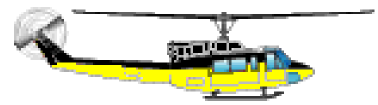

CHAPTER 7C

POWERPLANT

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ENGINE FUEL CONTROL SYSTEMS

GENERAL

The powerplant fuel system consists of separate but identical power section fuel control systems and a common torque control unit. Each power section fuel control system consists of a fuel pump, an automatic fuel control unit (AFCU), a manual fuel control unit (MFCU), a flow divider, a dual manifold with fuel nozzles, and a power turbine governor.

The primary purpose of each engine's FCU is to control that engine's power output to maintain a constant main rotor rpm during flight. In normal operation, both engines' FCU’s, in automatic (AUTO) mode, work together to maintain their N2 rpm between 97 and 100%. The N2 turbines are geared directly to the rotor, which maintains proper main rotor rpm. In the event of an automatic FCU malfunction, the pilot can control the affected engine by selecting the MANUAL mode and then, by use of the throttle, manually metering fuel flow to that engine to maintain its N2 rpm.

The pilot establishes which mode each engine's FCU will operate in by selecting either AUTO or MANUAL by means of the governor (GOV) switches on the engine control panel. Either or both engines may be operated in AUTO or MANUAL mode within normal limitations.

The powerplant fuel control systems are controlled by the pilot by means of two separate areas of control, the N1 power lever controls (Throttles), and N2 power turbine governor controls (the droop compensator and linear actuator).

The power lever control for each power section is a twistgrip throttle linkage from the collective stick that controls the gas generator speed governor scheduling cam in the AFCU and the metering and shut-off valves in the MFCU. This lever is normally open for flight (full twist grip). In this position, the lever, acts as a limit to the maximum gas generator (N1) speed, and is overridden by the power turbine pneumatic governing system. In emergency, for manual operation of the metering system, the twist grip can be used to control N1 speed.

Under automatic fuel control system operation, the droop compensator/linear actuator power turbine governor system maintains a constant, pre-selected N1 and rotor RPM, by means of the power turbine governors, pneumatic governor reset pressure systems, droop compensator and the linear actuator.

PT6T-3B FUEL CONTROL

The PW PT6T-3B engines each use a Bendix AVELEX Division DF-F2 gas turbine fuel control unit (FCU) which includes both manual and automatic fuel control sections (Figure 7-33). The FCU’s are controlled by throttles, N2 power turbine governors, and a single torque control unit (TCU).

The FCU’s are the hydro-pneumatic type, which utilizes throttle position, compressor discharge pressure (P3),N1, and N2 rpm signals.

A pneumatic pressure differential (Px/Py), generated in the automatic fuel control unit (AFCU) as a function of throttle position

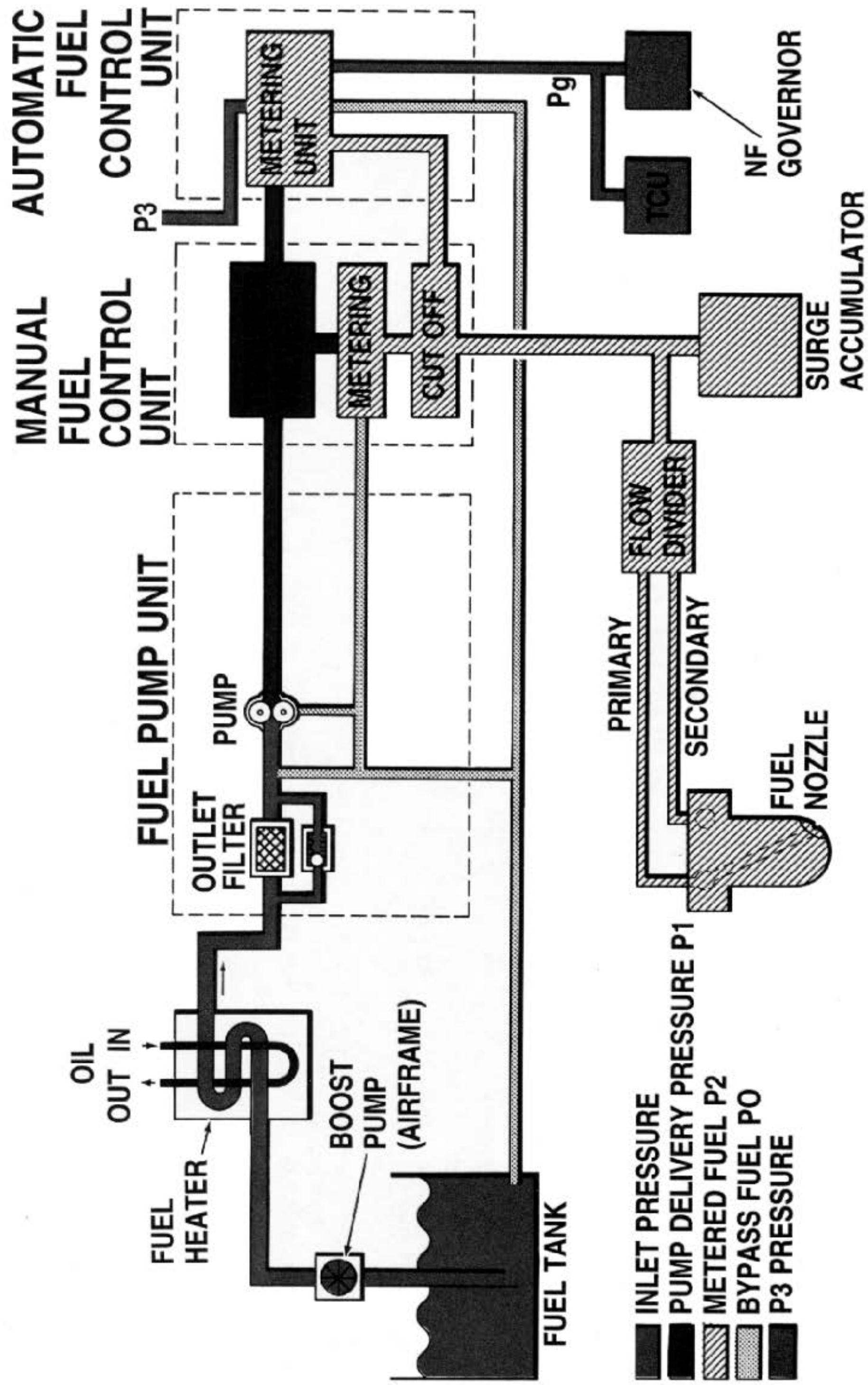


Figure 7-31 Fuel System Schematic

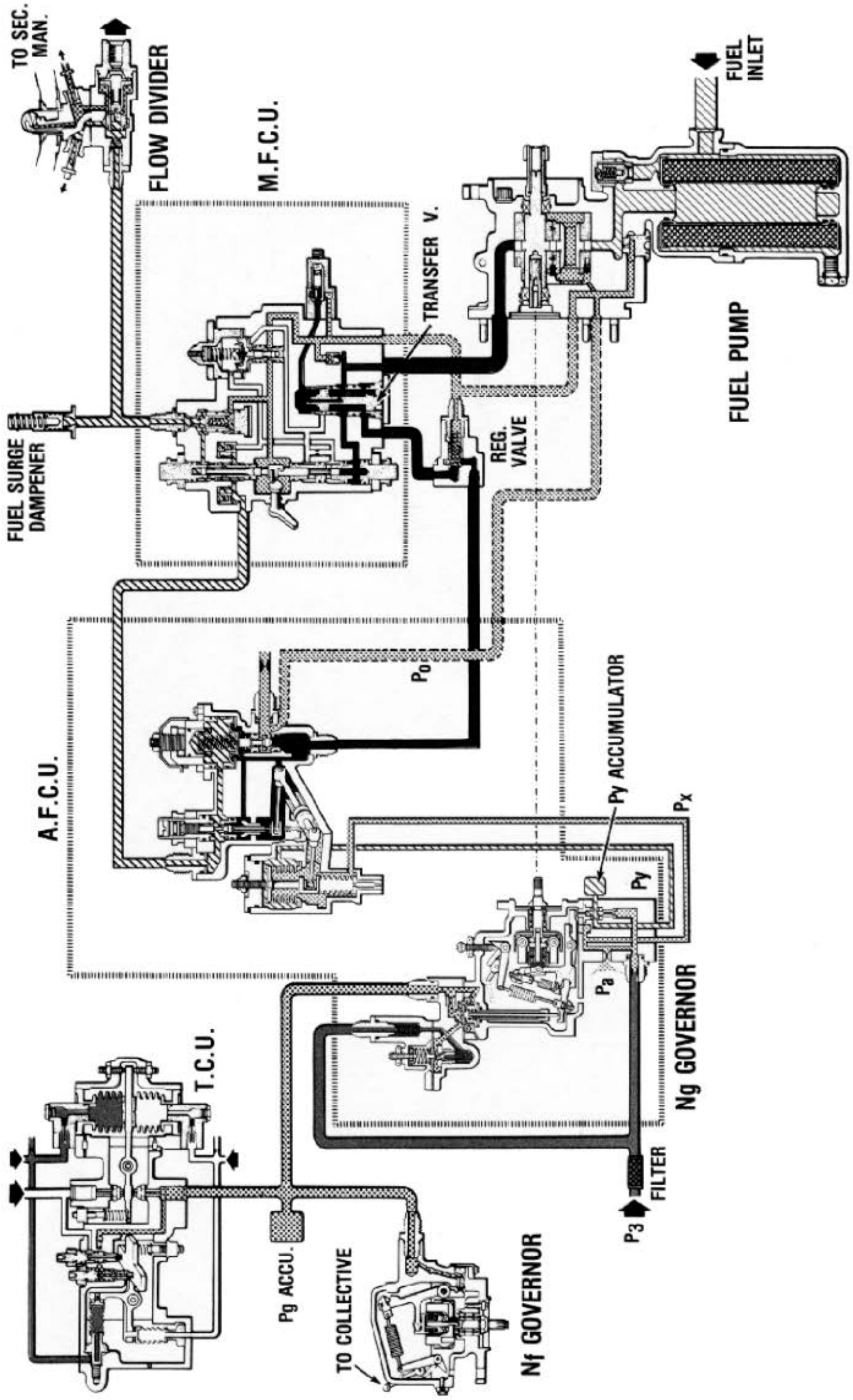


Figure 7-32 Engine Fuel Control System

versus N1 rpm, is the primary controlling signal to the AFCU metering valve. A second differential pressure (PG/PR), a function of throttle position versus N2 rpm, acts to modify the Px/Py differential in the AFCU.

