydraulic fluid. The housing contains hydraulic passages and provides a mounting surface for the hydraulic components. The cover provides mounting provisions for the electrical slip ring assembly. The adapter assembly is the non-rotating portion

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POWER PLANT

PROPELLER COMPONENTS

THE REGULATOR ASSEMBLY (Continued)

of the regulator and is held stationary by an adapter stop fitting mounted to the front of the gear box. The adapter assembly consists mainly of the pump power gear and the mechanical control mechanisms. The accessory mounting plate is attached to the stationary adapter assembly and mounts the electrical brush block assemblies, and external electrical and mechanical controls.

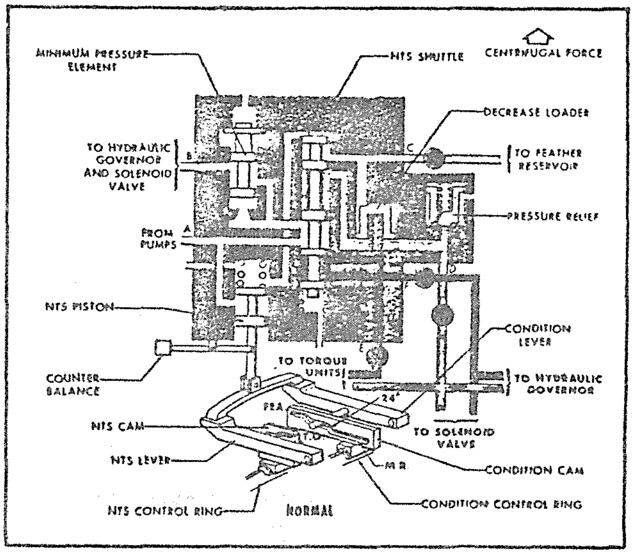
Hydraulic Pumps and Jitter Valve

The pump power gear is bolted to the adapter sleeve, and is a part of the adapter assembly. This gear is a fixed, or non-rotating, part. It is a means of driving the four hydraulic pumps which rotate about the gear. A cam is machined on this gear, and ground eccentric. The shoes, driving the jitter valve and the speed sensitive cylinder in the pitch lock valve, bear against this cam and the motion thus imparted to the jitter piston pulses the low servo pressure in the governor distributor element which results in an extremely sensitive governor.

There are four identical Pesco gear type pumps which furnish the hydraulic pressure necessary to operate the propeller. These pumps are bolted to the regulator housing and, therefore, rotate with the propeller and are driven by being in mesh with the fixed non-rotating pump power gear. At cruise RPM (1020) the output of the four pumps is approximately 5.5 gallons per minute. In the event of a damaged pump, reverse flow is prevented by a check valve contained within the pump.

Centrifugal Breather

A centrifugal breather is internally mounted on the regulator housing. When the propeller is static, the regulator assembly is a completely sealed unit. At approximately 220 propeller RPM, centrifugal force on a small valve piston overcomes the spring holding the valve closed and opens the valve to atmosphere through a small hole in the regulator housing. At this and higher RPM's the hydraulic fluid within the regulator has been centrifugally thrown away from the center and has formed a "dough-nut" pattern. Therefore, no hydraulic fluid leakage is experienced through the open valve during operation.



