MODULE 17

PROPELLERS

EASA Program, part. 66

(Licences B1.1, B1.2)

INTRODUCTION

Thought this notes, the student will learn about propeller construction, propeller pitch control, propeller synchronizing, propeller ice protection, propeller maintenance and propeller storage and preservation.

Additionally, the student can find typical exams that can help to understand better the exams criteria, and to consolidate knowledge on that.

Those notes follow the official program under the Commission Regulation (EC) 2042/2003 for Maintenance. This means:

Fundamentals

Blade element theory;
High/low blade angle, reverse angle, angle of attack, rotational speed;
Propeller slip;
Aerodynamic, centrifugal, and thrust forces;
Torque;
Relative airflow on blade angle of attack;
Vibration and resonance

Propeller Construction

Construction methods and materials used in wooden, composite and metal propellers;
Blade station, blade face, blade shank, blade back and hub assembly;
Fixed pitch, controllable pitch, constant speeding propeller;
Propeller/spinner installation.

Propeller Pitch Control

Speed control and pitch change methods, mechanical and electrical/electronic;
Feathering and reverse pitch;
Overspeed protection.

Propeller Synchronising

Synchronising and synchrophasing equipment.

Propeller Ice Protection

Fluid and electrical de-icing equipment.

Propeller Maintenance

Static and dynamic balancing;
Blade tracking;
Assessment of blade damage, erosion, corrosion, impact damage, delamination;
Propeller treatment/repair schemes;
Propeller engine running

Propeller Storage and Preservation

Propeller preservation and depreservation

1 FUNDAMENTALS

The purpose of a propeller is to convert the power developed by the engine into a useful force called '**Thrust**'. This force must be equal to and opposite in direction to '**Drag**' in order for the aircraft to remain in level flight without acceleration.

Aircraft propellers, whether powered by reciprocating engines or turbine engines, accelerate a large mass of air through a small velocity change, as opposed to the turbojet, which accelerates a small quantity of air through a large velocity change.

The cross section of a propeller blade is similar to that of an aerofoil and it will behave in a similar manner when moving through the air. As the blade is rotating as well as moving forward, the blade will meet the air at a positive angle of attack. This will produce 'lift' which acts along the axis of rotation of the engine, thus causing forward movement of the airframe as a result of thrust. The blade can be thought of as a rotating wing in essence.

There are two types of propeller, **fixed** pitch and **variable** pitch. The first section will deal with the **fixed** pitch propeller.

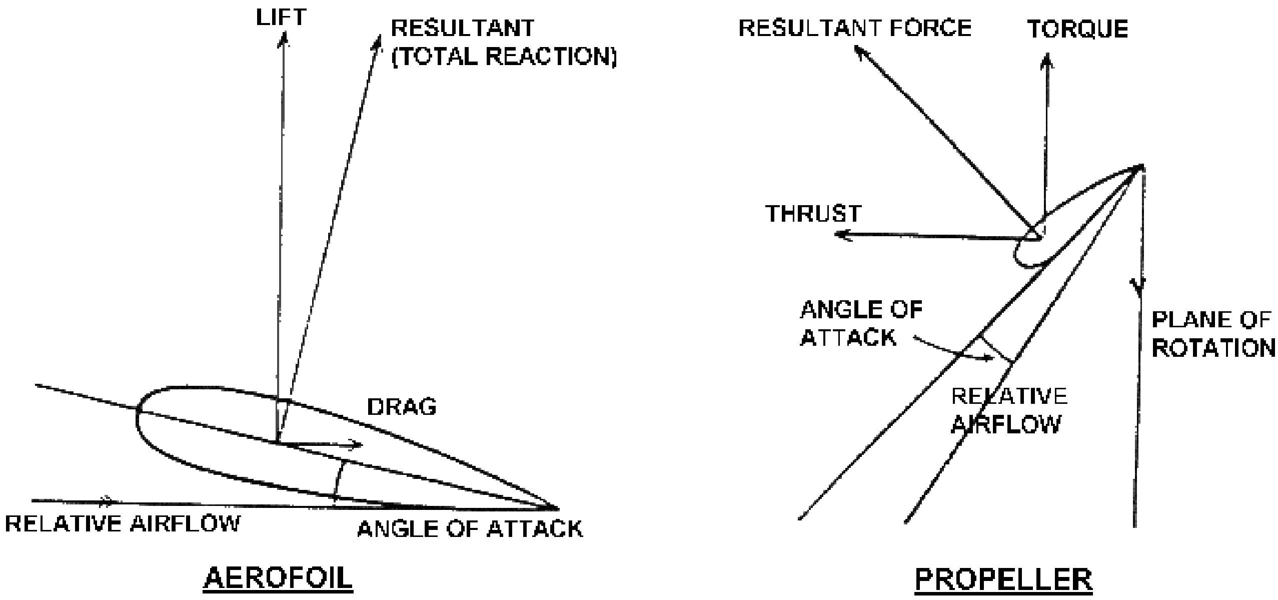
Propellers can be installed in several configurations: that of a '**tractor**' in which the propeller is mounted forward of the engine, and 'pusher' in which the mounting is aft of the engine.

Increase in power output has resulted in the development of four and six bladed units, but there is a limit to R.P.M. and efficiency, generally accepted to be approximately 500 m.p.h. However, recent advances in computer design, composite materials and blade aerodynamics, plus the continued development of the fan engines, do seem to indicate that the propeller, albeit in a vastly different form to the Wright Brothers' model, will be around for many years to come.

The development of variable pitch propellers is dealt with in depth in a later section.

1.1 BASIC PRINCIPLES

The propeller blade is of Aerofoil section with some changes in terminology and the forces produced as it moves through the air are roughly equivalent to the forces of lift and drag produced by an aircraft wing. These forces are called thrust and torque and are shown in comparison (Fig 1.1.) with an aerofoil.

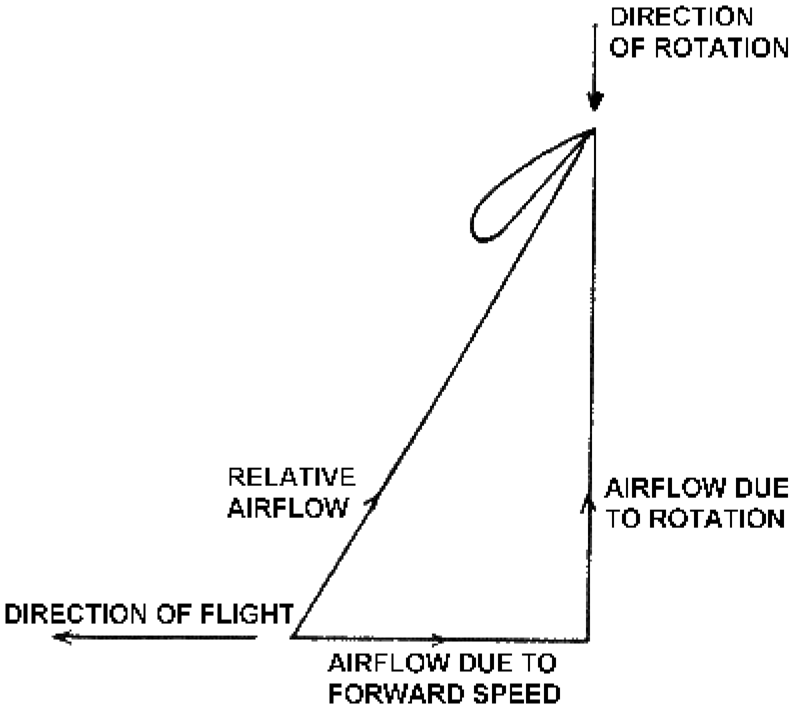


Comparison of Forces on an Aerofoil and a Propeller Blade
Figure 1.1.

Newton's Second Law states that **Force = Mass × Acceleration** and Thrust being a force, the same expression applies, being equal to the mass of air handled and the speed of the slipstream, less the speed of the aeroplane. Therefore, the power expended in producing thrust depends on the mass of air moved per second. On average, thrust constitutes 80% of the total horsepower absorbed by the propeller (torque). The other 20% is lost in friction and slippage. For any speed of rotation, the horsepower absorbed by the propeller balances the horsepower delivered by the engine.

1.2 PROPELLER TERMINOLOGY

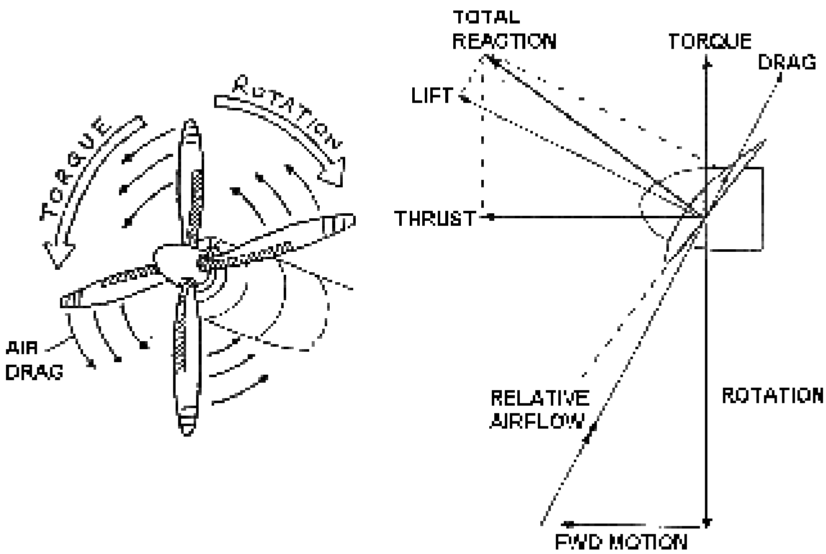
The terminology used in conjunction with propellers is illustrated in Fig 1.2. to Fig 1.4.



Airflow's due to Rotating Blade
Figure 1.2.

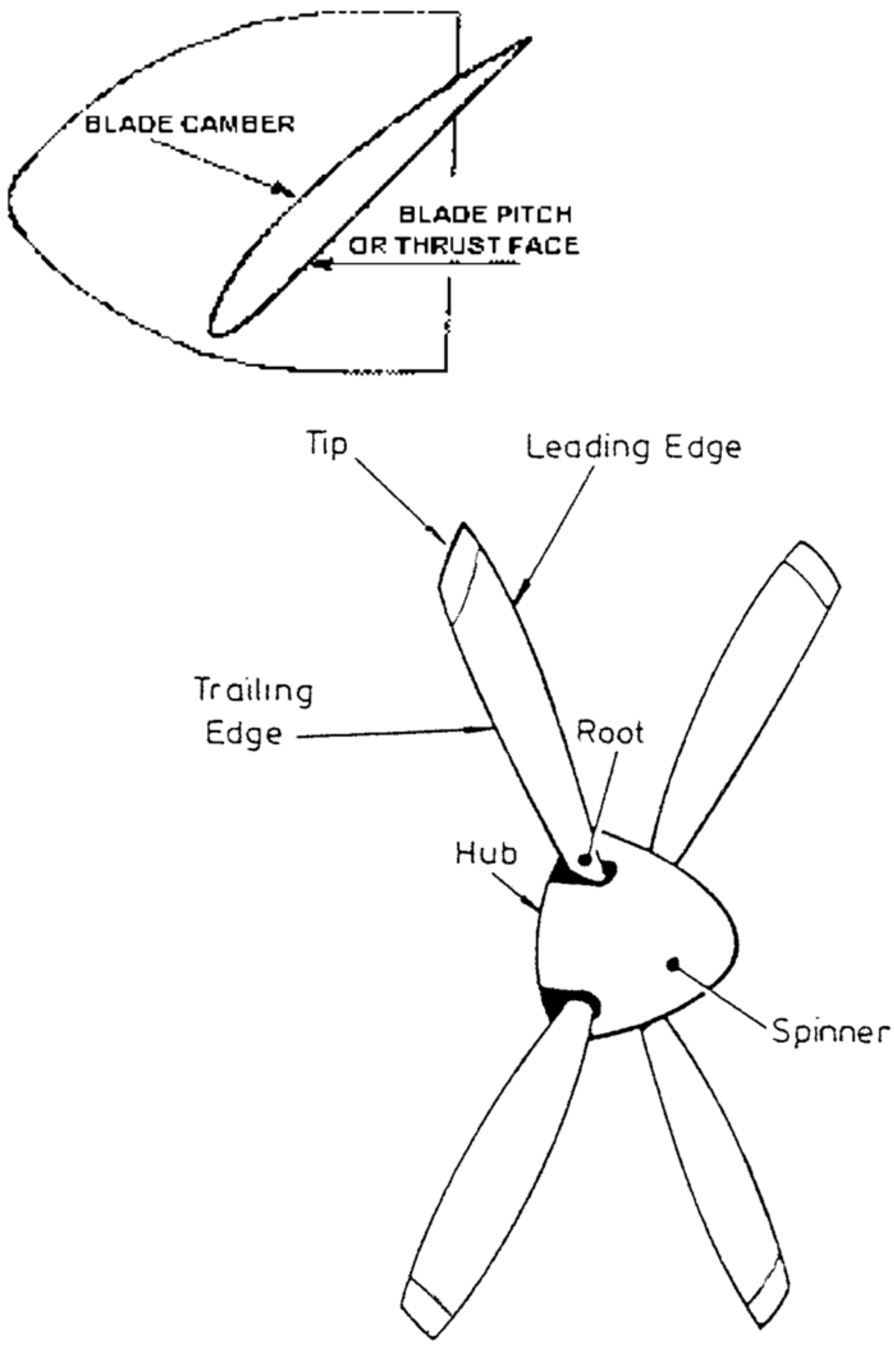
1.2.1 PROPELLER TORQUE

Propeller torque (Fig 3) is produced by the aerodynamic drag on the blades when in motion. Propeller torque acts in the plane of rotation and opposes engine torque. When propeller torque and engine torque are equal the propeller will rotate at constant speed.



Propeller Torque
Figure 1.3.

PROPELLER TERMS



Propeller Terminology

Figure 1.4.

1.2.2 BLADE FORCES

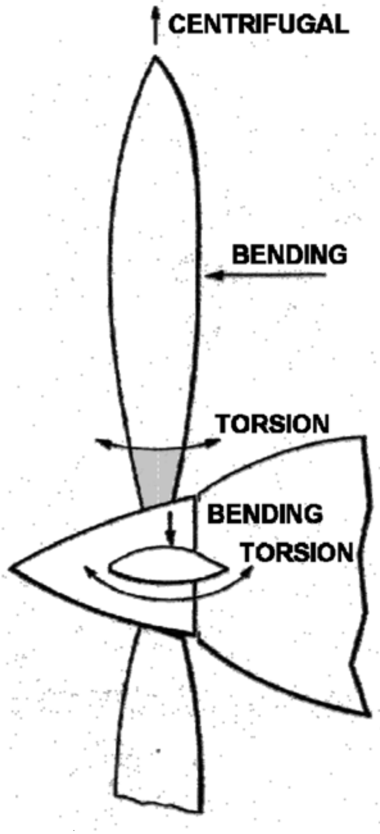
A propeller has to be capable of withstanding severe stresses that are greater near the hub and are caused by centrifugal forces and thrust. The force tending to through the blade from the hub is often as much as 22 tons. The stresses increase in proportion to the R.P.M. The blade face is also subjected to tension from the centrifugal force and additional tension from the bending. For these reasons, nicks or scratches on the blade can cause failure linked with stress corrosion.

1.2.3 BLADE RIGIDITY

A propeller must also be rigid enough to prevent flutter, a type of vibration in which the ends of the blade twist back and forth at high frequency around an axis perpendicular to the engine crankshaft. Flutter is often accompanied by a distinctive noise frequently mistaken for exhaust noise. The constant vibration tends to weaken the blade and may eventually cause failure.

1.2.4 FORCES ACTING ON PROPELLER BLADES

- **Bending** - Due to thrust and torque forces on the blade.
- **Centrifugal** - Caused by the propeller blade mass rotating at high speeds.
- **Torsion** - Due to the affects of CTM and ATM and pitch change loads.
- **Thrust** is the component acting at **right angles** to the **plane of rotation**.



Forces Acting on a Propeller

Figure 1.5.

- **Torque** is the component acting in the **plane of rotation opposing** engine torque and is the resistance offered by the propeller to rotation.

Thrust and Torque values developed by the propeller depend on the **angle of attack**, the **R.P.M.** and **air density**. As air density increases so will thrust, but as increased resistance is felt by the propeller, torque will also increase. Thrust and torque will alter in direct proportion to propeller speed and any increase in the Angle of Attack (below stalling speed) will produce more thrust and torque. There is an optimum angle of attack for all propellers, usually about 4°.

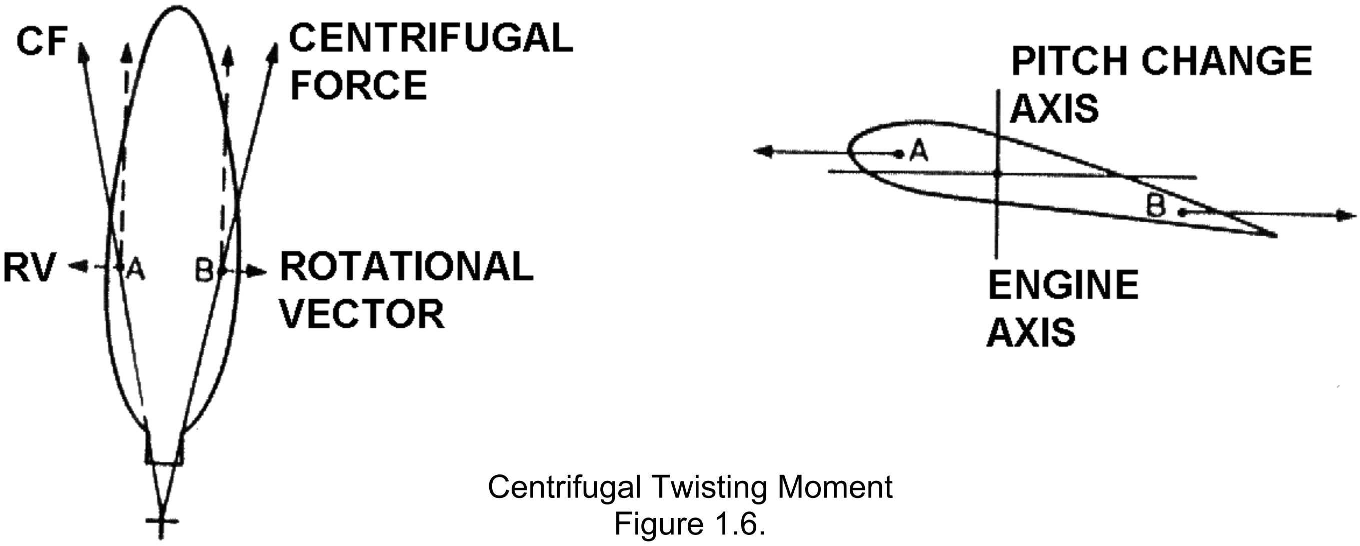
The aerodynamic of the propeller can most easily be understood if the action of the propeller is considered. The motion is both rotational and forward, and as far as the forces are concerned, the result is the same as if the blade were stationery and the air were coming at it from a direction opposite its path. The air deflection produced by this angle causes the dynamic pressure at the engine side of the propeller blade (the blade face) to be greater, thus producing thrust. The combined forces which produce thrust are shown in Table 1 below.

Table 1

Air Density	**Angle of Attack**	**Propeller Speed (R.P.M.)**
Increased air density produces increased Thrust. (Lift = CL $\frac{1}{2}\rho V^2 S$) Denser air offers greater resistance to the propeller i.e. Increased Torque.	An increase in Angle of Attack will produce more Thrust and Torque up to the stalling angle. The optimum Angle of Attack will give the best Thrust / Torque Ratio.	Thrust and Torque will alter directly with the speed of rotation.

- **Disc Area**. The area of the circle described by the propeller blade tips.
- **Blade Path**. The patch followed by the propeller blade in flight. The direction of the blade path is determined by the components of aircraft forward speed and propeller rotation and will determine the direction of the relative airflow.