High-pressure fuel to operate each engine's FCU is provided by the engine-driven fuel pump. Px, PY, PG, and PR pressures used in the FCU are all derived from compressor discharge pressure as modified in the FCU by functions of throttle position and N1 and N2 rpm.

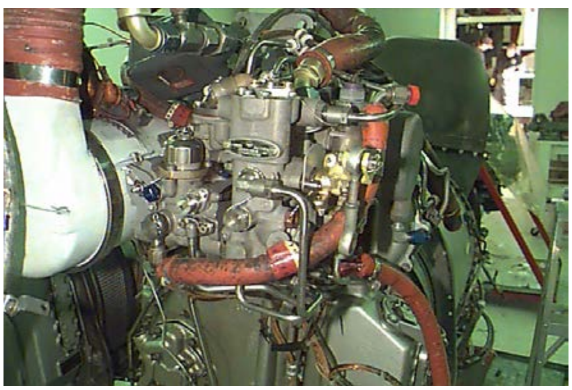


FIGURE 7-33 Fuel Control Unit

FUEL CONTROL COMPONENTS

Each engine's FCU actually consists of two separate units, a manual fuel control unit (MFCU) and an automatic fuel control unit (AFCU), which are mounted together on the N1 accessory section of each engine.

Two additional components, the N2 governor and the torque control unit (TCU), directly control operation of the AFCU by changing N2 governor reset pressure (Figure 7-34).

The N2 governor, mounted on the N2 accessory section and driven by the N2 power turbine, is controlled by movement of the cockpit collective pitch control and the N2 RPM increase/decrease (INC-DECR) switches located on the pilot's and copilot's collective heads.

The torque control unit, mounted separately on top of the combining gearbox, serves two functions: it limits total powerplant torque, and it balances the torque produced by the engines.

The twist-grip throttles on the pilot's and co-pilot's collectives directly control each engine's MFCU and that engine's N1 governor operations. N2 governing and functions of Px/Py and PG/PR differential pressures are inactive in the MANUAL mode of FCU operation.

Other components of each engine's FCU include a fuel control solenoid, a GOV switch, and associated electrical circuitry.

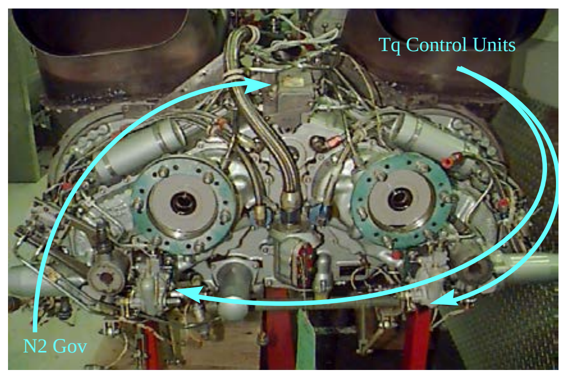


FIGURE 7-34 N2 Governor & TQ Control Unit

AFCU

The AFCU is mounted on the fuel pump and the gas producer speed governor is driven by the fuel pump outlet coupling at a speed directly proportional to the gas producer turbine speed. It has two main sections, the fuel section and the gas producer speed governor and enrichment section.

Fuel from the fuel pump is supplied to the fuel section of the AFCU through the transfer valve of the MFCU, for the regulation and metering of the fuel to the power section. Metered fuel leaving the AFCU is routed back through the cut-off valve and pressurizing valve of the MFCU, to the flow divider where it is delivered to the primary and secondary manifolds and the fuel nozzles. In parallel with the flow divider is a fuel line pressure surge damper to eliminate power surge during change from automatic to manual.

The second section consists of the gas producer speed governor, driven through the fuel pump outlet coupling, and an air regulator for operation of the governor reset diaphragm. The AFCU receives compressor discharge pressure air (P3 air), and with an air pressure regulator, provides metering control of the fuel section by means of sensing and control of governor reset pressure air (PG). Metering control is provided by three areas: Speed of the N1 section on the governor; power turbine speed; and the torque control unit pressure. The signal from the power turbine and torque control unit to the AFCU is in the form of PG air pressure.

These three signals result in the gas producer speed governor providing an acceleration and speed enrichment pressure signal as well as a governor servo pressure signal to the bellows portion of the fuel section. This provides the required fuel flow to the power section.

The Pg Air (Governor reset) pressure line is an external line connected between the AFCU, and the N2 Governor and TCU. Air pressure in this line is regulated by the N2 governor and TCU bleeding off more or less air pressure.

A 20 cubic inch accumulator is in each power section governor reset pressure (Pg air) line to dampen out surges in the governor reset pressure line when changes are made.

A heater is installed on the section of the Pg air line that is in the air inlet section to the engine to prevent condensation from freezing in the line resulting in full-rich metering signals. The heater is wrapped around the line and is self-contained and regulating to temperatures above 40° F.

MFCU

The MFCU is mounted on the fuel pump mounting, with the AFCU and is connected to the AFCU by means of a lever and spring linkage. Its functions under normal (automatic) operating conditions is to pass the fuel to the AFCU for metering, then back from the AFCU through the cut-off valve and pressurizing valve of the MFCU to the flow divider, manifolds and nozzles.

The MFCU consists of a transfer valve controlled by a solenoid valve; a manual metering valve and a shut-off valve controlled by the twist grip mechanical linkage, a pressurizing valve, and a by-pass valve.

When manual operation is necessary, the GOV AUTO-MANUAL control on the fuel panel is placed to MANUAL, the solenoid valve is energized to operate the transfer valve. The fuel pressure on the top of the transfer valve is bled off through the solenoid valve, fuel pump pressure positions the transfer valve UP, closing off fuel flow to the fuel section of the AFCU and opening the passage to the metering section of the MFCU.

CAUTION: Prior to placing the governor switch to MANUAL, rotate twist grip to flight idle, then position switch to MANUAL, open twist grip as necessary to control N2 RPM. When in MANUAL, the amount of fuel to the power section is controlled by twist grip position. Neither the gas producer (N1) governor, the power turbine (N2) governor, nor the torque control unit for that engine will have any control over the engine speed.

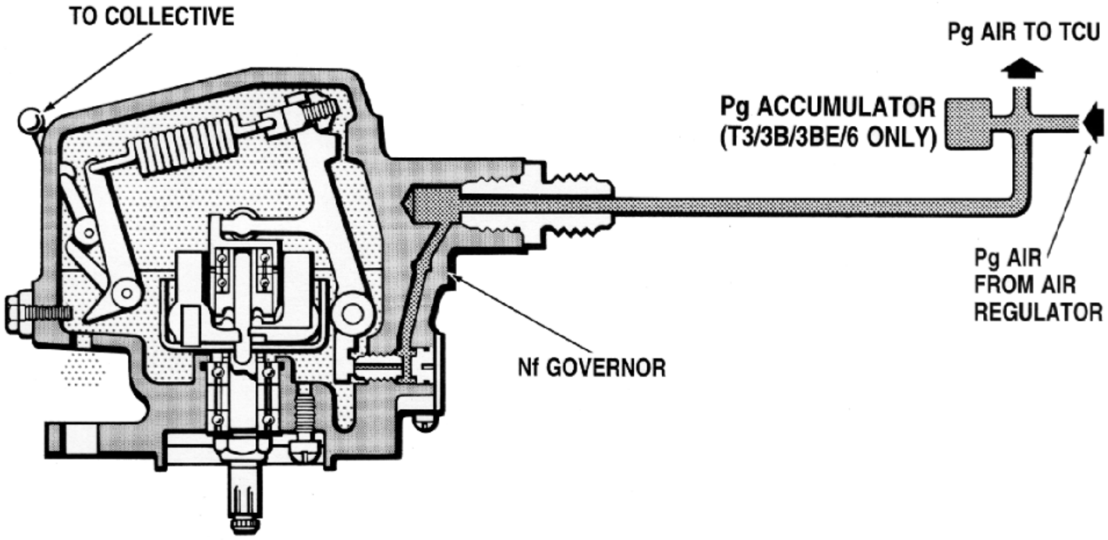


Figure 7-35 Power Turbine Governor

Power Turbine Governor

The power turbine governor for each power section fuel system is mounted on the rear of the reduction gearbox. It is driven at a speed proportional to the power turbine (N2) speed. When a power turbine speed change is sensed by the governor, more or less governor reset pressure (Pg) air is bled off, resulting in a change in position of the governor lever of the gas producer speed governor in the AFCU, which in turn changes governor servo pressure to the bellows, changing metering and varying the gas producer speed, to maintain the power turbine speed.