NTS FEATHER VALVE

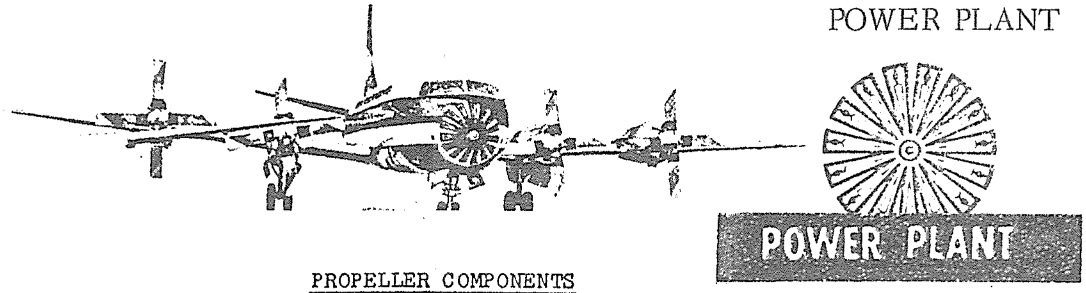
NTS Feather Valve

This valve contains five elements. Its primary function is to direct system pressure directly to torque units to increase the blade angle when actuated by an N.T.S. or the minimum pressure element allows the system pressure to build up sufficiently to move and operate the servo system of the hydraulic governor. After this pressure has been attained, this valve opens and directs system pressure to the hydraulic governor and the solenoid valve.

The decrease loader permits controlled drain (30 psi) to enter and fill the decrease BETA system during a rapid decrease in blade angle. This valve opens at about 5 psi and prevents the torque cylinder heads from being sucked inboard due to cavitation.

The pressure relief valve limits the decrease BETA system to a maximum of 825 psi. This valve relieves to the regulator (uncontrolled drain).

The NTS piston is counterweighted to remove the centrifugal field and in its normal position is spring loaded "down". In this position, the top side of the NTS shuttle is ported to drain. The NTS shuttle spring will hold the shuttle in its "up" position. With the shuttle in this position, port "C" to feather reservoir and decrease BETA fluid are blocked and fluid from the pumps is routed through the minimum pressure element to the solenoid valve and the hydraulic governor. Increase BETA fluid from the solenoid valve and/or hydraulic governor is directed to the torque units.



PROPELLER COMPONENTS

NTS Feather Valve (Continued)

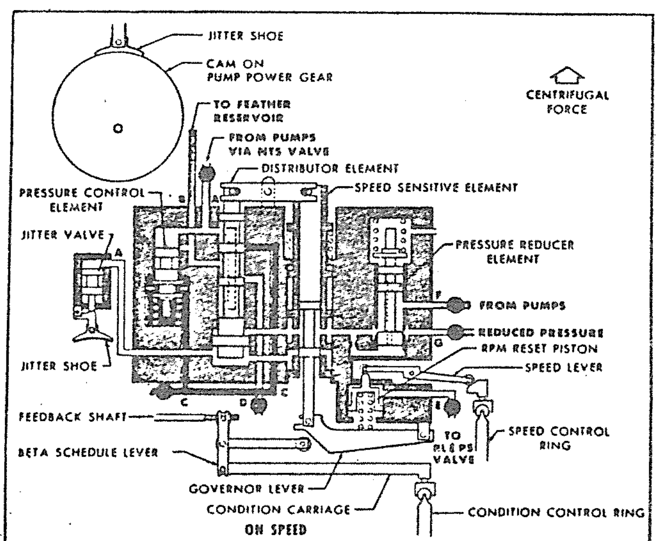
The NTS piston is moved mechanically to its up position by an NTS or feather signal which actuates the NTS control ring, NTS cam, and NTS lever. System pressure is now applied to the top of the NTS shuttle, moving it down against its spring. With the shuttle piston down, decrease BETA fluid is ported from the torque units to the feather reservoir, system pressure is blocked from the hydraulic governor and re-directed to the increase BETA (inboard) side of the torque units. Blade angle will increase as long as the NTS piston is held up and system pressure is available.

Emergency feather accomplishes the identical sequence as above except that the condition control ring and condition cam move to cam the NTS piston in the "up" position.

Movement of the power lever below a point 21-24 degree coordinator will drop the condition lever cam down to its lowest stop. This movement of the NTS carriage and rail assembly will decrease the mechanical advantage on the NTS linkage which would prevent an engine reduction gear NTS signal from moving the NTS piston enough to port system pressure to the top of the NTS shuttle. Thus, no increase blade angle can occur even though the reduction gears NTS system is actuated as might be the case in a high speed landing with the power lever in Flight Idle.

