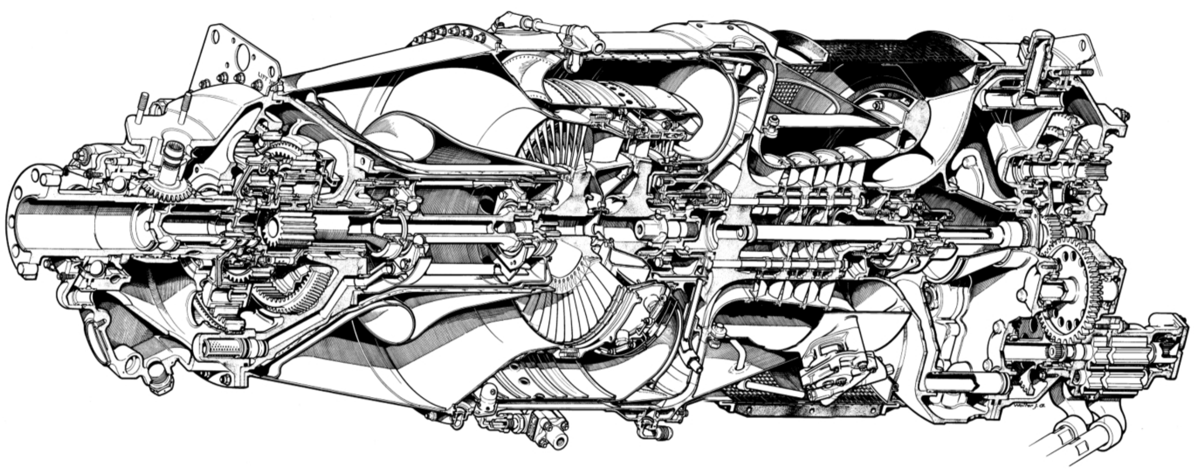
A ***FreeBee*** **Publication**

The Pratt and Whitney PT6A

Small Engine

Propeller Control System



PT6A-20 ENGINE

WARNING

FOR TRAINING PURPOSES ONLY

This is not an official publication!!!

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There are most commonly 3 levers on the control pedestal of a PT6 powered aircraft.

The Power Lever

The one closest to the pilot – left hand side is the power lever – sometimes abused by calling it a “Throttle” by those oafs who don't know better.

The purpose of the power lever is two-fold – first it controls the fuel schedule by the interconnect from the engine cambox to the fuel control unit. Second it controls the propeller blade angle as well as the fuel schedule when operating in the “Beta” mode.

Depending on the model of PT6 you can have different cambox operation – but in most cases the system will increase gas generator speed in the forward direction for increasing power to the maximum limit allowed and also will add gas generator speed when moved into the reverse position.

The second function of the power lever to control the propeller blade angle (NOT SPEED) when the engine is operated in “Beta” is accomplished by the cambox operation through a push/pull cable (Teleflex) control that is linked to the beta valve on the forward face of the propeller governor and the connection for blade angle feedback that is through a carbon block in a beta ring attached to the propeller.

The “Beta” range is from a degree or two above your prime blade angle – which is significantly ahead of the flight idle position.

Beta in the case of the PT6A-42 in a King Air 200 for example starts at about +21 degrees of blade angle all the way to – 14 degrees in reverse. Flight idle is about 11 degrees.

BETA IS DEFINED AS THE RANGE OF ENGINE OPERATION WHERE THE POWER LEVER CONTROLS THE FUEL SCHEDULE AND THE BLADE ANGLE OF THE PROPELLER.

It is an engineering term and can be used to indicate an operational mode or control function.

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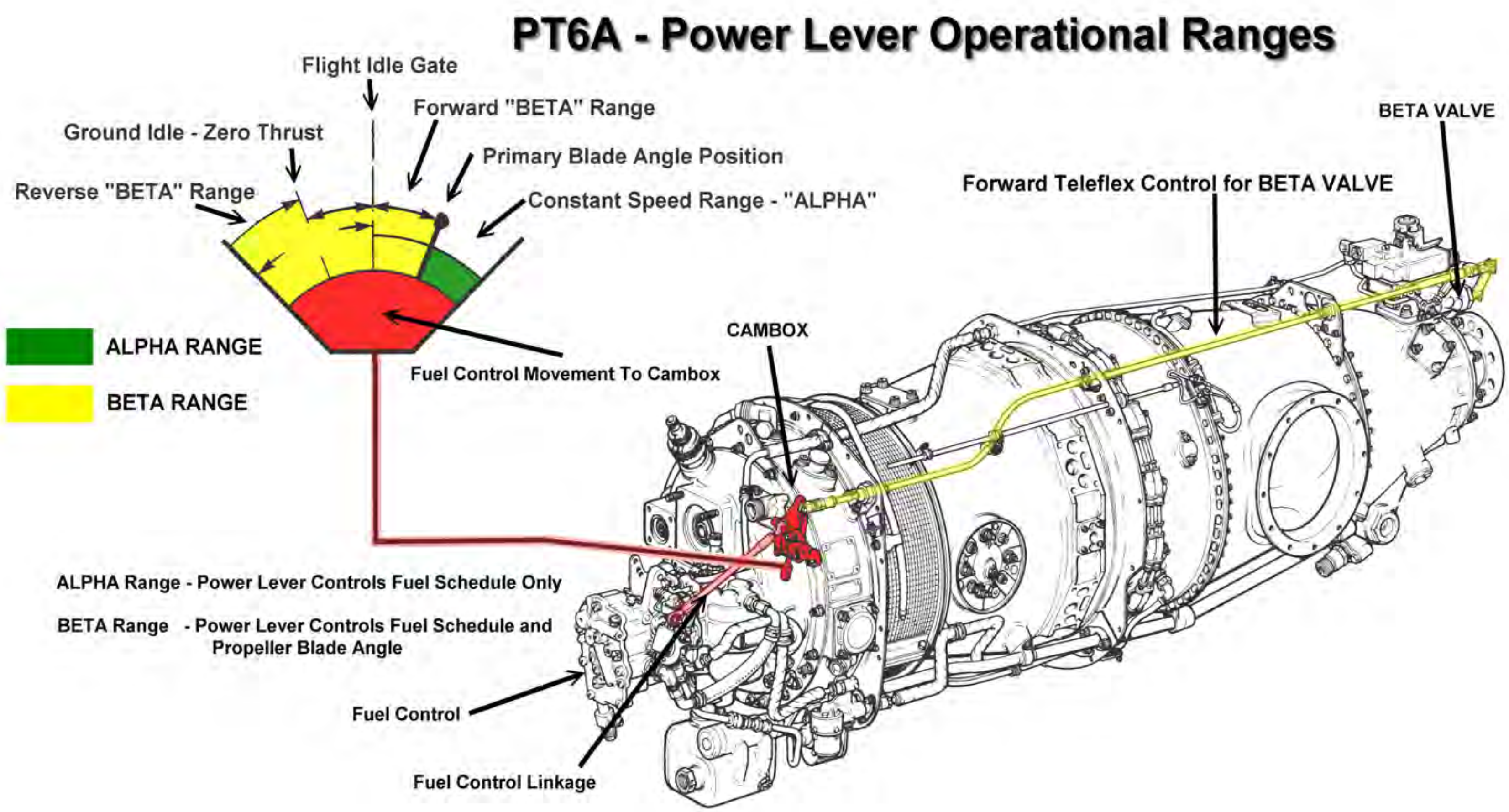
Power Lever Operational Ranges



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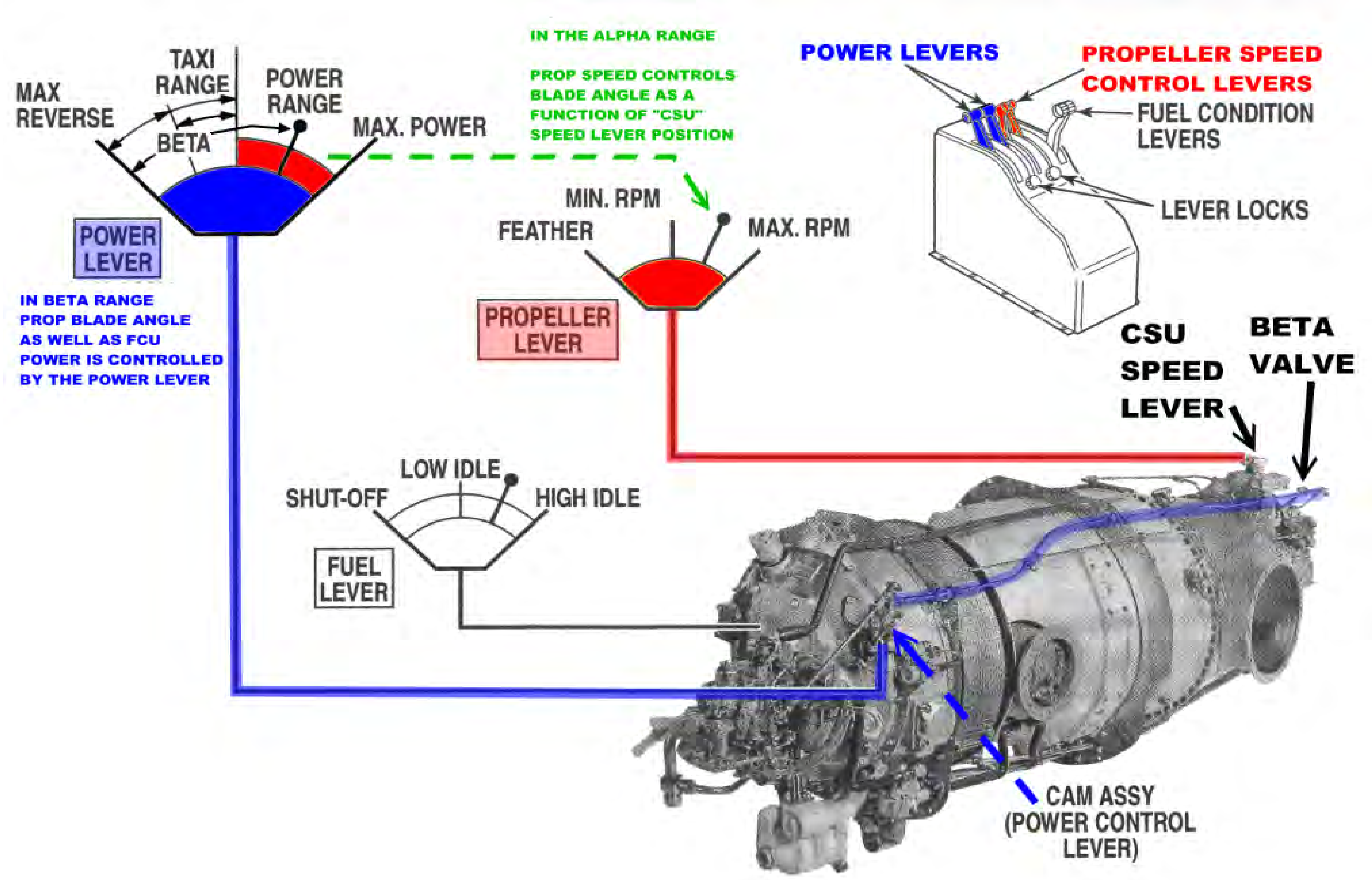
3 Lever Control System Overview



Propeller Speed Control Lever

The second lever on the control pedestal is the “PROPELLER” control.

It has 2 functions.

When pulled all the way aft it will feather the propeller.

When pushed out of the feather detent it will be in the “LOW” speed or minimum governing setting – and when advanced increases the speed of the propeller to the “MAXIMUM” speed setting.

When the power lever is moved from the flight idle gate the gas generator speed is increasing and the propeller blade angle is increasing as it is still in beta mode.

Just above the primary blade angle check prop speed and torque for the day condition the system will transition from beta to constant speed mode – sometimes referred to as “ALPHA” mode.

In this range the power lever will control only the gas generator speed and the propeller control lever will control the speed of the propeller through the constant speed governor.

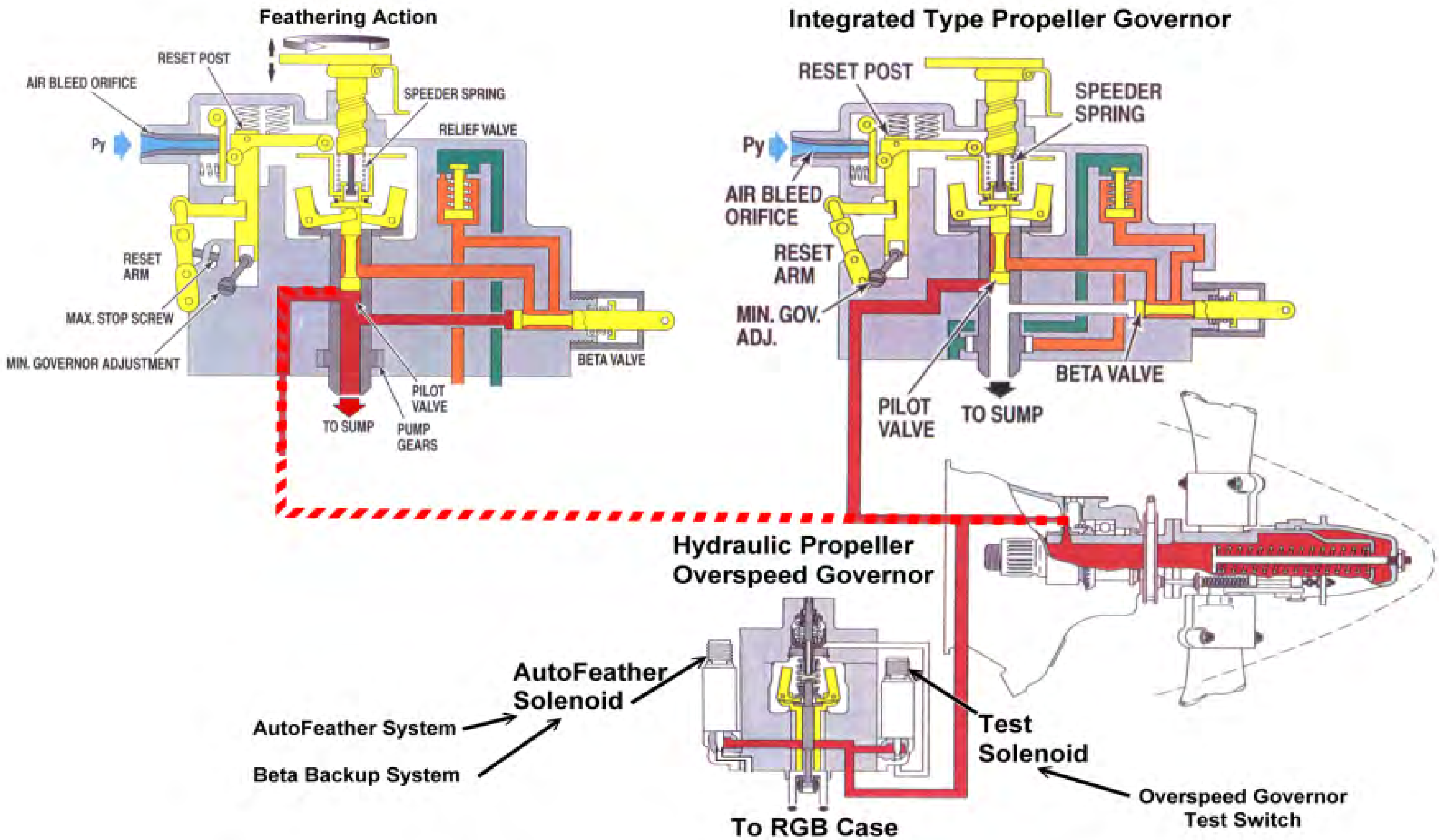
ALPHA IS DEFINED AS THE RANGE OF ENGINE OPERATION WHERE THE PROPELLER LEVER CONTROLS THE PROPELLER SPEED THROUGH THE CONSTANT SPEED GOVERNOR AND THE POWER LEVER CONTROLS ONLY THE FCU FUEL SCHEDULE.

It is an engineering term and can be used to indicate an operational mode or control function.

Integrated Governor Propeller Control System

There is only 1 Integrated Governor Installed on the Engine. The 2 modes of Propeller Control Lever Operations are Illustrated.

Feathering ***and*** ***Constant Speed***



Fuel Condition Lever

The third lever on the control pedestal is the “FUEL CONDITON” lever. The original purpose of the fuel condition lever was to simply shut off or turn on the fuel to the engine.

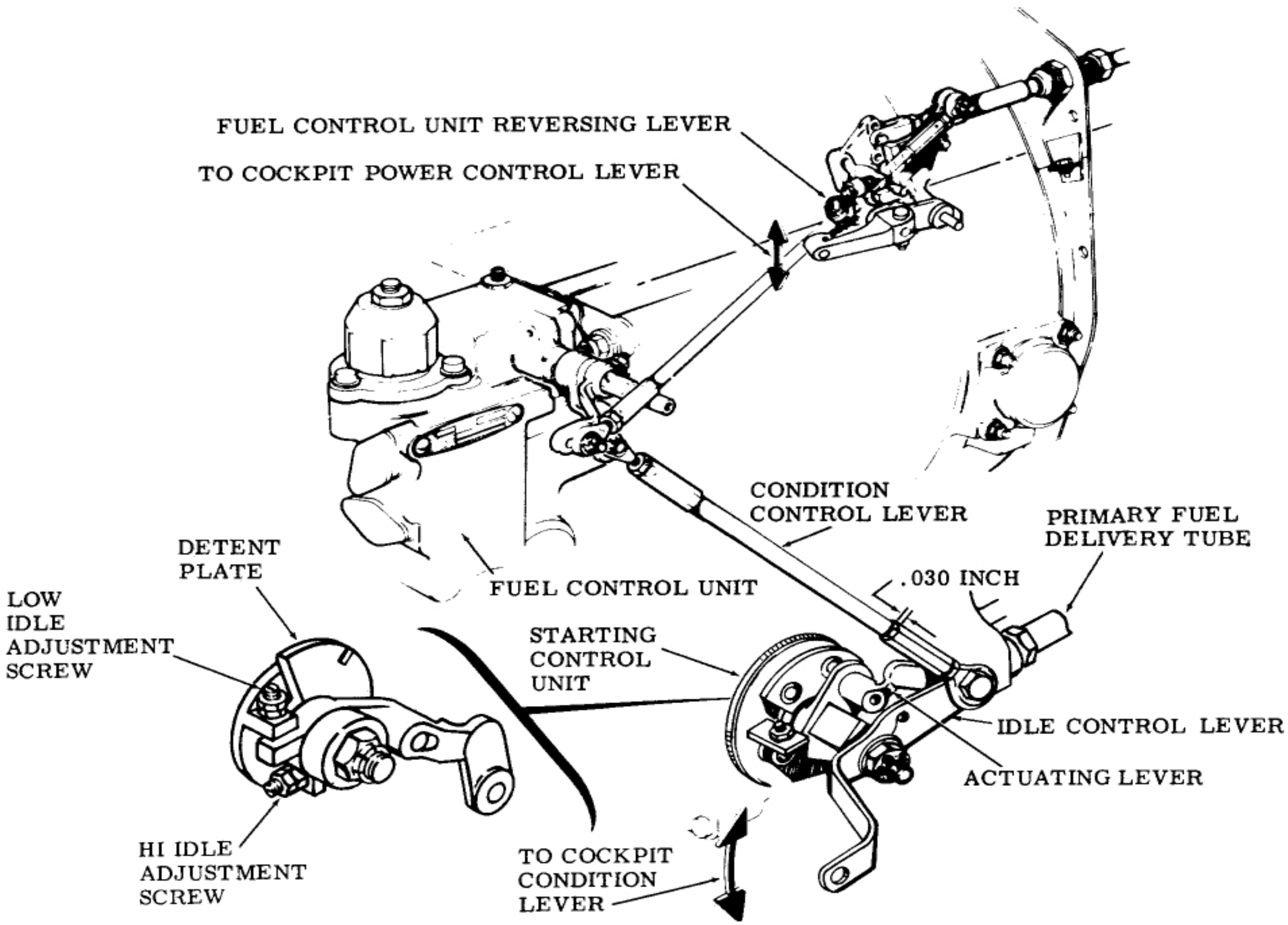
It is basically a HP (High Pressure) shutoff valve system that is operated by the flight crew to start and shut down the engine. It was modified on the Beech – as well as other aircraft – to include a low idle and a high idle position.