As power turbine speed increases Pg air pressure decreases, governor servo pressure decreases, fuel flow decreases. As power turbine speed decreases, Pg air pressure increases, governor servo pressure increases, fuel flow increases.

The droop compensator and liner actuator provide droop and RPM selective control to the pilot for N2/rotor RPM by controlling the power turbine governor.

Torque Control Unit

A single torque control unit, mounted on the center top portion of the reduction gearbox, receives torquemeter oil pressure signals proportional to the torque outputs of each power section. By controlling the governor reset pressure (Pg) in each power section fuel control system, the torque control unit both limits the total engine torque output, and maintains equal output of the two power sections.

Total torque from the powerplant to the transmission is limited by sensing torquemeter pressure from both power sections and adding them in summing or limiting bellows. At a specific total value (102 - 104%), the normally closed Pg orifices are opened to lower the governor reset pressure in each power section, reducing fuel flow and limiting the total torque. The torque control unit is in parallel with the power turbine governor in the governor reset pressure line.

Power section torque's are equalized by means of the opposing bellows sense any difference in torque of the two power sections, and restrict one of two normally open orifices. On the restricted orifice, governor reset pressure for that power section is increased, resulting in increased fuel flow to that power section. This equalized the torque upward, the low power section torque tends to increase to the upper.

Flow Divider

The flow divider is mounted at the 6 o'clock position on the gas generator case. It receives metered fuel from the FCU and delivers it to the primary and secondary fuel manifolds.

During starting, fuel enters the flow divider and at approximately 10 psi pressure at the flow divider, the piston moves to allow fuel flow to the primary manifolds and 7 of the 14 nozzles. The primary manifold is the forward manifold, identified by two weld joints on the nozzle.

As gas producer speed increases and fuel pressure increases to approximately 45 psi (30-35% N1), a piston is positioned to allow fuel flow not only to the primary but to the secondary manifold and the remaining 7 nozzles.

From the flow divider, the fuel is provided to the seven primary and seven secondary manifolds.

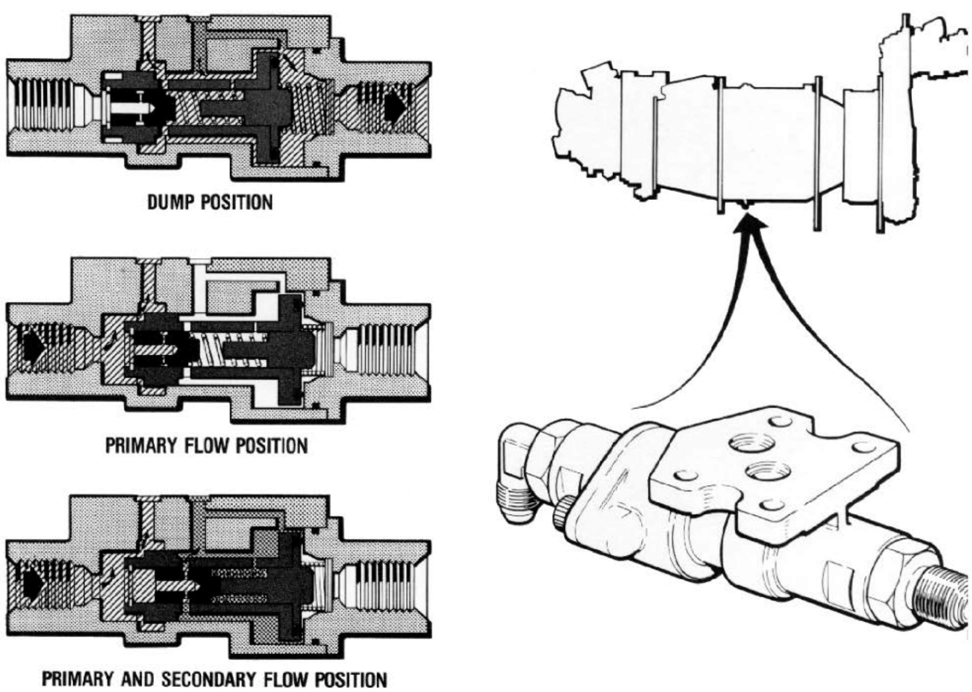


Figure 7-36 Flow Divider

With the twist grip positioned to the OFF position, the shut-off valve in the MFCU is closed, fuel to the flow divider is shut off, spring action moves the pistons to closed position and allows fuel to drain from both primary and secondary manifolds overboard, through the lower part of the combustion chamber drain.

FUEL CONTROL OPERATION

General

Pressurized (Figure 7-37), heated (Figure 7-38), and filtered fuel first enters the FCU through the manual fuel control section, which houses the auto/manual transfer valve, the fuel shutoff valve, and the manual metering valve (Figure 7-39).

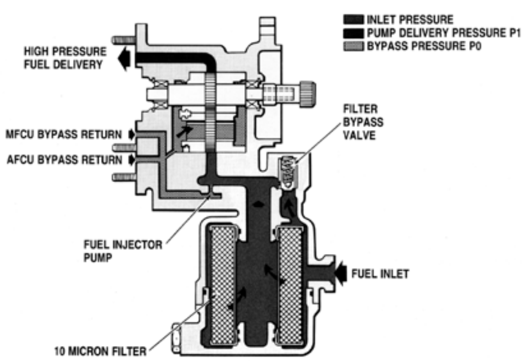


Figure 7-37 Engine Driven Fuel Boost Pump

The transfer valve is controlled by the GOV AUTO-MANUAL switch on the center pedestal. Each switch's electrical circuit receives DC power from its respective essential bus and is protected by a FUEL CONTR circuit breaker on the overhead console.

The shutoff valve and the manual metering valve within the MFCU are both controlled by that engine's twist grip throttle. With the throttle in the fully closed position, both the shutoff valve and the manual metering valve are also closed.

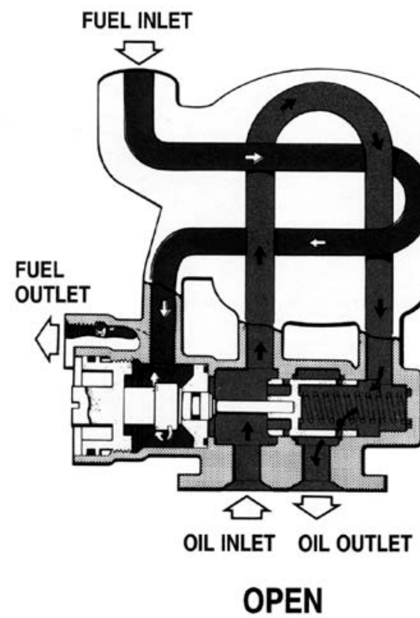


Figure 7-38 Fuel Heater

The engine normally operates in AUTO mode. This allows engine fuel pressure to position the transfer valve in the MFCU to direct fuel to the AFCU, where fuel is metered based upon inputs from the following:

Throttle position, which affects the N1 and N2 governors

The N1 governor, which changes Py air pressure

The N2 governor, which regulates PG air pressure

The rpm increase/decrease switch, which adjusts the N2 governor through the linear actuator,

Collective pitch changes, which adjust the N2 governor through the droop cam compensation system.

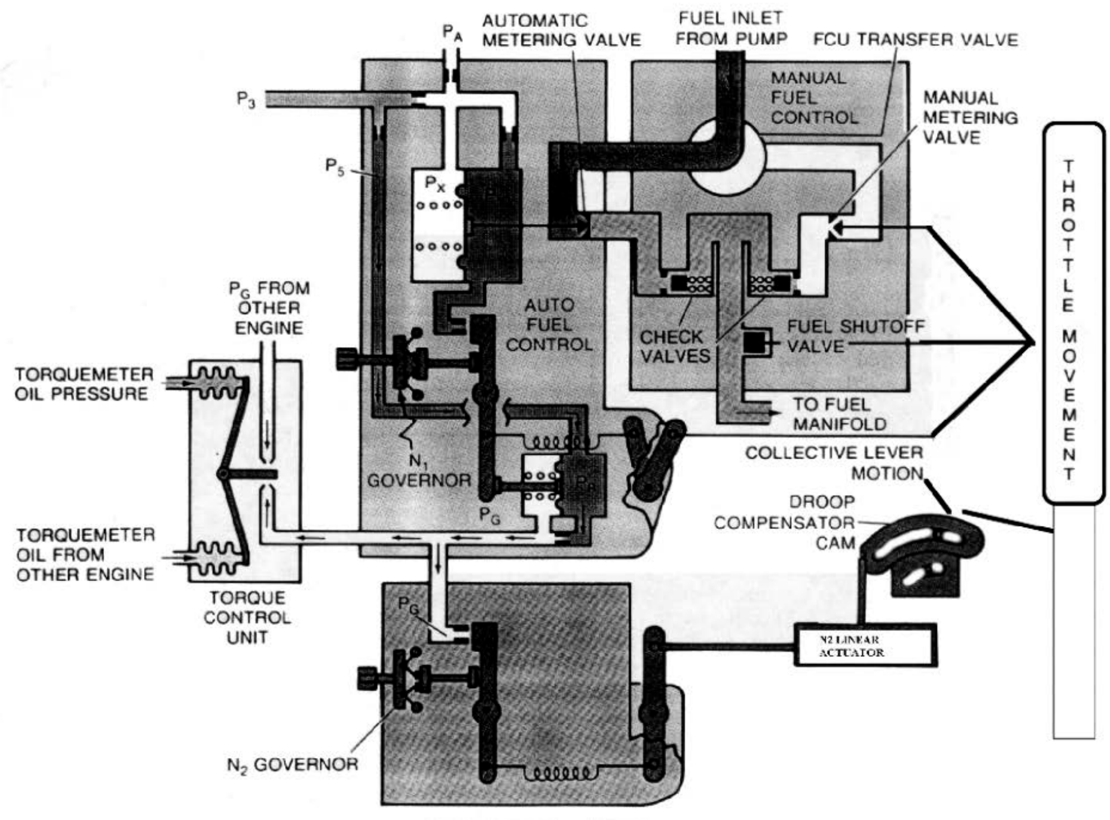


FIGURE 7-39 Fuel Control Automatic Mode

Rotor rpm changes, which affect the N2 governor speed.