- **CTM**. Centrifugal Turning Moment (refer to Fig 6). These are moments on the blades of a propeller when rotating, which due to centrifugal force, tend to turn the blades into fine pitch. It is caused by the masses of the blade leading and trailing the axis of rotation trying to align themselves in the same plane.



Centrifugal Twisting Moment
Figure 1.6.

- **ATM**. Aerodynamic Turning Moment. A weaker force than CTM normally acting in opposition and trying to turn the blade to **coarse pitch**.

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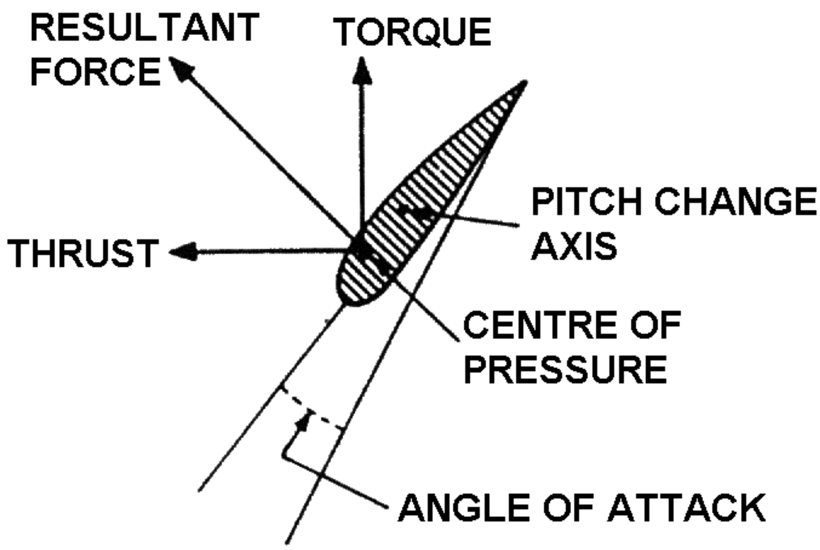
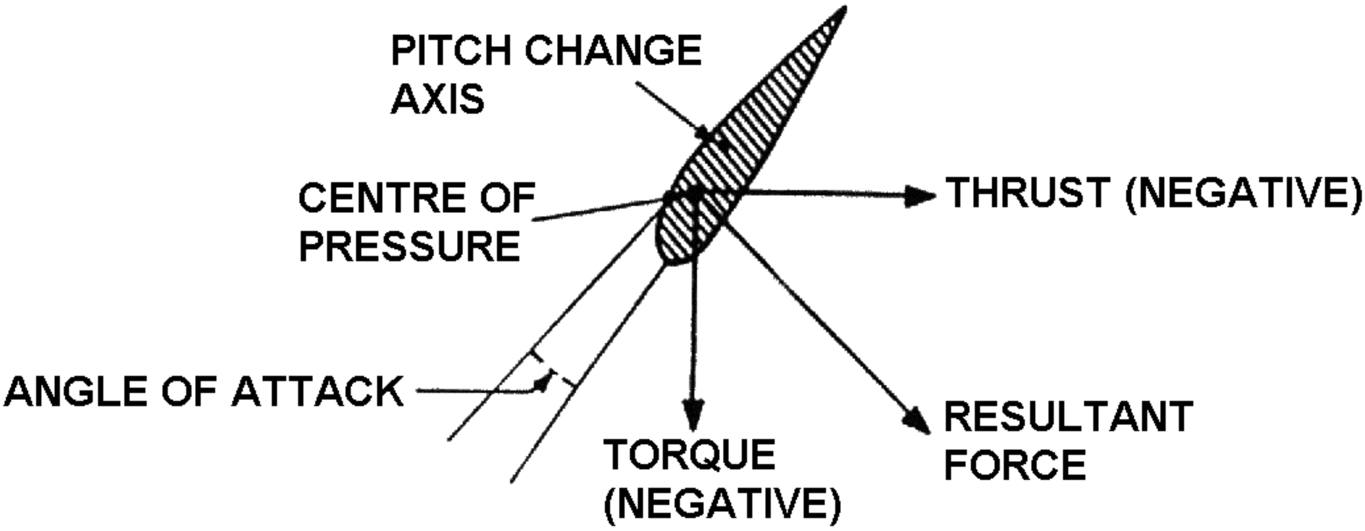


Aerodynamic Turning Moment

Figure 1.7.



Aerodynamic Turning Moment with Prop Windmilling.
Figure 1.8.

The blade's centre of pressure is forward of the **pitch change axis** and the moment of the resultant force turns the blade to **coarse pitch** (fig 1.7).

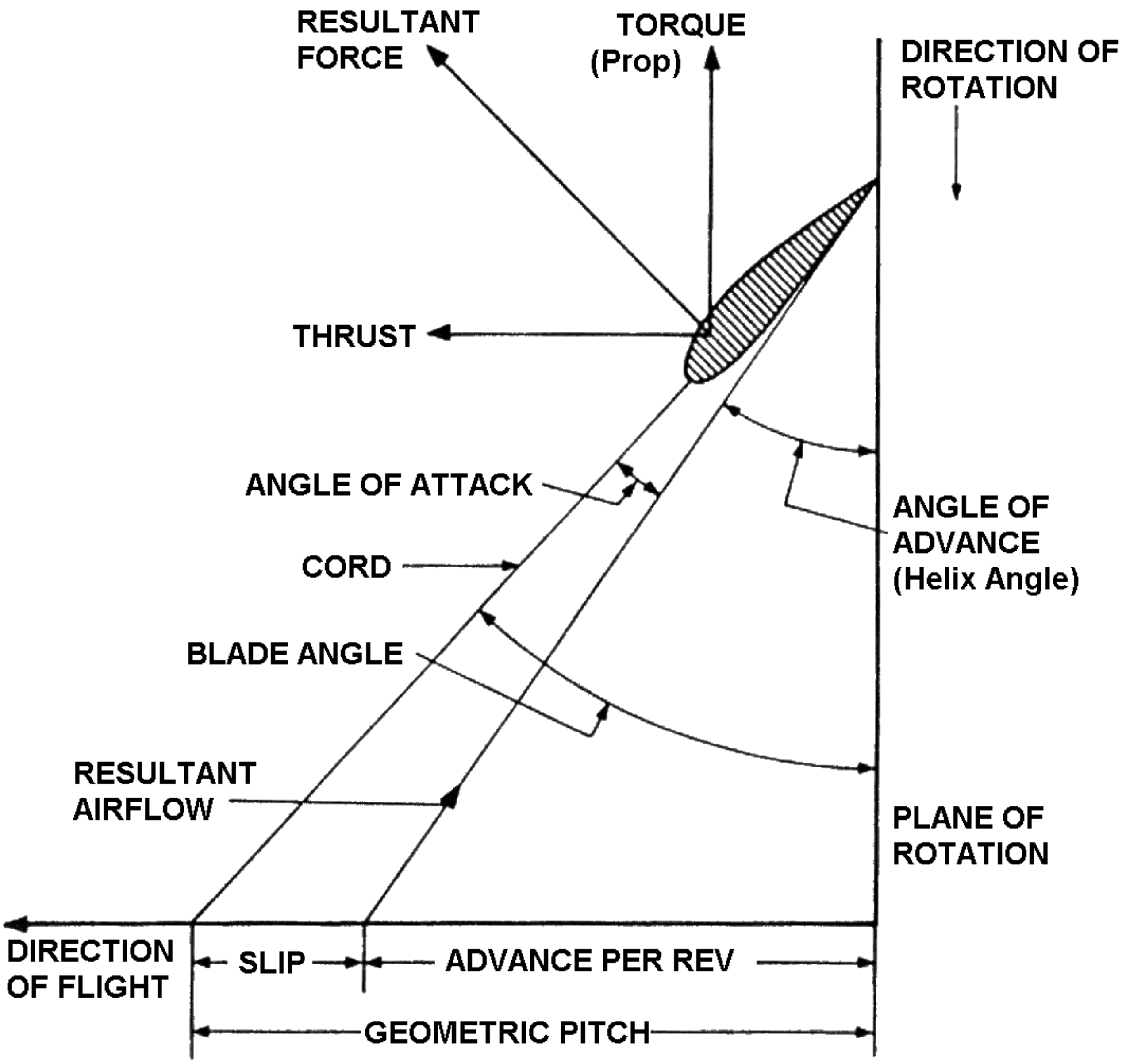
ATM acts with CTM to fine off the blades **only when the propeller is windmilling** (fig 1.8.).

In reverse pitch the ATM will turn the blade to a **coarser negative blade angle**.

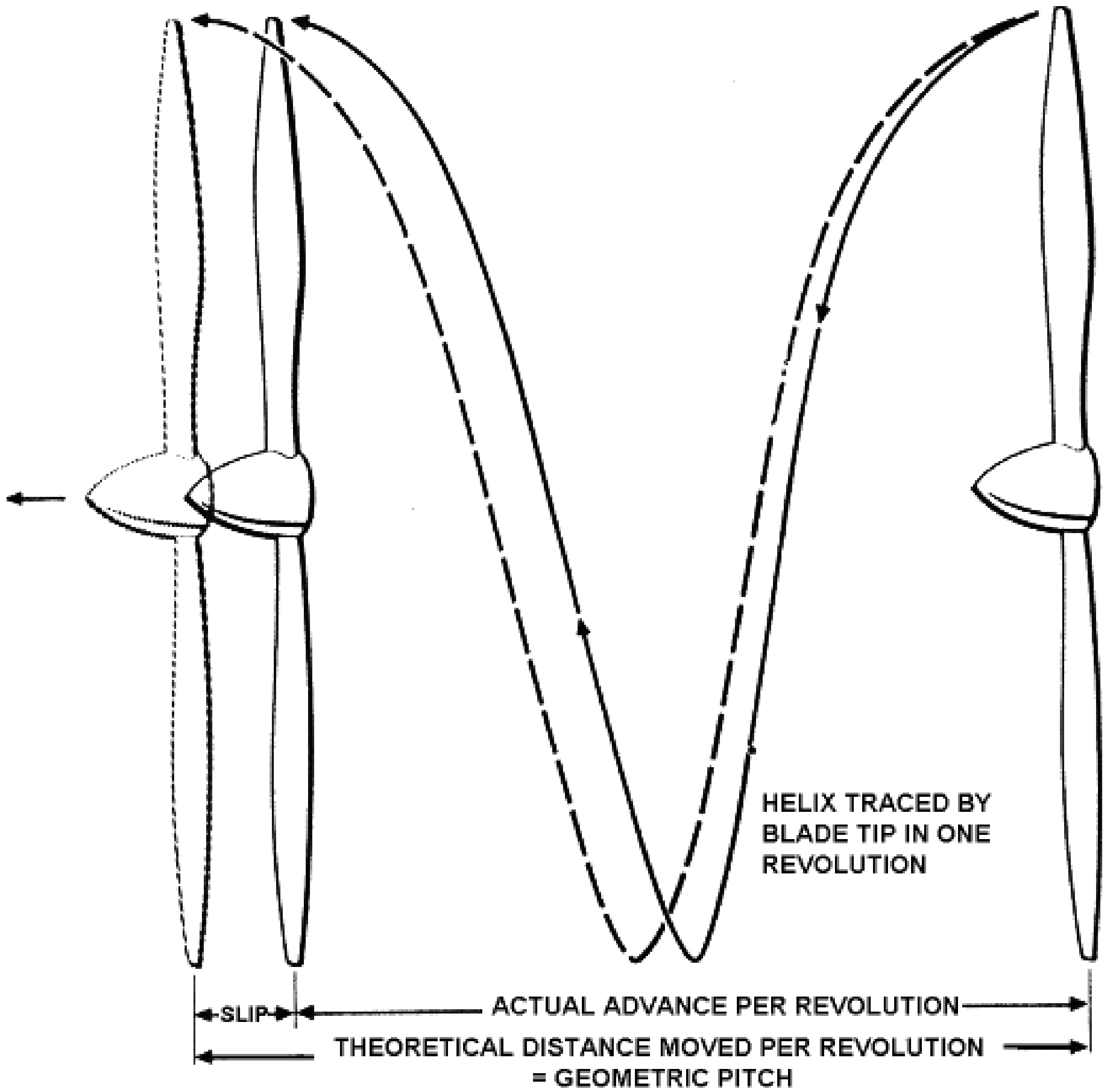
- **Geometric Pitch** (Fig 1.9. & 1.10.). The distance the propeller would move forward in one direction without slip.
- **Advance Per Revolution** (Fig 1.9). The actual distance moved forward in one revolution. It is not a fixed quantity, depending upon the aircraft speed and propeller RPM.
- **Slip** (Fig 1.9). The difference between the geometric pitch and the advance per revolution expressed as a percentage.

Slip= (Geometric pitch – Advance / Rev, Geometric Pitch) x 100

With **zero** angle of attack the **thrust** is **zero**.



Geometric Pitch
Figure 1.9.



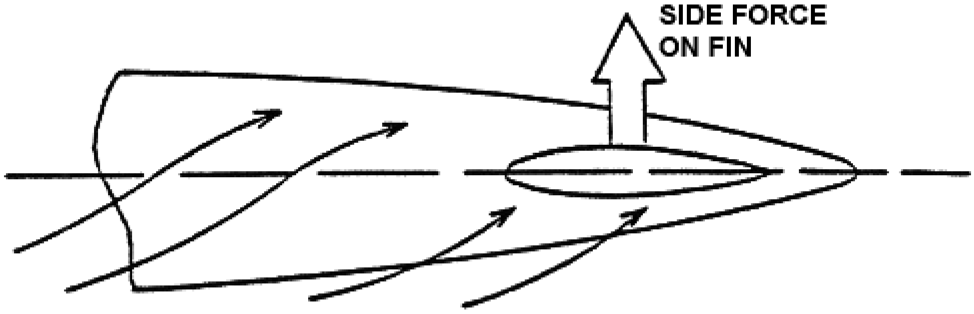
Geometric Pitch
Figure 1.10.

- **Gyroscopic Effect**. A rotating propeller has the properties of a gyro. If the plane of rotation is changed, a moment will be produced at right angles to the applied moment. For example if an aircraft with a right handed propeller is yawed to the right, it will experience a nose down pitching moment due to the gyroscopic effect of the propeller. Similarly if the aircraft is pitched nose up it will experience a yaw to the right. On most aircraft the gyroscopic effects are small and easily controlled.

- **Slipstream Effect**. In passing through the propeller the air is accelerated and given a rotational velocity.

  The parts of the aircraft that are in the propeller slipstream (Fig 11) will therefore have higher speed air passing over them than the parts outside the slipstream. The drag of these parts will therefore be higher, and the effectiveness of any control surfaces in the slipstream will be greater.

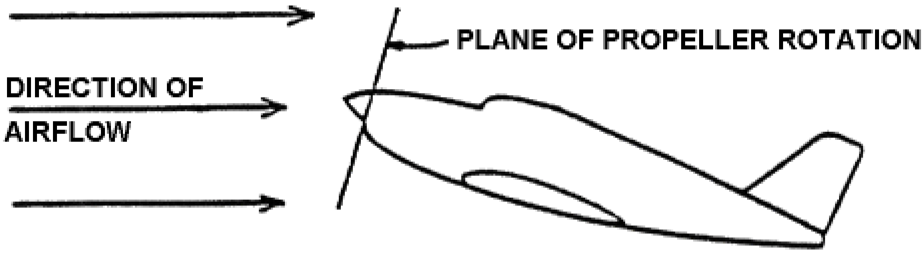
  The rotation given to the slipstream will cause it to meet the fin at an angle and so cause a yawing moment.



Slipstream Effect
Figure 1.11.

  This effect may be corrected by offsetting the fin or trimming the rudder.

  The amount of rotation given to the air will depend on the torque of the propeller, and so the yawing moment will depend on the power setting.

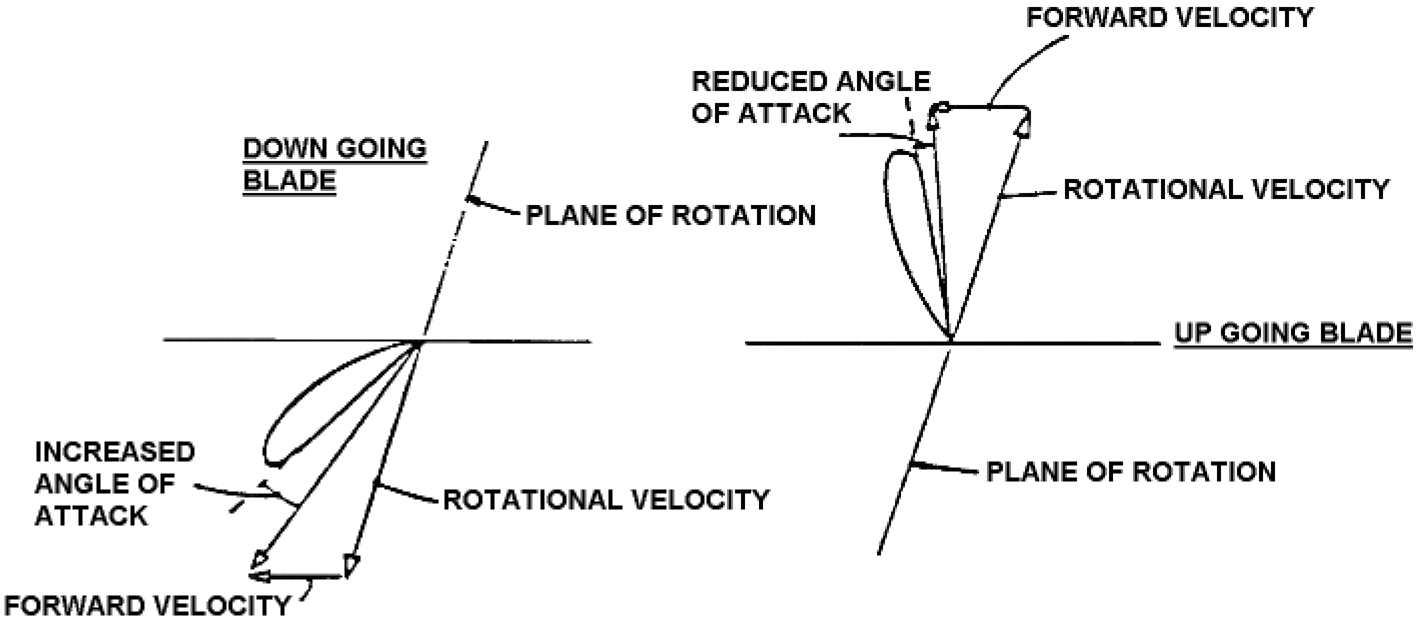


- **Asymmetric Effect** (Fig 12). In general the axis of the propeller will be inclined upwards to the direction of flight due to the angle of attack of the aircraft.

  This causes the down moving blade to have a greater effective angle of attack than the up going blade and therefore to develop a greater thrust.

Asymmetric Effect
Figure 1.12.

The difference in thrust on the two sides of the propeller (refer to Fig 13) disc causes a yawing moment. For a right hand propeller in a nose-up attitude the yaw will be to the left.



Thrust On The Two Sides Of The Propeller
Figure 1.13.

A similar effect can occur if the aeroplane is flying yawed, the asymmetry of the thrust causing a pitching moment is this case.

- **Solidity**. The ratio of total blade area to the disc area, the greater the solidity the more power can be absorbed by the propeller.

1.3 PROPELLER EFFICIENCY

The propeller is 80 - 87% efficient up to approximately 400 mph. Generally, beyond this performance will fall off, although new materials and improved blade technology are tending to increase efficiency.

