1. General

The propeller control system consists of the following components:

- Propeller Electronic Control (PEC) Unit
- Propeller Pitch Control Unit (PCU)
- High Pressure PCU Oil Pump and Propeller O/S Governor Units (referred to as overspeed governor)
- Propeller Feathering Pump
- Propeller System Sensors

The function of the propeller system is to modulate the propeller blade pitch to control the propeller speed in flight constant speed modes and in reverse, and to provide smooth thrust transients in response to PLA movement. This system also limits the minimum blade angle obtainable in flight. In addition, the system provides the ability to feather the propeller on demand, minimize cabin noise in synchrophase mode and automatically feather the propeller in the event of an engine failure, when the autofeather system is selected.

2. Propeller Electronic Control (PEC) Unit

The Propeller Electronic Control (PEC) (Figure 12.22-4) is a dual channel microprocessor-based controller which uses inputs from the aeroplane, propeller control system sensors, and the engine control system to control propeller pitch and speed. The PECs for both propeller systems are mounted in their respective engine nacelles.

Each unit performs a number of safety functions including Autofeather and Automatic Underspeed Propeller Control (AUPC) which causes the propeller to operate on the overspeed governor in the event if a drive coarse failure. It also provides an UPTRIM command to the FADEC of the working engine. All of these functions are isolated from the basic control functions of the PEC.

3. Propeller Pitch Control Unit (PCU)

The propeller Pitch Control Unit (PCU) is a hydromechanical device that interfaces with the propeller. Commanded electrically by the PEC, the PCU meters high pressure engine oil to a two stage servo valve mounted on the PCU. The PCU controls the flow of high pressure oil into the fine or coarse pitch chambers of the propeller pitch change cylinder as directed by the PEC so that the blades move in the desired direction to achieve the required system functions. In the event of electronic control malfunction, the PCU controls the minimum blade pitch that can be obtained in flight.

4. High Pressure PCU Pump and O/S Governor

The High Pressure PCU Pump/Propeller Overspeed Governor Unit provides the PCU with high pressure oil from the engine gearbox. The High Pressure pump is driven from the reduction gearbox. The Propeller Overspeed Governor Unit is an independent mechanical system used to limit the propeller overspeed in the event of a malfunction. The O/S Governor is a flyweight design, driven directly from the driver gear of the pump.

5. Propeller Feather Pump

The Auxiliary Propeller Feathering Pump Unit provides an independent means of feathering the propeller in the event of a failure of the primary means of feather. The auxiliary pump consists of a 28VDC electrical motor driving an external gear pump which supplies a secondary source of pressurized oil for feathering the propeller. The feather pump is also used for feathering and unfeathers the propeller as required for maintenance purposes.

6. Propeller System Sensors

The propeller system is fitted with a Magnetic Pickup Unit (MPU) to provide a signal to the PEC Unit. The PEC will use this signal for propeller speed governing as well as synchrophasing and to send to the ANVS for propeller balance monitoring.

12.22.3 Propeller Control

Pitch is controlled by modulating oil pressure on either side of the pitch change piston. The natural twisting moment applied to the blades is dominated in the inflight pitch range by the centrifugal twisting moment. This arises because the centre of mass of the blade does not coincide with the axis of pitch rotation. Each blade is fitted with a counterweight, phased around the blade root outer sleeve so that the blade's natural twisting moment in flight is towards high pitch. In the event of loss of hydraulic pitch change pressure during flight, the propeller will therefore assume a safe, high pitch, which is associated with minimal windmilling drag.

Around flat pitch, the natural twisting moment of the counterweighted blade is insignificant, and, at negative blade angles, acts towards negative pitch. Thus, final pitch following hydraulic failure in reverse will be towards the maximum reverse blade angle.

12.22.4 Propeller Modes

The PCU provides for governed constant speed operation through a propeller governor controlled by the condition levers at higher power. The power levers control the minimum blade angle to provide a smooth thrust response to PLA movement in the beta range. The manual feather mode is controlled by the condition levers or by the autofeather/alternate feather system.

a) Constant Speed Mode

During in-flight constant speeding operation, the PEC controls the servo valve to meter sufficient HP oil into propeller fine pitch to balance the net coarse-seeking moment applied to the blades by the blade forces and achieve the selected propeller RPM. These blade forces are dominated in flight by the blade counterweight effort, which is coarse-seeking at in-flight blade angles. Should the HP supply be lost, the blades will 'autocoarsen' to a safe, high-pitch, underspeeding condition, associated with low windmilling drag. Should the propeller underspeed for reasons other than loss of oil supply or servo valve failure, the servo valve will direct more HP oil into fine pitch to restore propeller speed. Should the propeller exceed the demanded speed, the servo valve will direct HP oil into coarse pitch to reduce propeller speed. This is somewhat simplified, since the PEC responds to acceleration as well as rpm error.