Hydraulic Governor

This valve contains five elements, and its primary function is to detect and proportionally correct any off speeds in excess of 25 ERPM. The valve is also used to mechanically and hydraulically select blade angle in the taxi or BETA range. In addition, the valve is mechanically positioned for increase BETA during emergency feather conditions. A source of servo, or reduced pressure, is also obtained from this valve.



HYDRAULIC GOVERNOR

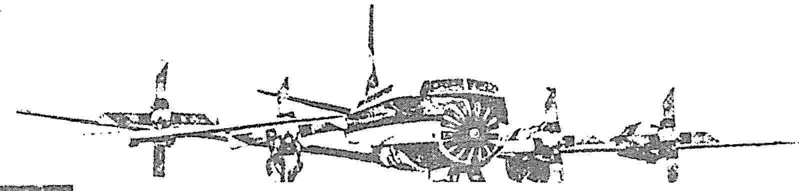
The pressure control element controls system pressure to 450 psi above increase BETA, or demand pressure. System, or pump, pressure is imposed on the top of the pressure control piston, opposing a spring requiring 450 psi system pressure to overcome. When system pressure is able to overcome this spring, fluid is ported to controlled drain. Aiding the spring, resisting system pressure's ability to depress the piston, is hydraulic pressure from the increase BETA system. Thus, before pump, or system, pressure can be ported to drain, or relieved, it must overcome increase pitch pressure plus 450 psi, ensuring that sufficient pressure is always available to move blades to a higher angle regardless of the demand.

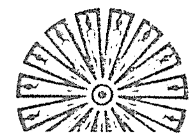
The pressure reducer element functions as a source of reduced, or servo pressure, and is used to position the distributor element of the governor, hydraulically adjust the governor to 15,000 ERPM when entering the BETA, or taxi range, keep the pitch lock disengaged, disengage the mechanical low pitch stop when entering the taxi range, and to hydraulically block out pitch lock in the BETA range.

System pressure enters between the two bottom lands of this valve, which is spring-loaded "down" and passes out through cylinder openings to the servo system. Reduced pressure is applied to the bottom of the reducer piston opposing the spring. As servo pressure reaches 450 psi, it will overcome the spring, push the piston "up" and close off the cylinder opening with the bottom piston land. As reduced pressure drops below this value, the lower pressure cannot overcome the spring, the piston is moved "down" and additional pressure, as required, can again enter the reduced pressure system, thus maintaining 450 psi reduced pressure regardless of system pressure. The reducer valve piston has an orifice drilled through its stem connecting the bottom of the piston, or servo area, to a point between the two top lands. This permits excessive reduced pressure to be bled to drain in the event of a high pressure surge and prevents a possible hydraulic lock.

The RPM reset element accepts reduced pressure on its piston when entering and during the BETA range, compressing the governor spring. This additional compression of the governor spring resets the governor RPM to approximately 15,000 ERPM from a normal 13,820 ERPM. Since the engine does not reach this speed, the governor is "under speed" and is effectively no longer speed sensitive.

The governing elements consist of a speed sensitive piston, lever and spring, a cylinder or movable sleeve around this piston, a distributor piston, and mechanical linkage interconnecting the distributor piston with the cylinder or sleeve around the speed sensitive piston.





POWER PLANT

PROPELLER COMPONENTS

Hydraulic Governor (Continued)

During a normal governing condition, reduced pressure from the pressure reducer element is ported to and around the speed sensitive piston, between the two piston lands, and is imposed on the top of the small area or top side of the distributor servo piston end. This pressure remains constant during all propeller operation, and tends to force the distributor piston "down" aided by a spring around the speed sensitive element cylinder. Opposing these forces is servo pressure applied to the bottom side of this servo portion of the distributor piston. This side, being of larger area than the top side. enables low servo pressure on the bottom side to move the piston "up" against reduced pressure on the top side plus the spring. Thus, if the fluid pressure on the bottom side of this element can be varied, the distributor piston can be moved up or down.