The original reason for this was the small PT6 engines would bog down if you turned on the generator,bleed air, or the air conditioner compressor with the engine at idle. The extra loading at idle will cause an increase in fuel flow by the fuel control unit to keep the engine at the idle speed. Under this condition with only idle airflow through the engine - the Inter Turbine Temperature will increase to the point that it will cook the engine.

On some installations the flight crew must remember to manually advance the power lever to 68% or 70% minimum to obtain sufficient airflow through the engine so when loaded with the generator, bleed air, and/or the air conditioner compressor it had sufficient airflow to absorb the extra heat from the increase in fuel commanded by the fuel control unit.

So the fuel condition lever was modified/designed to “Bump” up – mechanically – so when advanced to the full forward position the linkage at the fuel control gives an easy way for the flight crew to obtain the correct gas generator speed for operation of the airframe systems.

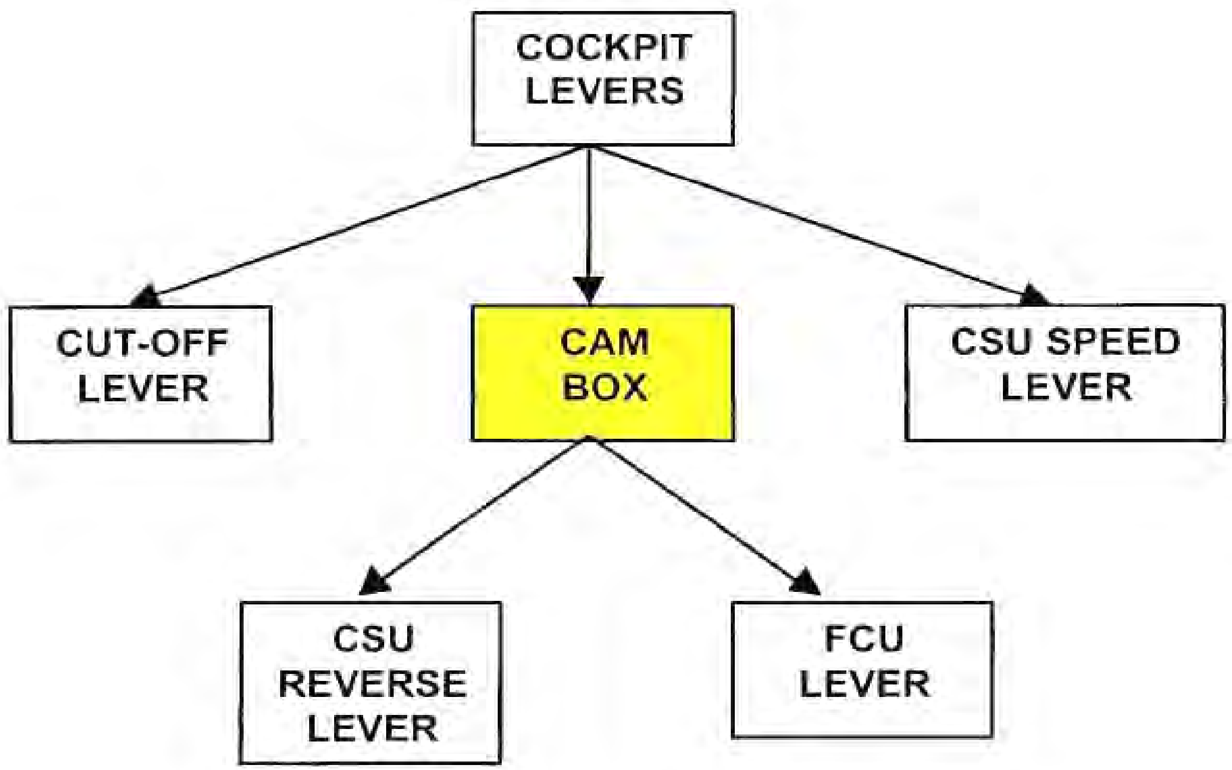
Start Valve Equipped Engine – High and Low Idle Capability



Flow Control Idle Adjustments

Basic Control Interaction

The interactions of the 4 governors on the PT6A engine are complex and have overlapping functions to protect the engine and propeller. The cockpit controls operate 2 of the governors directly – the Constant Speed Governor for Propeller Speed and the Fuel Control Governor for Gas Generator Speed Control. There is also a Fuel Topping (Nf) Governor that is reset to a lower speed value in Beta. A standalone Hydraulic Overspeed Governor is installed as a backup to the Constant Speed Governor. It is not adjustable from the cockpit.



Propeller System Operation

In order for the propeller system to function a mechanical oil pressure booster pump is incorporated into the base of the constant speed governor. This increased pressure is used to control the propeller from the feather (0 Psi) to Maximum Reverse – (Highest Oil Pressure approx 400psi). The oil pressure is delivered to a hollow propeller shaft by a “Transfer Sleeve”.

The propeller lever has direct control of the propeller governor in the constant speed range. In addition it can manually feather the propeller by moving the control all the way through the low speed gate into the feathering detent. This actuates a feathering valve that dumps governor boosted oil pressure back to the gear reduction case. The servo piston will move forward with spring pressure and blade counterweight force to the internal feather stop.

The propeller governor in all but the earliest of engines contains both the Constant Speed governor and the Fuel Topping governor. Control of the propeller speed in the Alpha range is a function of propeller lever position. When pushed fully forward the propeller governor lever is held against an adjustable stop and operates the propeller at 100% Np. When pulled aft to the low speed gate it will now reset the speeder spring pressure in the governor to give 70% Np. Variable propeller speed is then a function of the position of the propeller lever position from 70% to 100%.

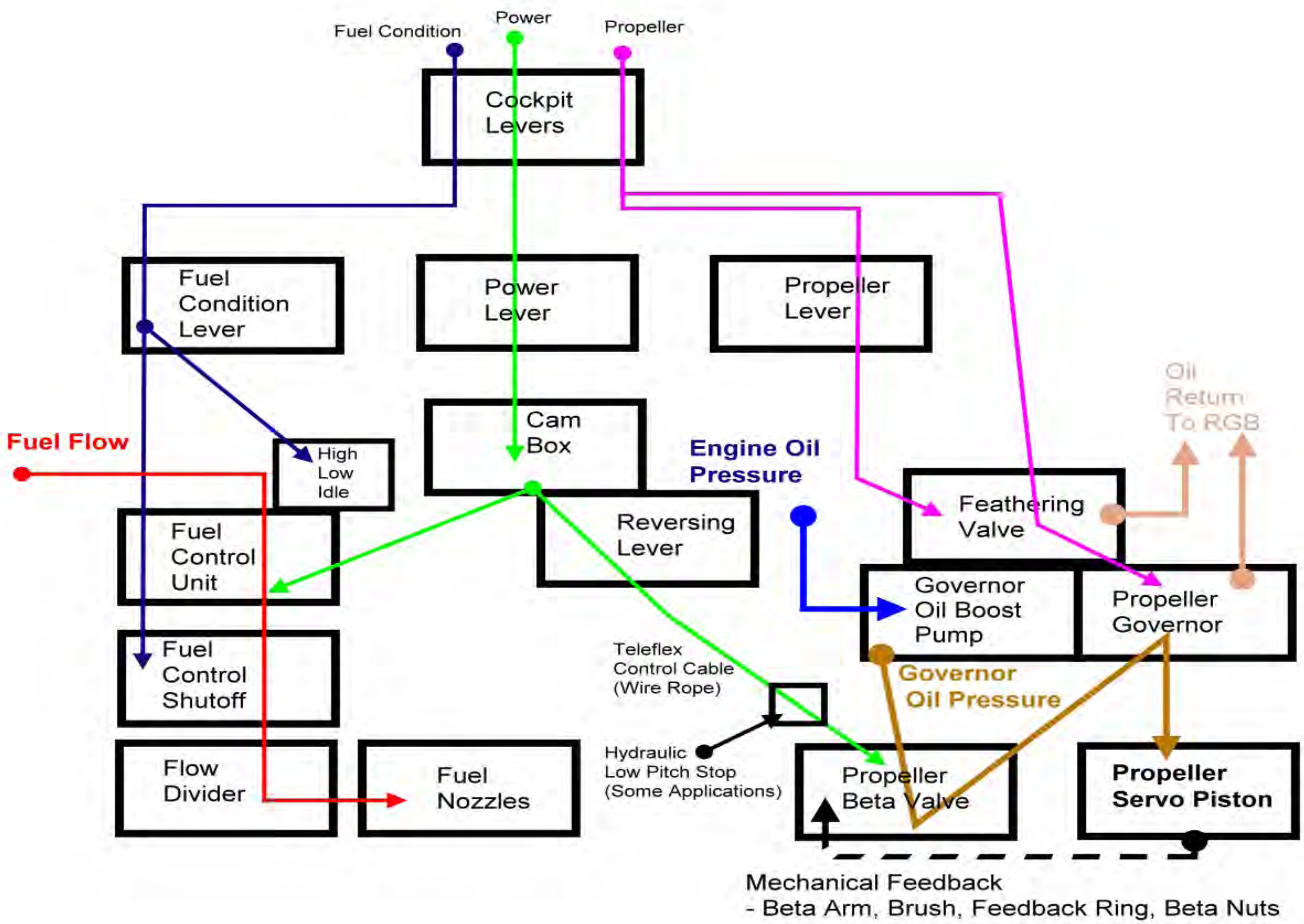
The power lever has 2 modes control – the propeller blade angle in Beta and the fuel schedule for the governor section of the fuel control unit as well as a reset capability for the fuel topping governor when operating in Beta/Reverse..

The propeller hydraulic overspeed governor is set for a specific speed and does not have a cockpit control for it's operation. There is a test function to reset the speed down below that of the propeller governor so it's operation can be checked on the ground.

The fuel topping governor or Nf governor comes in 2 styles. On very early engines it was a seperate unit mounted on the right hand side of the reduction gear case and connected with a multi-piece linkage. Later models have the fuel topping governor built into the propeller governor body.

Block Diagram For Engine Manual Control Operation *- Not shown is standalone (Automatic) Hydraulic Overspeed Governor*

The Propeller Governor contains both the Constant Speed Governor and the Fuel Topping Governor (Integrated Governor)



The Propeller

Counterweight type propellers are used on the PT6A engines. These propellers are designed such that in the event of a loss of hydraulic control oil pressure they will automatically move the propeller blades to the feather position. This is accomplished by the use of internal springs and counterweights.

Characteristics of a Counterweight Type Propeller

When looking at the design characteristics of a propeller control system we must first look at the forces acting on the propeller blades.

Centrifugal force – or its' opposite Centripetal Force.

This is the greatest force acting on the blades and the rotation of the propeller assembly causes the force to be developed. The amount of force is speed (RPM) related being a function of the square of the speed. In very simple terms 2 x the Speed = 4x the CF. The CF is contained by the design of the blade bearing race and the hub mount system. Although a huge force it is not much of a concern when operating the propeller as the bearing elements are sufficiently robust to contain the loading yet allow the blades to pivot and change blade angle with relative ease.

Aerodynamic Twisting Moment (ATM)

This force is produced by the airfoil shape of the propeller blade as it moves through the air. Like a wing it produces lift and the lift production is normally forward of the rotational center of the propeller blade. This causes the blade to move to a greater blade angle. It is referred to as ATM and it assists in moving the blade towards the feather position.

Centrifugal Twist Moment (CTM)

This force is produced by the effect of the center of mass of the spinning blade and its' relationship to the rotational center of the propeller blade. Most blades have the mass of the blades distributed such that the CTM force tends to move the propeller blade towards a lesser angle. CTM will assist in moving the blades towards the lowest blade angle.

Hydromatic and Aeromatic Propellers

There are propeller blade designs that have the blade mass in the opposite location and those propellers will see the blade angle increasing as the rotational speed increases. The “Aeromatic” series of propellers uses this design to increase the blade angle as a function of engine speed. These propellers are automatic and do not require a propeller control system. It is difficult to get the balance right so are in limited use.

The group of propellers that use CTM as a primary movement force to move the blades towards a low blade angle – being opposed by a controllable oil pressure force are called “Hydromatic Type” propellers.

CounterWeight Force (CWF)

Counterweights are fastened to propeller blades to “Counter” Centrifugal Twisting Moment (CTM). In this design the counterweights oppose the natural CTM produced and the net result is the movement of the propeller blade towards a greater blade angle. In a counterweight blade design the CTM force is less than the CWF thus the CWF moves the blades towards an high blade angle / feather.

Spring Forces

In addition the propeller control system can be designed with springs. These springs are used to move the blades into feather and keep them there. Thus the spring forces move the blades towards a greater blade angle / towards feather.

Governor Oil Pressure

The governor system uses engine oil delivered from the pressure system of the engine. A gear type pump installed in the base of the Propeller Control Unit is driven from the gear train of the reduction gear box. Attached to this drive shaft is also the mechanical flyweight governor. Since the PT6 is a free turbine the reduction gear box drive train is driven by the power turbine system. The main engine oil system pressure pump is however driven from the Gas Generator section (Ng).

This boosted system pressure is used to move the propeller blades in a single direction. Thus the governor is referred to as a “Single Acting Governor”. The boosted oil pressure is fed through the propeller governor system – beta valve – constant speed unit – feathering valve – and to the separate hydraulic overspeed governor mounted on the left side of the reduction gear box.

This governor oil pressure is used to change the volume of the servo piston chamber and displace the servo piston assembly. The governor oil pressure is supplied to the propeller through a transfer sleeve into a hollow propeller drive shaft and then accesses the piston chamber.

Propeller Piston

The servo piston slides axially inside the propeller assembly and is connected via linkages to the propeller blades. Movement of the piston fore and aft results in propeller blade rotation in the hub to change the blade angle. Installed in the hub and acting on the servo piston are springs that mechanically force the piston to the full rearward position when no other forces are present. When the piston is fully forward the propeller blades are rotated to the feather position. An external adjustable stop is used to select the correct feather angle to ensure the propeller does not windmill when feathered in flight.

When the piston is moved by the governor oil pressure plus the centrifugal twisting moment (CTM) all the way to the rear of the propeller hub the propeller blades will be in the full reverse blade angle position.

Thus governor oil pressure is a variable force that is assisted by Centrifugal Twisting Moment to the zero degree pitch and from that point to full reverse by the addition of Aerodynamic Twisting Moment.

Governor oil pressure plus CTM / CTM+ATM forces are opposed by the ATM from zero degree to feather plus Counterweight Force plus Spring Forces.

Constant Speed Flyweight Governor

A flyweight governor system connected to a sliding spool type valve is used during constant speed operation to change the governor oil pressure / flow to the propeller piston chamber.

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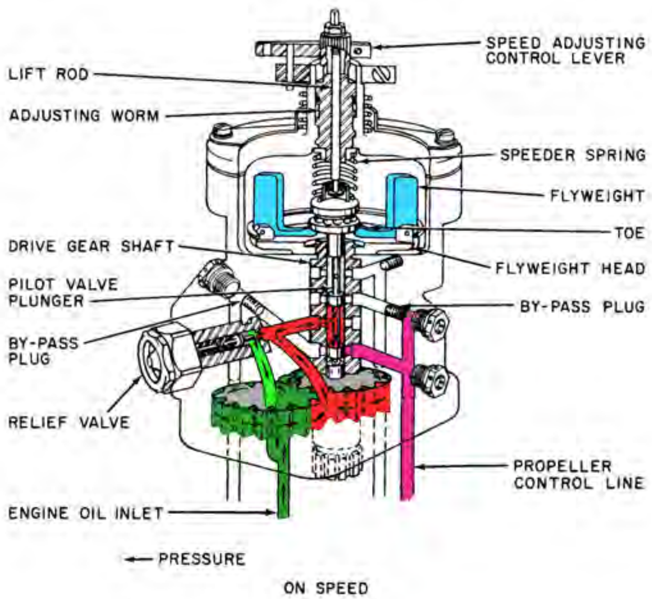
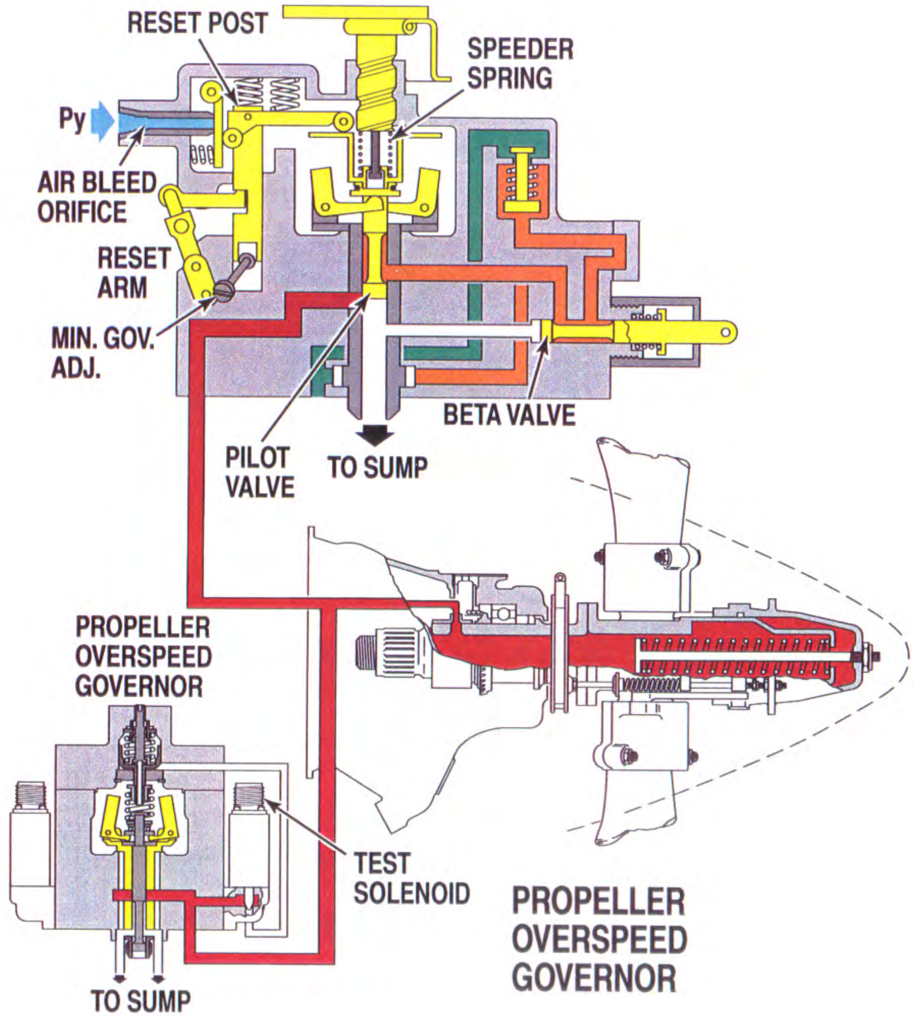
Hydraulic Propeller Governors - Theory of Operation

A Propeller Governor is an engine RPM sensing device and high pressure oil pump.

In a constant speed propeller system, the governor responds to a change in engine RPM by directing oil under pressure to the propeller hydraulic cylinder or by releasing oil from the hydraulic cylinder.

The change in oil volume in the hydraulic cylinder changes the blade angle and maintains the propeller system RPM to the set value. The governor is set for a specific RPM via the cockpit propeller control that compresses or releases the governor speeder spring.