Constant speeding mode is entered when the propeller speed reaches 850, 900 or 1020 rpm, according to which speed is selected by the Condition Lever. HP oil for constant speeding passes through the OSG before it reaches the servo valve. Should the servo valve stick at a fine pitch selection, propeller rpm will increase until approximately 105% (1071 RPM), when the OSG will start to isolate the propeller control system from HP oil. Rpm will then drop due to propeller counterweight action, the OSG will reconnect HP supply and a stable governing condition at

105% (1071 RPM) will be quickly achieved. Safe overspeed governing is therefore provided, regardless of failures in the servo valve, PEC or electrical supply.

The OSG can be tested on the ground by operating the PROP O'SPEED GOVERNOR test switch on the Pilots Side Panel on the flight deck.

b) Beta Mode

The Beta range is from a power lever position above FLIGHT IDLE (called flight beta) to below DISC position. When the propeller is in the Beta mode, blade angle is set by the power lever input.

c) Beta Range

During on-ground 'beta control' (Power Lever below Flight Idle), the PEC directs the servo valve to meter oil into fine or coarse pitch to achieve the desired blade angle. The PEC receives PLA signals via the FADEC. In effect the system operates in closed loop blade angle control. Provision is made to limit the rate of change of blade pitch to prevent overtorques and over and underspeeding during transients.

It should be noted that during approach, when airspeed is relatively low and at low power settings, the propeller will enter beta control (flight beta), although entry into the ground beta range is prevented. As soon as propeller speed increases, the PEC automatically re-enters constant speeding mode.

The fine pitch in the in-flight, constant speeding mode is limited to 16°. This hydraulic cut-off of pressure oil constitutes the flight fine 'stop' interlock. The function of the Flight Fine Stop is to maintain a minimum pitch consistent with a positive counterweight effort towards coarse pitch, thus ensuring the effectiveness of the OSG throughout the in-flight pitch range. In addition to this 'hard' protection is a 'soft' flight fine 'stop' of 16.5° that is programmed into the PEC and is operative while the Power Lever is at or above Flight Idle, i e., in normal in-flight operation, pitch does not fall below 16.5°. To enable lower blade angles than 16°, with weight on wheels the Power Lever must be brought back below Flight Idle.

Bringing the Power Levers below Flight Idle and enabling blade angles lower than 16° causes the PROPELLER GROUND RANGE lights to turn on. A detent on the Power Lever quadrant prevents unintentional movement of the lever below Flight Idle during flight.

Movement into ground beta also causes the OSG to be locked out by a ground beta enable valve (GBE). This is so that transient overspeeds as the propeller moves through flat pitch (0°) in ground operation do not interfere with pitch control by isolating the HP supply and thereby causing pitch hang-ups dorment. Failure of the GBE spool to move to its inflight position (causing loss of overspeed protection) is isolated by a scheduled OSG test.

When the Power Lever is in the beta range, propeller speed is generally governed by the FADEC and engine fuel system at 660 rpm (N_P underspeed governing). It should be noted that propeller speed protection on the ground is by the engine, since speed here is engine driven rather than airspeed driven. FADEC overspeed protection may operate inflight, but would naturally be effective only in limiting overspeed due to runaway of the normal engine fuel governor. Since the FADEC controls fuel flow to the engine according to a power schedule with torque and engine speed limits according to Power Lever position, it is able to protect the engine and propeller from the high torque that would result from an inadvertent propeller feather.

d) Inadvertent Ground Beta Selection in Flight

The PLA should never be moved below the FLIGHT IDLE gate in flight. Ground beta lockout system prevents blade angles below flt fine event in the event of inadvertent selection below FLIGHT IDLE. If the PLA is inadvertently moved below the FLIGHT IDLE gate in flight it should be immediately moved back above the gate.

WARNING Never move the power levers below FLIGHT IDLE in flight.

NOTE: A Beta warning horn will sound if the gate is raised in flight.

e) Reverse Speed Control

In this mode the system operates in closed loop propeller RPM control, maintaining the propeller speed between 660 and 950 RPM. The engine schedules fuel based on a power schedule versus PLA, with a maximum limit of 1500 SHP. At low airspeeds it is possible that the propeller could reach the maximum reverse stop, the propeller rotational speed is then controlled by the engine overspeed governor, and can increase up to 1020 RPM.