This efficiency can be expressed as followed:

Propeller efficiency = f(work down by propeller, work down by engine) x 100

The drag on an aircraft travelling at 300ft/sec is 1100 lbs and if the engine produces 750 Shaft Horsepower the propeller efficiency is as follows:

Work= Force $\times$ Distance

Drag = Thrust (in level flight)

Work Done by Propeller / Sec	=	Thrust $\times$ Speed
	=	1100 $\times$ 300 ft lbs
Work Done by Engine	=	HP / Sec
	=	750 $\times$ 550 ft lbs (1 HP)
Propeller Efficiency	=	*f(1100-300, 750-550) x 100 = 80%*

Note that if the aircraft is stationary with engine running, thrust is produced, but as there is no forward movement, propeller efficiency is zero. At high forward speeds the slip could be zero, i.e. no angle of attack, therefore no thrust. With no thrust the propeller efficiency is zero.

When power is changed into thrust, the drag (or torque) created by the propeller limits engine speed. To be efficient, obviously the propeller should absorb all the power available. This is achieved by making a compromised design as power absorption creates limitations.

Propeller design with regard to diameter, number of blades and blade shape is governed by the power to be absorbed. The tip speed must not approach the speed of sound or efficiency will be lost; this limits diameter. Aircraft design also limits propeller design. Low slung engines mounted close to the fuselage require small diameter propellers; larger propellers require a longer undercarriage.

- Diameter
- Blade Angle
- Chord
- Change of Angle of Attack
- Camber of Aerofoil

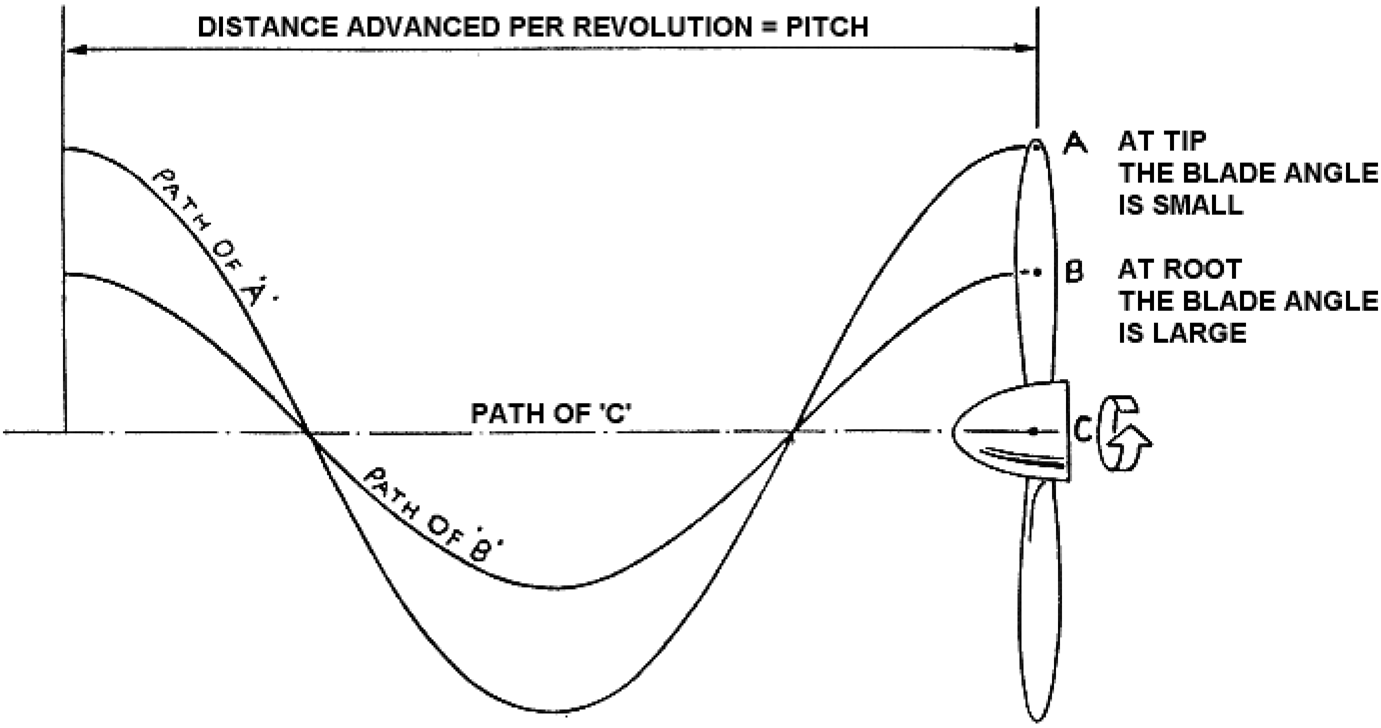
In higher powered engines, a reduction gear is usually fitted. This allows the engine to run at its most efficient speed while allowing the propeller to turn at its most efficient speed.

1.3.1 BLADE TWIST

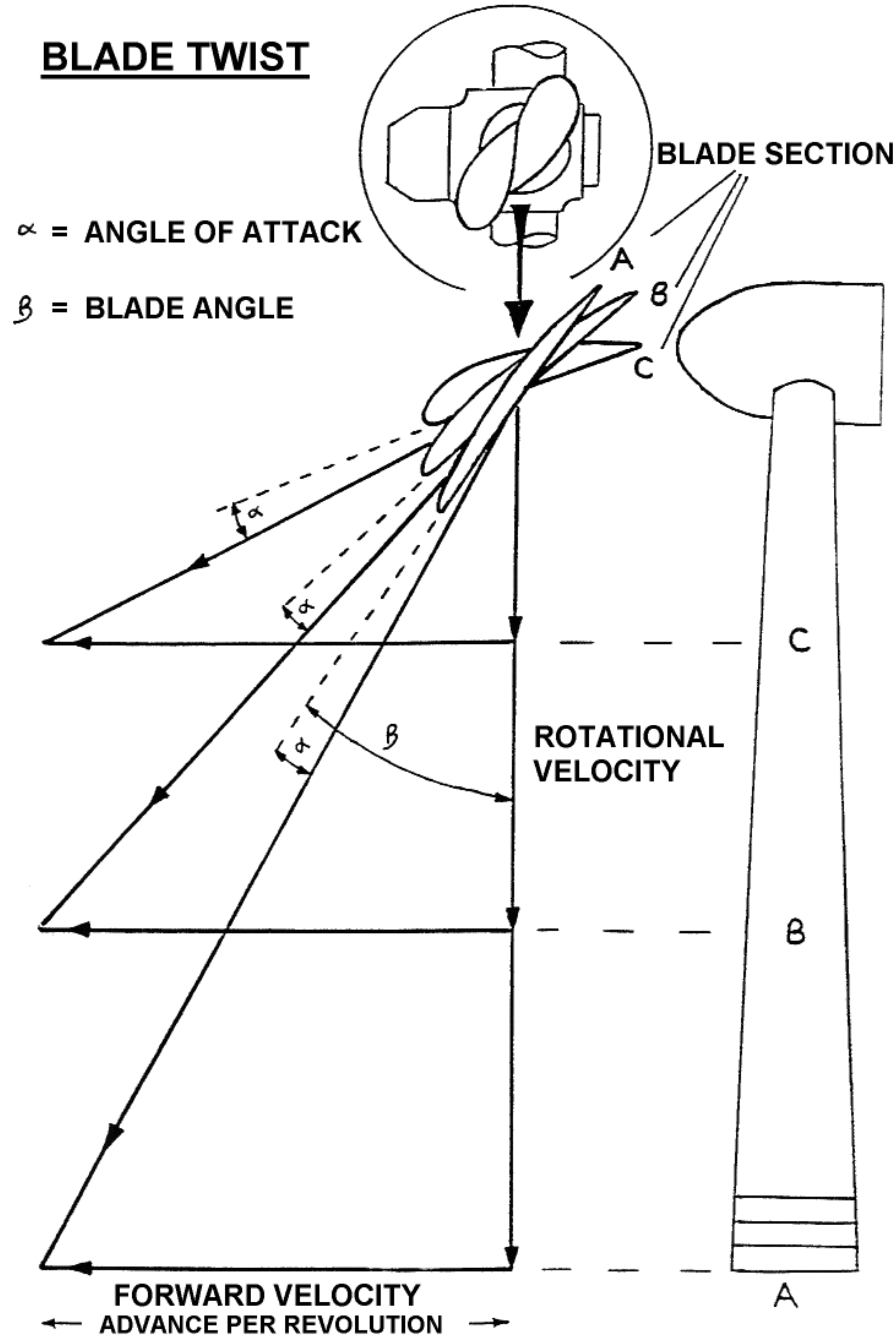
Rotational velocity and its effect on the Angle of Attack depends on the radius of the blade element in question. A blade element near the blade root (hub) will have a much lower rotational velocity than a blade element near the blade tip (refer to Fig.1.14). Rotational velocity is usually expressed as NR where R is the position of the element from hub centre and N is the propeller R.P.M.

It will be seen that in order to maintain an efficient angle of attack along the length of the blade, a reducing blade angle is necessary from root to tip. This progressive change in blade angle is called blade twist. It is best understood by considering the requirement for each section of the blade to produce an equal amount of thrust and to advance the same distance in one revolution. Ensuring that the angle of attack remains constant along the total length of the blade is a major factor in achieving this.

For a single revolution of the propeller, the amount of air handled depends on the bit of air a propeller takes. Therefore the blade angle is a means of adjusting the load on the propeller to control the engine R.P.M.



Paths of Blade Elements showing Variation in Blade Angle
Figure 1.14.



Blade Twist
Figure 1.15.

1.3.2 PROPELLER VIBRATION

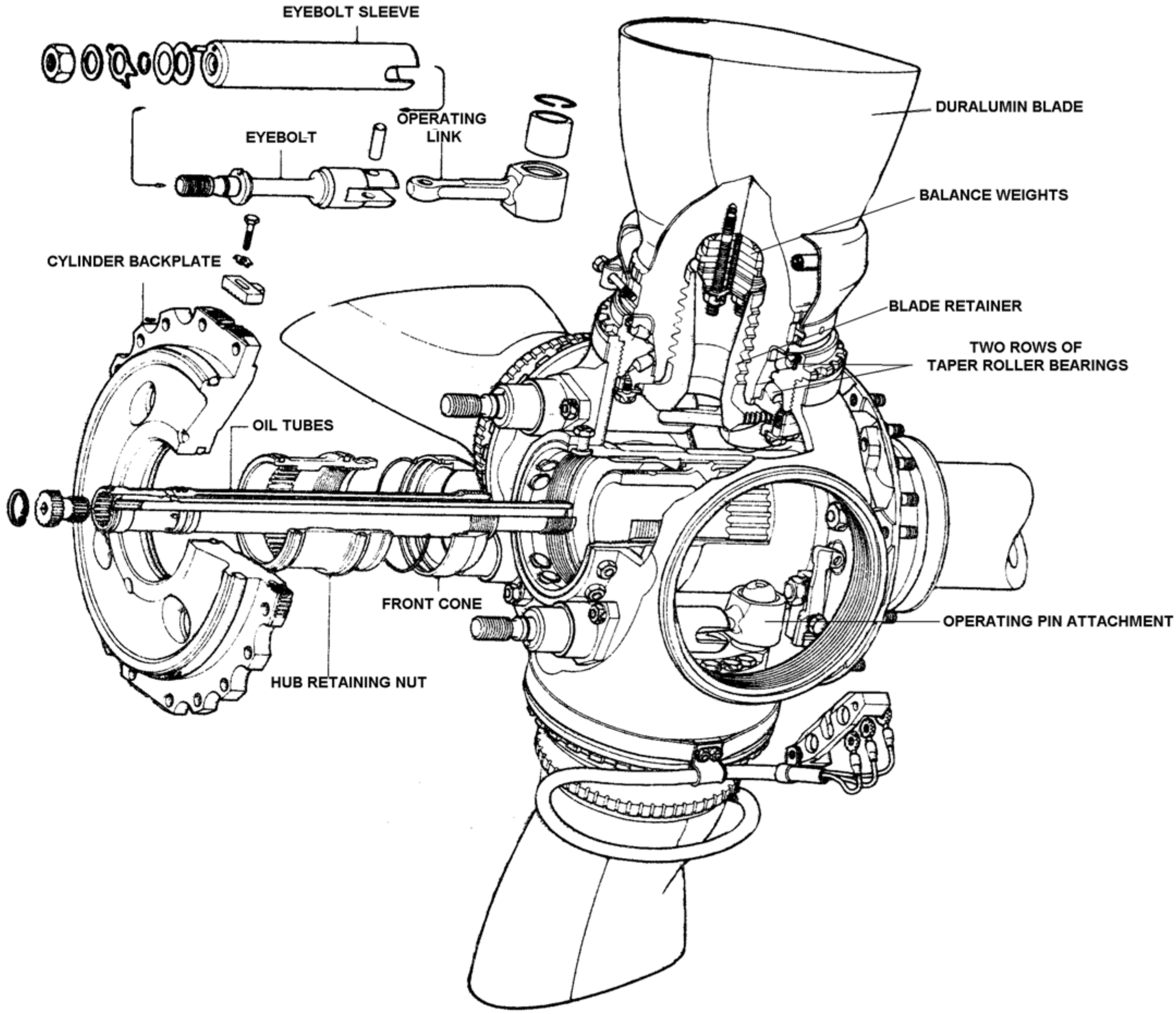
Vibration has always been a major problem in aircraft operation. The lightweight structure has so little mass that it cannot dampen or absorb vibrations that disturb the occupants, fatigue the structure, and cause cracks.

There are two sources of propeller-induced vibration; those caused by an out-of-tract condition and those caused by an out-of-balance condition.

2 PROPELLER CONSTRUCTION

2.1 METAL PROPELLERS

Most metal propellers have forged alloy blades protected from corrosion by anodising and often further protected by polyurethane enamel. A few propellers with hollow steel blades are still flying, but these are usually found only on special-purpose aeroplanes.



Metal Blade Construction (Dart)
Figure 2.1.

2.2 COMPOSITE PROPELLER BLADES

Laminated wood, forged aluminium alloy, and brazed sheet steel propellers have been the standard for decades. But the powerful turbo-propeller engines and the demands for higher-speed flight and quieter operation have caused propeller manufacturers to exploit the advantages of modern advanced composite materials.

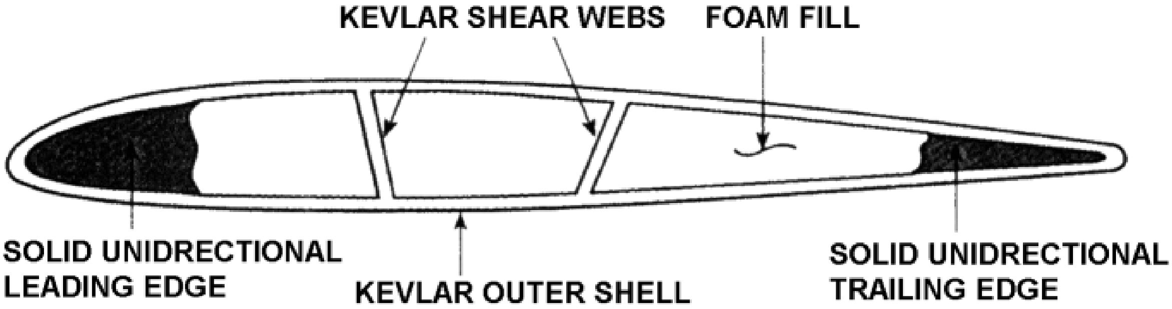
Composite material used in propeller manufacturing consist of two constituents; the fibres and the matrix. The fibres most generally used are glass, graphite, and aramid (Kevlar™), and the matrix is a thermosetting resin such as epoxy.

The strength and stiffness of the blades are determined by the material, diameter, and orientation of the fibres. The matrix material supports the fibres, holds them in place, and completely encapsulates them to protect them from the environment.

Because the fibres have strength only parallel to their length, they are laid up in such a way that they are placed under tensile loads.

The typical Hartzell composite propeller, like that in Figs.2.2. to2.4. below, has a machined aluminium alloy shank, and moulded into this shank is a low-density foam core. Slots are cut into the foam core and unidirectional Kelvar shear webs are inserted. The leading and trailing edges are made of solid sections of unidirectional Kelvar, and laminations of prepreg material are cut and laid up over the core foundation to provide the correct blade thickness, airfoil shape, pitch distribution, planform, and ply orientation. The outer shell is held in place on the aluminium alloy shank by Kelvar filaments impregnated with epoxy resin wound around the portion of the shell that grips the shank.

Some Hartzell blades have a stainless steel mesh under the final layer of Kevlar to protect against abrasion, and a nickel leading edge erosion shield is bonded



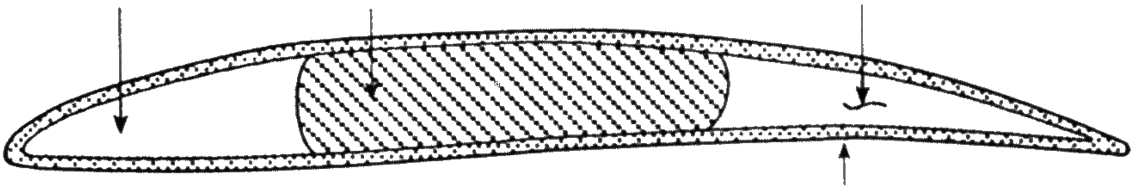
Cross Section of a Hartzell Propeller Blade
Figure 2.2.

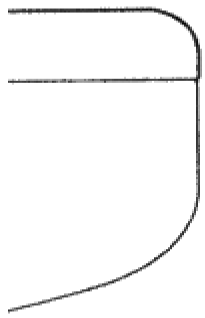
in place.

The entire blade is put into a blade press and cured under computer-controlled heat and pressure.

PRIMARY RETENTION WINDINGS

SHIELD





CROSS SECTION OF A HAMILTON-STANDARD COMPOSITE PROPELLER BLADE

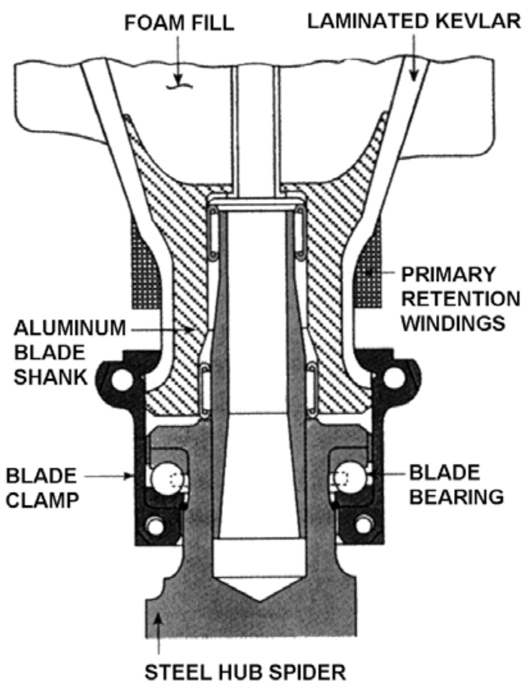
SHANK OF ALUMINUM PLUG

Figure 2.5.

LAMINATED KEVLAR

PLAN VIEW OF A HARTZELL COMPOSITE PROPELLER BLADE

Figure 2.3.



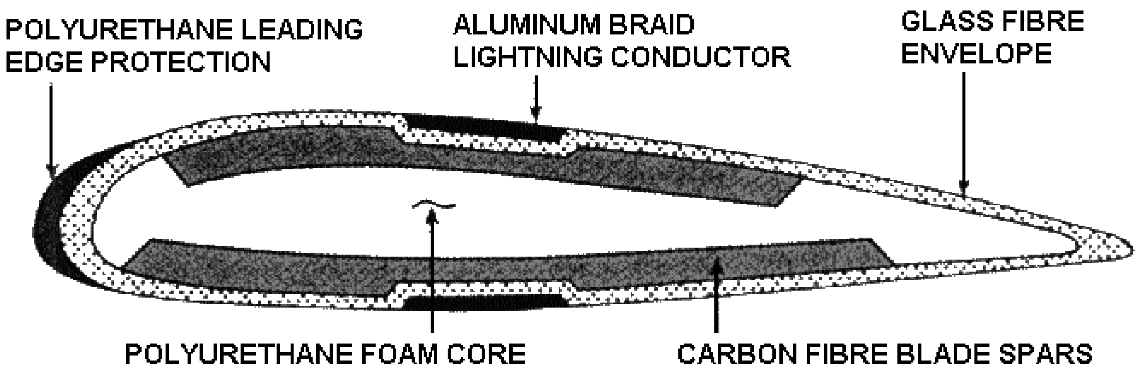
METHOD OF BLADE RETENTION OF A HARTZELL COMPOSITE PROPELLER BLADE

Figure 2.4.