The TCU which changes PG air pressure

After metering in the AFCU, fuel is routed back to the MFCU, where it proceeds past the shutoff valve, when opened by the throttle, out of the MFCU to the flow divider, fuel manifolds, nozzles, and combustor

Selecting MANUAL Mode

When the pilot selects the manual mode of FCU operation by moving the GOV switch to the MANUAL position, electrical power energizes a solenoid which redirects fuel pressure to hold the transfer valve in the MFCU position and allows fuel to enter the MFCU only. The pilot must now use the twist-grip throttle to position the manual metering valve to control fuel flow to the engine.

CAUTION

Never place the FCU in MANUAL unless the throttle is at flight-idle stop or below. Also, if DC electrical power fails while in MANUAL mode, fuel pressure will return the transfer valve to the AUTO mode of operation.

Automatic Fuel Control Operation

Starting

With airframe electrical power applied,

engine fuel supply systems energized, and the selected engine's throttle closed, the pilot engages the starter. Energizing the starter activates ignition, initiates compressor rotation, and drives the engine fuel pump through the N1 accessory section gearing.

As the compressor spools up, compressed air is supplied to the combustor section, compressor discharge pressure (P3) is sent to the AFCU, and fuel pressure increases within the FCU. Fuel, however, is prevented from going to the combustion section by the shutoff valve in the MFCU, which is held closed by the throttle. The N1 governor begins to establish a Px/Py pressure to position the auto metering valve to the correct opening to provide light-off fuel scheduling.

At 12% N1 rpm, with both ignition and compressed air available in the combustor and the auto metering valve positioned to the start-flow setting by Px/Py air, the throttle is opened to the flight-idle position.

This opens the shutoff valve in the MFCU and allows metered fuel from the AFCU to pass through the MFCU and on out to the flow divider. At 12% N1 fuel pressure has increased to the point where it has sufficient force to open the primary valve of the flow divider, and fuel flows through the primary manifold to the seven primary fuel nozzles in the combustion section.

Light-off should occur within 15 seconds of opening the throttle to flight idle and is indicated by increasing ITT and continued acceleration of the N1 rpm, which should continue until flight idle rpm is achieved. Acceleration fuel is controlled by the increasing P3 air pressure, which changes Px/Py differential and moves the auto metering valve. Flight-idle fuel flow is preset by a throttle linkage adjustment to provide 61±1% N1 rpm. N2 governing has not yet begun.

With the engine started, exhaust gases impinge on the N2 turbine wheel, causing it to rotate. N2 rotation activates the associated Sprague clutch in the C-box and begins to drive the main rotor. This is indicated by the N2 needle "marrying" with the NR needle and both beginning to accelerate. With N1 rpm stabilized at 61%, N2/NR will increase to approximately 65%, depending upon atmospheric conditions.

N2 Governing

General

The pilot slowly rotates the throttle to the fully open position. This results in a request for N1 acceleration that causes increased P3 and Py air which opens the auto metering valve and increases fuel flow.

N1 rpm and N2/NR rpm increase accordingly until N2 governing takes over at approximately 95% N2 rpm. N2 governing for "flat pitch" (collective control fully down) is preset at 95±1% by N2 governor throttle rigging adjustment. 95%±1% N2/NR is with only one engine's throttle fully open. With the second engine's throttle fully open, N2/NR stabilizes at 97±1%. There is always a 2% N2/NR difference between single-engine and twin-engine operation.

N1 rpm above 75% N1, with N2 governing functioning properly, will only be as high as necessary to maintain 97 to 100% N2/NR

During N2 governing, N1 engine speed is regulated solely by changes in PG air pressure, which control the AFCU metering valve. PG air pressure is changed by either the engine's N2 governor, which reacts to changes in N2/NR caused by dynamic loads acting on the rotor system, or PG air changes caused by the torque control unit.

The FCU's operation is designed so that an increase in PG air results in an increased fuel flow while a decrease in PG air results in a decreased fuel flow. Since the N2 governor increases PG air when it senses an under-speeding or low N2/NR rpm or decreases PG air when it senses an over-speeding N2/NR rpm, it provides only the power that is needed to maintain proper rpm.

CAUTION

The pilot should never switch to MANUAL mode with the throttle above the flight-idle position. In the AUTO mode, with the throttle fully open, the manual metering valve in the MFCU is also fully open. Only the automatic metering valve of the AFCU is limiting fuel flow. If the GOV switch were moved to MANUAL, the AFCU would be completely by-passed, and maximum fuel flow through the MFCU to the engine would occur. This will cause an immediate and very rapid increase in engine power, most probably resulting in engine over temperature, a main rotor over speed with damaging results, and other component damage.

N2 Governor Controls

Each engine's N2 governor is controlled by two pilot-activated cockpit systems: the RPM increase/decrease (INC-DECR) switches, located on each pilot's collective control head, and by movement of the collective flight control itself. Both devices work through the same mechanical linkage which is attached to both N2 governors by a jackshaft (Figure 7-40).

The RPM INC-DECR switch operates an electrical linear actuator which allows precise adjustment of N2 rpm within the range of 97 to 101.5%. Both the pilot's and co-pilot's GOV rpm switches have three positions: spring-loaded center off, forward INC, and rearward DECR. Electrical power for both switches and the single actuator is provided from the No. 1 essential bus and is protected by the FUEL CONTR circuit breaker.

Beeping the INC/DECR switch moves a control arm which rotates a jackshaft that moves cams within both N2 governors. With the INC-DECR switch in the full decrease position, the N2 speed stop cam maintains a minimum of 97% N2/NR rpm (when both engines throttles are full opened). As the switch is beeped to INC, the cams rotate and change the minimum N2/NR rpm. Full "beep" is preset to provide a maximum of 101.5% N2/NR (both engines operating).

The RPM INC-DECR switch allows the pilot to adjust NR rpm as desired for flight conditions, normally between 97 and 100%. The switch also allows the pilot to compensate for the 2% loss of N2 rpm that will be experienced if an engine fails.

A droop compensator cam is attached between the collective flight control mechanism and the RPM INC-DECR linear actuator (Figure 7-40). The purpose of this cam is to adjust the N2 governors for the significant changes in power required that occur when the collective pitch is increased or decreased. Without the droop compensator cam, main rotor rpm would droop (slow down) significantly when the collective is increased and overspeed excessively when the collective is decreased.

When the collective control is moved, the droop compensator cam moves to adjust the N2 governor speed set cam, above the beep switch setting, and proportional to the amount of collective pitch change.

Two protective devices are incorporated in the N2 governor controls to prevent mechanical problems from affecting N2 governor operation.