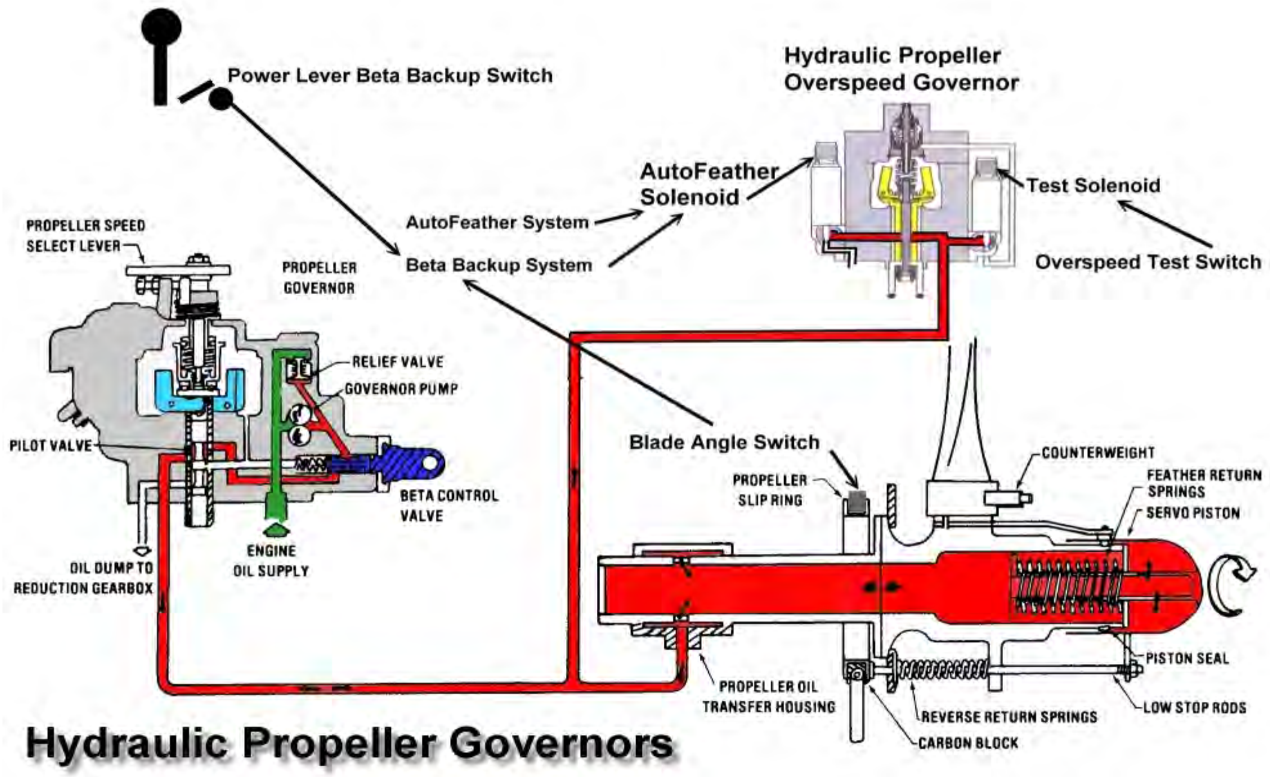




Onspeed Condition

When the engine is operating at the RPM set by the pilot using the cockpit control, the governor is operating **onspeed**.

In an onspeed condition, the centrifugal force acting on the flyweights is balanced by the speeder spring, and the pilot valve is neither directing oil to or from the propeller hydraulic cylinder.

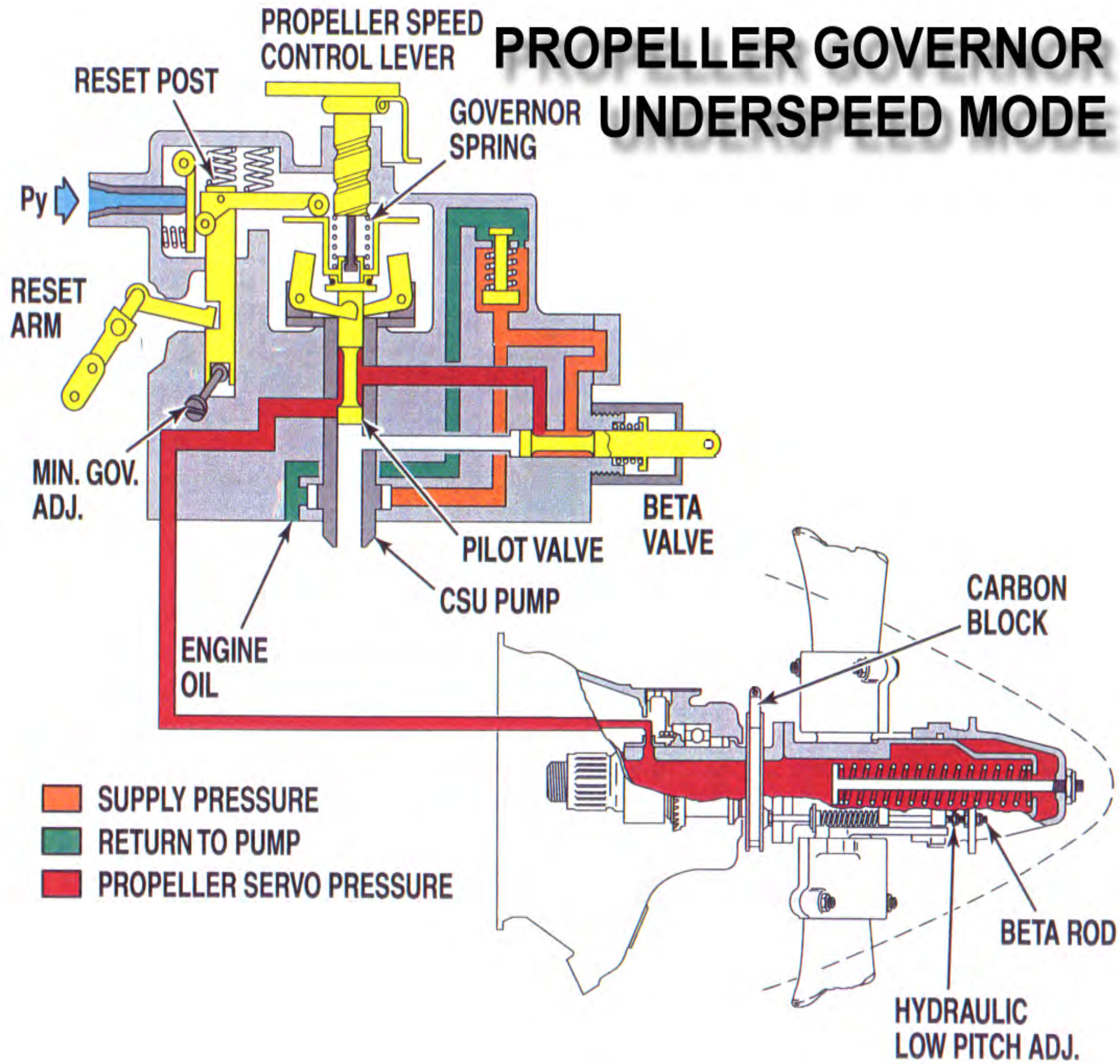


Underspeed Condition

When the engine is operating below the RPM set by the pilot using the cockpit control, the governor is operating **underspeed**.

In an underspeed condition, the flyweights tilt inward because there is not enough centrifugal force on the flyweights to overcome the force of the speeder spring.

The pilot valve, forced down by the speeder spring, meters oil flow to decrease blade angle and increase engine RPM.

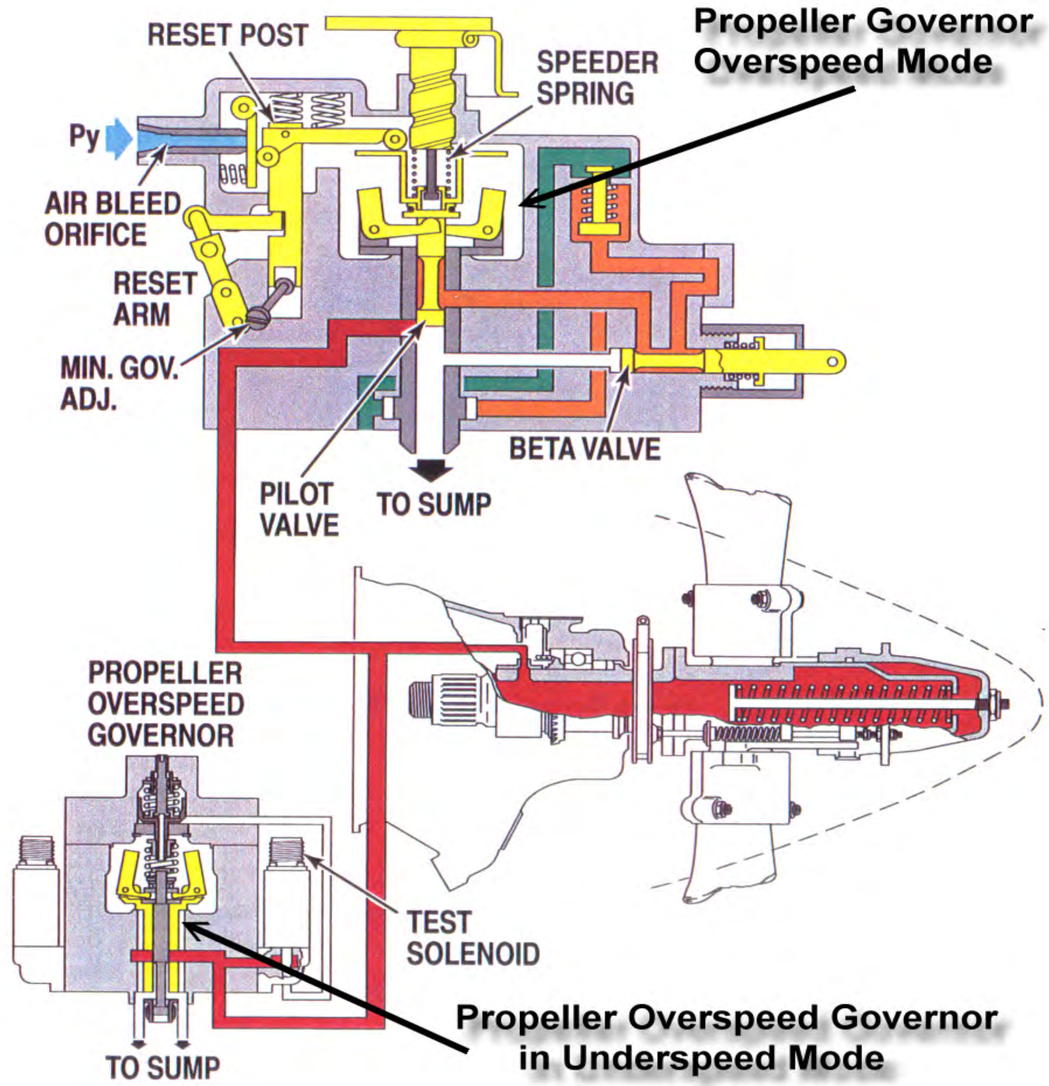


Overspeed Condition

When the engine is operating above the RPM set by the pilot using the cockpit control, the governor is operating **overspeed**.

In an overspeed condition, the centrifugal force acting on the flyweights is greater than the speeder spring force. The flyweights tilt outward, and raise the pilot valve.

The pilot valve then meters oil flow to increase propeller blade angle and lower engine RPM.

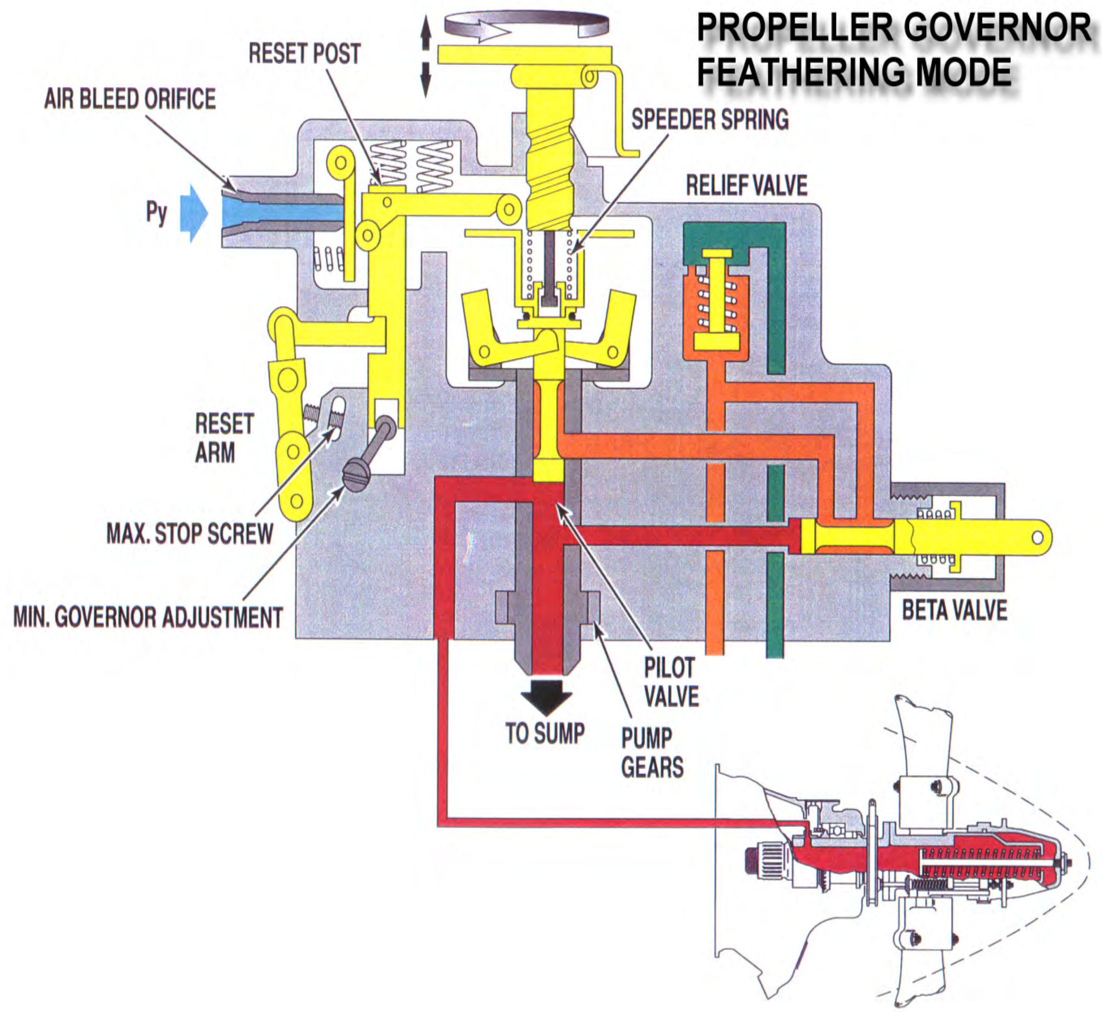


Feathering Governors

Feathering governors allow oil to be pushed from the propeller to the engine drain to increase propeller pitch to feather.

On early engines this was accomplished by lifting the pilot valve and mechanically forcing the valve to dump control oil back to the engine reduction gear box.

Later engines with the integrated propeller governor use a separate feathering valve that opens and dumps control oil pressure back to the engine reduction gearbox.



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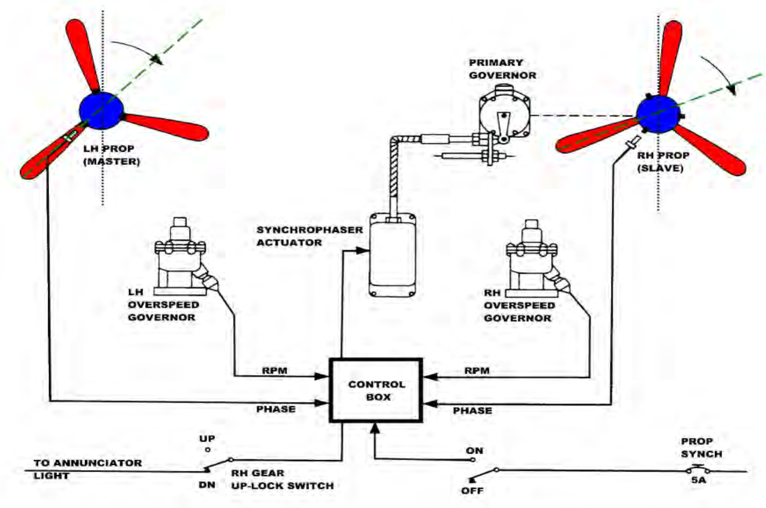
Propeller Synchronization and Synchrophasing Systems

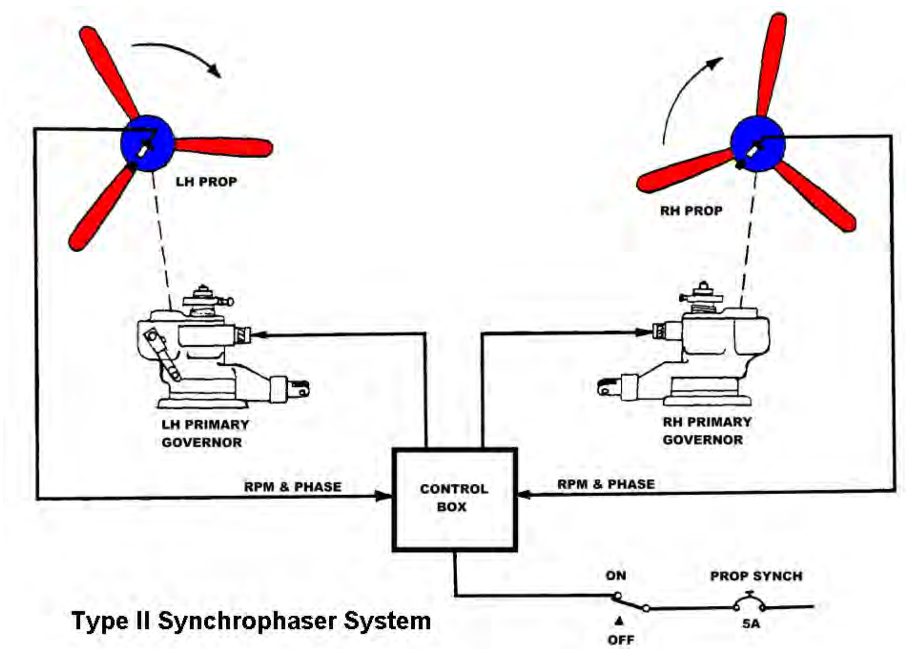
A synchronizing system can be employed in a multi-engine aircraft to keep the engines operating at the same RPM. Early aircraft used the Type 1 while later aircraft used the Type II.

A synchrophasing system not only keeps RPM of the engines consistent, but also keeps the propeller blades operating in phase with each other.

Both synchronizing and synchrophasing systems serve to reduce noise and vibration.