This mode is similar to forward speed control, except that it operates in reverse, i.e. driving more negative to absorb more power and reduce propeller RPM.

12.22.5 Propeller Overspeed Governing

The propeller overspeed governor incorporates a hydraulic section and an electronic section.

The hydraulic section (OSG) controls blade angles hydraulically by dropping the high pressure oil supply when prop rpm exceeds approximately 1071 RPM. During an overspeed condition propeller rpm is reduced by increasing blade angles. When propeller rpm decreases below the overspeed point, the overspeed governor restores normal propeller control. If the propeller goes back to an overspeed condition, the cycle is repeated, resulting in a continuous fluctuation in prop rpm in and out of overspeed until the cause is removed.

The electronic section uses FADEC N_P overspeed circuitry to signal the Fuel Metering Unit (FMU) to reduce the amount of fuel being supplied to the engine, when an overspeed of approximately 1122 RPM is reached. Reducing fuel to the engine causes power to drop, in turn lowering the propeller rpm. When N_P drops below the overspeed point, the governor allows the FMU to restore normal fuel flow.

The hydraulic section of the overspeed governor is locked out in reverse and the FADEC electronic section is the primary means of protection from overspeed in reverse.

12.22.6 Propeller Synchrophasing System

When the speeds of both propellers are within a predetermined difference of each either in flight, the PEC enters a synchrophasing mode to reduce propeller noise. Synchrophasing acts to reduce cabin noise by ensuring that the relative position, or phase difference, between the slave propeller and master propeller is controlled to a demanded angle. This system does not operate at take-off. The phase angle is calculated by timing the differences between the master and slave propeller Magnetic Pickup Unit (MPU) signals over a complete propeller revolution. The phase demand is determined by the CLA position.