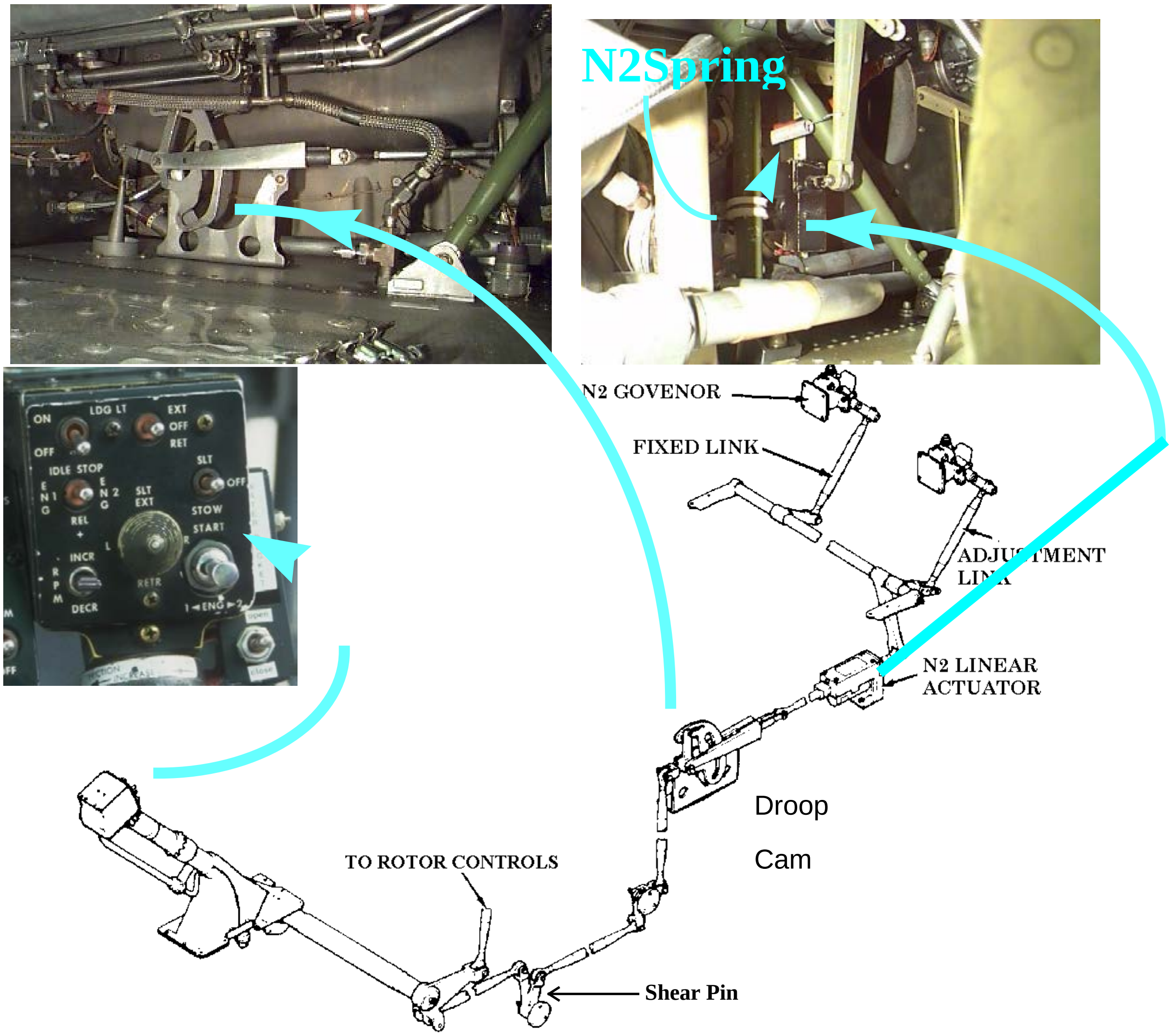


Figure 7-40 RPM Beep Switch and Droop Compensator

A shear pin is incorporated in the droop compensator linear actuator linkage to ensure that any malfunction or jam in the linkage can be overridden by the pilot. A force of approximately 40 pounds applied to the collective flight control will cause the pin to shear and separate the compensator from the collective control.

A spring is installed between the airframe and the control arm of the rpm increase/decrease jackshaft mechanism which will pull the control arm to the forward position and provide full increase rpm (101.5%) in the event that either the actuator becomes disconnected from the control arm or the collective droop compensator linkage becomes disconnected from the collective flight control linkage.

N2 Governor Operation

Each engine's N2 governor is mounted on that engine's N2 accessory section and is driven by its N2 gear reduction system. The 2 governors are the flyweight type and can change PG air pressure to their respective AFCU's.

Since the N2 gear reduction section of each engine drives the main rotor through the C-box combining gear, main drive shaft, and main transmission, any changes in main rotor rpm will be transmitted directly back through the same gear train to each engine's N2 gear reduction and its N2 governor.

A decrease in rotor rpm causes a decrease in the flyweight governor speeds, which causes the N2 governors to increase PG air pressure. Conversely, an increase in rotor rpm causes an increase in the flyweight governor speeds, which causes the N2 governors to decrease PG air pressure. These changes in PG air pressure are transmitted through pneumatic air pressure lines directly to each engine's AFCU.

System Operation

Each engine and its FCU operate independently using PG air as their controlling force as long as their twist-grip throttle is fully open. Increasing an engine's PG air pressure results in an increased fuel flow to the engine. Decreasing an engine's PG air pressure decreases that engine's fuel flow. Changes in fuel flow to each engine's N1 combustion section result in more or less exhaust gas being available to drive the respective N2 turbine wheel. More exhaust gas produces higher N2 rpm power while less exhaust gas results in a decrease of N2 rpm power.

By controlling PG air pressure to its respective engine, the N2 governor can maintain the proper rotor rpm. Since both N2 governors work independently, rpm control can be accomplished by either engine if one engine should fail or by both engines working together.

TORQUE CONTROL UNIT

General

While the N2 governors are primarily concerned with providing rpm control by changing PG air pressure, the torque control unit (TCU) can also change PG air pressure to each engine's FCU to perform its primary functions of limiting the total torque produced by both engines combined and of balancing the power output of the engines (Figure 7-41).

The TCU has two separate sections: one section is the equalizing or balancing section, and the other is the limiting section.

To perform these functions, the TCU must know the power (torque) output of each engine, which it receives by means of torque-sensing oil pressure directed to it from each engine's torque pressure-sensing system. Within the TCU, each engine's torque meter oil pressure is sent to expandable metal bellows in both the balancing and the limiting sections. These bellows expand or contract depending upon each engine's torque output to create changes in the PG air pressure going to each engine's AFCU.

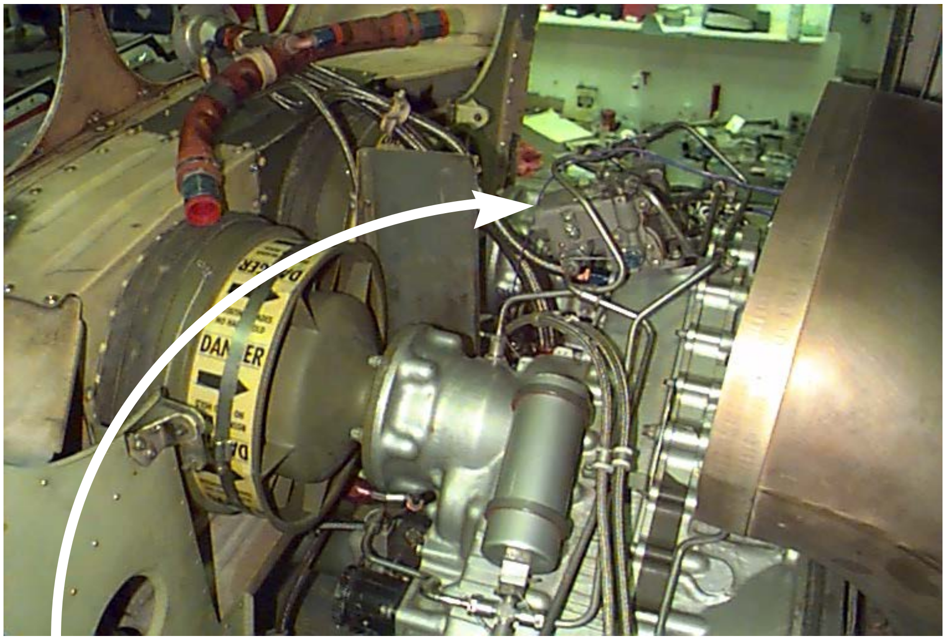


Figure 7-41 Torque Control Unit

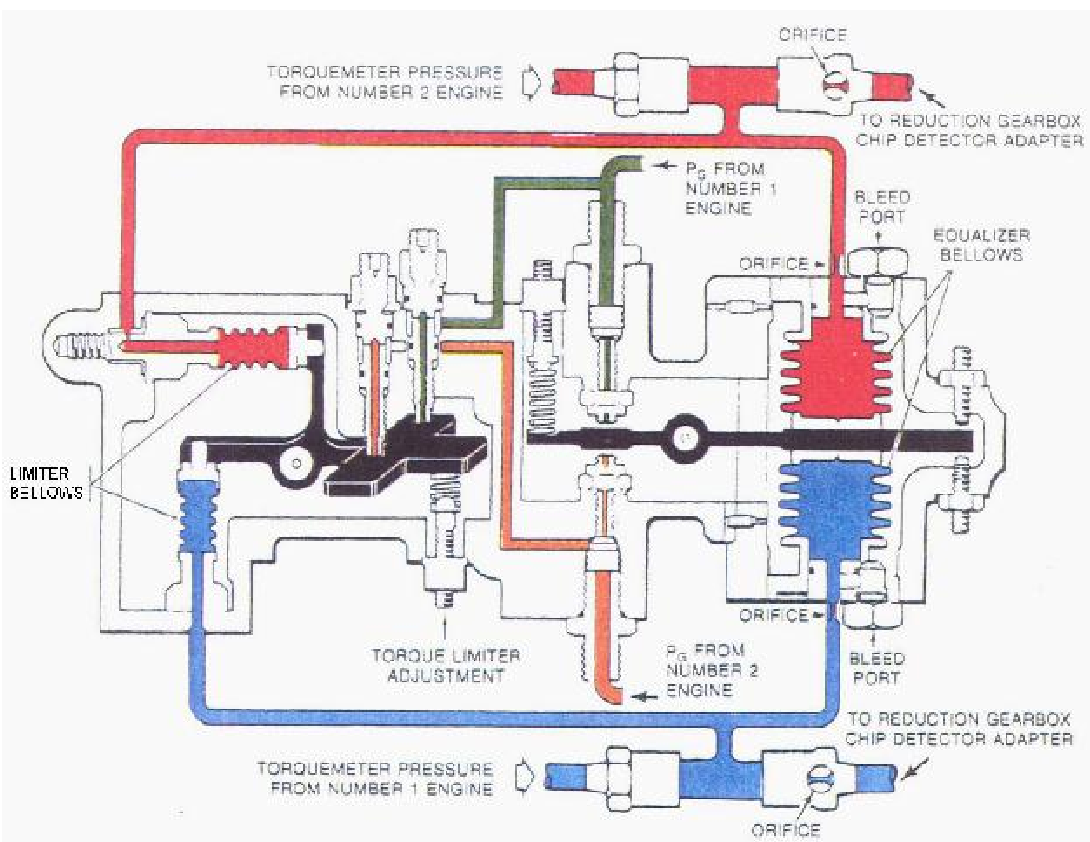


Figure **7-42 Torque Control Unit Diagram**

Torque Control Unit Operation

General

The two functions of the TCU are discussed separately below. Both functions require proper engine torque sensing, which, in turn, requires proper engine oil pressure. A failure of one engine's oil pressure system will cause the TCU to malfunction.