Synchrophaser System



Type II Synchrophaser System

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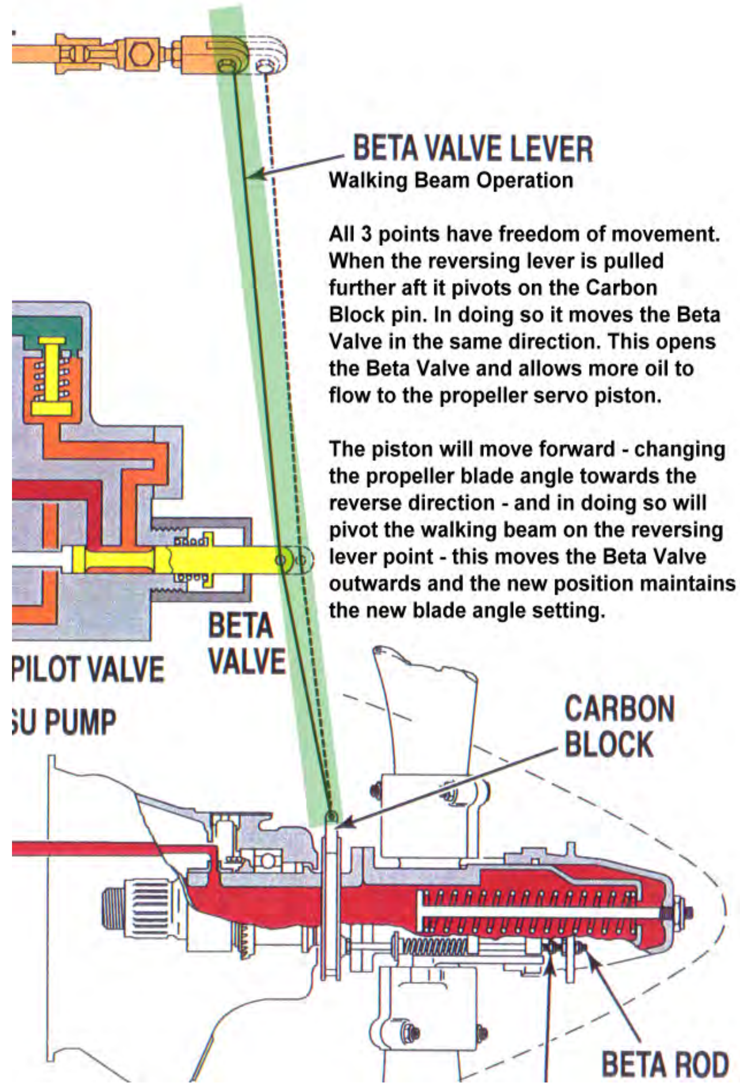
Operation in the Beta Range

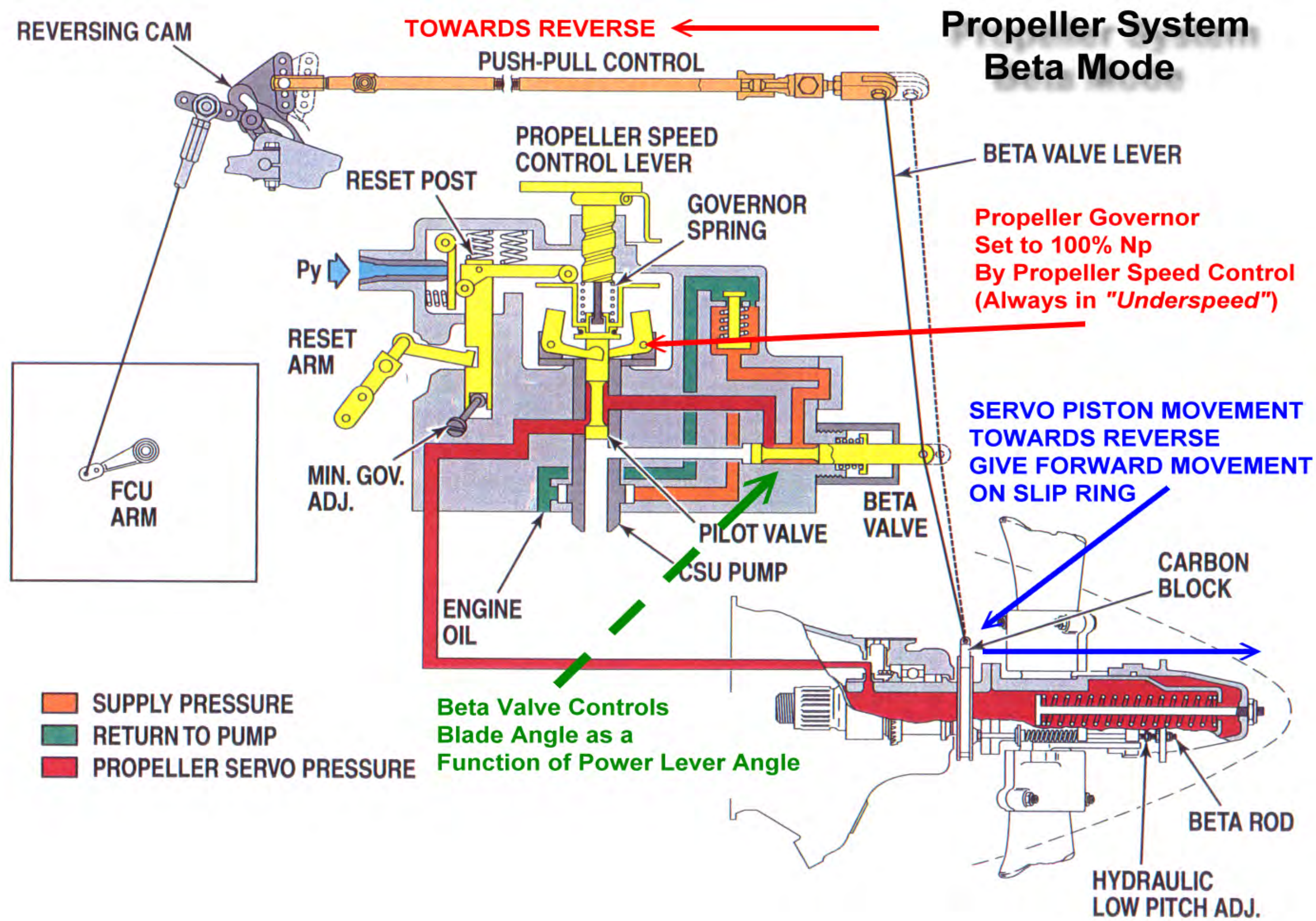
When entering Beta range the control of the propeller changes from a propeller speed control through the propeller governor to control of the propeller blade angle by the Power Lever.

This is accomplished by the use of a hydraulic valve placed upstream of the CSU control spool valve, a walking beam assembly with one end of the beam connected to the slip ring brush block and the other end connected to the mechanical teleflex cable system operated from the Cam Box mounted on the right side of the rear engine case.

Using the walking beam system the beta valve can be operated to control the governor oil pressure delivered to the propeller piston chamber.



The "Action / Re-Action" Beta Valve Walking Beam System



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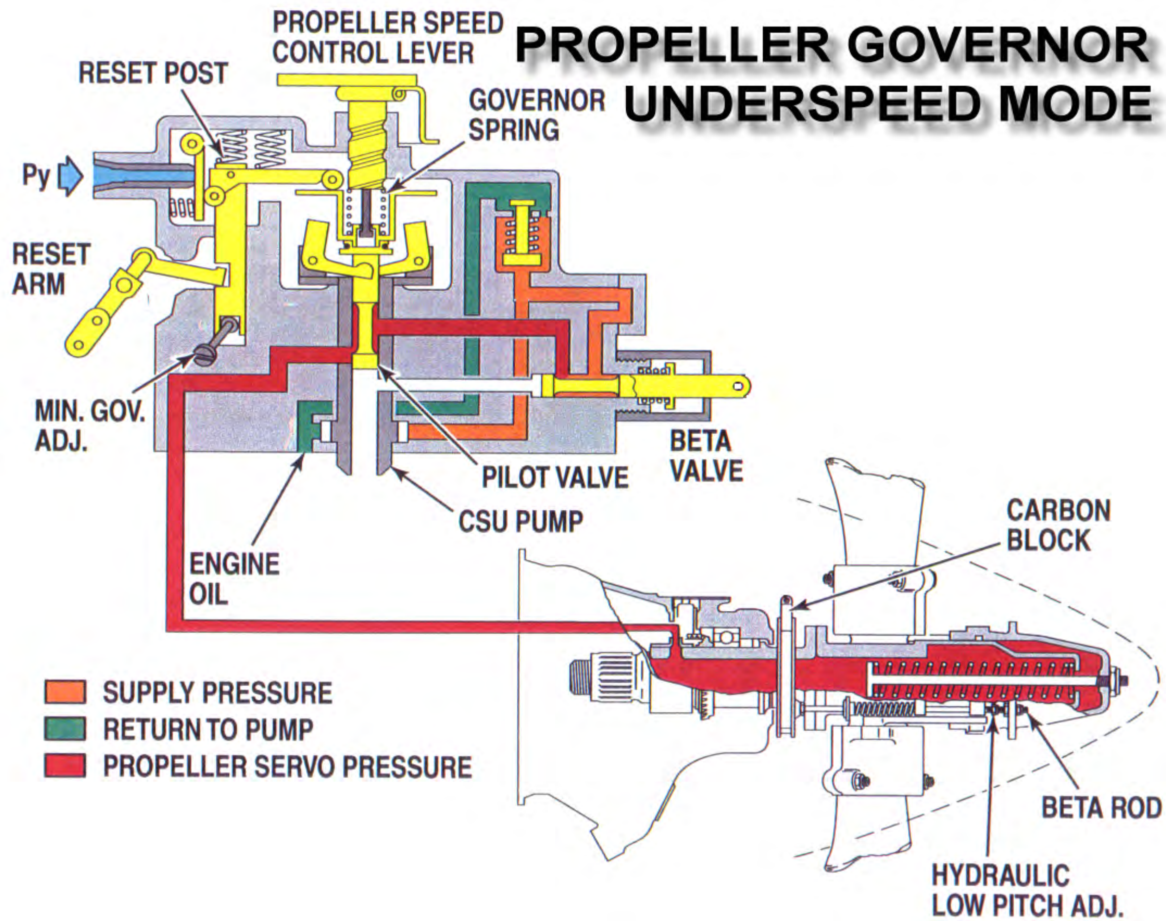
Constant Speed Control Inhibition

During Beta mode operation the CSU spool valve needs to be forced to the fully open position to allow the Beta Valve control of the oil flow.

This done simply by placing the propeller control in the full forward position – which is asking for a 100% propeller speed – with the propeller speed less than 100%.

Thus throughout the beta mode the CSU is always in an underspeed condition relative to the commanded and actual propeller speed.



Fuel Topping Governor Operation in Alpha Range

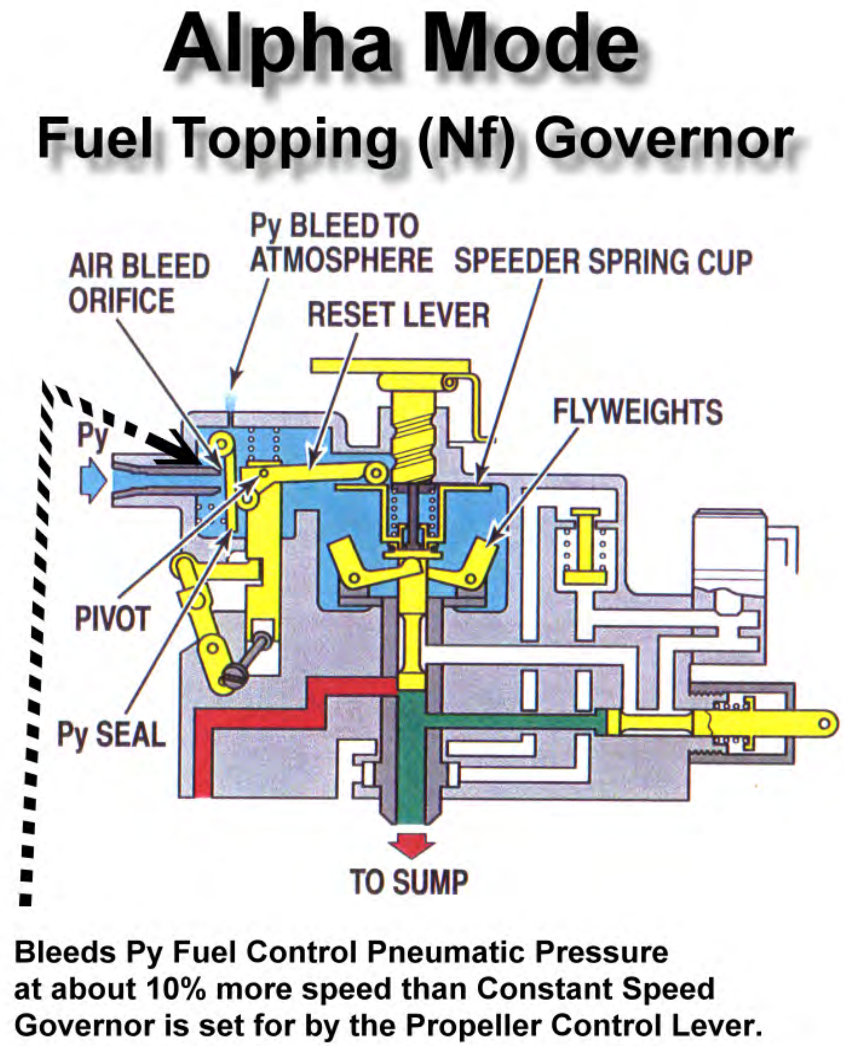
The fuel topping governor is used as a safeguard in Alpha Mode.

It is preset inside the propeller governor to 10% higher than the selected propeller speed.

In the event of a CSU malfunction that would cause the blade angle to be driven towards a lower blade angle and the resultant engine and propeller overspeed the Fuel Topping Governor will operate at 10% above the existing selection.

Thus in cruise with a 75% propeller speed selected and a system failure that results in a propeller overspeed the still functioning flyweight governor will now activate the Fuel Topping Governor Py Air Bleed at about 85% propeller speed and will govern the propeller speed by modifying the fuel flow through the Fuel Control Unit located on the Gas Generator Accessory Drive Case.

This would have the same effect as a reduction in power by moving the power lever rearward but is accomplished automatically by the "Differential Bellows" section of the FCU.



Reset of the Fuel Topping Governor in Beta Range

When we enter the Beta Range the interconnect linkage on the walking beam connection point with the teleflex cable repositions the reset arm and in the full reverse position has reset the Fuel Topping Governor to 5% less than the selected speed.

Since operation in Reverse requires the propeller lever to be set to the 100% Np position the action of moving the propeller blade angles hydraulically through the mechanical control and Beta Valve assembly has reset the Fuel Topping Governor to 5% less it stands to reason that the maximum propeller speed allowed by the Fuel Topping Governor is about 95%.

The above action prevents the propeller Constant Speed spool valve from operating – which is a very good thing!!!

If for example the reset of the Fuel topping governor was not accomplished and the fuel topping governor was still set to 10% above the Propeller control it would then operate at about 110% Np.

In reverse this would be a disaster. As the power is applied in reverse the speed would now exceed the 95% normal limit for fuel topping and at 100% Np the constant speed governor would sense an overspeed condition and restrict/dump the oil flow to the propeller piston. The propeller blades will now move towards the feather position. Before they can get there they have to transition the propeller blades through Zero Degrees and then to a sufficiently greater blade angle to absorb the engine power being developed – this will never happen because: ***The propeller and engine would have failed with the excessive speed as it is unloaded through the zero pitch position.***

The same effect would take place if the Hydraulic Overspeed Governor was to activate at 104%.

The placement of the propeller control lever on early engines was a condition that had to be met in order to go through the Flight Idle Gate. On engines with integrated governors it is not such a dire thing because on these governors the Nf section is always reset by the reset arm and linkage to a speed value of about 5 – 6% less than the speed selected. So if the flight crew didn't put the propellers to 100% Np and had left them at say 85% Np - the Nf governor will now operate in reverse at about 80% Np by the mechanical action of the reset linkage.

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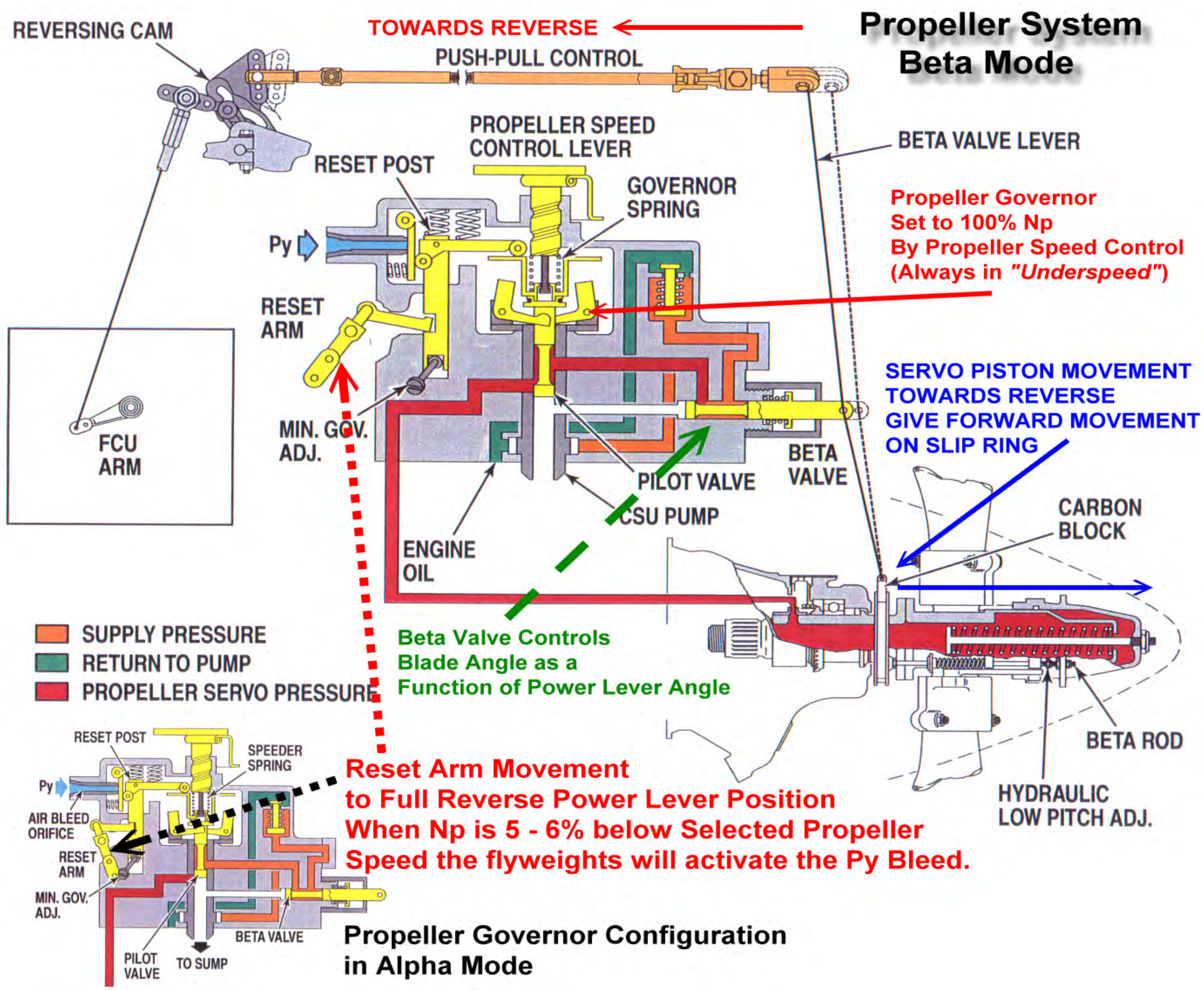
Fuel Topping (Nf) Governor Operation in Beta – Full Reverse



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Governor Configuration on the Engine

It is very important to understand that you have 3 governors looking out for you in Alpha Range.