The Hamilton-Standard blade has tremendous strength and fatigue resistance because of its solid aluminium alloy spar enclosed in a glass fibre shell (Fig. 2.5).

The spar is machined to its correct configuration and placed in a mould cavity, and the core foam is injected around it. The foam is cured and is removed from the mould. Glass fibre cloth, with the correct number of plies and the proper ply orientation, is then laid up over the cured core. The complete lay-up is then placed in a second mould that has the shape of the finished blade. The resin matrix is injected to impregnate all the fibres, and is cured with heat and pressure.

The Dowty Rotol composite propeller blade has two carbon fibre spars that run the length of the blade on both the face and back and come smoothly together at the blade root. The carbon fibres and pre-impregnated glass fibre cloth are laid up with the proper number of plies and in the correct ply orientation and are placed in a mould. Polyurethane foam is injected into the inside of the blade, and the entire unit is cured under head and pressure.

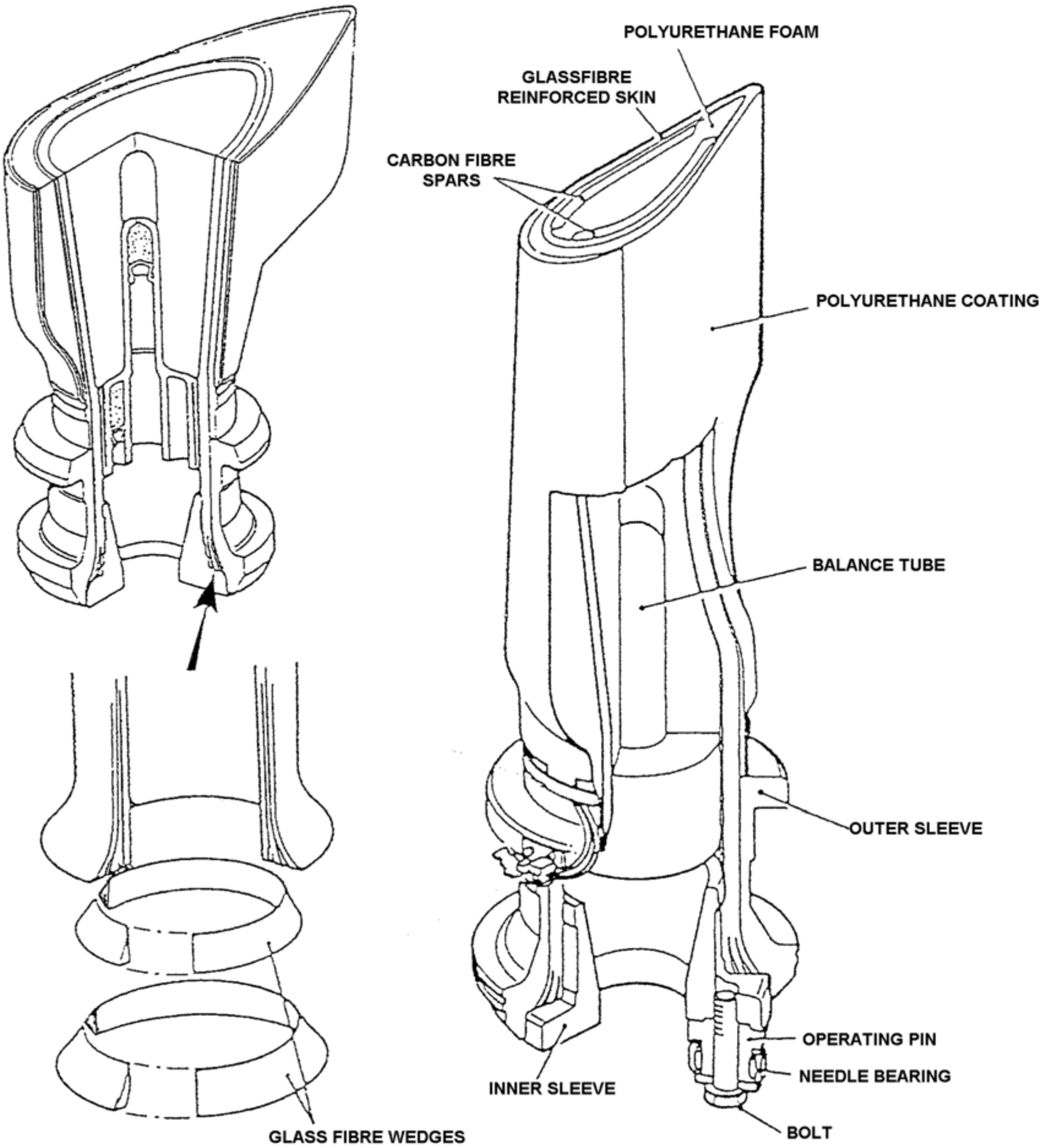


CROSS SECTION OF A DOWTY ROTOL COMPOSITE PROPELLER BLADE

Figure 2.6.

Figure 2.7.

The Dowty Rotor blade is secured in the hub by expanding the carbon fibres spars with tapered glass fibre wedges and locking them between the inner and outer sleeves (Fig. 2.7).



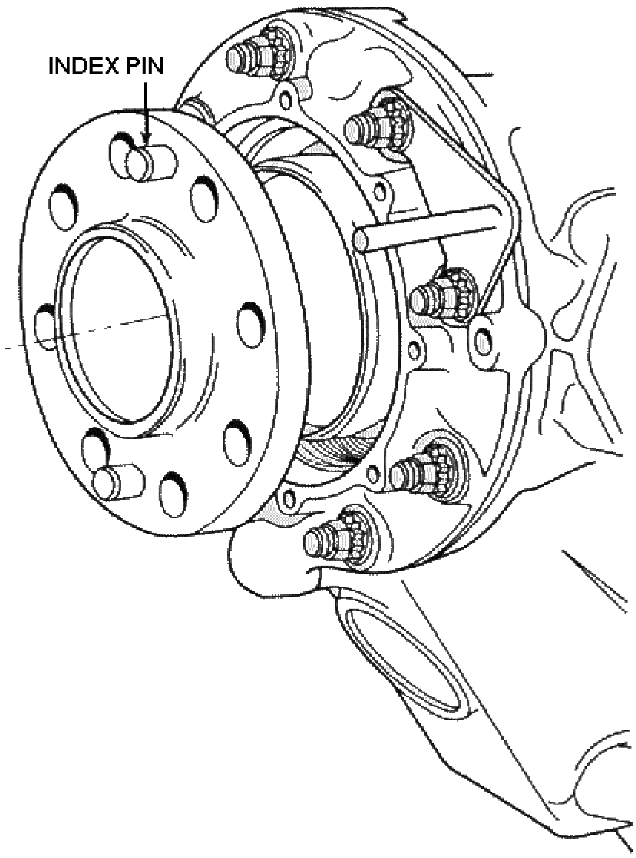
Method of Blade Retention Using Glassfibre Wedges (Dowty Rotol).
Figure 2.7.

Composite propeller blades are much lighter than metal blades capable of absorbing the same amount of power. The lighter blades impose less centrifugal loading on the hub, allowing it to be made lighter. Composite blades have very low notch sensitivity, and their foam cores absorb much of the vibration that would damage metal propellers. While composite blades currently cost more than metal blades, their greater efficiency and longer life make them much more cost effective.

2.3 PROPELLER SHAFTS

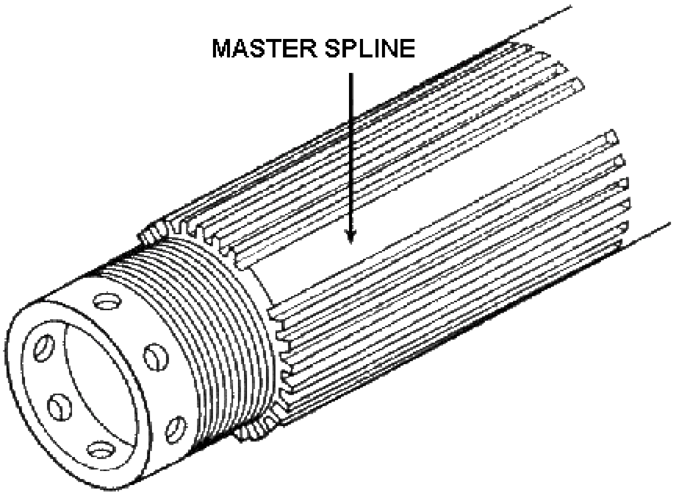
Most modern engines, both reciprocating and turbine, have flanged propeller shafts. Some of these flanges have integral internally threaded bushings that fit into counterbores in the rear of the propeller hub around each bolt hole. Propellers with these bushings are attached to the shaft with long bolts that pass through the propeller. On others the flange has a ring of holes and bolts pass from the engine side into threads in the propeller.

Some flanges have index pins in the propeller flange so the propeller can be installed in only one position relative to the shaft (Fig. 2.8.) this done for synchronising and/or synchrophasing.



A Flanged Propeller Shaft with an index pin
Figure 2.8.

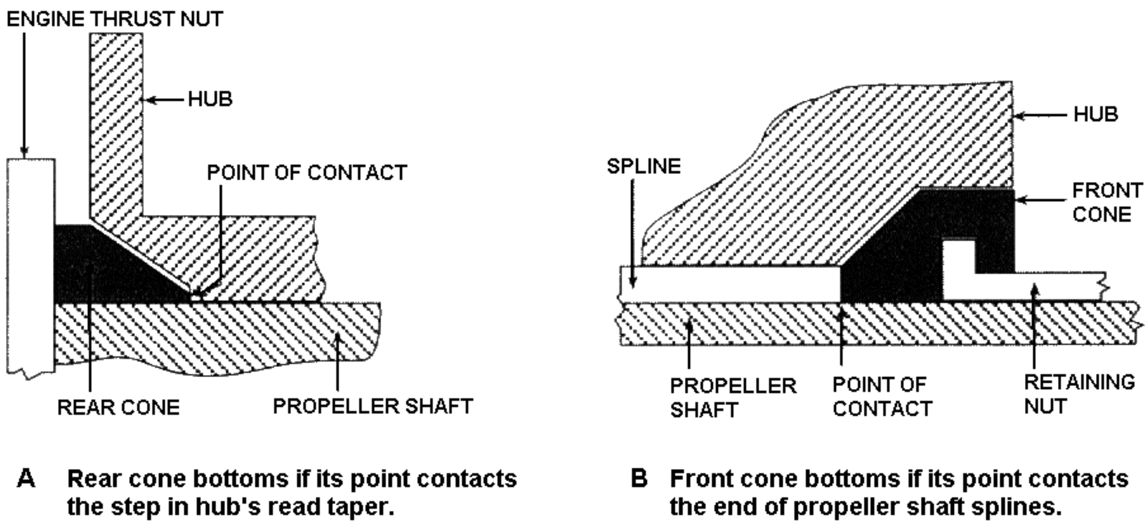
The most popular type of propeller shaft on reciprocating engines built through World War II and on the larger turboprop engines is the splined shaft. The sizes of splined shafts are identified by an SAE (Society of Automotive Engineers) number, SAE 20 splines are used on engines in the 200-horsepowered range; SAE 30 splines are used in the 300- and 400-horsepowered range, and SAE 40 in the 500- and 600-horsepowered range. SAE 50 in the 1,000-horsepowered range and SAE 60 and 70 are used for larger engines.



Splines are longitudinal grooves cut in the periphery of the shaft. The grooves and lands (the space between the grooves, Fig. 2.9.) are the same size, and one groove is either missing or has a screw in it to form a master spine. The purpose of the master spline is the same as the index pin.

A splined Shaft With a Master Spline.
Figure 2.9.

The inside of the propeller hub is splined to match the shaft and the hub is centred on the shaft with two cones (Fig 2.10.). The rear cone is a single-piece split bronze cone, and is considered to be part of the engine. The front is a two piece hardened steel cone and is considered to be part of the propeller. The two halves are marked with the same serial number to ensure that only a match set is used. Prior to attaching a this type of propeller, a check is carried out to ensure correct contact of the cones. Engineers blue is applied to the cones and the propeller is fitted and torqued up, the propeller is then removed and there should be an even 80% contact around the cone on the propeller as seen by the blue, if there is not the cone can be stoned to fit, or replaced.

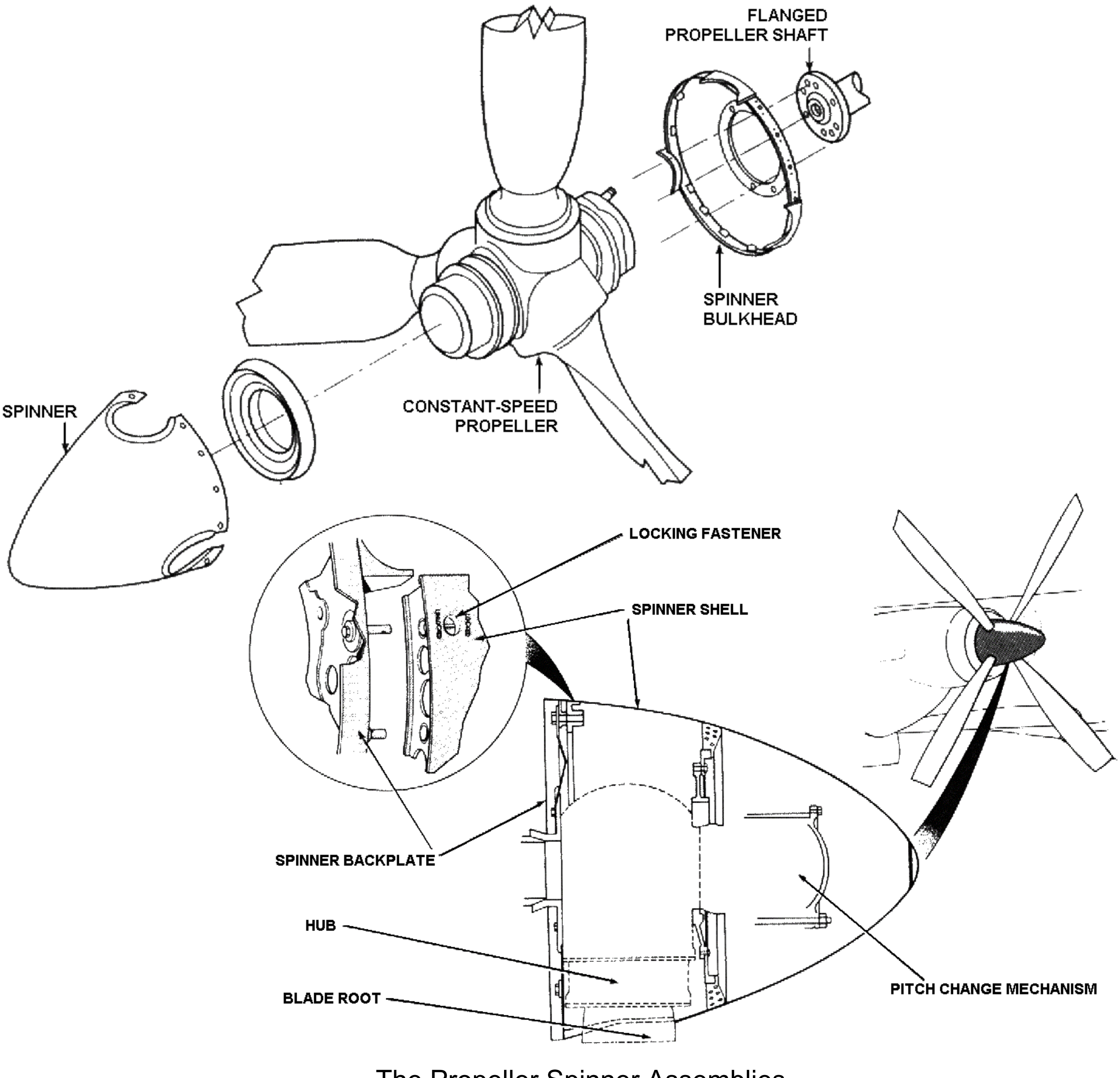


Propeller Shaft Centring Cones

Figure 2.10.

2.4 PROPELLER SPINNERS

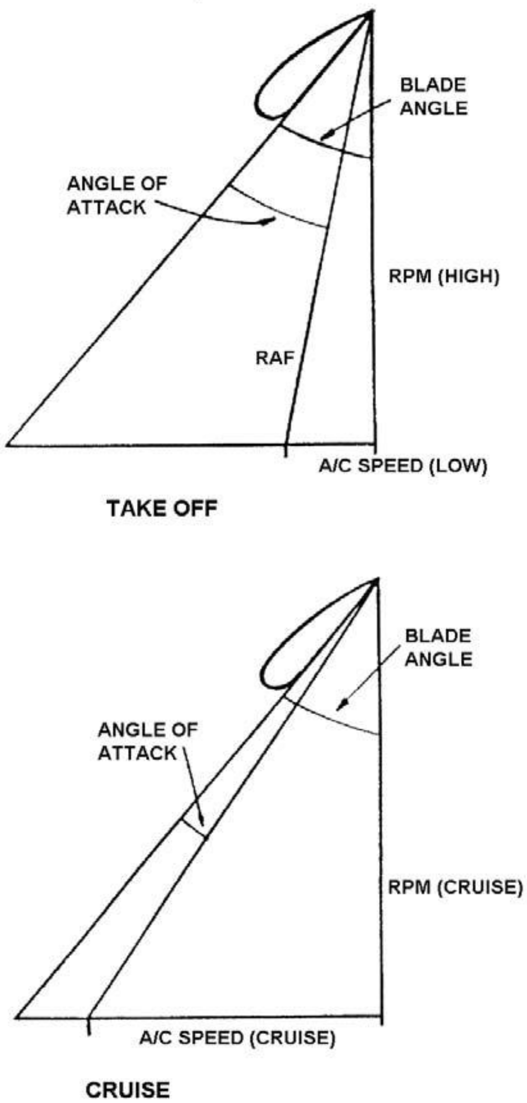
All modern propeller-driven aeroplanes have spinners (Fig 2.11.) over their propeller hubs. These spinners have the dual aerodynamic function of streamlining the engine installation and directing cool air into the openings in the cowling. The diagram below shows a typical spinner installation over a constant-speed propeller. The spinner bulkhead is installed on the propeller shaft flange and held in place by six spinner attaching bolts. The propeller is then installed so that the dowel pins in the propeller hub align with the holes in the flange. The propeller attaching nuts are installed and tightened to the torque value specified in the airframe maintenance manual.



The Propeller Spinner Assemblies
Figure 2.11.

2.5 DISADVANTAGES OF A FIXED PITCH PROPELLER

- A fixed blade angle will only be efficient at one combination of airspeed and RPM.
- During take off (Fig. 2.12.) the angle of attack will be large because the airspeed is low with a high RPM.
- With the blades nearly stalled, the acceleration is poor and a long take off run is required.
- At cruise conditions (Fig. 2.12.) the angle of attack is small and the forward speed is limited to prevent an engine overspeed.
- The fixed pitch propeller has to compromise to improve take off performance by reducing the cruise performance.



Propeller Angle of Attack During Take-Off and Cruise

Figure 2.12.