The TCU will affect an engine only when its FCU is in AUTO mode. Since the TCU changes PG air, it can affect torque output only when the AFCU is controlling the engine. With one engine in AUTO and the other in MANUAL, the TCU will limit AUTO engine torque if total torque goes high, but will not equalize AUTO engine torque if its torque falls below MANUAL engine torque.

Engine Torque Equalizing (Balancing)

To prevent undue wear on one engine or the other or on engine components such as the combining gearbox, engine torque's should be balanced as closely as possible. Initial torque balancing is accomplished during engine "rigging" when the engines are installed (See figure 7-40, Adjustment Link). Thereafter, during flight, the TCU provides limited torque equalizing and is designed to bring the torque of the lower engine up to the torque level of the higher engine.

Each engine's torquemeter oil pressure enters the TCU and is sent by a T-fitting to both the equalizing and limiting sections. In the equalizing section, torquemeter oil pressure is directed to its respective equalizer bellows, which can lengthen or shorten in response to changes in that engine's torquemeter oil pressure.

The equalizer bellows are located in opposing positions with the free end of each bellows touching an equalizer beam. Higher torquemeter oil pressure in one bellows or the other will cause that bellows to push the equalizer beam out of its neutral position.

At the opposite end of the equalizer beam are two opposing PG bleed-air ports, one on each side of the equalizer beam. With the beam held in neutral by a spring, the bleed-air ports are slightly away from the beam and allow a continuous bleed-off of PG air from both ports. Equalizer beam movement closer to one port or the other will restrict PG air bleed and increase its PG air pressure. The PG bleed-air port on each side of the equalizer beam is for the engine opposite the torque oil pressure bellows on that side.

See Figure 7-42 for an example of how the equalizing section works.

With the No. 1 engine producing more torque than the No. 2 engine, the No. 1 engine torquemeter oil pressure lengthens the No. 1 engine equalizer bellows, which pushes the equalizer beam out of its neutral position.

The far end of the equalizer beam is moved closer to the PG bleed-air port of the No. 2 engine, which restricts the amount of PG air that is allowed to bleed from the port and increases PG air pressure to the AFCU of the No. 2 engine. This causes an increased fuel flow to the No. 2 engine.

As the No. 2 engine increases its power output, its torquemeter oil pressure increases and lengthens the No. 2 engine equalizer bellows, which counteracts the No. 1 engine bellows, forcing the beam back to neutral.

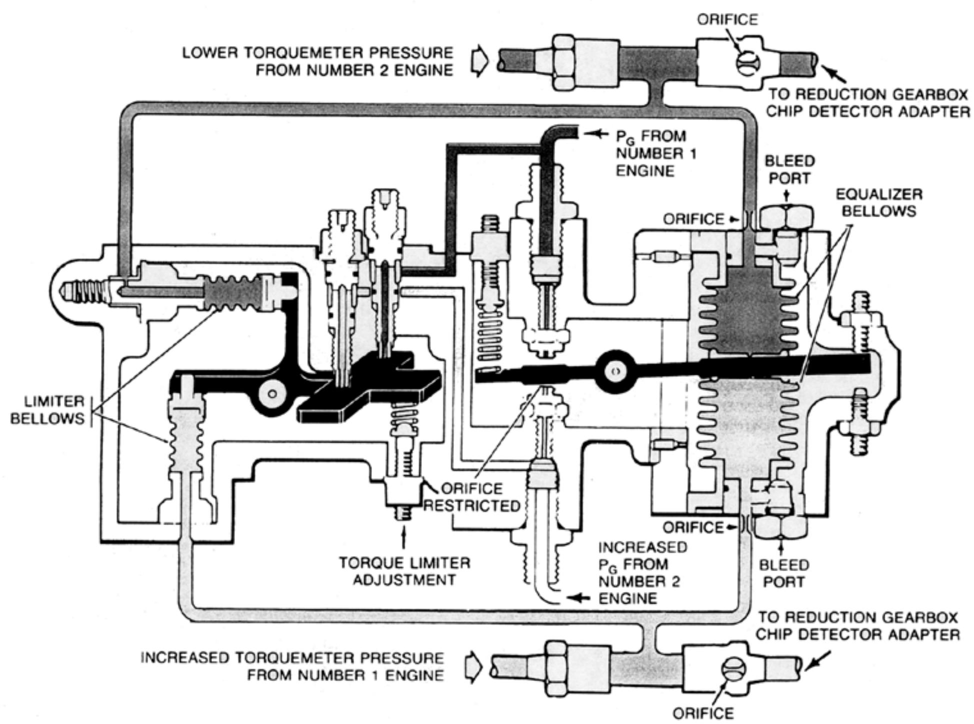


Figure 7-43 No. 1 Engine Torque Higher that No. 2 Engine Torque

When the equalizing beam moves back to neutral, No. 2 engine PG air is no longer restricted, and its pressure stabilizes to maintain a balanced torque output with that of the No. 1 engine. Torque balancing is a continuous process which is basically undetectable by the pilot.

NOTE: The maximum allowable torque split of 4 % referenced in the FM is not a function of the TCU. It is a function of engine control rigging.

Torque Limiting

The other half of the TCU is dedicated to torque limiting (Figure 7-44). This section limits the total torque of both engines to ensure that their combined torque does not exceed an amount that would damage the main transmission. The TCU is maintenance-adjusted to approximately 110% to ensure that the 100% FM limit can actually be reached.

The torque-limiting section also uses torquemeter oil pressure for its operation and also controls each engine's PG air pressure.

As stated above, torquemeter oil pressure from each engine is also directed to the two limiter bellows, which can also lengthen or shorten with increased or decreased torque produced by each engine.

However, the limiter bellows work together, and their expansions, if great enough, jointly operate a limiter lever, which is normally held against two PG bleed-air ports by an adjustable limiter spring. Each bleed-air port is co-connected to its respective equalizing bleed-air port and its engine's AFCU.

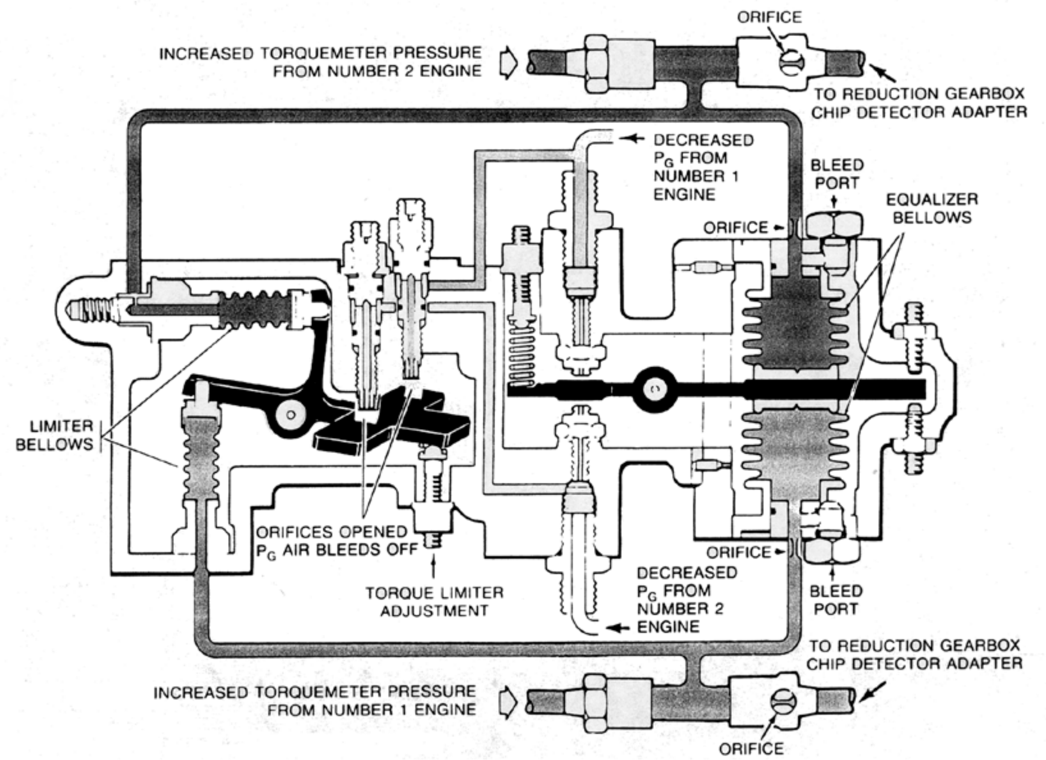


Figure 7-44 Torque Limiting

When the sum of both engine torque's is less than approximately 110%, the torque limiter spring holds the limiter lever firmly against the bleed air ports. However, if the total torque produced by both engines goes high enough, their torquemeter oil pressures will expand their limiter bellows sufficiently to move the lever against the limiter spring and away from the PG bleed-air ports.

As the limiter lever moves away from the two ports, PG air is allowed to bleed off, which causes the PG air pressure to each engine's AFCU to be decreased. The decrease in PG air causes the AFCU's to reduce fuel flow to both engines, which decreases each engine's torque output.

When total torque is sufficiently reduced, the limiter bellows contract and allow the limiter spring to move the limiter lever and cap off both PG bleed-air ports.

Under normal operation, the limiting function of the TCU will never occur since the pilot should limit total torque to 100% or below.

Normal FCU and TCU Operation

The engines' FCU's, in AUTO mode, and the single TCU working together will normally maintain proper rotor rpm while sharing the torque load between the two engines.