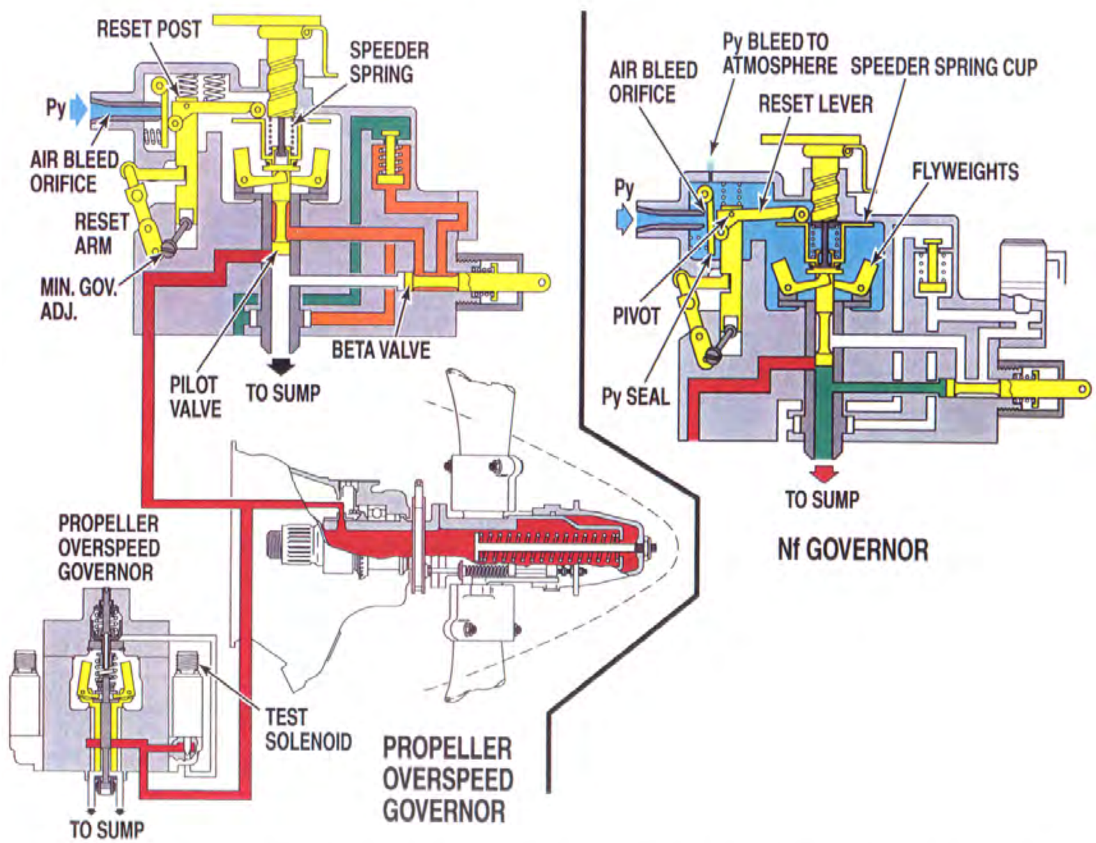
Normal operation of the propeller governor, operation of the Fuel topping Governor at about 5% Np higher than is selected in the CSU, and a back-up independent Hydraulic Overspeed Governor set at about 104 – 106% Np.

You only have only a single governor looking out for you in Beta / Reverse – the Fuel Topping Governor. Interference from the CSU or the Hydraulic Overspeed Governor will cause catastrophic engine / propeller failure.

Knowledge of this single point should be sufficient to keep you from entering the ground operational portion of the Beta Range in the air.

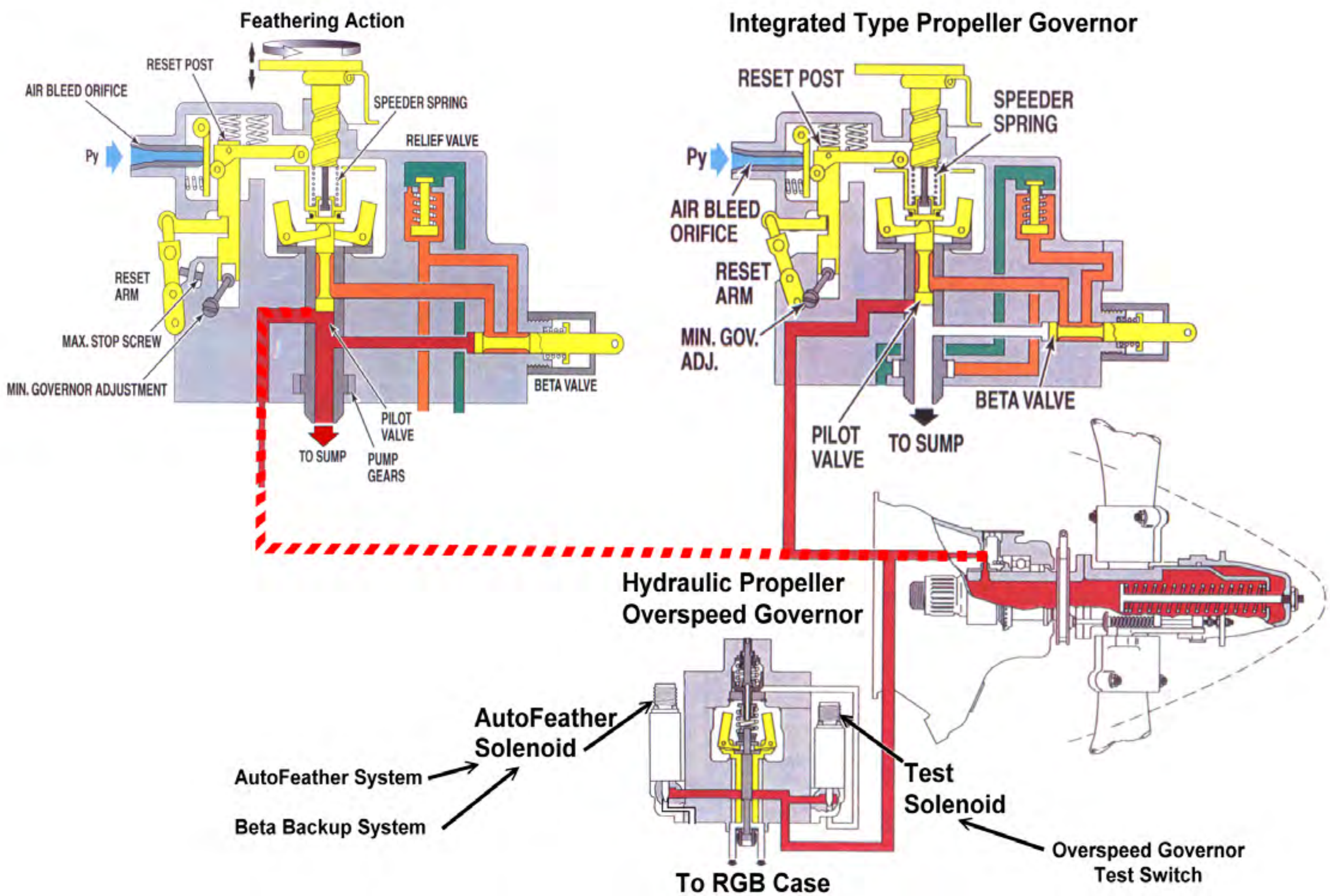
There are reasons for the Flight Idle Gate – this is one of them.

Fuel Topping Governor Nf Operation



Hydraulic Overspeed Governor In Underspeed

Integrated Propeller Governor with Independent Hydraulic Overspeed Governor



Hartzell Propellers – *Manufacturers Description*

Feathering and Reversing Propellers
HC-(D,E)(4,5)( )-3( ) Series

The propellers described in this section are constant speed, feathering and reversing.

They use a single oil supply from a governing device to hydraulically actuate a change in blade angle.

The propellers may have four or five blades and are used primarily on Pratt & Whitney turbine engines.

A two piece aluminum hub retains each propeller blade on a thrust bearing. A cylinder is attached to the hub and contains a feathering spring and piston. The hydraulically actuated piston transmits linear motion through a pitch change rod and fork to each blade to result in blade angle change.

While the propeller is operating the following forces are constantly present, 1) spring force, 2) counterweight force, 3) centrifugal twisting moment of each blade and 4) blade aerodynamic twisting forces. The spring and counterweight forces attempt to rotate the blades to higher blade angle while the centrifugal twisting moment of each blade is generally toward lower blade angle. Blade aerodynamic twisting force is generally very small in relation to the other forces and can attempt to increase or decrease blade angle.

Summation of the propeller forces is toward higher pitch (low RPM) and is opposed by a variable force toward lower pitch (high RPM). The variable force is oil under pressure from a governor with an internal pump that is mounted on and driven by the engine. The oil from the governor is supplied to the propeller and hydraulic piston through a hollow engine shaft.

Increasing the volume of oil within the piston and cylinder will decrease the blade angle and increase propeller RPM.

Decreasing the volume of oil will increase blade angle and decrease propeller RPM. By changing the blade angle, the governor can vary the load on the engine and maintain constant engine RPM (within limits), independent of where the power lever is set. The governor uses engine speed sensing mechanisms that allow it to supply or drain oil as necessary to maintain constant engine speed (RPM).

If governor supplied oil is lost during operation, the propeller will increase pitch and feather. Feathering occurs because the summation of internal propeller forces causes the oil to drain out of the propeller until the feather stop position is reached.

Normal in-flight feathering is accomplished when the pilot retards the propeller condition lever past the feather detent. This allows control oil to drain from the propeller and return to the engine sump. Engine shutdown is normally accomplished during the feathering process.

Normal in-flight unfeathering is accomplished when the pilot positions the propeller condition lever into the normal flight (governing) range and restarts the engine. As engine speed increases, the governor supplies oil to the propeller and the blade angle decreases.

In reverse mode of operation, the governor operates in an underspeed condition to act strictly as a source of pressurized oil, without attempting to control RPM. Control of the propeller blade angle in reverse is accomplished with the beta valve.

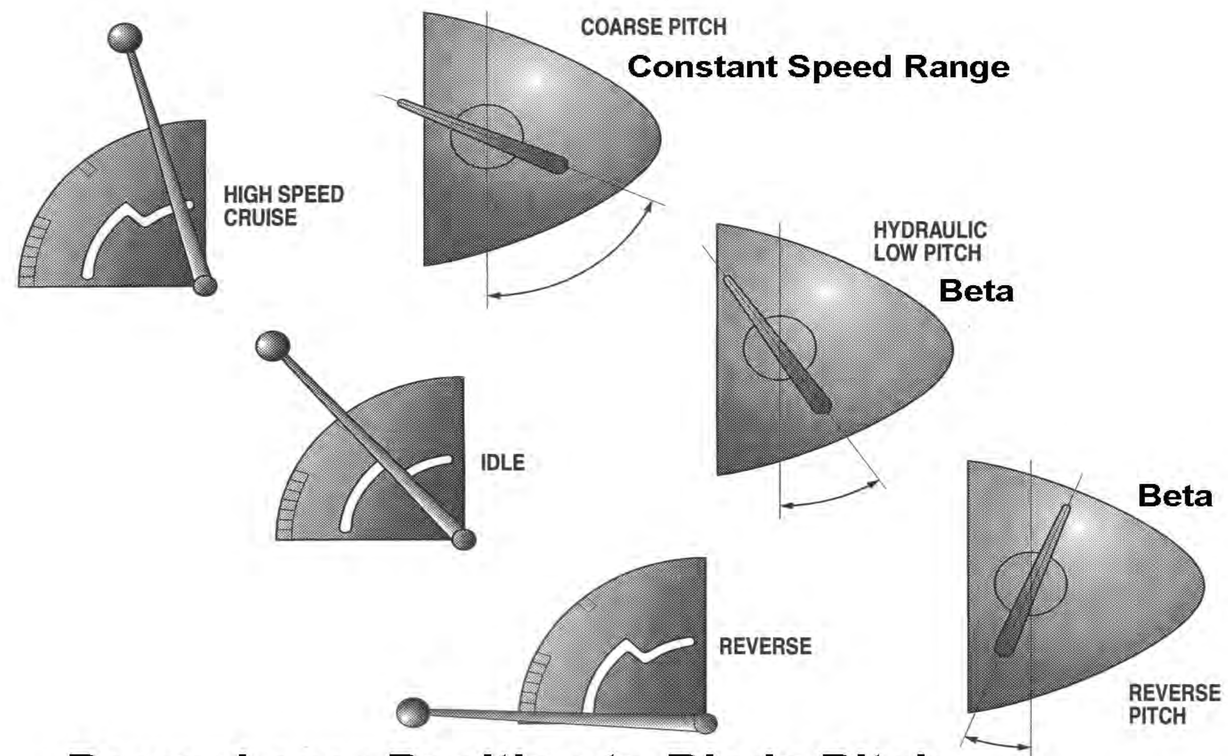
Note: The beta valve is normally built into the base of the governor.

The propeller is reversed by manually repositioning the cockpit-control to cause the beta valve to supply oil from the governor pump to the propeller.

Several external propeller mechanisms, which include a beta ring and carbon block assembly, communicate propeller blade angle position to the beta valve.

When the propeller reaches the desired reverse position, movement of the beta ring and carbon block assembly initiated by the propeller piston, causes the beta valve to shut off the flow of oil to the propeller.

Any additional unwanted movement of the propeller toward reverse, or any movement of the manually positioned beta valve control toward high pitch position will cause the beta valve to drain oil from the propeller to increase pitch.



Power Lever Position to Blade Pitch

Typical Engine Start to Idle

Engine Controls set to the start configuration.

Power lever at the Flight Idle stop.

Fuel Condition Lever in “Cutoff” Position.

Propeller control – normally set to 100% - some aircraft started with Propeller Control in Feather.

Fuel Pumps on as required.

Ignition switches on or start position.

Generator switches normally “OFF” - some systems allow starting with switches “On”.

Start Switch to “Start” position – some lock in position – some have to be held.

Gas generator rpm noted rising – prop slowly starting to rotate.

Condition Lever to the Low Idle position when start speed of gas generator obtained – typically 12 – 14% Ng.

Fuel flow indication – engine light-off – Ng increasing – monitor rate of speed change and watch ITT.

Normal start accomplished – no limits exceeded, starter switched off at correct speed.

Engine Idle – *at the Flight Idle Gate*

On the acceleration of the engine to idle; if the propeller control is set to the 100% position the propeller has / will come out of feather with the rotation of the power section.

Since the Power Lever is at the flight idle gate the propeller will unfeather into a high blade angle with the movement of the propeller piston.

Since the propeller is in an underspeed condition relative to the 100% Np selected the propeller piston will continue to move until the Beta Nuts are contacted by the piston linkage. Further movement with the servo piston contacting the beta nuts will pull the slip ring forward.

As the slip ring moves forward it pulls on the brush block end of the walking beam.

This action pulls forward on the Beta Valve which at a predefined point will control the governor oil pressure / flow and maintain the Flight Idle Blade Angle on the propeller blades.

After start and unfeathering of the propeller the engine is running at low idle with the propeller blades at flight idle angle.

Engine Power from Flight Idle to Max Power

Advancing the Power Lever from the Flight Idle position simultaneously increases the fuel flow schedule of the Fuel Control Unit (FCU) and progressively increases the propeller blade angles by moving the control end of the walking beam.

This action initially moves the Beta Valve out which reduces the flow to the propeller piston and allows the pressure to drain – the springs, ATM, and Counterweight Force move the blades towards the feather stop.

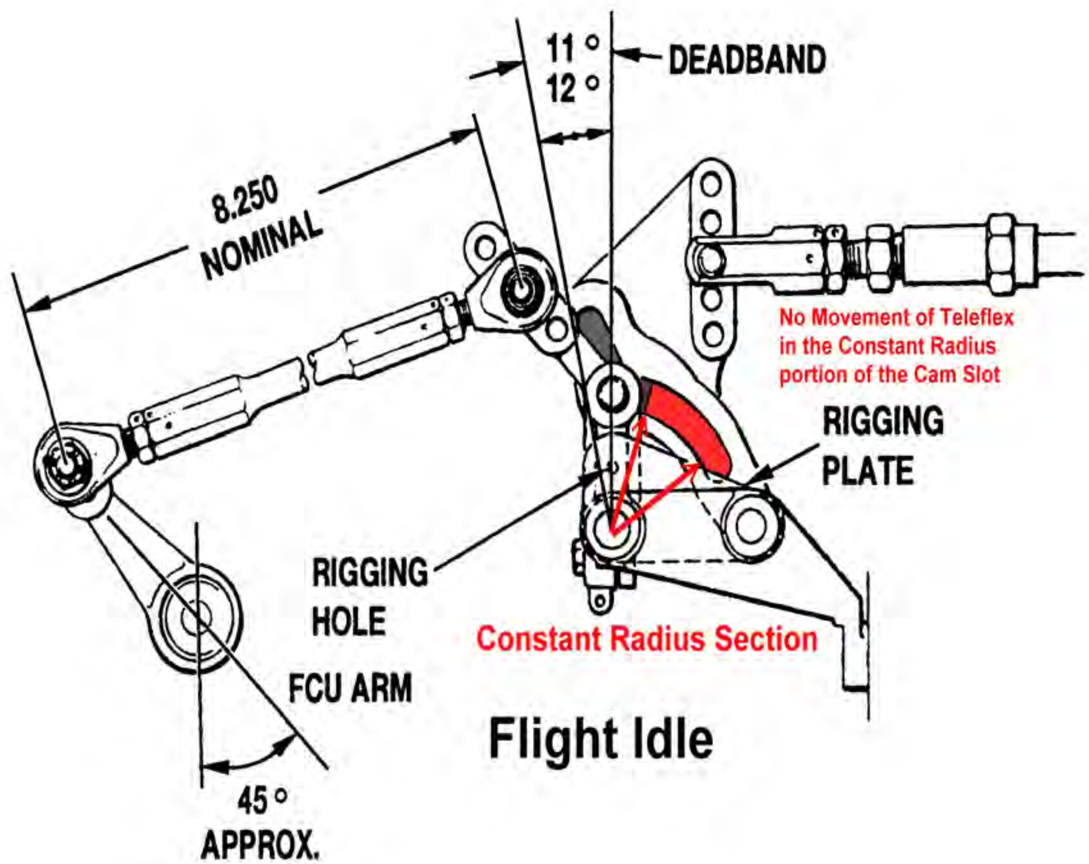
At a designed point (Just forward of the Flight Idle Blade Check (Primary Blade Angle Check) point the Cambox enters into a constant radius portion of the slot and no further movement of the walking beam is possible.

Further movement of the Power Lever will add more fuel flow to the engine and the propeller will increase to the 100% Np speed.

Further additional movement / power will cause the Constant speed Unit to regulate the blade angle to maintain a maximum of 100% Np.

As the Power Lever is pushed forward the engine torquemeter will register the torque applied to the reduction gearbox and propeller.

Monitoring the torque and propeller speed will determine the horsepower the engine is developing.



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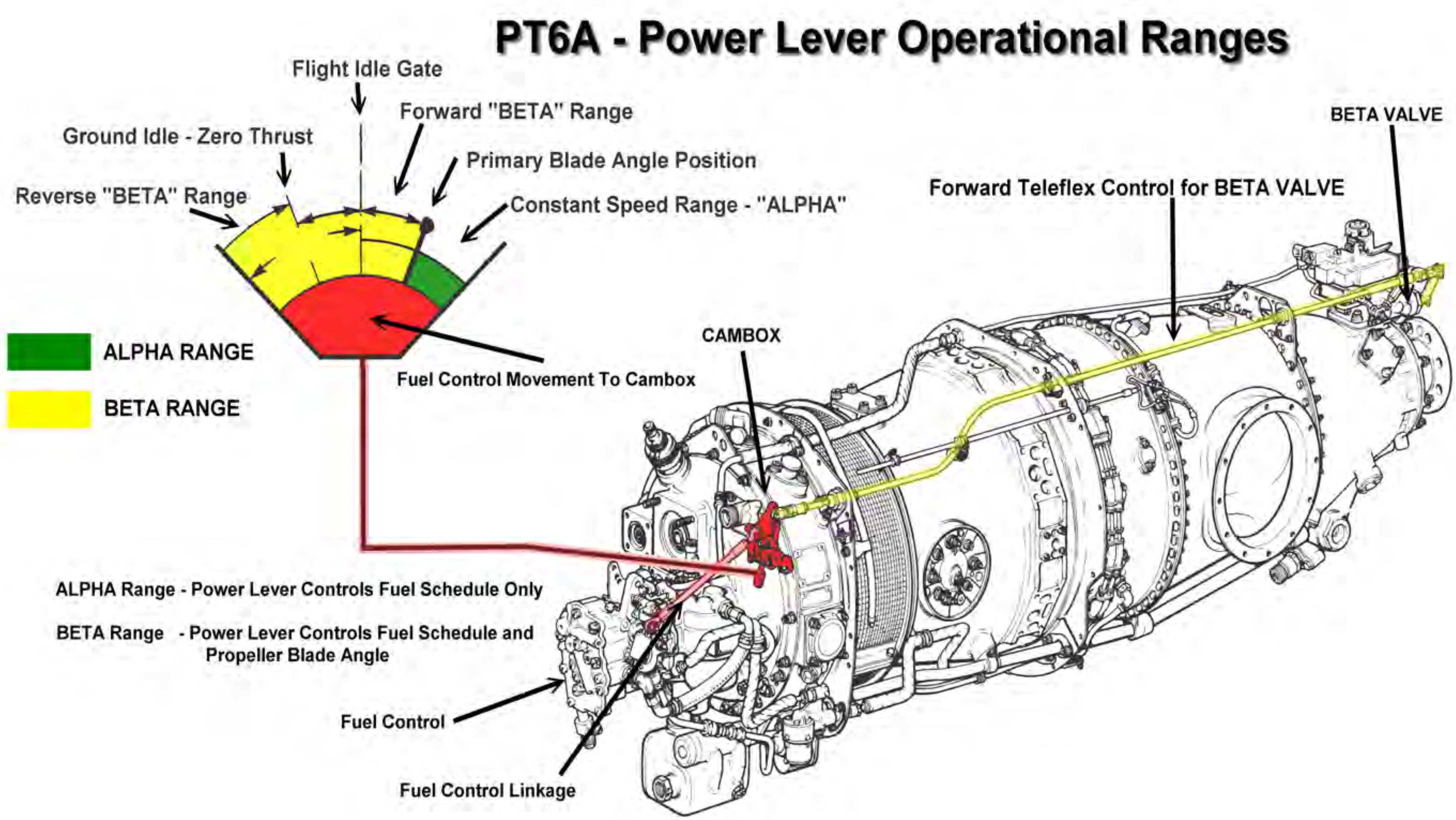
Flight Idle – to Max Power



Constant Speed Range (Alpha Range)

Once we are out of the Beta range we have entered the constant speed range sometimes referenced as the Alpha Range.