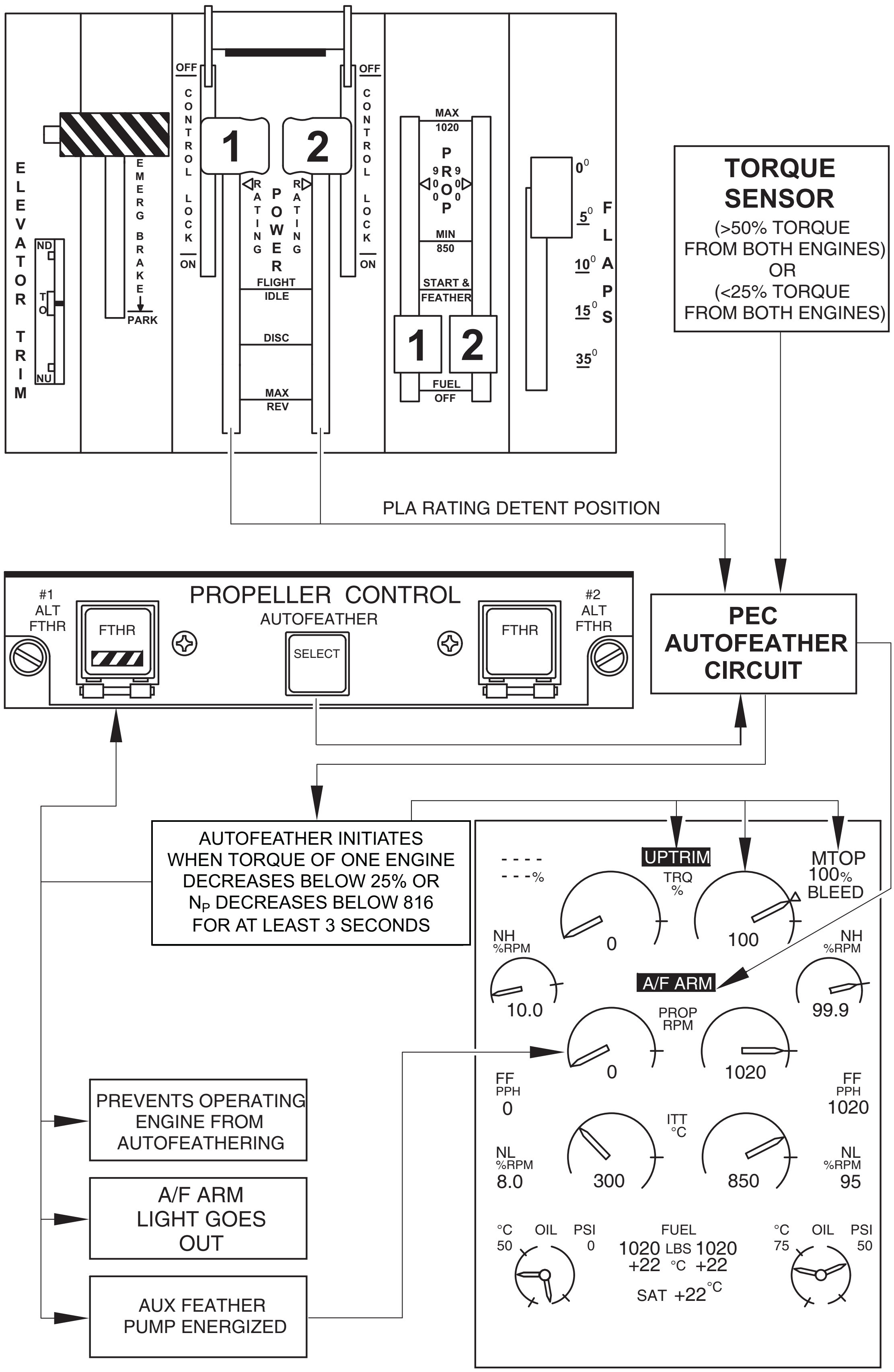

Figure 12.22-5 Autofeather Schematic

12.22.7 Propeller Feathering Systems

Propeller feathering systems provide:

- Autofeathering
- Alternate feathering and unfeathering
- Manual feathering

a) Autofeather

The autofeather system provides automatically initiated propeller feathering following an engine failure during take-off, and power uptrim of the operating engine (Figure 12.22-5). Autofeather is selected on for take off only, using the AUTOFEATHER switchlight on the engine instrument panel. This causes the SELECT light to turn on, and displays A/F SELECT on the ED. The ARM light will turn on when both engine torques exceeds a minimum value of 50% and both power levers are advanced beyond 60° PLA.

NOTE: If autofeather ARM advisory does not appear on ED, take-off must be rejected.

Uptrim is triggered (regardless of autofeather selection) when

- the torque of the failed engine falls below 25%, or
- when N_P (as indicated by the torque sensor) falls below 80%, and
- the PLA is in the detent rating, and
- MTOP is not set.

Either of the first two condition must be confirmed by both torque sensor signals. The low speed condition accommodates the failure case of a propeller autocoarsening or inadvertently feathering, causing loss of thrust but not low torque. Uptrim is also directly signalled when an autofeather occurs. Dual uptrim signals are sent to the FADEC of the working engine to increase its power by approximately 10%. The effect of this is to replace normal take-off power (NTOP) rating with maximum take-off power (MTOP) rating.

If Uptrim occurs independent of autofeather, it may only be disarmed by moving both power levers below the rating detent position.

Autofeather is triggered from the armed state when the torque of the failed engine as indicated by both torque signals falls below 25% for at least three seconds. Following a 3-second delay, the propeller of the failed engine will feather. When one propeller is autofeathered, the autofeather function of the other propeller is automatically disarmed. The AUX feathering pump is also activated for approximately an 30 second period. This makes sure adequate oil pressure is available for propeller feathering. The AUX (feather and unfeather) pump provides a backup source of oil pressure to the propeller pitch-change mechanism. The pump is supplied oil from an auxiliary oil reservoir built into the propeller Reduction Gear Box (RGB) to permit autofeather in the event of loss of engine oil pressure. The respective feathering pump advisory light in the FTHR switchlight turns on when the auxiliary feathering pump electrical contractor is closed.

The autofeather system can be disarmed by:

- Pushing OFF the autofeather switchlight
- Retarding one or both power levers to flight idle
- Remote propeller autofeathered.

CAUTION Propeller may unfeather if AUTOFEATHER switch is selected off before condition lever is selected to FUELOFF.

The N_P underspeed cancel signal prevents the FADEC from raising N_H in an attempt to maintain propeller rpm as the feathered propeller speed decreases below 660 rpm.

b) Alternate Feather

Operational back-up/alternate feathering is accomplished by operating the #1 or #2 ALT FTHR switchlight on the PROPELLER control panel. Provided that the Condition Lever is at START/ FEATHER or FUEL OFF, the alternate Feathering Pump is energized with opposite secondary 28V DC bus power through a 30-second time relay.

Pressure oil from the Feathering Pump operates a back-up feather valve in the PCU. This ensures the propeller can be feathered regardless of failures in the normal control system. The Feathering Pump is mounted on the Propeller Reduction Gearbox, which has internally a dedicated oil volume available for backup feathering.