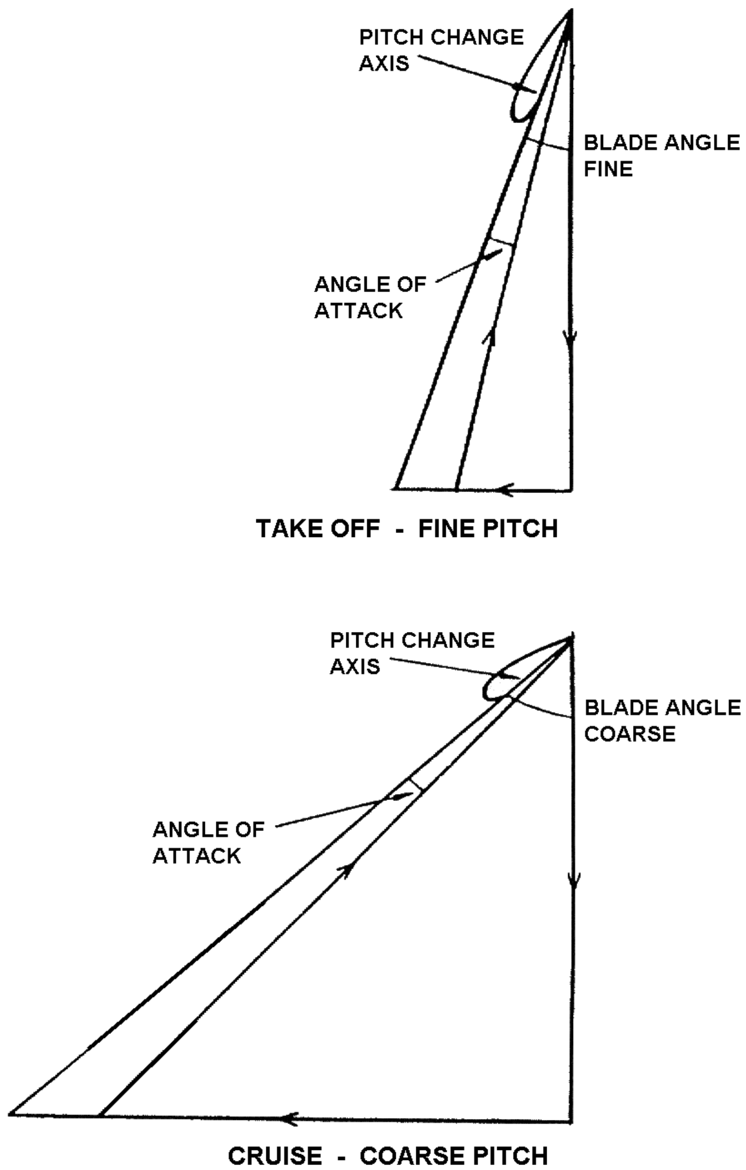
2.6 TWO PITCH PROPELLER

To improve the propeller performance a two pitch propeller was evolved, it enabled two blade angles to be selected.

- For **take off** and **climb** a low blade angle or **Fine Pitch** (Fig 28)is used.
- For **cruise** a large blade angle or **Coarse Pitch** (Fig 28) is selected.

This improves the performance in both conditions as the angle of attack is near the optimum for take off and cruise.

The Two Pitch propeller is limited as it behaves like a fixed pitch propeller once the selections are made.



Take off and Cruise on a Two Pitch Propeller
Figure 2.13.

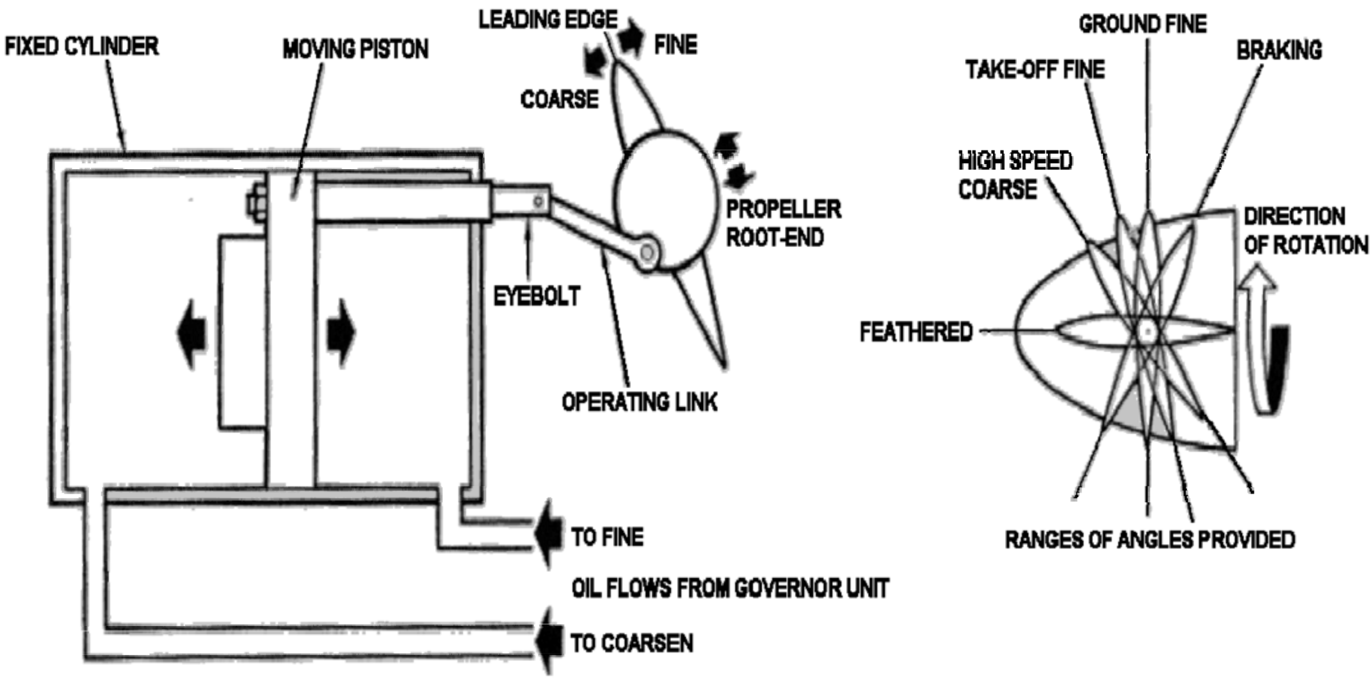
2.7 CONSTANT SPEEDING PROPELLER

The definition of a Constant Speeding propeller is 'A propeller, the pitch setting of which varies automatically to maintain a preselected constant rotational speed'.

The variable pitch propeller overcomes the disadvantages of the fixed and two pitch propellers by maintaining the best propeller speed to suit the engine power output. The propeller control unit (PCU) or constant speed unit (CSU) maintains the selected RPM through all changes in flight conditions without any assistance from the pilot, it will automatically select the optimum angle of attack for the propeller blades at all times.

Other facilities will be incorporated into the mechanism to enable 'feathering' and power on braking.

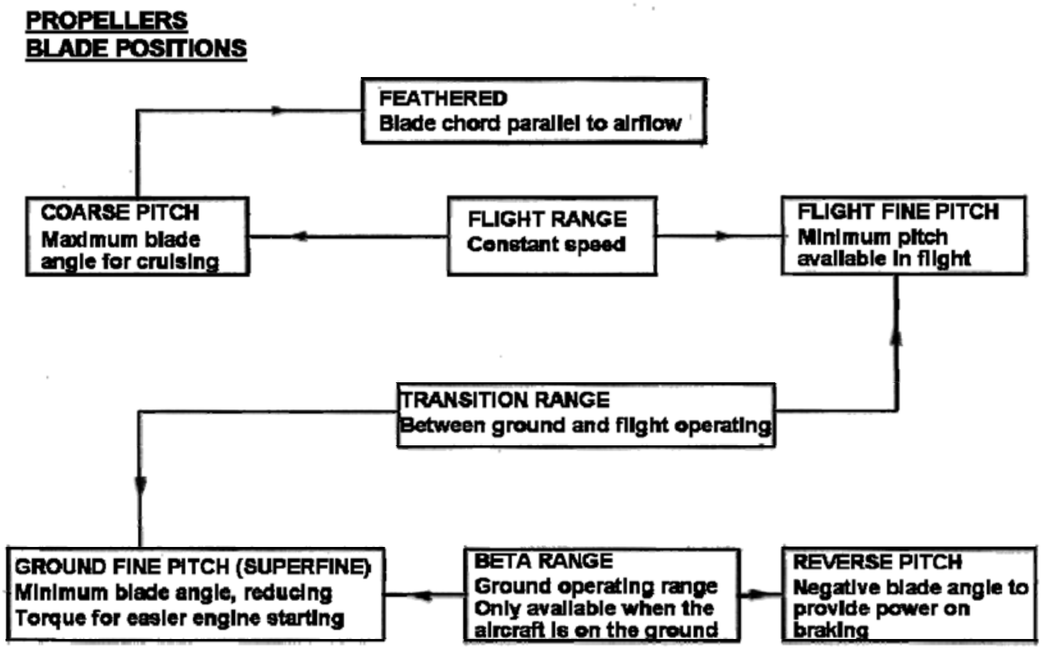
Figure 29 Illustrates the principles of operation of a fixed cylinder constant speed system.



PRINCIPLE OF OPERATION (FIXED CYLINDER TURBO-PROPELLER)

Fig. 29

Figure 30 shows the different Propeller blade positions

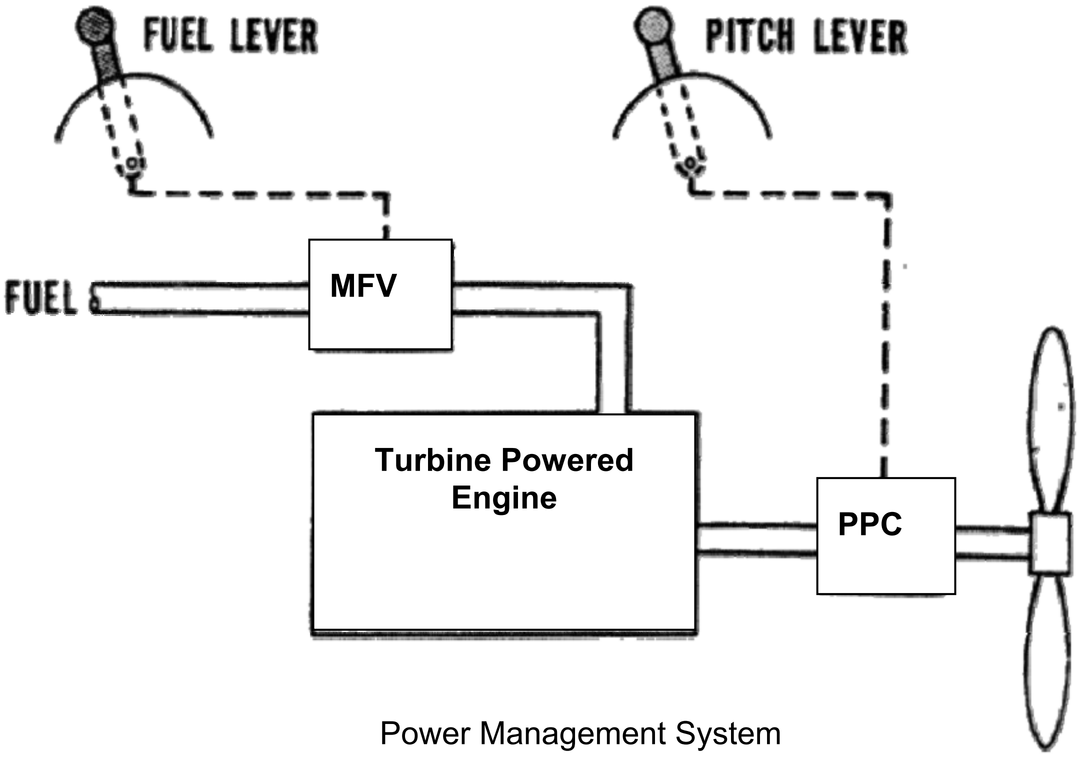


Propeller Blade Positions

Fig.30

3 PROPELLER PITCH CONTROL

Before looking at propeller pitch control an understanding of the relationship between the 'Power Lever' and the 'RPM (condition / speed) Lever' with regard to power management control, the following text is related to a 'fixed shaft', coupled turbo, propeller (Fig. 31).



Power Management System

Fig. 31

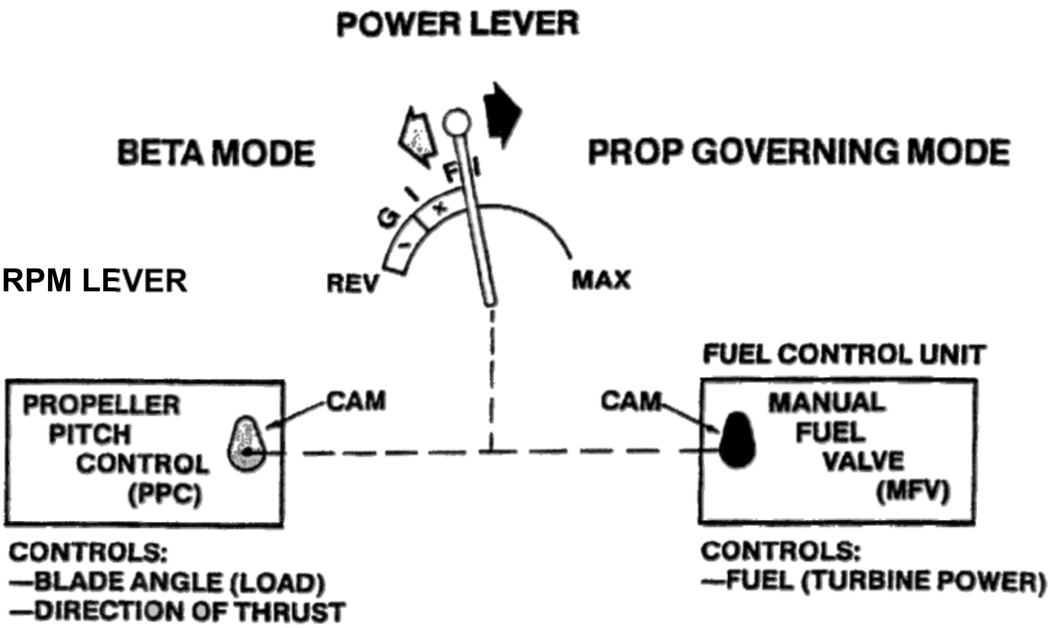
The function of the power management system is to provide a means for controlling load and power. To do this a basic system utilising a lever to control power, and separate lever to control propeller load might be used. Moving the fuel lever alone would cause RPM to increase or decrease, but until the pitch lever is moved no real thrust would be produced. The same could be said about using the pitch lever alone. RPM fluctuations can be caused by varying propeller load, but no real operator of such a system was extremely good, both levers could be worked simultaneously. This would keep RPM constant and give useful thrust with power.

Rather than depend on the skillful movement of two separate levers the two functions are incorporated into one lever, the **Power Lever**. Through a system of cams and linkages it will be rigged to give two modes of operation, 'BETA' mode and 'Prop Governing' mode.

When the power lever is moved between Flight Idle (FI) and Reverse (Rev) it will be operating in the BETA mode with the Propeller Pitch Control (PPC) directly controlling blade angle. From FI to Max. the propeller governor will adjust blade angle in response to the fuel flows demanded by the Manual Fuel Valve (MFV) situated with the Fuel Control Unit (see Fig. 32).

When the power lever is advanced forward from the flight idle detent, the propeller pitch control cam will normally hold the propeller at a fixed pitch. The manual fuel valve cam will then cause fuel to increase and RPM to increase eventually giving authority to the propeller governor, see following diagram.

Note: The propeller pitch control unit is **not** the propeller governor (PG).

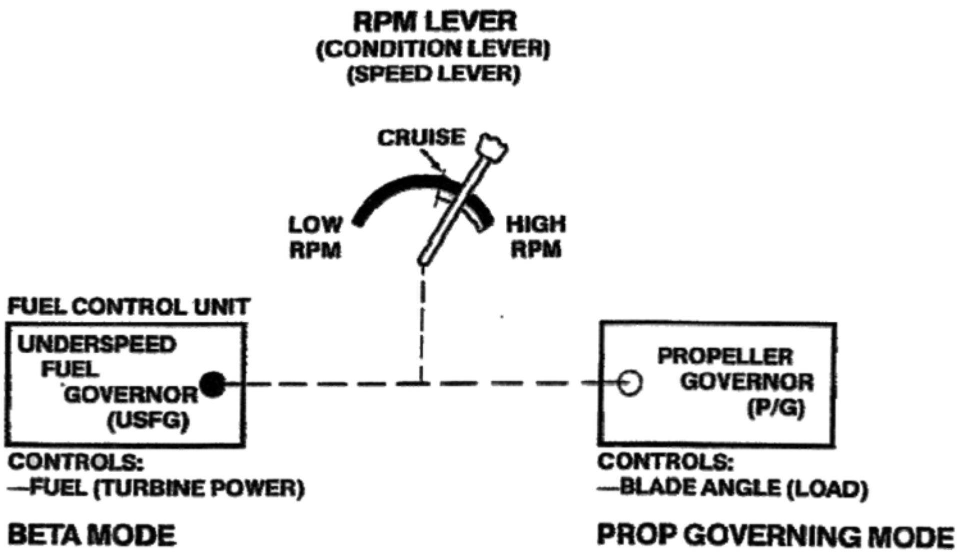


Power Control System

Fig.32

3.1 RPM LEVER

Earlier with the constant speed theory it was pointed out that the engine, with load and power equal, would operate at basically one RPM. Because of different operating conditions, such as taxiing or cruise, it becomes necessary to operate at some other RPM besides 100 percent. This is due to the need for noise reduction, fuel economy or operation at minimum load. The only function of the speed lever is to set engine operating RPM. To aid the speed lever, it is linked to the underspeed fuel governor and the propeller governor. The speed lever is used to 'calibrate' or set each governor RPM limit. With the speed lever in the low or taxi position, the underspeed governor is set to 96 percent RPM. When the speed lever is advanced to the high or takeoff position the underspeed governor is set to 97 percent RPM, the propeller governor is set to 100 percent RPM and will not be effective till this RPM is attained by forward



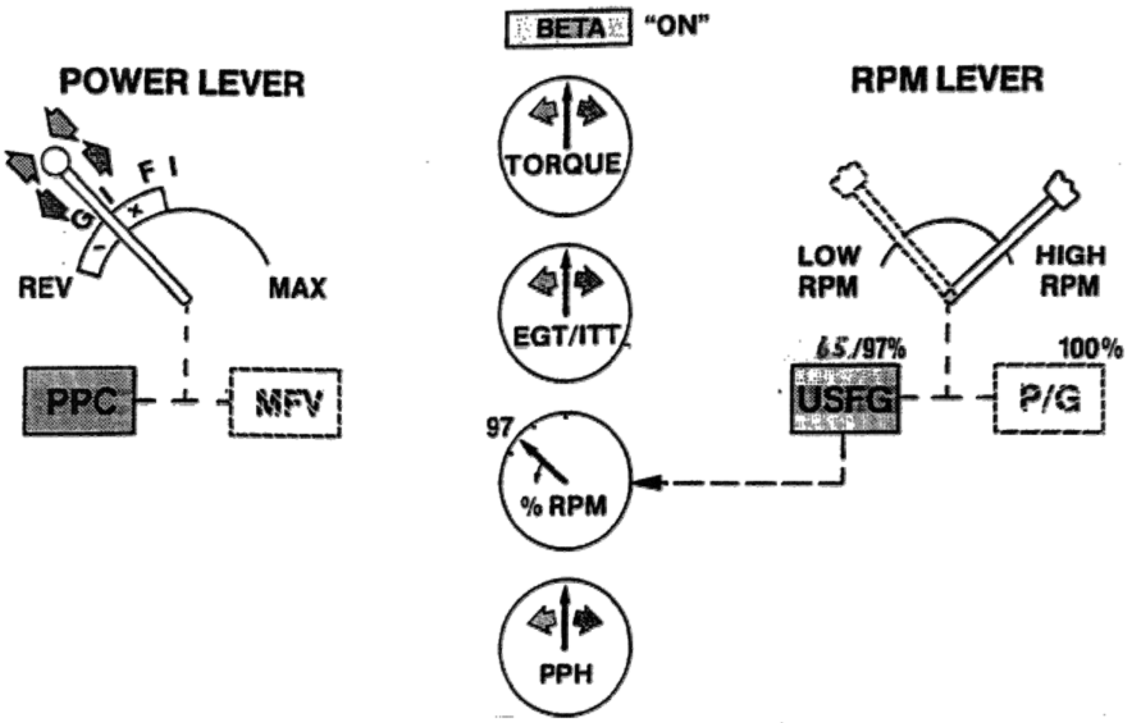
Engine RPM Control

Fig 33

movement of the power lever.