In this range the engine is operated like any constant speed engine with power (Ng Speed) being set by the Power Lever and Propeller speed (Np) being controlled by the CSU as selected by the Propeller Control Lever.

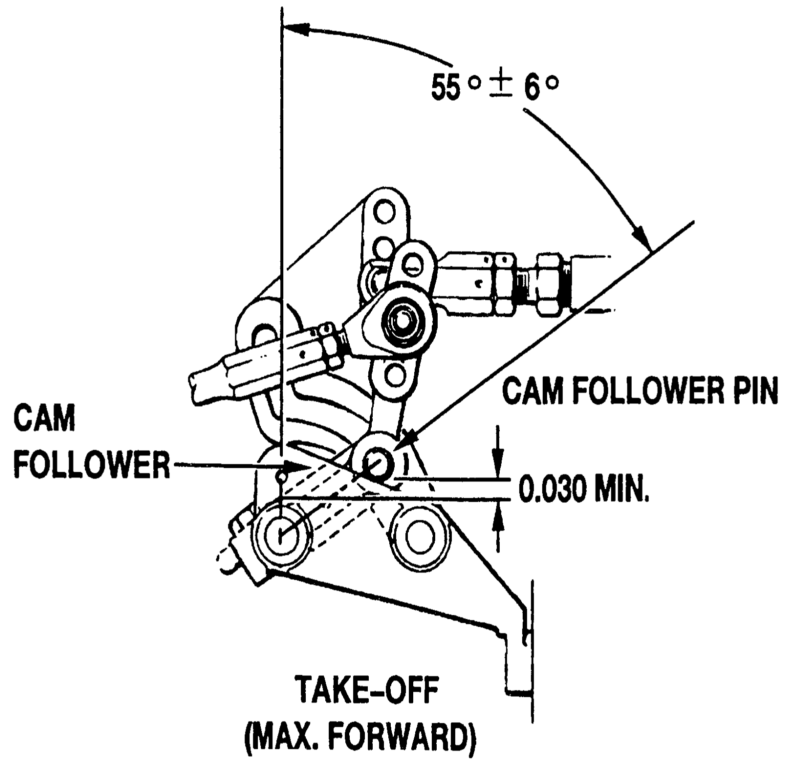
In this range the propeller speed can be controlled from 100% to about 70%Np.

In the Alpha Range the Gas Generator Speed is being selected by the Power Lever position. Ng is governed by the flyweight governor inside the FCU.

The propeller speed Np is being governed normally by the CSU portion of the Propeller Governor.

Should a malfunction occur there are 2 systems that automatically limit the propeller speed.

The Fuel Topping Governor will operate at about 10% above the propeller speed lever setting.



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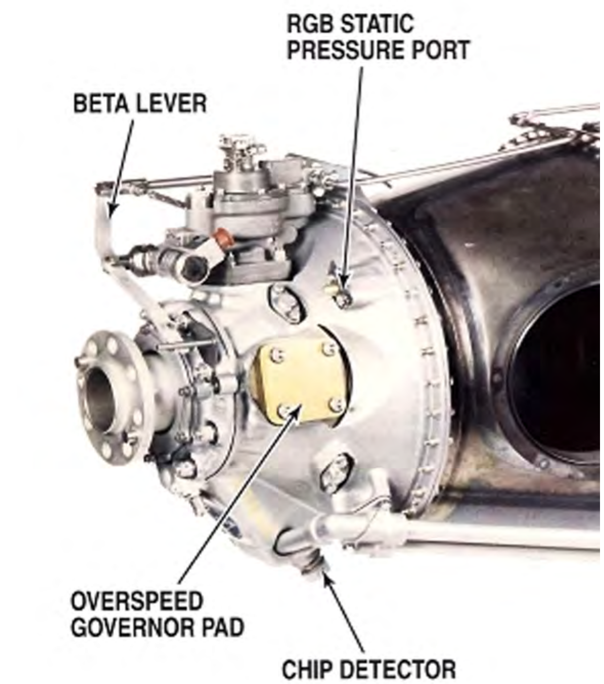
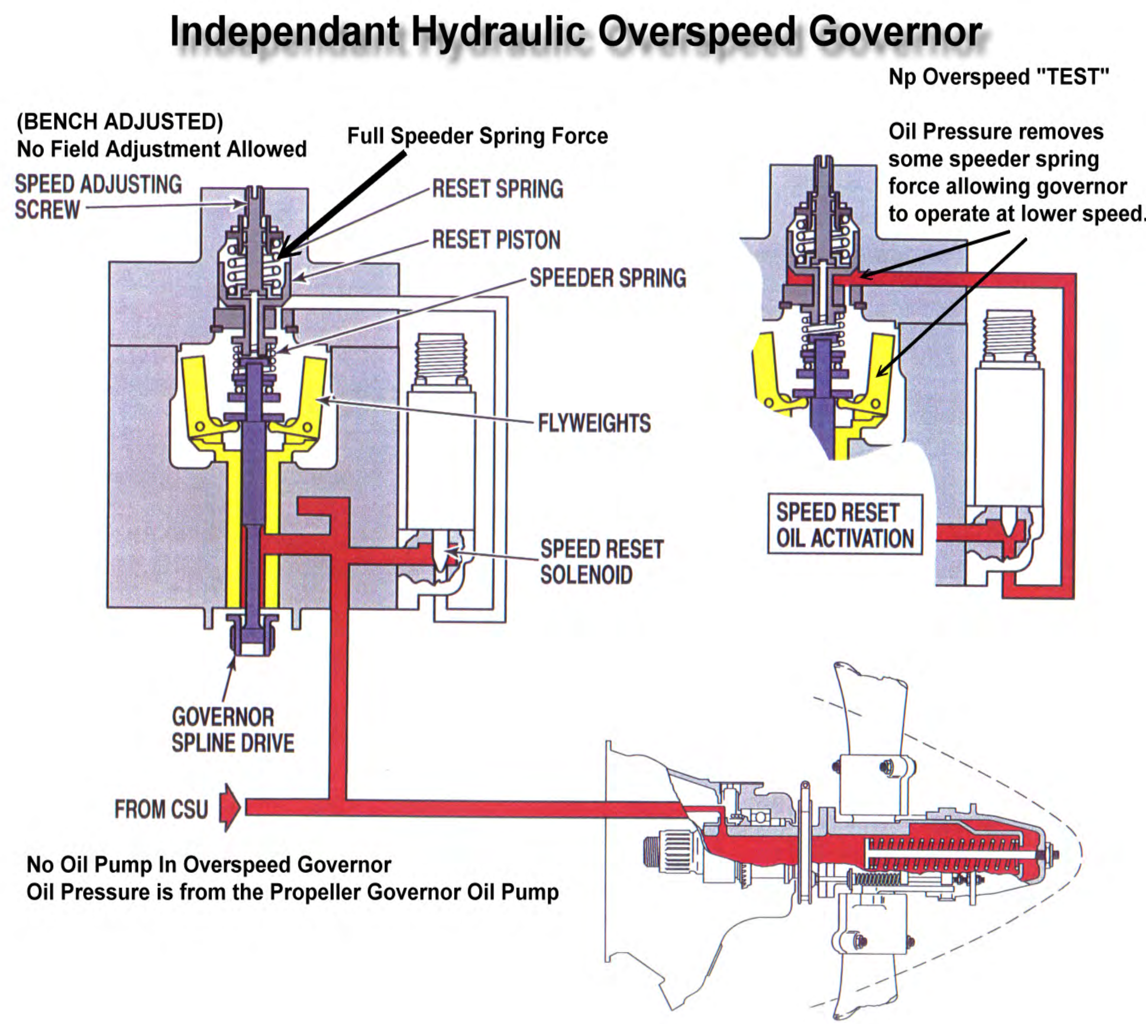
Hydraulic Overspeed Governor

A further backup system in the form of a completely separate stand-alone governor, the Hydraulic Overspeed Governor is preset to operate at about 106% Np.

This completely independent governor sits on it's own drive pad on the left side of the engine.

Under normal operation this governor will never operate.

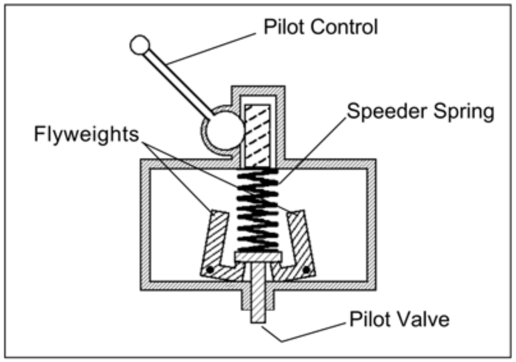




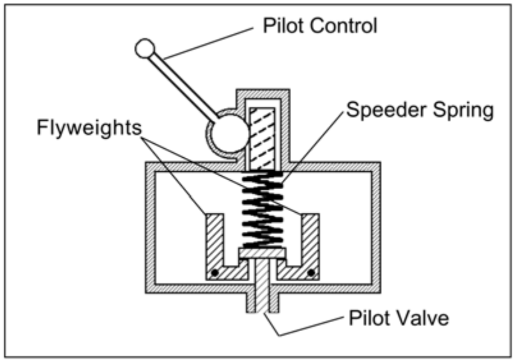
The constant speed section of the propeller governor consists of the flyweight assembly that is mechanically driven from the propeller gear reduction box drive shaft through the governor oil pump used to deliver the high pressure required to move the blades against the springs, counterweights, and ATM.

Inside the rotating drive shaft is a spool type valve – referred to as the pilot valve – that moves up and down in the ported shaft.

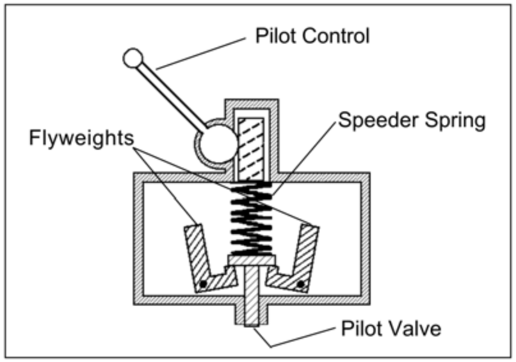
The valve is positioned to allow more flow/pressure to the propeller (Underspeed Condition) or to block the flow (Onspeed Condition) or to restrict the flow / dump oil pressure back to the reduction gearbox. Overspeed Condition).



Governor in Underspeed Condition



Governor in Onspeed Condition



Governor in Overspeed Condition

Propeller Lever Speed Control in Constant Speed Operation

In the constant speed mode with the power lever set – a backwards movement of the propeller control lever will cause the propeller speed to decrease – and the torque to increase. There is no appreciable effect on the gas generator speed due to the free turbine design of the engine. Moving the propeller lever forward would result in an increase of propeller speed and a decrease in torque.

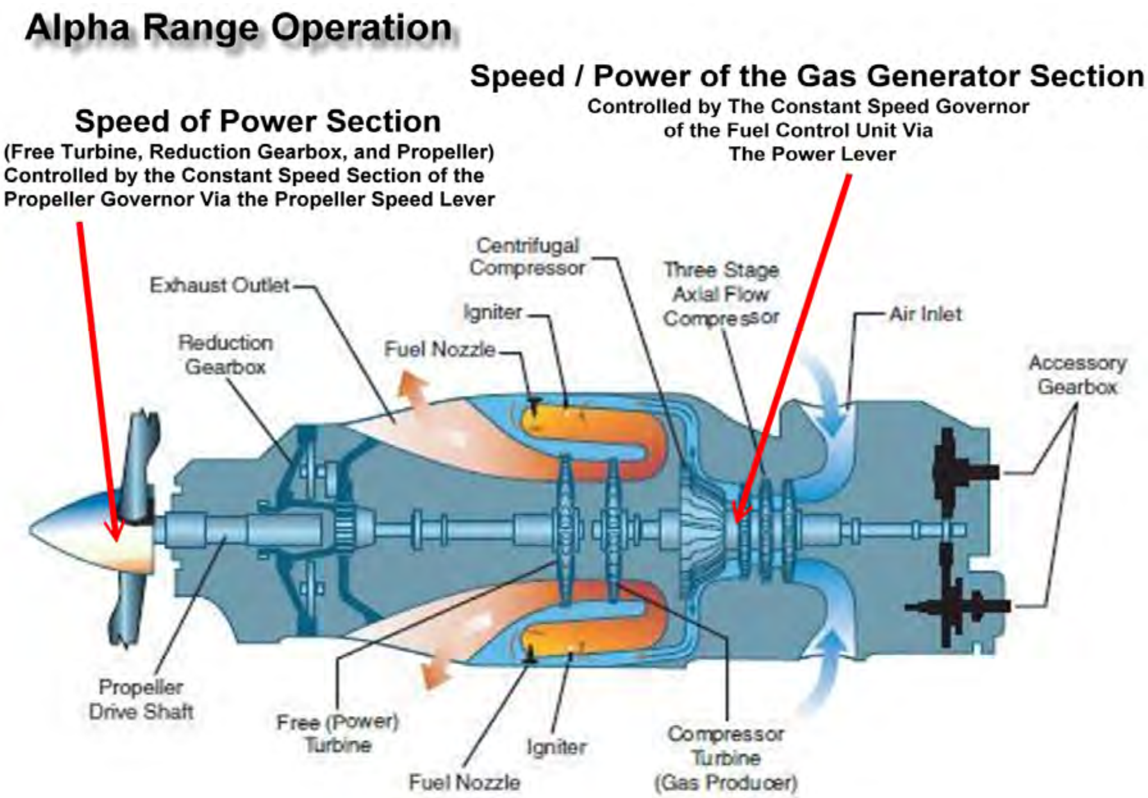
In the constant speed mode with the propeller lever set to give a specific propeller speed advancing the power lever would result in an increase in gas generator speed (Ng) – no increase in propeller speed (Np) – and an increase in torque. A reduction of the power lever will give us the opposite – less Ng – Less torque – but Np remains constant.

Outside of the constant speed range things happen differently.

During constant speed operation the beta valve is held in the open position by the rigging geometry of the linkage.

Constant speed power lever operation does not input movement into the beta valve system. This is due to the geometry of the cam slot on the cam box mixing lever.

During operation in the alpha mode the power lever is free to move in the cam slot – but due to the constant radius of the forward portion of the slot it does not input any movement to the teleflex control to the beta system walking beam.



Alpha Range Exits

There are 2 normal methods of exiting the alpha range;

The first is to retard the power lever towards the flight idle position far enough to reach the end of the constant radius slot and begin to move the linkage to the beta valve. At this point you will have also reduced the fuel flow that sitting on the ground would be below the 100% prop governor setting and the propeller governor would now be in an underspeed condition. We have now transitioned into the beta range.

In the air things can happen a bit differently – since the forward airspeed of the aircraft can drive the propeller the constant speed unit will maintain the propeller speed at what it is set at. With forward speed and the propeller control aft of the 100% stop the retarding of the power lever will reduce the fuel flow but the propeller speed will still constant speed until the lever is pulled far enough aft that the beta valve closes sufficiently to restrict / dump high pressure governor oil which will move the blades towards higher blade angles. Once the blades move the linkage system will contact the beta nuts and further forward movement will cause the slip ring / beta brush arm to move forward. When the brush block arm moves sufficiently it will “Reset” the beta valve position to allow just the right amount of oil into the propeller to maintain the selected (by the Power Lever) propeller blade angle. More to follow when we investigate the Beta Range.

The other way to exit Alpha range is to feather the propeller. Feathering the propeller is accomplished manually by moving the propeller control fully aft – through the detent - into the feather position.

Normal shutdown procedure is to move the Power Lever to the flight idle stop before feathering so as to not overtorque the propeller and gearbox. However this is not a locked process – meaning that at full power you could manually feather the engine and cause huge amounts of damage.

The movement fully aft of the Propeller Control mechanically operates the pilot valve or an external hydraulic valve that opens and dumps governor high pressure oil back to the case.

On some aircraft an “Auto-Feathering” system is installed. This system looks at the power being produced by the engine and at a specific very low setting indicative of an engine failure it will feather the engine through an electric solenoid designed to dump governor high pressure oil back to the reduction case.

On many aircraft a “Opposite Side Protection” system is installed. This disables the auto-Feather system on the other engine thus preventing a double engine failure due to a malfunctioning autofeather system.

Aircraft can have auto-feathering with application of the fire bottle discharge.

Aircraft can have “Power Uptrim” on the opposite engine when autofeathering. This makes more power available if required on the remaining engine(s).

Constant Speed Unit Failure Modes

Failed input drive – no rotation of the high pressure pump – springs, counterweights, and ATM move propeller blades to the feather position. - Under this condition the Nf (Fuel Topping Governor) will also be disabled.

Failure of the propeller to respond to governor commands – if speed goes above 104-106% Np the hydraulic overspeed governor will dump governor high pressure oil to maintain 105 – 106% - this is effective if the system will allow the blades to be moved. Depending on the failure mode – if the flyweight governor is still operational the propeller speed will increase to about 10% higher than the propeller control is set and the fuel topping governor will modify the fuel control unit (FCU) fuel flow to limit the propeller speed. Under this condition moving the power lever forward in an attempt to increase power will have no effect due to the controlling nature of the fuel topping governor.

Operation of the Hydraulic Overspeed Governor

The hydraulic overspeed governor is a redundant safety system install to ensure safe operation of the engine should the constant speed governor fail.

If oil pressure is available and propeller control is not compromised the hydraulic overspeed governor will operate at a higher speed setting (prevents interference) than the constant speed governor. The governor is physically mounted on a different drive pad and is adjusted for correct operation on a propeller test stand. It is not field adjustable like the constant speed governor. For most of it's life it just sits there doing nothing.

Testing the Hydraulic Overspeed Governor

Since this governor is set (Non-adjustable) higher than the constant speed governor we have no way to test it's operation under “Normal” operation. We can however test the governor on the ground by a special procedure. With the engine running at idle – set the Propeller Speed Control Lever to the full forward (100%) position. Locate the “Propeller Overspeed Governor Test” switch and select to the “TEST” position. Maintaining the switch in the TEST position advance the power lever until the propeller constant speeds. This will happen at a much lower value than the 100% setting on the Constant Speed Governor. The propeller is now constant speeding on the Hydraulic Overspeed Governor.
What happens when we select the TEST position is we send a control voltage input to the “Reset Solenoid” on the Hydraulic Overspeed Governor. This allows governor oil pressure to be applied against the full spring pressure and reduced the total spring pressure of the speeder spring in the overspeed governor. This has the effect of reducing the governing speed – to a value below the 100% setting of the constant speed governor.