The speed sensitive piston tends to move "up" with an increase of speed, and "down" with a decrease of speed due to changing centrifugal forces on the piston opposed by a constant loading by the governor spring. As the speed sensitive piston moves "up", fluid and/or pressure is relieved from the bottom of the distributor piston, causing it to move "down". Should the speed sensitive piston be moved down by the governor spring (under speed) additional servo fluid will be ported to the under side of the distributor piston, and move it "up". Thus, speed versus governor spring pressure can and will control, hydraulically, the positioning of the distributor piston. Linked to the distributor, through a rocker arm, is the sleeve or cylinder around the speed sensitive piston. A movement of the speed sensing piston then, causing a distributor piston movement, will through this mechanical linkage feed back to the speed sensitive element and stop the initiating signal. This forms a proportionalized governor. The greater the off speed, the greater distributor piston movement, and thus a higher rate of blade angle change results.

System pressure is fed into the distributor element between the two top lands of the distributor piston, and through a hole in the stem of the piston, between the two bottom lands. The area between the two center lands is ported to controlled drain (feather reservoir).

A movement of the distributor piston inboard, or "down" (overspeed), results in system pressure entering the increase BETA line to the torque units. At the same time, the decrease line is ported to the center area of the distributor and to controlled drain.

A movement of the piston outboard, or "up" (under speed), results first in porting increase BETA to controlled drain which will reduce increase BETA pressure, and allow CTM to lower blade angle, then if under speed is severe enough (unfeather or full negative) will port system pressure to the decrease BETA line.

During synchronization, the slave governor's spring is reset, as necessary, by the rotary actuator through the speed control gear, pinion screws, speed control ring, and a cam arrangement to the speed setting of the master engine. This identical system is also used to obtain a fuel governor overspeed check, bypassing the normal high limit synchronization switch and resetting the governor to approximately 15,000 ERPM. The governor spring is also reset to about 15,000 ERPM when entering the taxi range by application of reduced pressure to the RPM reset piston. The movement of this piston will compress the governor spring.

The jitter valve previously mentioned is a separately mounted valve within the regulator although, hydraulically, it is considered a part of the governor. The purpose of the jitter valve is to jitter, or pulse, the low servor pressure used to shift the distributor piston, thus keeping the system "alive" and reduce the off speed necessary to obtain a correction.

The flight idle (20° BETA), or hydraulic low pitch stop, is obtained by blade angle movement through a feed back shaft and carriage assembly. Should blade angle attempt to drop below 20° due to insufficient engine power, the movement of the blade through the feedback shaft will cause a roller to contact the governor lever on a cam slope, preventing a further reduction in blade angle. An increase in blade angle is permitted, as necessary, to hold RPM within governing speed.

BETA follow-up is obtained in the identical manner as above, except that the hydraulic low pitch stop is adjusted to a higher angle by movement of the power lever 68° to 90° co-ordinator. This movement results in a repositioning of the BETA schedule lever to a new fulcrum point. The highest possible minimum blade angle is obtained with a 90° coordinator lever position and should be 31.5° BETA. *Resets hyd low pitch stop from 20° 31.5° BA.*

Cruise 50-55° BA

Taxi, or blade angle selective range is obtained in a manner similar to BETA follow-up. However, in this range, reduced pressure from the rotary selector of the pitch lock and stop valve acting on the RPM reset piston, resets the governor to 15,000 ERPM and thus is always underspeed. Being under speed, the speed sensitive piston will always be "down" as far as the governor carriage roller, against the governor lever, will permit.

If a lower blade angle is selected by retarding the power lever, the roller will be withdrawn and the speed sensitive piston will move "down", hydraulically calling for a reduction in blade angle. As the blade approaches the new selected angle, the speed sensitive piston will again be repositioned to a "no flow" postion by movement of the blades through the master gear, feedback drive gear, feedback shaft assembly, and carriage roller against the governor lever.