3.1.1 BETA MODE

In 'beta' or ground mode (Fig. 34) of operation the pilot has manual control of propeller load through the propeller pitch control. The range of operation for the power lever is from flight idle to reverse. In this case the manual fuel valve cam is cut such that it has no effect in this area. Speed control is a function of the underspeed governor. Normal range for the speed lever in beta mode is from low to high. For beta operation the effect of bringing the power lever behind flight idle is that fuel is reduced to the point that RPM drops below the setting of the propeller governor. The underspeed governor then assumes control of fuel to maintain the selected minimum RPM. If the speed lever were high, this RPM would be 97 percent. The need for a beta mode derives itself from the need to manually demand a reverse pitch to bring the aircraft to a stop after landing. Also thrust directional control is needed to provide adequate control of the aircraft for taxiing.

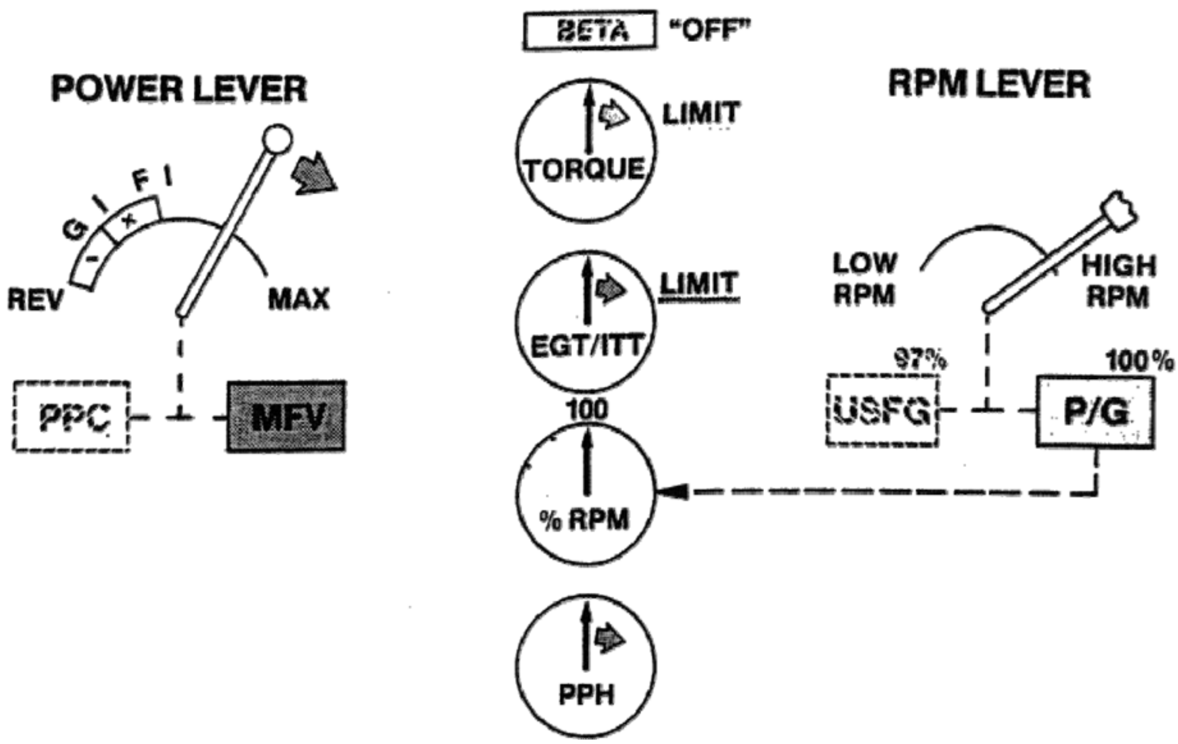


The Beta Mode

Fig. 34

3.1.2 PROPELLER GOVERNING MODE

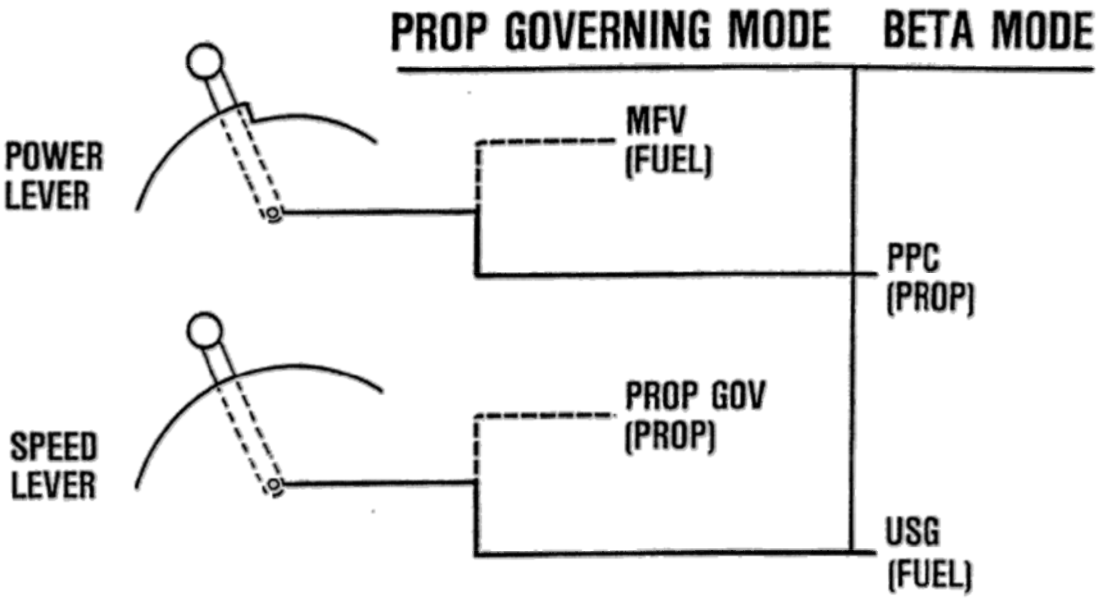
The speed lever is placed in the high position. The engine is operating at 97 percent. As the power lever is advanced ahead of the flight idle detent this causes the power lever cams to react by momentarily holding a fixed pitch and increasing fuel. As RPM increases, it reaches overrides the underspeed governor and reaches the propeller governor setting of 100 percent. The propeller governor then takes control of blade angle and increases it to maintain the selected RPM by equalling load with the power demand. This is known as 'propeller governing mode' of operation. Because of the cut of the cam the propeller pitch control has no effect so the propeller governor has automatic load control. The underspeed governor is effectively overridden by the manual fuel valve (Fig 35).



Propeller Governing Mode

Fig. 36

In the prop governing or inflight mode (Fig 37), the range of operation of the power lever is from flight idle to maximum. The effective component is the manual valve. Normal propeller governing mode quadrant of operation for the speed lever is from cruise to takeoff, or high. As previously stated the increased fuel demand drives RPM to the setting of the propeller governor which changes the blade angle of the propeller to equal the demanded power.



The Prop Governing/In-flight Mode

Fig. 37

To sumarise, during flight the manual fuel valve is the effective component giving a manual power demand. The propeller governor, the other effective component, is responsible for automatic load control to equal with the manual power demand and maintain the selected engine RPM. This is known as 'propeller governing mode'.

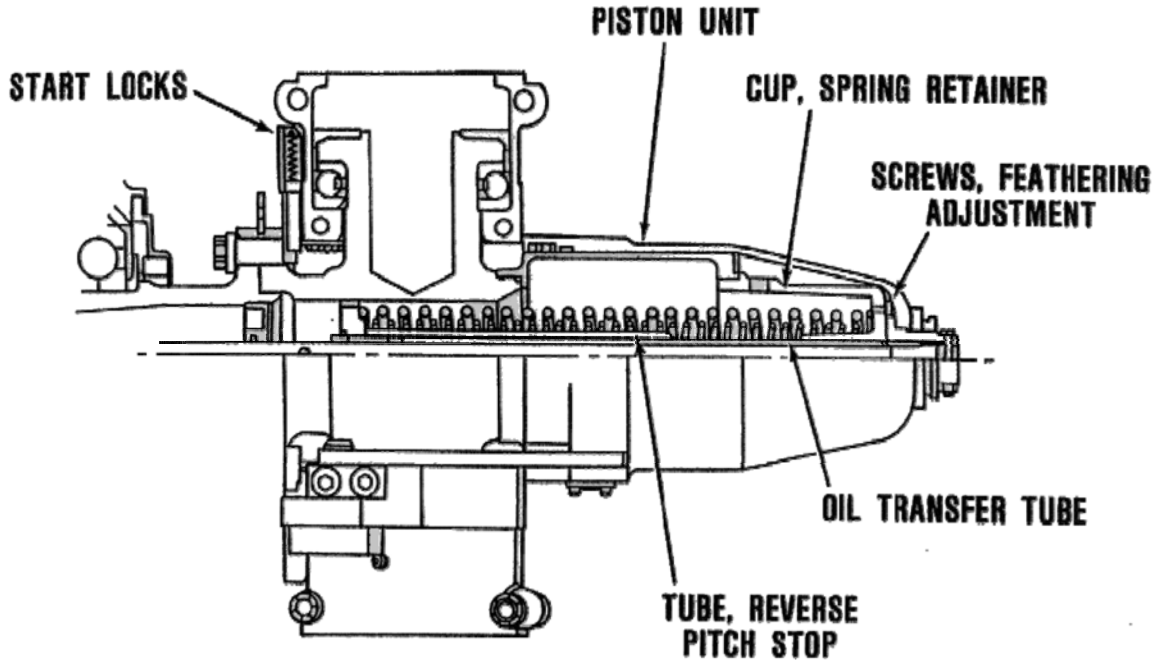
For ground operation, the propeller pitch control provides manual load control, the underspeed governor automatically controls fuel flow in response to load changes. This equals power and load to maintain selected engine RPM. This is called 'beta mode'.

The propeller control system is designed to operate in either of two modes. These modes are; the propeller governing or flight mode and beta or grounding operating mode. In the propeller governing mode, the propeller governor meters oil to the propeller as a function of engine speed, power requirements, and pilot demands through the power lever. In the beta or ground operating mode, oil is metered to the propeller by the propeller pitch control, and the propeller blade angle is controlled directly by the power lever movement.

A pressure switch in the propeller hydraulic control system is used to power an indicator light on the cockpit instrument panel. The light is illuminated when the propeller is operating in beta mode and out when the propeller is operating in governing mode.

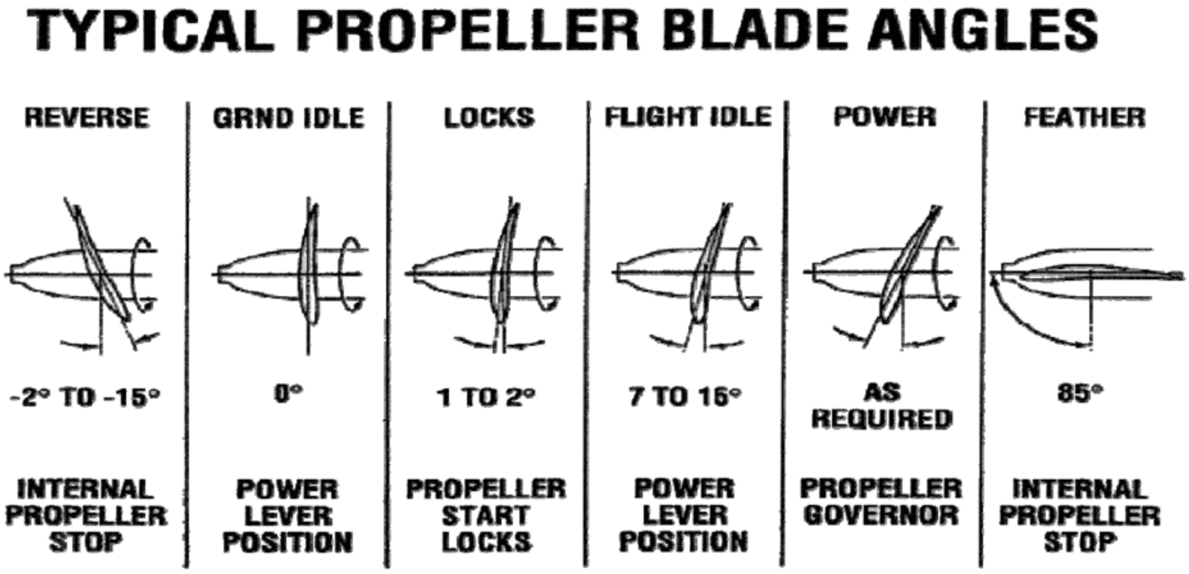
If the engine should lose power during flight, a negative torque sensing system is used to automatically effect movement of the propeller blades toward the feather position.

The propeller control system consists of a propeller, oil transfer tube, propeller governor, propeller pitch control, propeller feathering valve, propeller unfeathering pump, and a negative torque system. The oil transfer tube treads into the propeller piston and extends into the propeller pitch control. Propellers used on this system are spring loaded to feather and require oil pressure from the propeller control system to decrease pitch angle. The propellers that are typically selected for use are illustrated in Figs. 38 to below.



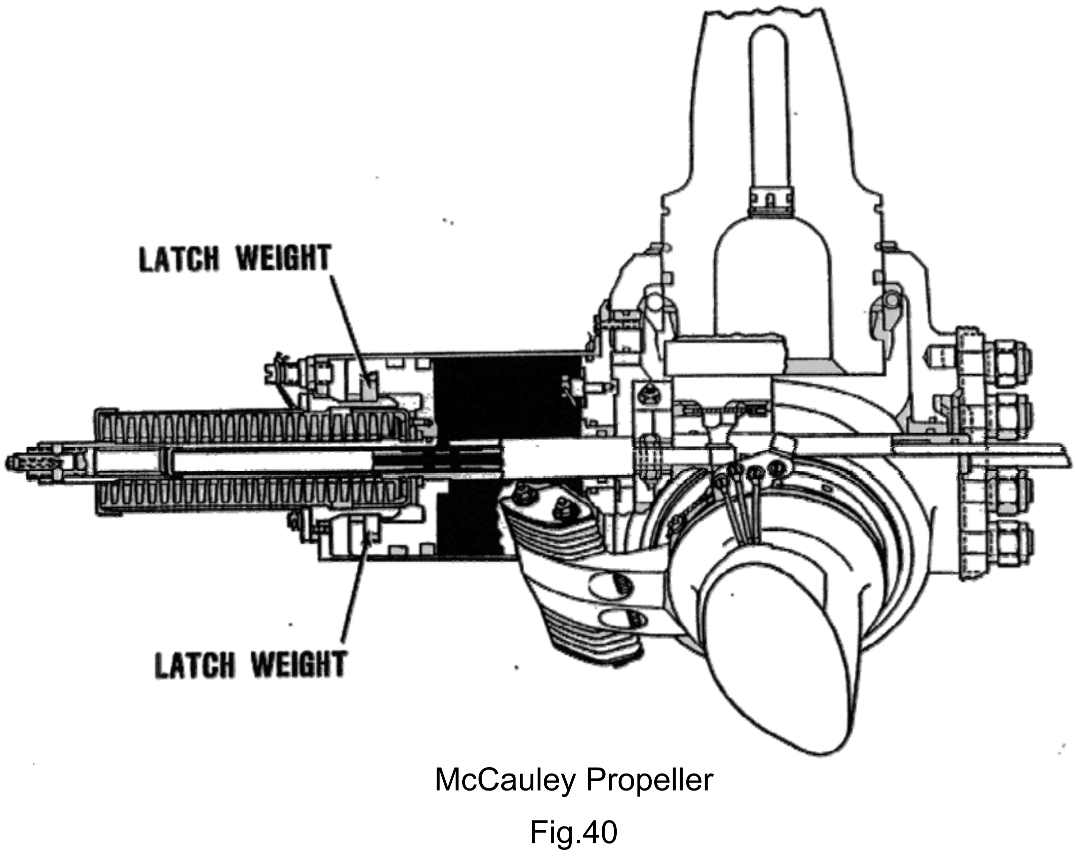
Hartzell Propeller

Fig 38



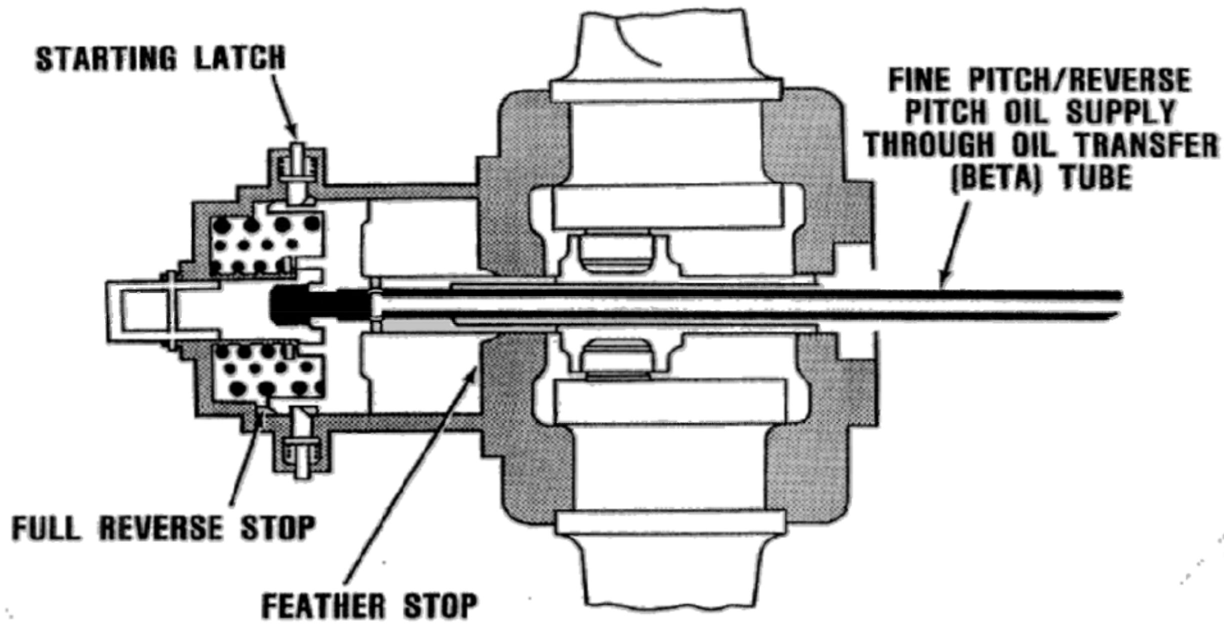
Typical Propeller Blade Angles

Fig. 39



McCauley Propeller

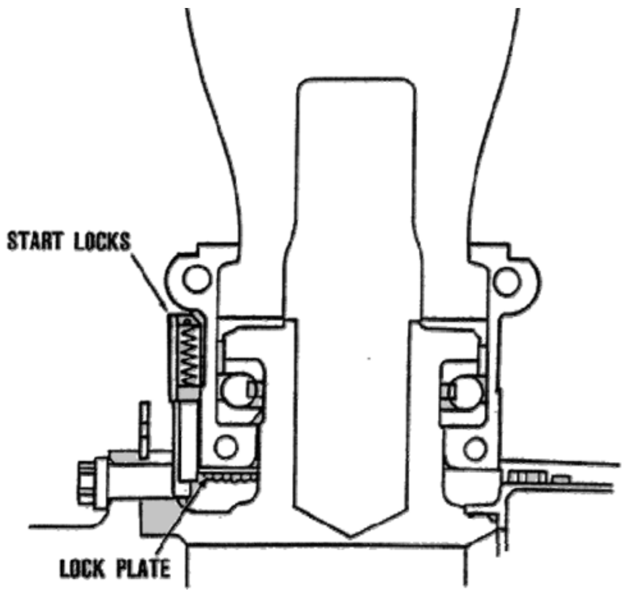
Fig.40



Dowty Rotol Propeller

Fig.41

To minimise the propeller aerodynamic load on the starter and power supply, propellers have 'start locks' to hold the propellers at or near a flat pitch angle during ground starting of the engine. The start locks are spring loaded pins that hold the propeller blades to a flat position. Fig 42 illustrates a typical Hartzell Propeller with the start locks engaged. At the base of each propeller blade hub is a plate that engages the locking pin. The Hartzell propeller is always installed or removed with the blades in a feathered position. This prevents the load of the heavy feather spring from distorting the start lock arrangement.