Make sure you keep holding the switch to the TEST position and reduce the power by the power lever back to flight idle setting. Allow the switch to reselect the “Normal” position and then to ensure the solenoid has closed run the power lever up and check the constant speed operation of the propeller governor. This ensures the overspeed governor is not interfering with the operation of the propeller constant speed governor. Yes it has happened so do the check!!

Fuel Topping Governor Speed Test

The only operational test of the Fuel Topping Governor is to check the propeller speed in full reverse. It must not exceed the book value – maximum of about 94 – 95%Np.

Maintenance Test – Fuel Topping Governor System

Operation of the Fuel Topping Governor System – but not the actual governor can be accomplished by removing the FCU Bleed line at the Propeller Governor.

With the line uncapped – open – the FCU should roll all the way back to the Minimum Flow configuration. This engine speed is slightly below normal low idle speed.

Sometimes this test is done to determine if the propeller governor has a fault that is causing the bleed of FCU control pressure when there should be none. In this case the engine appears to be fuel limited – in other words the engine will not produce rated power – and fuel flow is low and ITT is low.

With a defective fuel topping section (ie Leaking Valve) the removal and capping of the line will isolate the bleed source and the engine parameters will return to normal. Just remember with the line disconnected you do not have Fuel Topping Governor protection!!

Maintenance check for the operation of the fuel topping governor is to remove the linkage from the propeller governor fuel topping reset arm and secure in the “REVERSE” position with locking wire. Run the engine and the proper operation of the fuel topping governor is that it should limit the Np at about 5 – 6% less than that selected for the constant speed governor.

The above 2 tests should indicate that you have a fully working system.

Constant Speed (ALPHA) mode to Full Reverse Mode

In order for us to go to full reverse we need a couple of things that are pre-set.

The first is that we must have the Propeller Governors set to the 100% - full forward position.

This is for 2 reasons – the first is that we always need the Constant Speed Governor in an underspeed condition to give unrestricted access for the Beta Valve. The second is it keeps the propeller speed up in the event of a rapid application of power – like for a missed approach / go-around.

This keeps cockpit workload to a minimum and prevents sluggish engine performance. It is so important that some aircraft have a mechanical interlock between the propeller control lever and the power lever gate release.

Without the propeller lever being fully forward it is not possible to move the power lever through the flight idle gate. Other aircraft simply have a warning annunciation to remind the flight crew.

As we move the power lever aft towards the flight idle position we transition from Alpha Range to Beta Range.

Once below the transition point further movement of the power lever controls both the fuel schedule and the propeller blade angle through the walking beam and Beta Valve operation.

Operation in this range from the transition point to the flight idle gate is “Forward or Air BETA Range”

On some aircraft we have a further system blocking the entry past flight idle. This is often a configuration system that basically tells the system that the aircraft is on the ground. It can consist of landing gear switches and or flap position switches / interconnects.

Once the aircraft is “On The Ground” the gate is released and the Power Lever is free to transition towards reverse.

On the way to reverse the engine will transition through the “Idle Dwell” and the “Ground Fine position.

All movement of the power lever in this direction is BETA – some aircraft manufacturers call the range from Ground Fine / Zero Thrust to full reverse “Beta Plus”. Beta Plus simply means beta in reverse Plus added power.

Idle Dwell Range

As we come back from the flight idle gate we enter a range where the fuel flow is at a minimum and does not change even though the blade angle is changing. This range is called the “Idle Dwell”. Typically it is about +3 to -3 degrees of propeller blade angle and right smack in the middle of it is “ZERO PITCH”. This may also be the “GROUND FINE” position but doesn't have to be. The engine / propeller combination makes a distinctive noise when transitioning through the Idle Dwell range that is often referred to as “DISKING”. It is a unique sound that once heard is easy to remember.

Further movement of the Power Lever rearward will Cause the propeller blades to enter the “REVERSE BETA RANGE.

Depending on which cam box assembly you have installed on the aircraft you can have one of the following conditions. Some aircraft are restricted to amount of power produced in revers due to aerodynamic or airframe strength limitations.

Quiet Taxi Cam

The full movement of the power lever to reverse does not significantly increase the propeller speed.

Normal Cam

The full movement of the power lever to reverse adds power in a linear format and is often less than full power available.

STOL Cam

The full movement of the power lever to reverse adds power up to the full control of the fuel topping governor.
This is very effective but very noisy.

Again the fuel topping governor is reset on the way to reverse by the reset linkage on the Propeller governor. This changes the position of the fuel topping governor “TopHat” and allows the Fuel topping governor to operate at about 5 – 6% less speed than the constant speed governor. Thus the reset lever ensures the constant speed governor is isolated and does not interfere with the operation of the BETA system.

Once again – if the constant speed governor, the hydraulic overspeed governor, or the feathering valve was to operate to dump high pressure governor oil (Overspeed Condition for the governors – inadvertent opening of the feather valve) the decrease in oil pressure to the propeller piston assembly would allow the springs and counterweights to move the blades towards the feather position. The problem here is that we have a power loaded propeller with about 12 or so degrees of negative pitch that suddenly has the blades move towards feather which until the blades transition to about 12 degrees positive pitch are going to unload the propeller. The resulting overspeed may not be contained causing serious damage and possible blades / engine disintegration. Any malfunctioning of the propeller governor should be treated as a very serious condition. It is possible for the dual constant speed governor / fuel topping governor to have a failure that may not be serious in the forward flight mode but be deadly once in reverse.

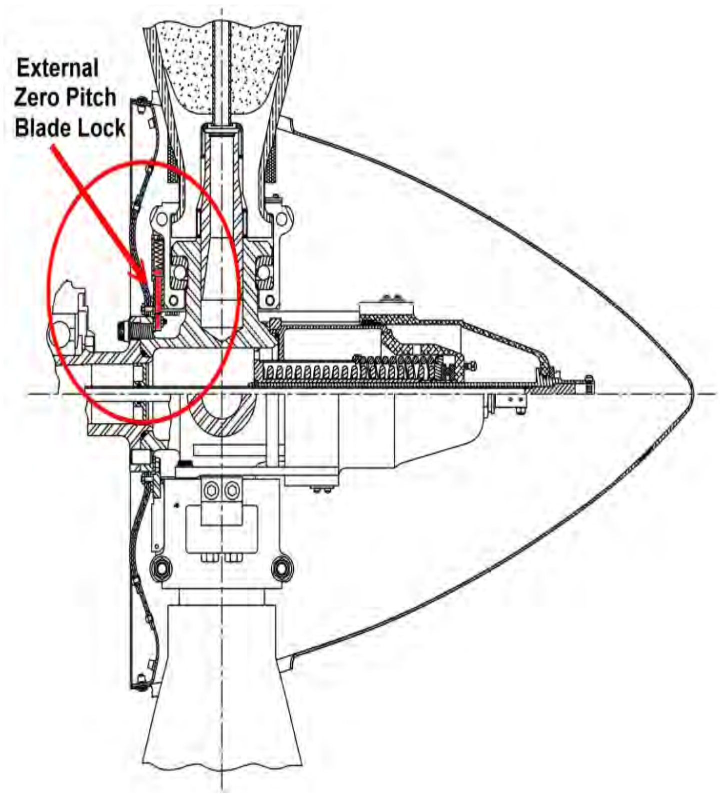
Engine Shutdown

Return the power lever to the flight idle gate before shutdown and allow the engine to stabilize before pulling the fuel condition lever through the shutoff gate. Monitor for a clean shutoff by fuel flow cut and the sound of the engine stopping.

Some aircraft want you to feather the propeller before shutdown – others don't. Whatever the manual says is what you do.

Engine shutdown with "Zero Pitch Locks"

Some propeller assemblies are fitted with the zero pitch locks or latches. These are most often found on float equipped aircraft and the concept here is to start the engine at a zero thrust configuration so that you don't get a big surge forward when the prop comes out of feather on start-up.



Engine shutdown is simple in this case. Before pulling the fuel condition lever to the shutoff position you need to use the power lever to place the propeller blades a little bit in reverse.

When the engine is shutdown in this manner you maintain the slight backwards force on the power lever and as the propeller slows down during the stop the centrifugal pins are spring loaded to the protruding position.

As the propeller oil pressure drops the feather springs will drive the blades towards feather but the latch pins are now in the way of the latch plates and the propeller bladed will be held in the zero thrust position.

Beta Backup System

Some aircraft have an electrical system designed to prevent the propeller blades from entering the range below Flight Idle Blade Angle.

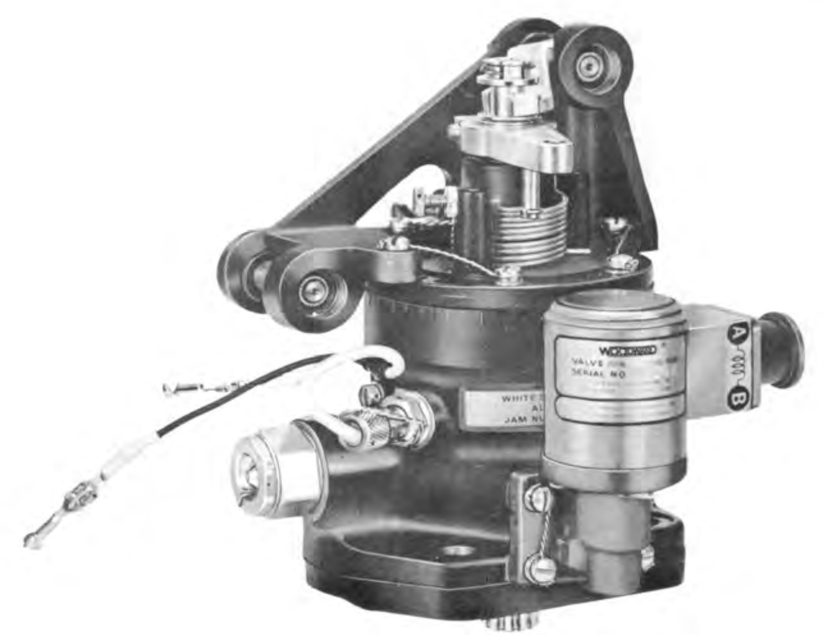
Simple system – switches on the power lever to tell the system the power lever is at Flight Idle or above and a set of blades switches that tell the system when the blade angles are below the Flight Idle Blade Angle.

This mis-configuration system operates with a system malfunction such that the propeller blades being driven below the flight idle blade angle in flight will activate the blade switches and the system will activate an electrical solenoid on the propeller governor that blocks the flow of high pressure oil to the propeller piston thus preventing any further movement towards ground fine / reverse. Blade angle switches are adjusted to be operational just below the flight idle blade angle. In addition a warning light is illuminated on the flight deck.

Beta Backup System Test

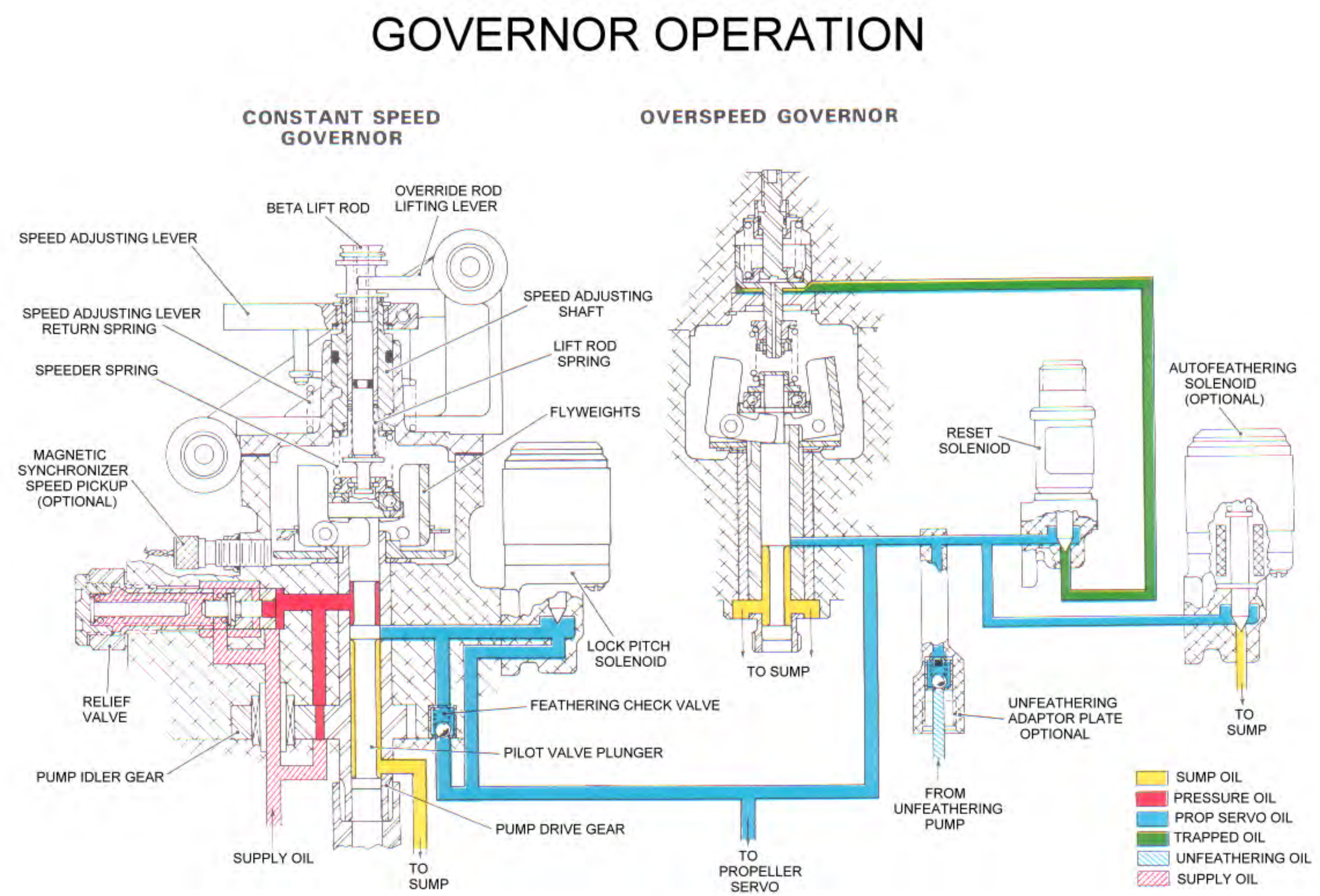
At low power – flight idle condition the Beta Backup TEST switch is activated – this sends a signal to the system to enter flight mode – but with the power lever switches inhibited.

Moving the Power Lever towards reverse a little bit will drive the blade angles below the flight idle switching point and the system will activate the lock pitch solenoid to prevent further movement of the blades. The system will cycle during the test as the high pressure oil to the propeller drops due to the leakage at the transfer sleeve and the blades are driven towards a higher blade angle.

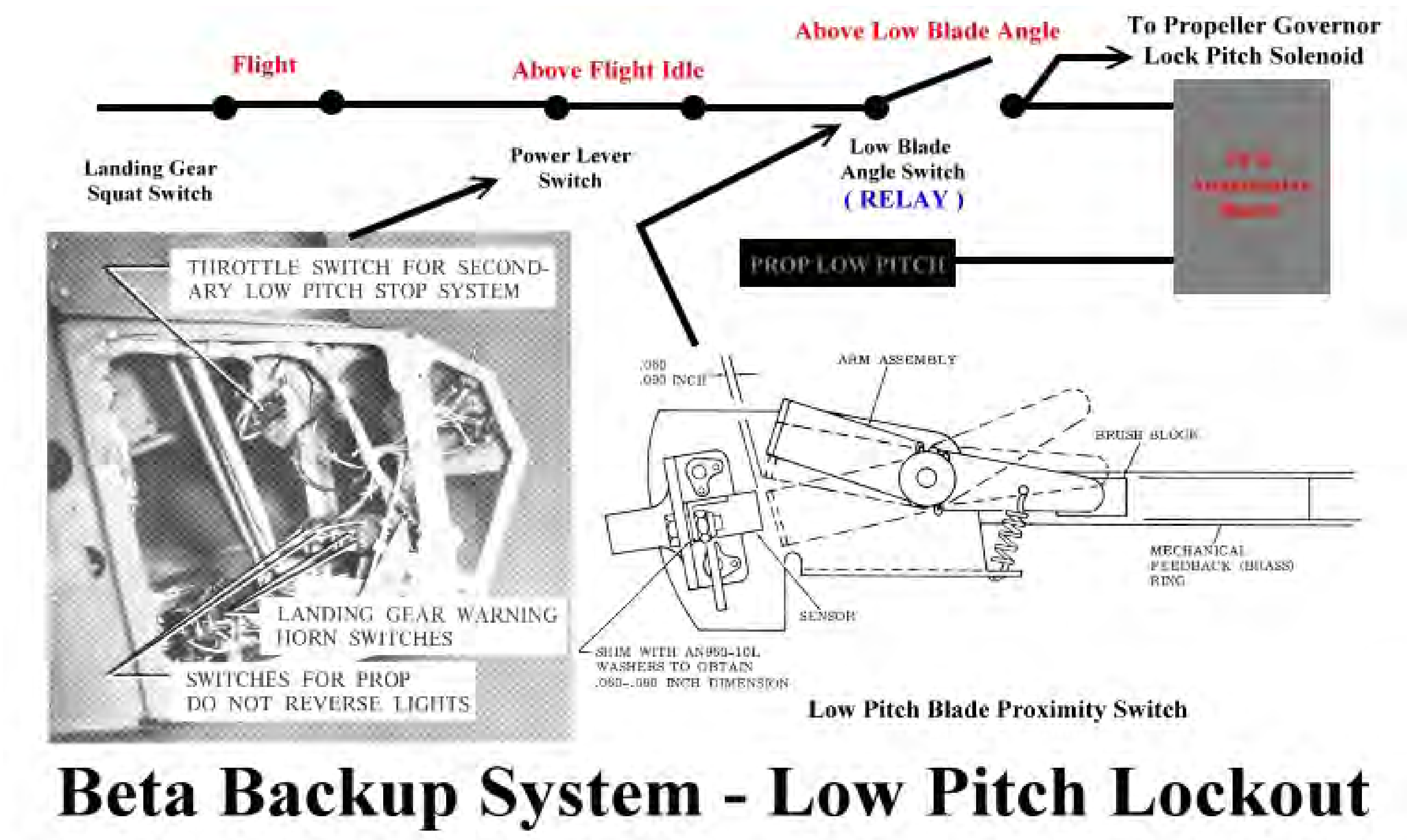


REVERSING GOVERNOR WITH MAGNETIC PICKUP AND LOCK PITCH SOLENOID

Early "Zed Gap" Type Governor With Lock Pitch Solenoid



Beta Backup System



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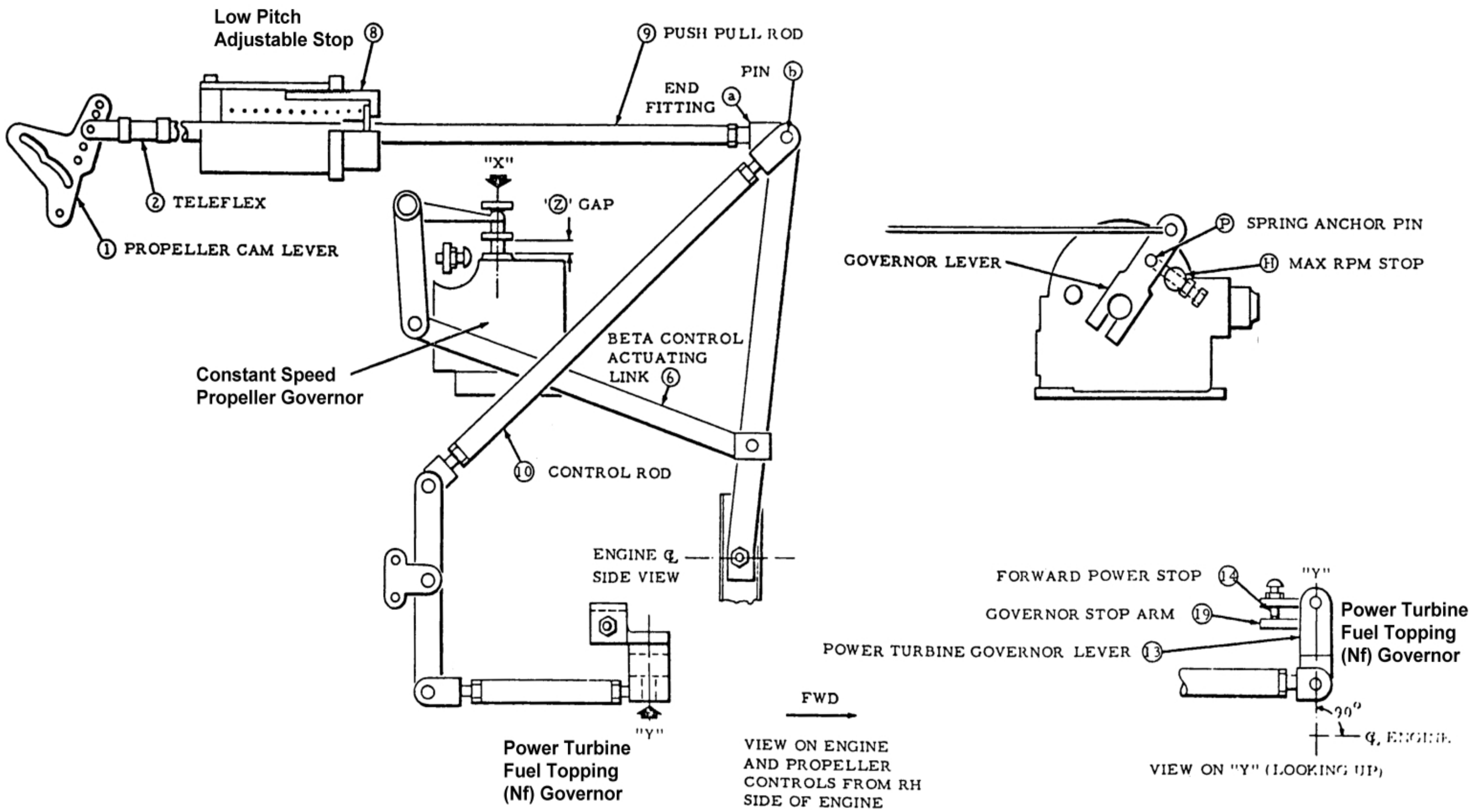
Early Zed Gap Governor System – Non Integrated Governor – *Reference Only*



UNDERSTANDING PRIMARY BLADE ANGLE TORQUE CHECK

Flight Idle Blade Angle

The most important blade angle setting on the PT6 propeller installation is the flight idle setting.