ENGINE FAILURE

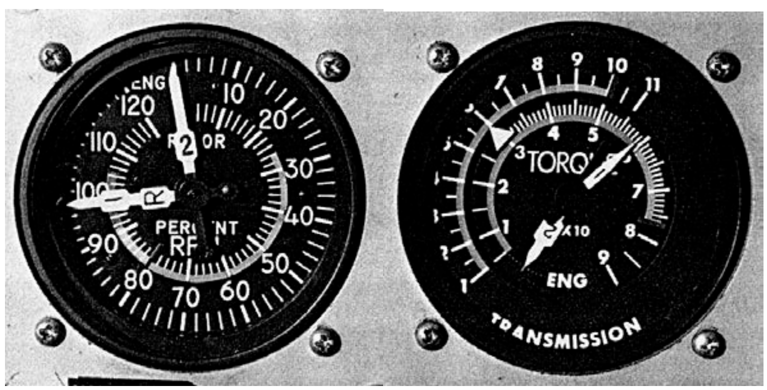
Should one engine fail, for whatever reason, the remaining engine will attempt to maintain rotor rpm by increasing torque output to the level needed or to the maximum it is capable of producing This occurs as a function of N2 governing.

As one engine fails, main rotor rpm begins to decrease. The loss of rotor rpm is sensed by the remaining engine's N2 governor through the combining gear and reduction gear-train. The N2 governor attempts to correct for the loss of rpm by increasing PG air pressure to its AFCU which, in turn, increases the remaining engine's torque output.

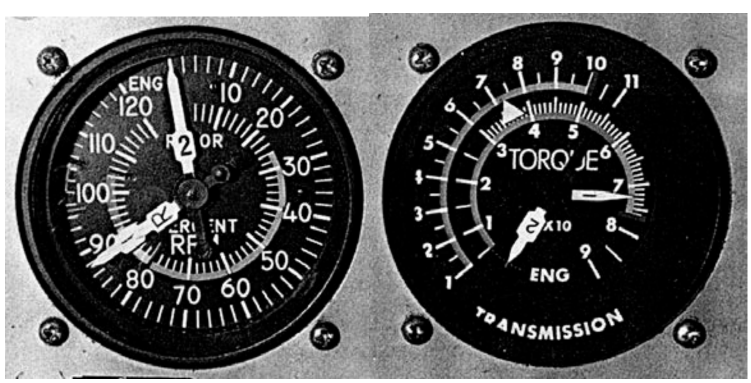
Whether the remaining engine will be able to maintain proper rotor rpm is a function of two things: (1) the total torque being used to fly the helicopter at the time of the engine failure and (2) the maximum torque that the remaining engine is capable of producing under the existing ambient conditions.

The first factor, the total torque being used, is often simply referred to as flying with high power demand or flying with low power demand. What is considered a high or low power demand is the second factor, maximum power available from the remaining engine if one were to fail.

As an example, assume that we are in cruise using 81% total transmission torque at sea level on a standard day. Both engines are operating normally with each engine providing 40.5% torque or half of the total required.



ENGINE FAILURE DURING LOW POWER DEMAND



ENGINE FAILURE DURING HIGH POWER DEMAND

Figure 7-45 Engine Failure Indications Low and High Power

If one engine fails, the remaining engine attempts to provide all 81% torque necessary to continue cruise flight. Unfortunately, even the best engine will probably produce only about 73% torque because of N1 limiting (topping). Since the remaining engine cannot provide all the power required, a serious loss of rotor rpm will occur unless the pilot takes corrective action; i.e., reduce power required to a level below what the remaining engine can provide (Figure 7-45).

Should an engine fail while operating at a total transmission torque which is less than the amount of torque that can be supplied by one engine, there will be only a slight loss of rotor rpm, and the remaining engine will provide all the power required to fly the helicopter (Figure 7-45).

Any time an engine loses power, there will be some loss, at least 2%, of N2/NR rpm due to the laws of conservation of energy.

FUEL CONTROL MALFUNCTIONS

General

An FCU is said to malfunction any time it fails to fulfill its primary purpose of maintaining rotor rpm. Although there are numerous possible causes of FCU malfunctions, the actual malfunction is generally referred to as either a "highside FCU failure" or a "low-side FCU failure."

More correct terminology would be to say that the FCU malfunction has caused its engine to go to maximum power output (high side) or that the FCU malfunction has caused its engine to go to low power output (low side).

The effect in the helicopter is that a high-side failure causes one engine to produce too much power while a low-side failure causes an engine to produce too little power. These sudden changes in engine power output can significantly affect rotor rpm. The severity of these effects on rotor rpm depend upon whether the helicopter is being flown under high or low power demand.

Three pilot actions are required if a FCU malfunction occurs:

1. Determine the type of FCU malfunction, either high side or low side.
2. Determine which engine has experienced the malfunction.
3. Take corrective action as required.

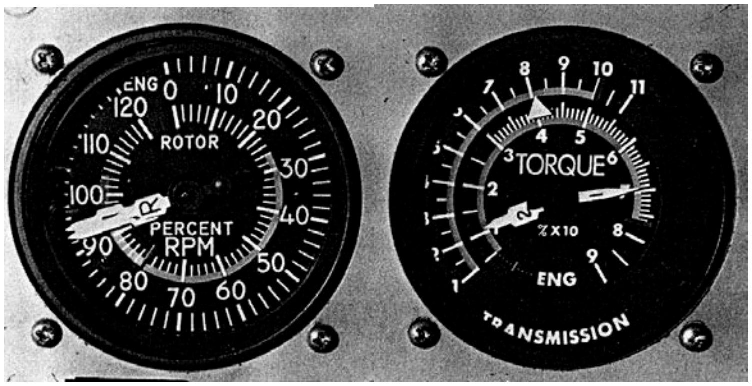
Determining the Type of FCU (Governor) Malfunction

Normally, any malfunction involving the engines and/or their power output requires the pilot to check rotor rpm to ensure continued safe flight. Since rotor rpm is essential to helicopter flight, the pilot must ensure rotor rpm is properly maintained. In any emergency/malfunction situation, always fly the helicopter first.

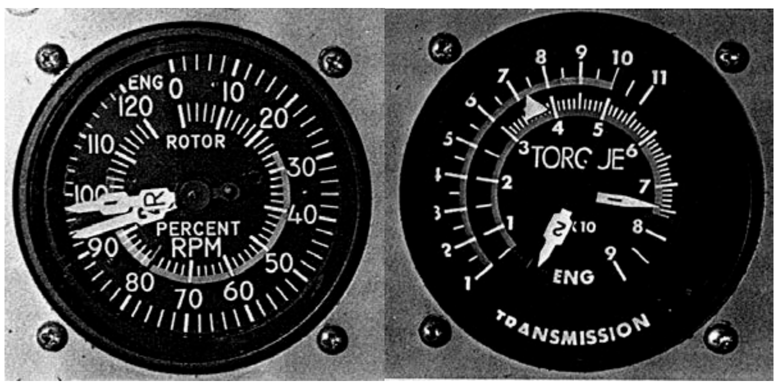
This is also precisely the correct action to determine what *type* of FCU malfunction has occurred; check the triple tachometer

Low-Side FCU Failure

Due to the laws of conservation of energy, a low-side FCU failure *always* causes some loss of rotor rpm (Figure 7-46). The severity of loss of rpm depends on whether high (above maximum OEI) or low (at or below maximum OEI) power is being used.



LOW-SIDE FCU FAILURE DURING HIGH POWER DEMAND



LOW-SIDE FCU FAILURE DURING LOW POWER DEMAND

Figure 7-46 Low-Side FCU Failure Indications

The extent of power loss on an engine that has experienced a low-side FCU failure is difficult to predict because it depends upon what has caused the malfunction. Power loss may range from the affected engine merely decelerating to or near flight-idle rpm to a complete engine failure or anywhere in between.

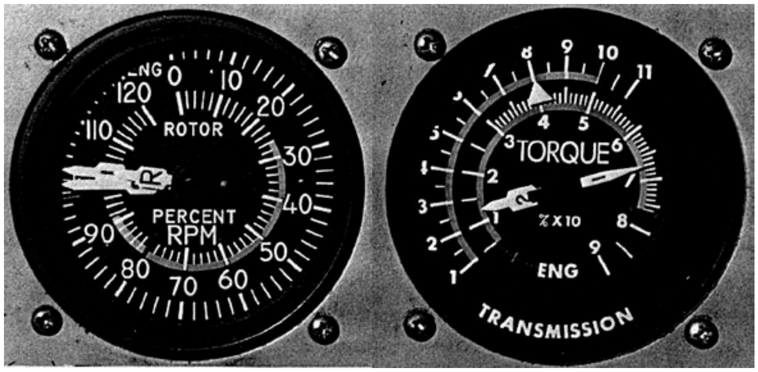
The key factor in identifying a low-side FCU failure is that it *always* results in some loss of rotor rpm, as indicated on the triple tachometer.

Also, remember that a low-side FCU failure may have all the characteristics of an actual engine failure, including a low rpm audio tone and advisory light, a left yaw of the nose, etc. The pilot must check the N2 and N1 of a failed engine to determine if the problem is an FCU or engine failure.