Hartzell Propeller with the start locks engaged

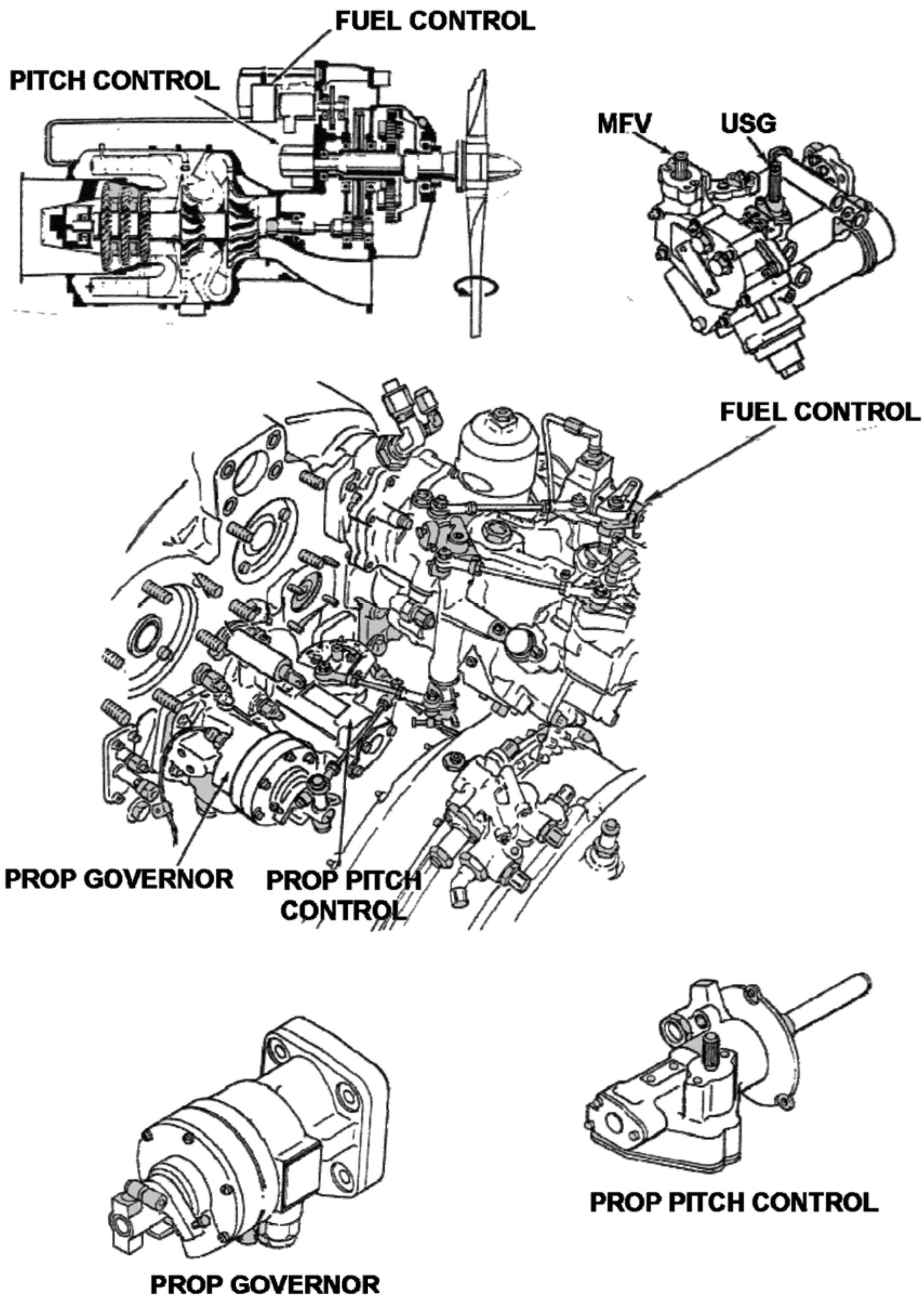
Fig 42

The Dowty Rotal and McCauley propellers have locking pins that restrain the piston in the propeller dome. The single acting propeller is spring loaded to the feather position. During engine operating this spring force is overcome by oil metered from the power management system. However, if the operator fails to put the propeller on the start locks during shutdown, the blades must be moved from a feathered position to a flat pitch for ground starts. A nacelle mounted propeller unfeathering pump is used to put the propeller on the start locks. The procedure for this is to position the power lever to the reverse position, actuate the unfeather pump switch. Oil is then routed to the propeller pitch control through the oil transfer tube to the propeller. Pressure overcomes the spring force and causes the propeller to rotate toward the reverse position. When the start latches engages, the unfeather pump is de-activated.

3.2 PROPELLER CONTROL MECHANISMS

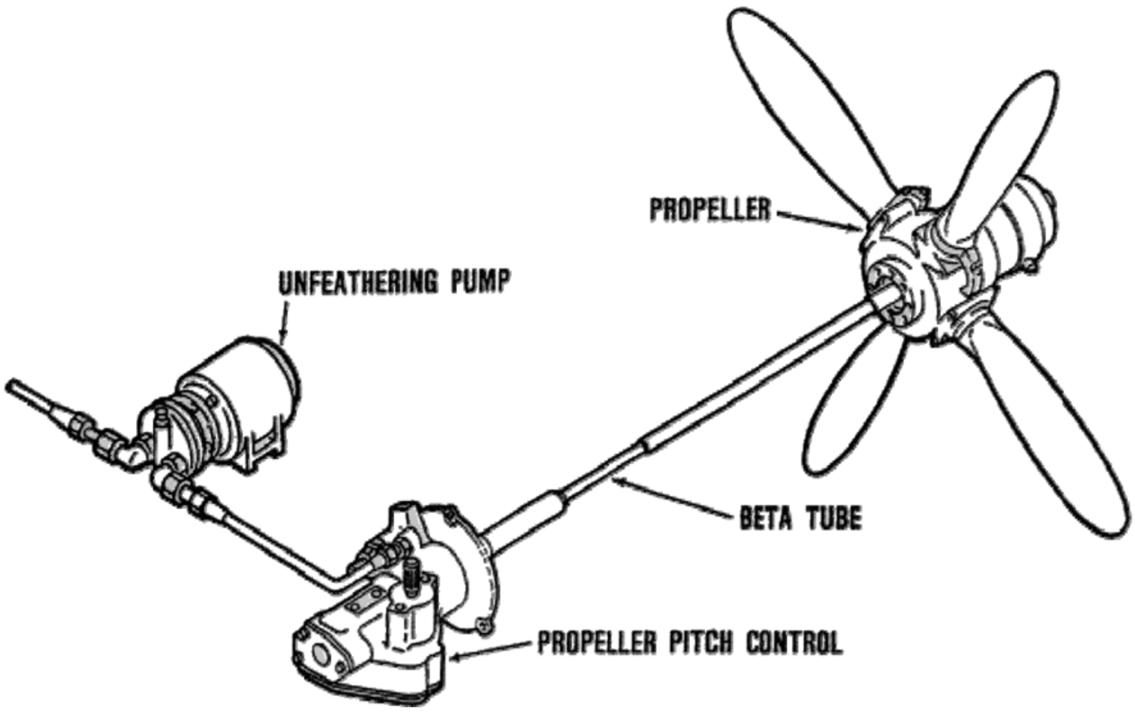
The propeller control mechanisms used on turbo props vary from manufacturer to manufacturer. The example given in the previous chapter on 'Power Management' illustrated the fuel control method (manual fuel valve and underspeed governor). Prop governor and prop pitch control is covered in this chapter, these components will be over viewed and a typical single acting propeller control mechanism explained.

See next page:



Fuel and Propeller Controls

Fig. 44

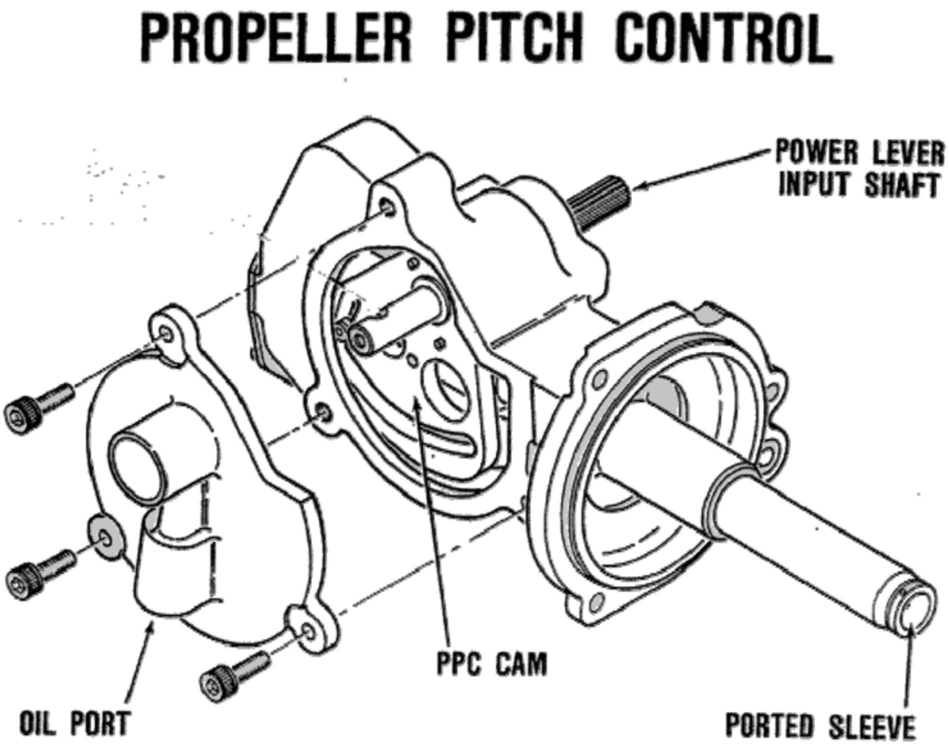


Oil Transfer Tube (Beta Tube)

Fig 45

The oil transfer tube (beta tube) (Fig. 45) is threaded into the propeller piston and extends aft, through the engine propeller shaft, and into the propeller pitch control. The tube portion housed within the propeller pitch control ported sleeve has oil ports through which propeller governor discharge oil is routed to the propeller dome. During beta mode, the oil transfer tube is positioned by power lever movement of the servo-valve in the propeller pitch control which meters oil pressure to the piston to position blade pitch angle. During propeller-governor mode, the governor meters oil pressure through the propeller pitch control and oil transfer tube directly to the propeller piston.

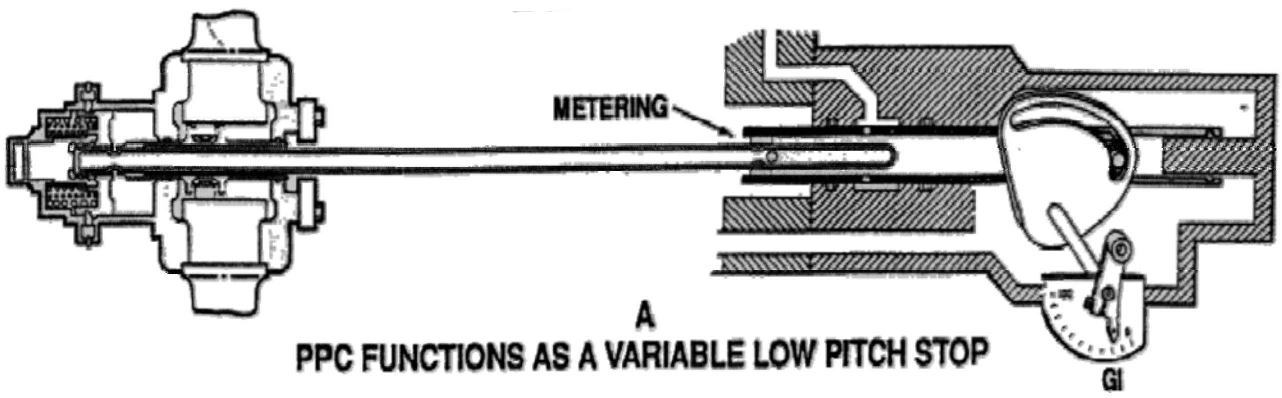
The power lever is mechanically connected to the propeller pitch control and the manual fuel valve in the fuel control. Movement of the power lever results in the rotation of a cam in each control unit. Movement of the cam results in the ported sleeve being extended or retracted within the propeller pitch control. The function of the propeller pitch control in beta mode is to meter oil from the propeller governor pump into the propeller through the beta tube.



Propeller Pitch Control

Fig 46

Advancing the power lever rotates the propeller pitch control cam (Fig 46), which moves the ported sleeve to the right. This action uncovers the holes in the beta tube, as illustrated in View 'A' above. The oil pressure from the propeller piston area drains into the gearcase through the uncovered holes in the beta tube. The reduction in oil pressure allows the propeller springs and counterweights to move the piston to the right, increasing propeller blade pitch angle. The propeller piston continues to move until the holes in the beta tube re-align with the ported sleeve bushing in the propeller pitch control. As illustrated in View 'B' above, oil pressure is now metered in the right amount to hold the propeller blade pitch angle to the selected position.

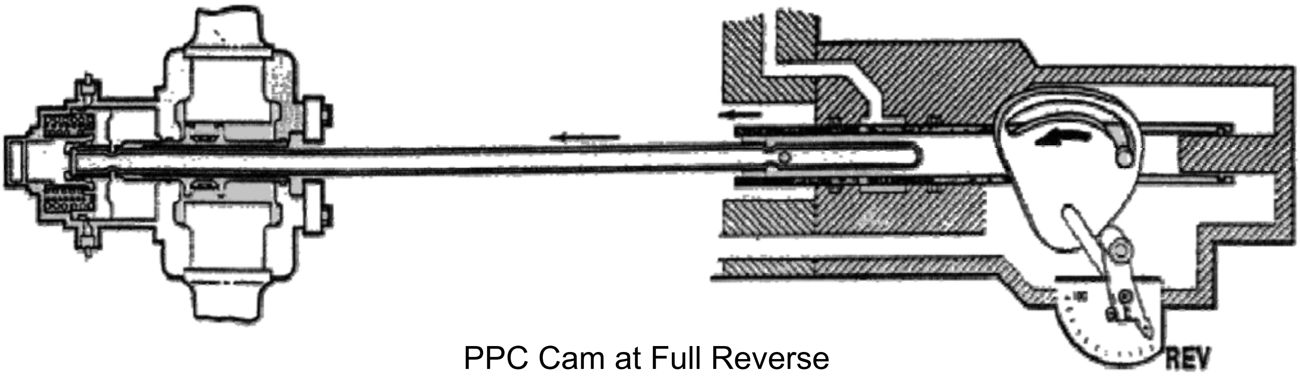


Beta Mode with Power Lever in Ground Idle Position

Fig 46

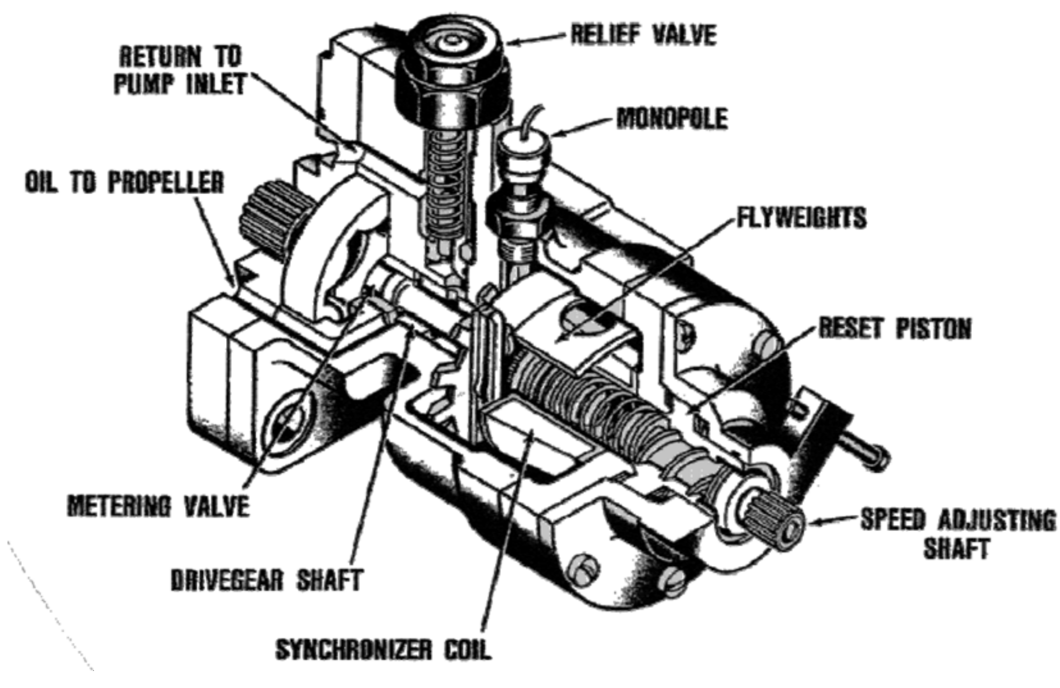
Fig 46 shows the beta mode of operation, with the power lever positioned at ground idle. The ported sleeve bushing meters oil to the propeller piston, which balances the oil pressure against the force of the propeller springs and counterweights. The natural tendency of the propeller springs and counterweights is to move the piston to the feather stop. Oil pressure from the propeller governor pump opposes this action and attempts to fully compress the springs. The small metering holes in the beta tube meter allows only enough oil to balance the forces of the propeller. If the springs were to push the beta tube too far into the ported sleeve, additional pressure from the pump will enter the beta tube, moving the piston to the left to rebalance the forces. Likewise, if the piston were subjected to too much oil pressure, it will move to the left and allow the beta tube holes to bleed the excess oil into the gearcase.

Fig. 47 shows the propeller pitch control cam positioned to full reverse. The ported sleeve completely covers the holes in the beta tube allowing full oil pressure from the propeller governor pump (Fig. 48) to enter into the propeller. The high oil pressure compresses the springs and positions the propeller piston to the internal mechanical stop, and the propeller blades to the full reverse position.