The flight idle angle on some engines can be physically measured using a blade protractor – and a source of hydraulic pressure being applied to the propeller system.

The fixed shaft TPE331 prop system has this capability as the installation require an auxiliary pump for operation of the propeller – often referred to as the “Unfeathering” pump as it's primary purpose is to place the propeller on the start latches if the propeller is in the feathered position before attempting a ground start and to be used to unfeather the engine while in flight for an air start.

Start Locks on the PT6

As the PT6 is a free turbine the propeller doesn't normally require a shutdown on start latches for a subsequent start. In fact the PT6 can be started with the propeller locked in position.

Start latches are used on float plane installations to prevent the aircraft lunging forward at the dock when the feathered blades move through the coarse / fine pitch positions to the zero pitch position.

Start latches are engaged by selecting the propeller slightly into reverse on engine shutdown and as the oil pressure available to the prop decreases so does the rpm of the propeller.

When the speed is reduced below a specific amount the centrifugal forces that keep the start lock in the retracted position is reduced and the spring force drive the locks to the extended position. The normal forces on the propeller – think big feathering spring – will drive the propeller blade angle towards feather but the start locks are now in the way only allowing the blade angle to move to the zero pitch position.

Other Engines "Using The Auxiliary Pump" To Set Flight Idle

On engine installations that have an auxiliary pump, the pump can be used on the ground – or an external pump connected to the system can be used to set the flight idle blade angle.

This is accomplished by energizing the pump – moving the power lever towards reverse to just move the blades off the start latches and then mechanically retract the latches so that the selection of the power lever to the flight idle position will allow the blades to move to the blade angle set by the rigging of the engine controls.

A propeller protractor set on the blade can now physically measure the angle and if incorrect the required control changes can be made to ensure the correct angle is achieved.

The aircraft pump can only be run for a short period of time before it will have exhausted the oils supply so when doing this check you need to be aware of the time limitation.

When using an external pump you will have a lot longer time frame – but you need to remember that you are dumping oil into the reduction gearbox that will have to be drained before the engine is started.

Since we do not have a pump installation on the PT6 this process will not be available to us.

Importance Of Having The Correct Flight Idle Blade Angle

The flight idle position of the Power Lever and the resulting propeller blade angle is critical.

It must be the same on both engines. (Yaw on landing if incorrect)

It establishes the correct "SINK RATE" of the aircraft for descent and the flare on landing.

It establishes the correct landing speed – blade angle too high – excessive speed – "Land Long". Blade angle too low – slow – possible to "Land Short".

It prevents a Low Blade Angle in flight that could cause excessive drag – resulting in structural overloads, and prevents a reduced airflow issue over the control surfaces. On some aircraft operating below the correct blade angle "Blankets the Tail" making directional control difficult.

The Primary Blade Angle Check Concept

When we look at the maintenance task of performing the primary blade angle check we are “Indexing” the power lever position – fuel flow – and propeller blade angle at the extreme forward end of the “BETA” range.

In order for us to fully understand what is taking place we need to re-visit some fixed pitch propeller theory and then apply this theory to our variable pitch condition.

Fixed Pitch Propeller Operation

A fixed pitch propeller is selected to absorb a specific horsepower.

The diameter is chosen and the correct blade angle is twisted into the blade.

The blade profile is selected to give the correct amount of solidity – ie. - “Paddle” blades are often shorter than a “Toothpick” blade profile.

Once designed we have no method of changing any of the parameters - thus the term “Fixed”

When I run an engine with a fixed pitch propeller on a standard day and input a specific horsepower the propeller will turn at a specific speed. Often the day is not “Standard” so pressure and temperature graphs are used to determin the correct propeller speed.

This concept will be applied to the PT6 when completing a primary blade angle check.

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The Primary Blade Angle Check Process

Some Unchanging items:

The diameter of the propeller doesn't change.
The blade profile doesn't change.
The Prime blade angle check is always done at a specific propeller speed.

A specific horsepower on the PT6 is developed with a specific gas generator speed and that gas generator speed is a function of power lever position.

Using the Primary Blade Angle Check Chart

We look at the chart and correct if required for non standard day conditions (Density Altitude) and determine what the “Target Torque” is for the existing conditions.

When we run the engine and advance the power lever to deliver the propeller speed required for the check we have indexed the power lever to the fuel control.

We now check to see what our torque reading is and this is important because we have a specific power being developed and the torque reading is a measure of the current blade angle of the propeller.

Typical Primary Blade Angle Chart for 3 Bladed Propeller

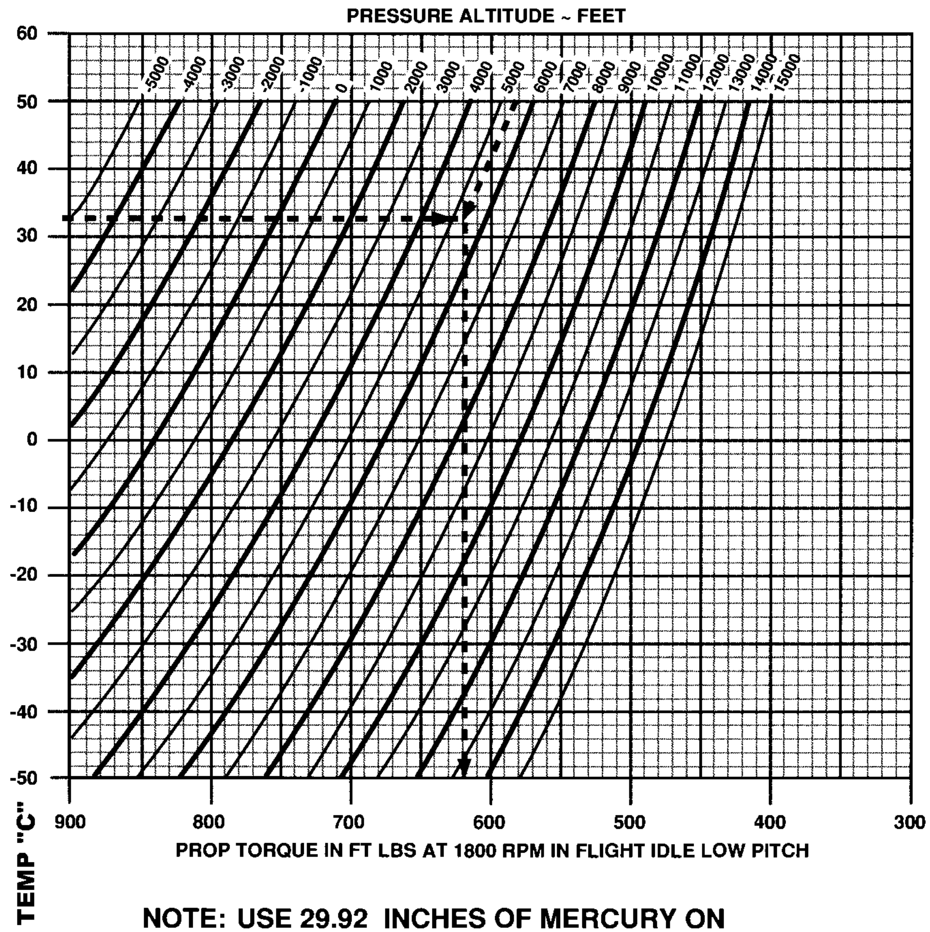
1 – Input Ambient Temperature
2 – Input Pressure Altitude
3 – From Chart Obtain Target Torque

4 – Run Engine – Set Propeller Speed Lever at 100% - Advance Power Lever to Obtain 1800 RPM on Propeller.

5 – Record Actual Torque Reading and Compare to Target Torque as calculated using the Graph.

6 – Shut down engine and adjust if required.

FOR 3 BLADED McCAULEY PROPELLER
SUBTRACT 50 LBS OF TORQUE



NOTE: USE 29.92 INCHES OF MERCURY ON ALTIMETER AND READ ALTITUDE TO OBTAIN PRESSURE ALTITUDE

Correcting Higher or Lower Torque Readings

If our torque is higher than the target torque then our blade angle is to great – we need to not how much too high the torque is and apply the corrective action to reduce the blade angle to obtain the the correct torque.

If our torque is lower than the target torque then our blade angle is too low – we need to note how much too low it is and apply the corrective action to increase the blade angle to obtain the correct torque.

Moving the Power Lever to The Flight Idle Gate

Once we have the torque correct for the day's condition when we move the power lever to the flight idle we will “REINDEX” the blade angle to the correct value for the installation.

Remember that the Prime Blade Angle Check is done in beta – where we are hydraulically controlling the blade angle through the beta valve and the feedback ring/carbon block assembly.

Moving the power lever to the flight idle gate will decrease the propeller blade angle by the specific amount determined by the rigging geometry of the cambox at the back of the engine.

Now we have the correct flight idle propeller blade angle.

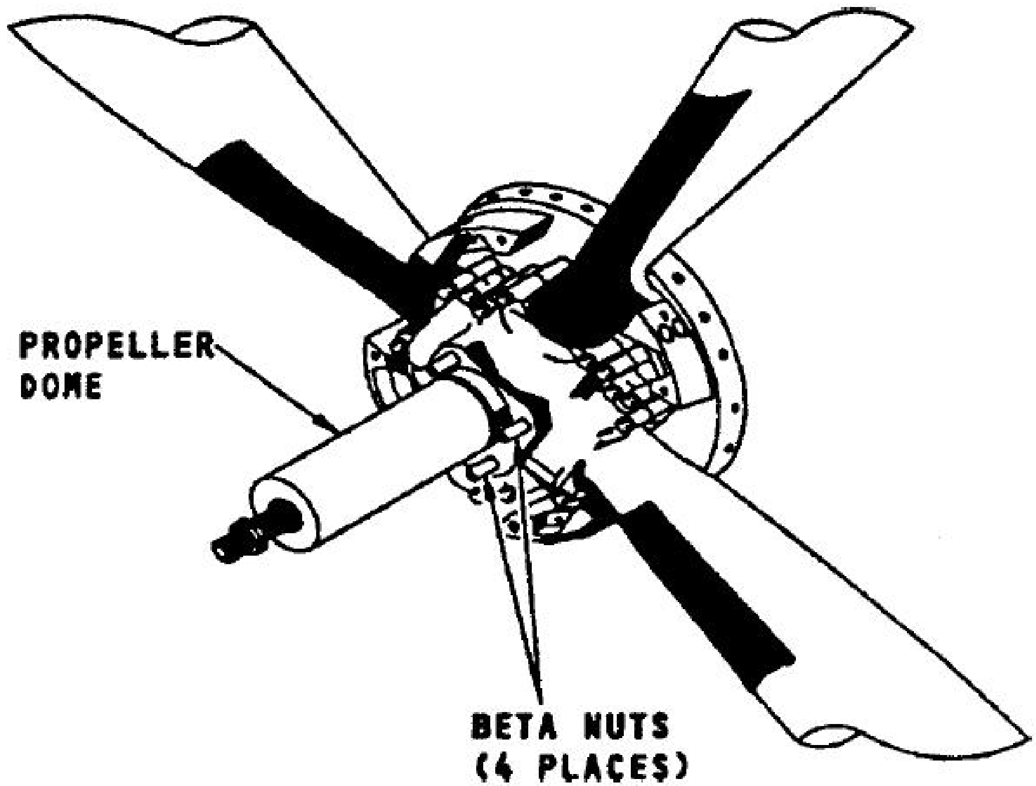
Propeller Changes And Modifications Affect The Primary Blade Angle Check

When a different propeller or a different cambox is installed the values for the primary blade angle check will change.

It is very important that the modification documents are consulted to obtain the correct values and method of adjustment for the system actually installed on the aircraft.

Changing Primary Blade Angle Torque bu Adjusting the Beta Nuts

It is important to adjust the Beta Nuts in small increments – ie 1 flat at a time – and to do all blades equally.



BETA NUT ADJUSTMENT

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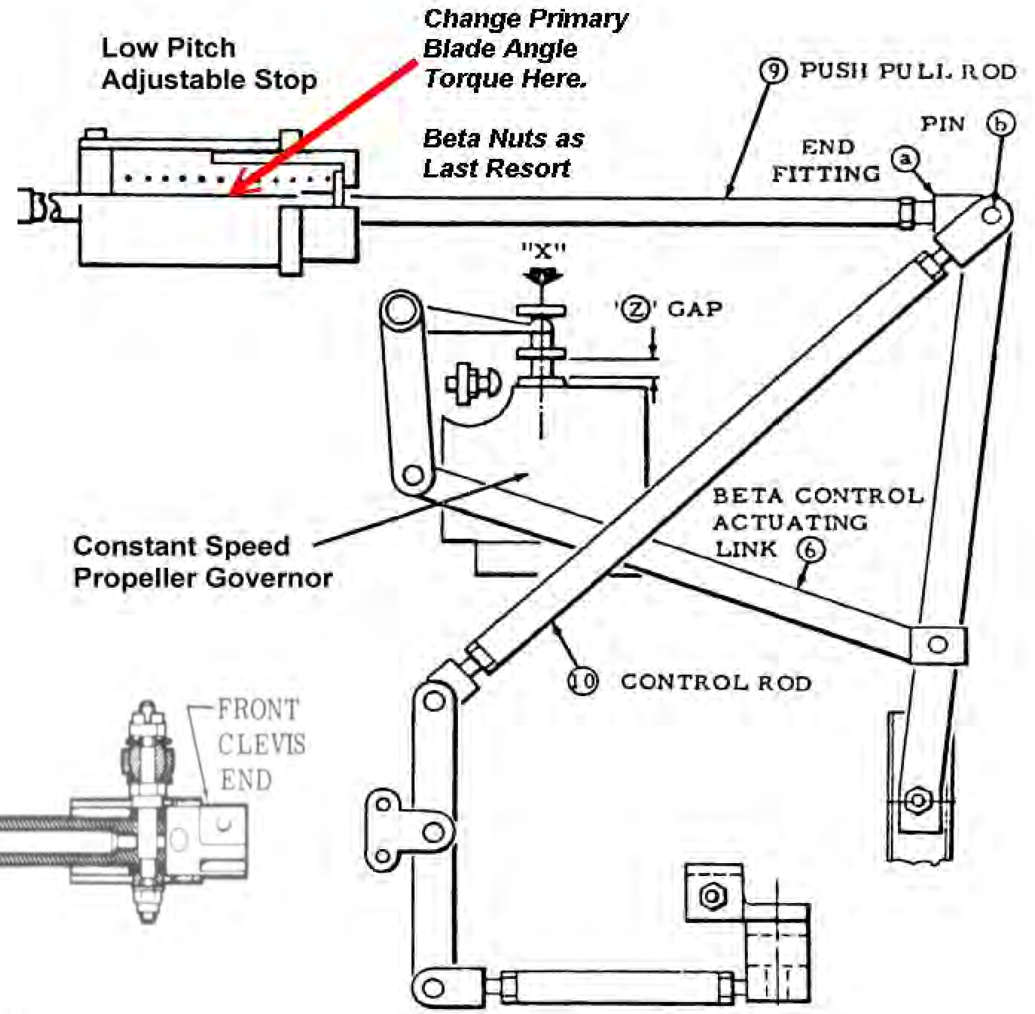
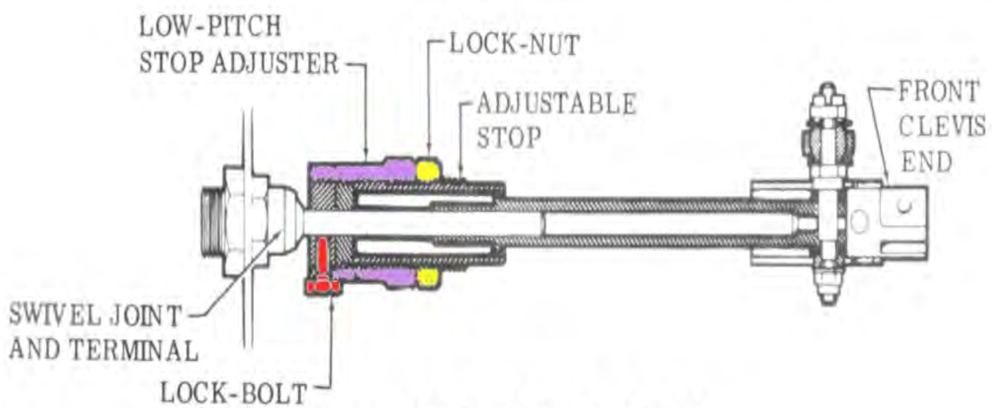
Hydraulic Low Pitch Stop Adjustment.

Primary method to change torque is to adjust the hydraulic low pitch stop located on the top of the engine forward teleflex cable.

Beta Nuts are adjusted as a last resort.





Low Pitch Adjustable Stop

A *FreeBee* Publication

References

P&W PT6A – Maintenance Manuals / Training Manuals
Beech Aircraft – Maintenance Manuals / Training Manuals
DHC Aircraft – Maintenance Manuals / Training Manuals

Hawker / Beech / Raytheon Publications and Photos.

A special thanks to all the illustrators for the above publications. Without your drawings and diagrams, this guide would not have much impact. Wherever possible I have left the accreditation on the drawings.

The truth is that the "Company Illustrator" is usually the last to gain any recognition for their work. - Thanks.