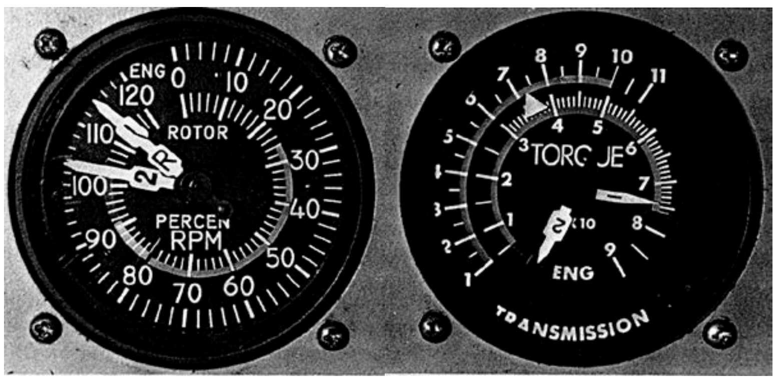
High-Side FCU Failure

A key factor in identifying a high-side FCU failure is that it *never* results in a loss of rotor rpm but may, in fact, cause a significant and possibly dangerous rotor overspeed (Figure 7-47).

The severity of an overspeed, and whether or not it occurs, depend upon whether high (above maximum OEI) or low (at or below maximum OEI) power is being used to fly the helicopter.



HIGH-SIDE FCU FAILURE DURING HIGH POWER DEMAND



HIGH-SIDE FCU FAILURE DURING LOW POWER DEMAND

Figure 7-47 High-Side FCU Failure Indications

Remember, there *cannot* be a loss of rotor rpm with a high-side FCU failure. Additionally, due to the increased power output of the high-side engine, the helicopter will yaw *right,* no rpm audio tone will be heard, but the RPM advisory light may illuminate due to high rpm.

The triple tachometer is the primary instrument for identifying the type of FCU malfunction that has occurred. A loss of N2/NR rpm indicates a low-side FCU failure. No loss or an overspeed of N2/NR rpm indicates a high-side FCU failure. Determining the type of FCU failure first ensures that the affected engine can be properly identified and corrective action taken.

Separate procedures for high-side and low-side FCU malfunctions are provided in the *FM.* These procedures differ since the cause of each malfunction and the way it affects FCU operation are different.

The following discussion is directed toward FCU corrective operation and should not be construed as replacing *FM* procedures.

In either case, high side or low side, the initial indication of a problem will be a Torque Split. Then look to see if you have high or low RPM in relation to what you had when things were normal. If the RPM is high then you have a High Side. On which engine? Look at the Torque gage again and it will be the high engine. The same is true of a low side governor failure. Check the RPM and if it is low then you have a low side governor failure. On which engine? Check the Torque gage and the low side failure will be on the engine with low torque.

High-Side Causes and Corrective Actions

One form of high-side FCU failure results when the shaft that drives the N2 governor breaks. This break causes the N2 governor to slow down and to falsely sense that the main rotor is slowing down when, in fact, it is turning at a normal rate. The perceived slowdown causes the N2 governor to increase *PG* air pressure to its AFCU to increase power output to drive the N2 turbine wheel faster and thus return the rotor rpm to its proper value.

Because of the broken shaft, the N2 governor does not sense any change in N2 rpm, and it increases PG air pressure even more.

The N2 governor continues to increase PG air pressure to its AFCU until the engine is producing maximum power. This all happens so rapidly that all the pilot sees is a sudden increase in the power of one engine, a high-side FCU failure.

The problem is that the AFCU is getting too much PG/PY pressure, which is holding the automatic metering valve in the AFCU wide open, allowing maximum fuel flow to the engine. There are two ways to temporarily fix the problem in flight: (1) reduce PG/PY pressure, or (2) switch to the MANUAL mode of FCU operation.

Py air pressure can be reduced indirectly in flight by decreasing the throttle toward flight idle, which puts an upper limit on the N1 governor in the AFCU and causes NI rpm to decrease. As N1 rpm decreases, so does compressor discharge pressure (P3) and, of course, Py air pressure.

As P3 air pressure decreases, the automatic metering valve closes and reduces fuel flow to the engine. By judiciously reducing the throttle, the pilot can reduce fuel flow to the engine and temporarily correct the high-side failure.

Under certain circumstances, manually reducing the throttle may either have no affect on the engine or result in an unstable reduction of power, which causes N2 rpm and the resultant torque "surging." If this happens, the pilot has no other choice than to reduce the throttle completely to flight idle and switch to the manual mode of operation.

Low-Side Causes and Corrective Actions

One form of low-side FCU failure results when the PG air line that transmits PG air pressure between the N2 governor, the TCU, and the AFCU develops a leak or breaks. The leak/break causes a loss of PG air pressure to that engine's automatic metering valve.

Without sufficient pressure to hold the valve in the proper position, the auto metering valve moves toward the minimum-flow position. This reduces fuel flow to the engine and results in a loss of engine power. As the engine's N1 rpm decreases, so does compressor discharge pressure and Py air pressure, which causes a further decrease in engine power output. Engine performance will continue to decrease until minimum AFCU fuel flow is reached. The engine may continue to run at or near flight-idle rpm, or it may flame out.

The AFCU reacts so quickly to the loss of PG air pressure that the pilot is aware only of the loss of engine power or flameout attributable to the low-side FCU failure.

With no PG air pressure to control the AFCU, the AUTO mode is useless. The pilot must enter the MANUAL mode of the FCU to be able to provide fuel to the engine in sufficient quantity to produce the power required.

WARNING

Before selecting MANUAL mode, *always* reduce the throttle of the affected engine to the flight-idle position. Failure to do so will result in the manual metering valve being wide open and allowing maximum unregulated fuel flow to the engine. This may result in engine over-torquing, over-heating, or over-speeding.

If the engine has flamed out as a result of an FCU failure, it can be restarted in the MANUAL mode using *FM* procedures.

MANUAL FUEL CONTROL OPERATION

Any time one engine is being operated in the MANUAL mode (Figure 7-48) or the throttle is being used to manually control a high-side failure, the torque of the manual or affected engine should be kept slightly (4 to 5%) below the torque of the normally operating engine.

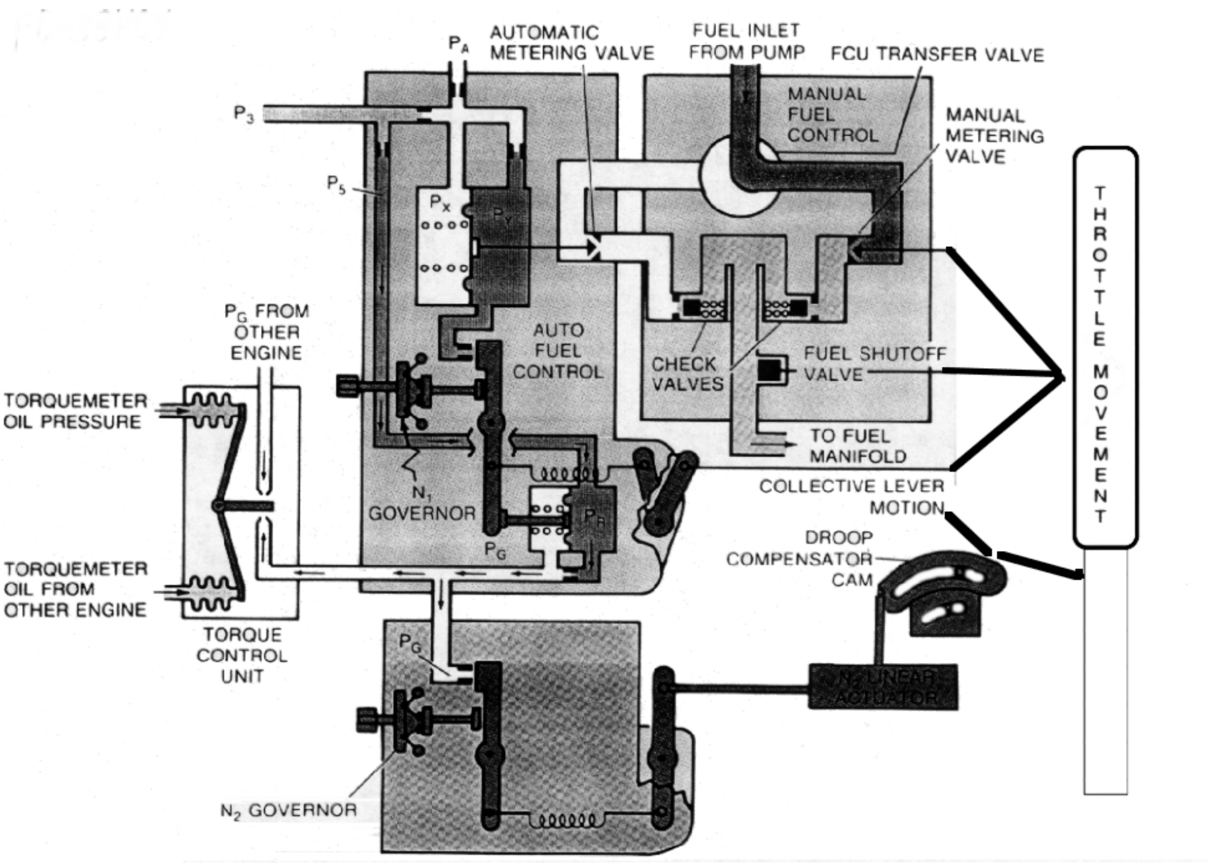


Figure 7-48 Fuel Control Manual Mode

This will allow the FCU of the normal engine to maintain proper rotor rpm and compensate for minor dynamic disturbances while the manually controlled engine provides assistance in the form of power only.

When large power/collective changes must be made, the manually controlled engine must be adjusted slightly before or simultaneously with the collective change. Failure to carefully control the manual engine can result in serious under-speeding or over-speeding of rotor rpm, as well as possible over-heating or over torque of the engines.