The aux feather pump is provided for the following reasons:

- To give a back-up feather function when the primary feathering system is inoperative.
- To enable the propeller to be feathered when the gearbox rpm. is too low to maintain oil supply to and from the HP pump.
- To enable the propeller to be unfeathered on the ground for maintenance reason.

c) Manual Feathering

Propeller manual feathering is used during engine shutdown by selecting the appropriate condition lever to the START & FEATHER and/or FUEL OFF.

c) Propeller Behavior with NO AUTO FEATHER

The propeller behavior when an engine flame with **NO AUTO FEATHER** is that the propeller RPM goes down to 770-850 with PL in detente.

When performing the correct engine shutdown procedure by pulling PL back to flight idle the propeller RPM increases to 1020 giving a secondary yaw. When pulling CL to start and feather and fuel off the propeller goes to 0 RPM.

The explanation of why the propeller can maintain governing operation or drive the blade angle in response to PLA movements after the engine has flamed-out, is that the High Pressure (HP) pump in the Overspeed Governor Unit (OSG) continues to provide normal motive oil pressure as long as the propeller is wind-milling.

It does not take large volumes of oil to hold the blades in position, therefore, most of the output from the HP pump just cycles around the pump through the Pressure Regulating Valve.

As the engine core is also wind milling in a "flame-out" scenario, there is sufficient N_H to pump some oil to the propeller to make up any deficit.

When you command the blades to feather, this is a different story. A combination of a large oil volume demand and the propeller RPM dropping off as the blades coarsen causes the HP pump output to fall rapidly and the blades only drive into a semi-feathered condition. The Aux Feather pump is then required to complete the feathering process.

1-When the flameout occurs, the propeller speed decreases very fast. Since the Condition lever stays at MAX the propeller speed request stays at 100%, so the PEC reduces the beta angle in order to reaches 100% propeller speed.

2-When the beta angle reaches 26 Deg, the beta angle is lower than the beta request so the PEC control mode goes from "FORWARD SPEED" mode to "BETA" mode.

3-The beta request stays at 26 deg until the pilot retard the PLA to FLT IDLE. When the PLA is at FLT IDLE, the beta request falls to 16.5 so the propeller speed accelerates to 100% creating a small yaw.

4-When 100% prop speed is reached the PEC goes back to "FORWARD SPEED" mode.

12.22.8 Fault Classification

The PEC continuously monitors itself and connected equipment for failures. Fault codes are sent to the FADEC. Detected faults can be advisory or cautionary, or critical.

a) Advisory Faults

Advisory faults are faults, which are automatically accommodated by the PEC and have no associated operational impact: these faults will normally be annunciated on request to maintenance crew only.

b) Cautionary Faults

Cautionary faults are faults requiring special pilot instructions; the PEC caution light will be turned on by a PEC discrete. Faults which have implications for subsequent aeroplane dispatch cause a “Powerplant No Dispatch” message to appear on the Engine Display (ED) message area (visible to the flight crew).

All cautionary faults mean that beta control below FLIGHT IDLE is unavailable.

c) Critical Faults

Critical failures involve either hydraulic, electrical, software or hardware malfunctions in which results in a total or partial loss of control of the propeller.

In the absence of electrical power, loss of output from both PEC control lanes or failure of both servo valves, the servo valve is designed to give a coarse pitch selection. The propeller will then move towards feather. The reason for propeller feathering is to achieve minimum drag on the aeroplane from the propeller.

12.22.9 Automatic Underspeed Protection Circuit (AUPC)

AUPC circuit is independent of the control software and protects against failures which drive the propeller in the coarse direction.

AUPC is armed with PLA at or above Flight idle, CLA above START & feather, and torque above 50%, providing both Autofeather and Alternate Feather are inactive. It is triggered if N_P drops below 816 rpm while torque remains above 50% for 1 second. AUPC activation is annunciated by #1 or #2 PEC caution light.

When AUPC triggers, an unmodulated drive fine signal is sent to the PCU servo valve causing the pitch change mechanism to be driven on to the hydraulic fine pitch stop in the PCU. At higher airspeeds, this will result in speed governing on the OSG. A trigger latch prevents loss of AUPC at low torque once it has triggered, providing arming conditions are maintained.

AUPC will not trigger below 50% torque. Should a software problem cause a drive coarse signal to the PCU servo valve at low power the propeller will feather. Under this condition, an increase in PLA to above the 50% Tq level will activate AUPC which will then latch, and the propeller will operate on the OSG or hydraulic flight fine stop and the OSG will prevent overspeed of the propeller.

During autofeather, the autofeather drive coarse input has higher priority than AUPC drive fine input, therefore the AUPC can not override the autofeather function.

The AUPC incorporates test logic to simulate the appropriate inputs and confirm the correct outputs. Testing is automatically accomplished during autofeather test, and is confirmed (or otherwise) via the appropriate autofeather test message on the ED.