PPC Cam at Full Reverse

Fig 47

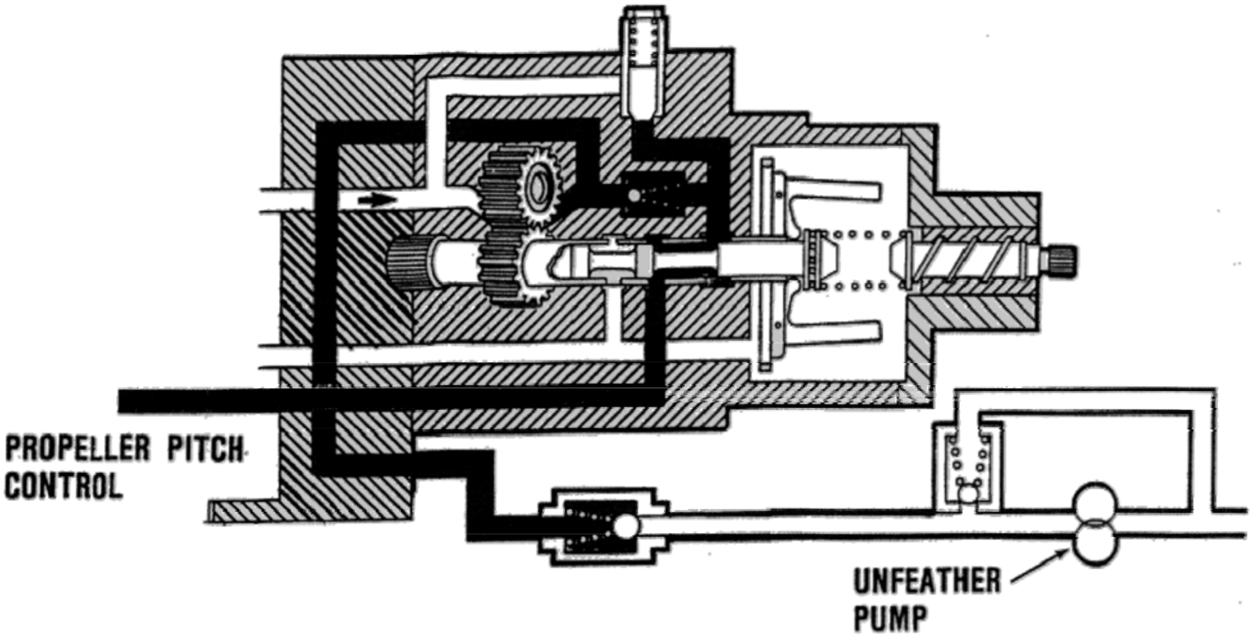


Propeller Governor Pump Assembly

Fig. 48

The propeller governor (Fig 49) is mounted at the rear of the reduction gearcase and provides a constant engine RPM during the propeller governor mode of operation. The gear driven propeller governor shown here is composed of a high pressure integral spur gear, or gerotor pump, sliding metering valve, and a flyweight-type governor. Engine lubricating oil is internally directed to the propeller governor oil pump inlet. The oil pressure is boosted through the propeller governor to about 450 psi, and in response to engine speed demands the propeller governor flyweights control the sliding metering valve to control metered oil pressure. The metered oil flows into the propeller pitch control and through the oil transfer tube to route oil pressure into the propeller dome and piston to control the propeller pitch blade angle.

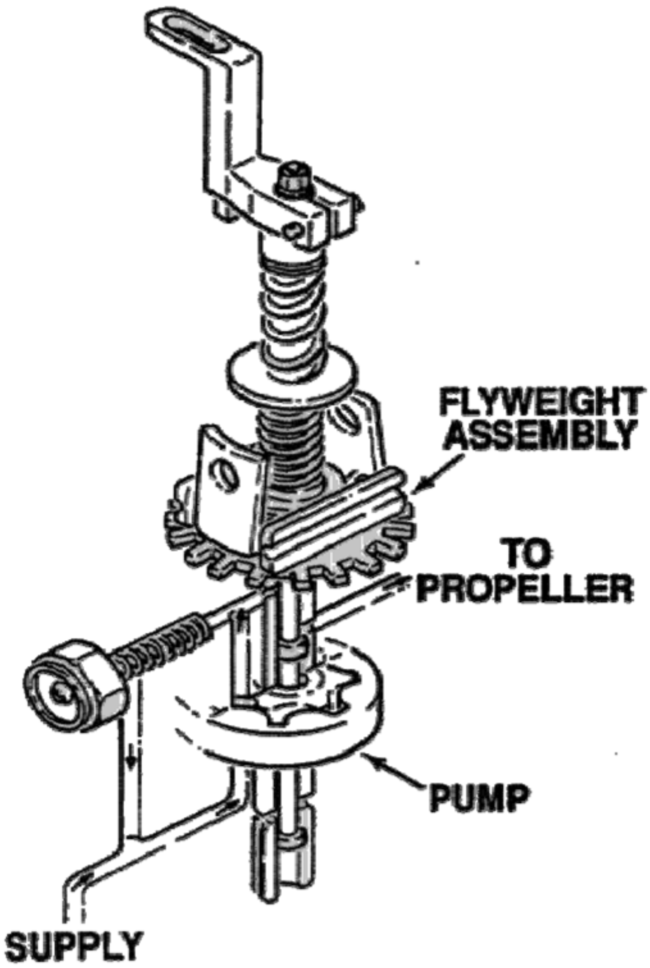
Note: The synchroniser coil and monopole are part of the propeller RPM synchronising system.



Propeller Governor

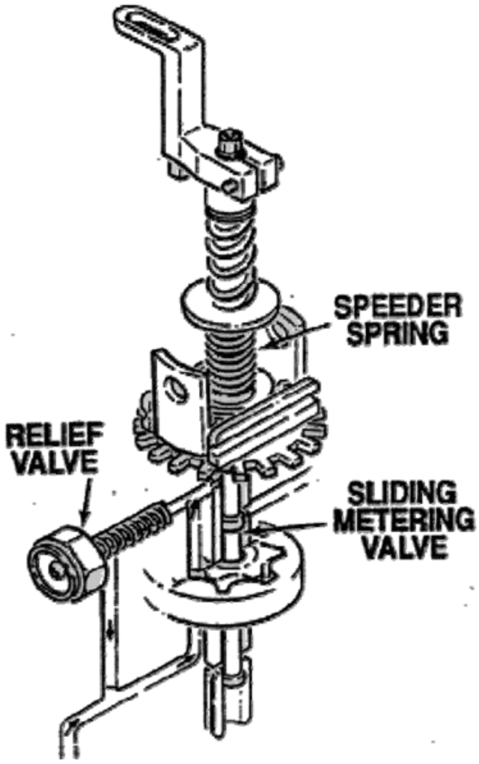
Fig 49

Fig. 50 shows the results of putting the aircraft into a climb situation. Initiating the climb increases the load on the propeller causing a reduction in engine speed. The reduced centrifugal force causes the speeder spring to move the flyweights inwards. The metering valve opening increases the oil pressure to the propeller, which reduces the propeller blade pitch angle and load. This automatically controls speed to maintain the selected RPM setting.



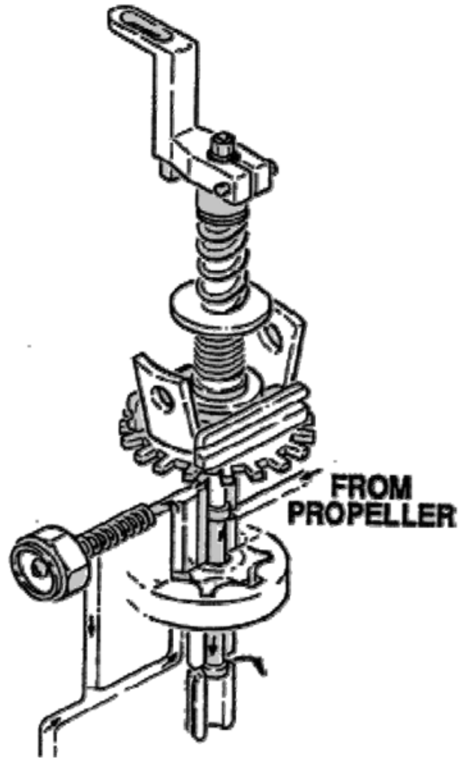
Underspeed

Fig. 50



On Speed Condition

Fig 51 (a)



Over-speed Condition

Fig 51 (b)

Fig 51(a) shows an 'on-speed' condition, the outward force of the flyweights and the spring forces are balanced. This results in the metering valve covering the oil metering port to the propeller. Oil is effectively trapped in the propeller system holding the propeller blades to a selected pitch angle.

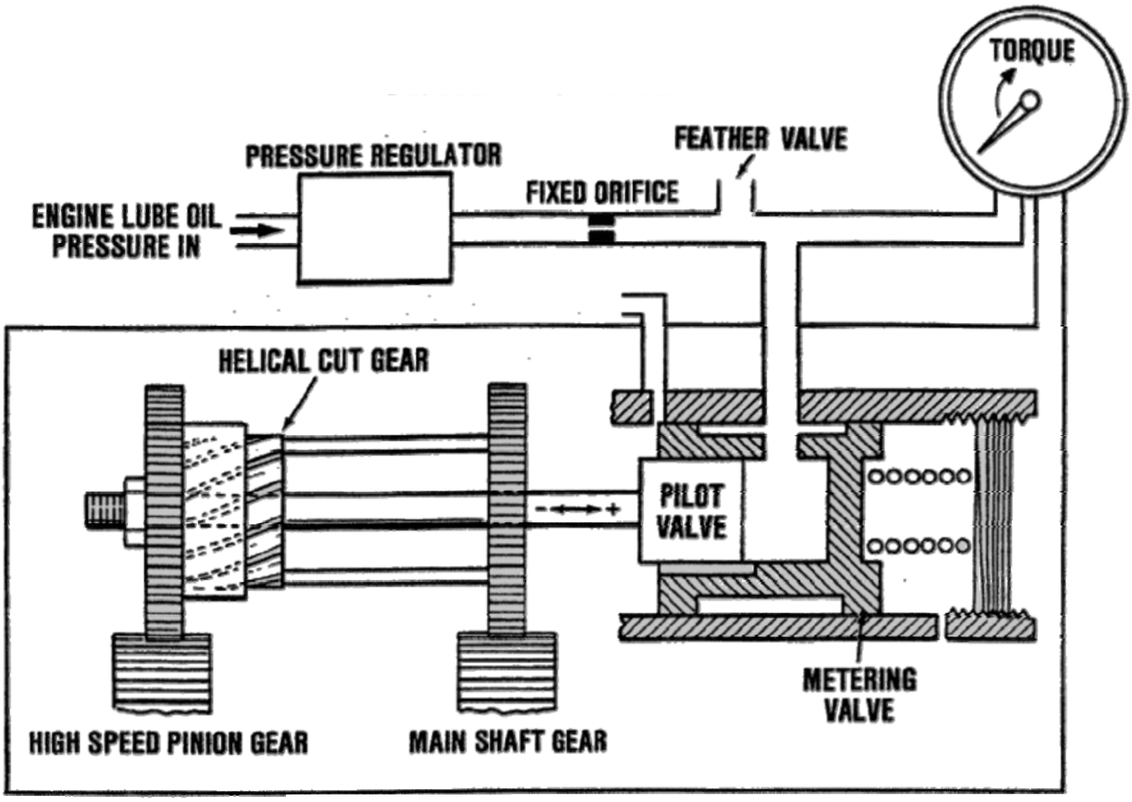
Lowing the nose of the aircraft and descending to a lower altitude reduces the load on the propeller and increases engine speed. As a result of increasing the airspeed the pitch angle of the propeller blades are too low to absorb engine power. As the engine speed starts to increase, the flyweights, Fig 51(b), move outward lifting the metering valve. The metering valve opens and meters propeller control oil to the gear case, which increases the propeller blade pitch angle to maintain the speed setting.

Operating in propeller governor mode during ground testing yields similar results as flight operation. Advancing the power lever adds fuel and power causing an increase in engine speed. The propeller governor responds by reducing oil pressure, increasing propeller pitch angle to maintain the selected engine speed. Retarding the power lever reduces fuel flow and power. The excess propeller blade angle causes a reduction in engine speed. The propeller governor decreases propeller pitch angle maintaining engine speed.

3.2.1 FEATHERING THE PROPELLER

If there is an engine failure in flight, the propeller would windmill creating drag and increasing any damage that had occurred in the engine. Feathering is the procedure by which the propeller blades are turned beyond the coarse pitch position until they are edge on to the airflow. This action stops rotation and reduces the drag of the stationary propeller to a minimum.

As present we are only considering the single acting propeller mechanism which adopts the use of a spring to force the propellers to the feathered position. Students should be aware that on some hubs a nitrogen charge within the hub provides the force to feather. Double acting variable pitch propellers which will be looked at later use electrical feathering / auxiliary oil pump to provide the force for feathering.



Simplified Torque Sensor System

Fig. 53

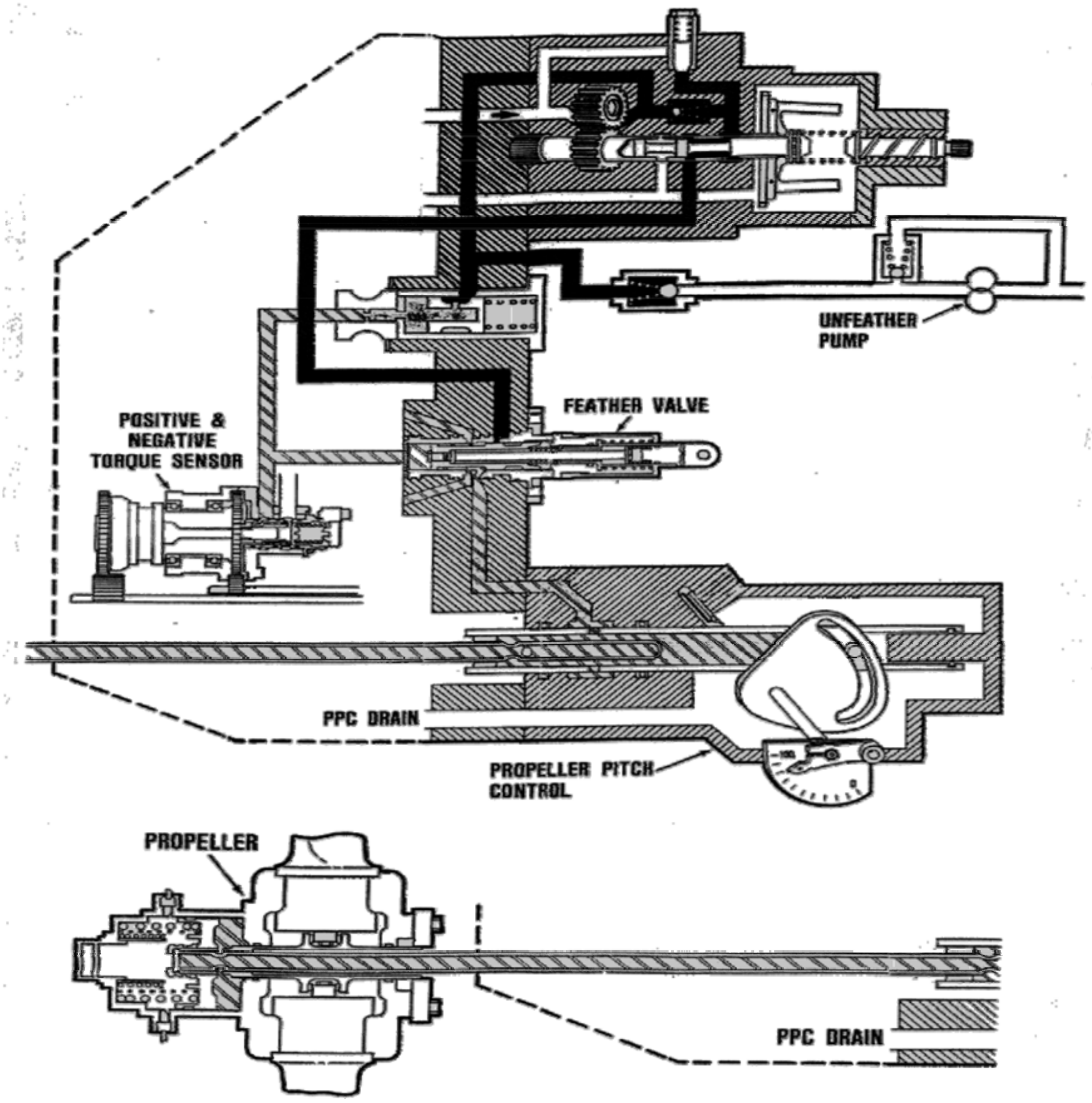
Because of the dangers at overspeed all turboprops will have some form of **Auto Feather** which will be activated by a negative torque signal, these devices may give an electrical signal to energise a solenoid or hydro-mechanical as seen in Fig 52.

The torque sensor is a pressure regulator and regulates the 'torque' pressure as a result of the twisting action of the torsion shaft. The pressure in the reduction gearcase operates at less than ambient due to the action of the oil system scavenge pumps that pump oil and air out of the case. The torque sensor and metering valve sense this pressure. The torque sensor pilot valve is mechanically positioned and any change in case pressure will change the measured torque pressure. The gearcase pressure must be added to the torque sensor pressure. A pressure gage can measure the case pressure and this value added to the torque sensor pressure will give a corrected torque valve.

The propeller feathering valve is externally mounted on the rear of the reduction gearcase. The feathering valve is hydraulically actuated by the negative torque sensor and can be manually actuated by pilot control. The feather valve prevents high pressure control oil from entering the propeller dome and piston, which allows the spring-loaded propeller blades to move towards a feathered position.

Positive torque is when the engine is driving the propeller. If the engine should have an inflight shutdown, the windmilling propeller will drive the engine. This is considered to be negative torque. When the propeller is driving the engine, a torque sensor within the reduction gearcase senses a negative input. The negative torque system automatically effects a movement of the propeller blades toward the feather position. That propeller will not feather, however, it will continue to windmill. The negative torque system is automatic drag reduction and not an automatic feather system.

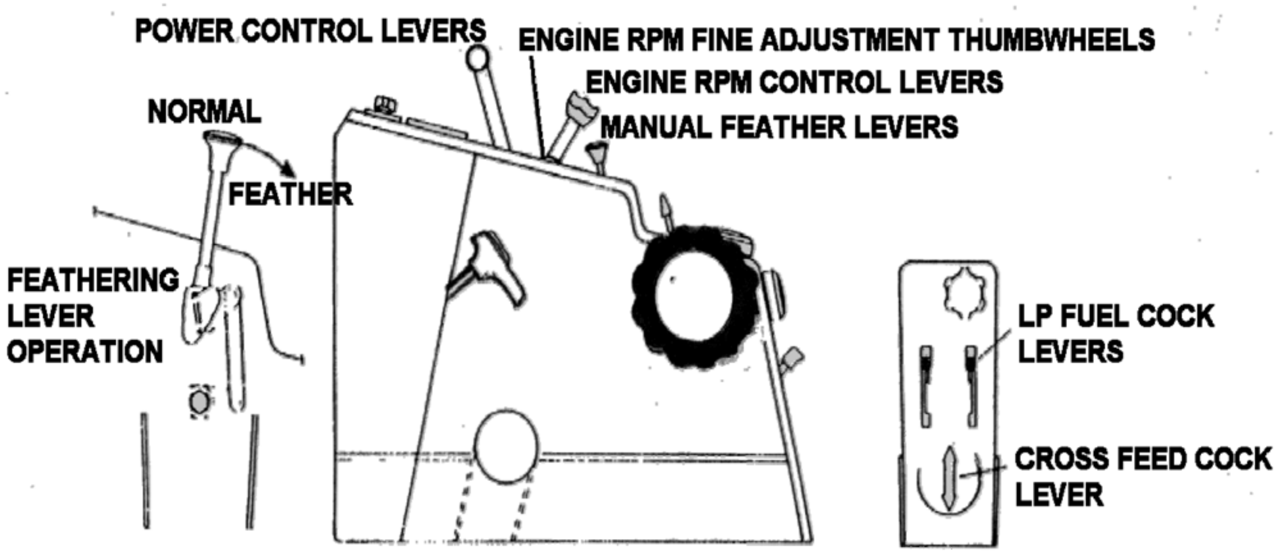
To feather the propeller, the pilot must actuate the feathering valve from the cockpit. The negative torque system in operation is illustrated in Fig. 55. The engine has experienced an inflight shutdown and attempts to decelerate, the propeller governor senses an underspeed condition, and increases oil pressure to the propeller to reduce blade pitch angle. The propeller, driven by the slipstream tries to cause the engine to accelerate. The propeller is now driving the engine, which causes the negative torque system to actuate. The power input required from the propeller moves toward feather. The power reduction causes the negative torque system to activate. The power input required from the propeller to actuate the negative torque system reduces as the propeller moves toward feather. The power reduction causes the negative torque system to de-activate, reducing propeller blade angle, again tripping the negative torque system. This action causes cycling of the propeller, mode commonly called NTSing.



Negative Torque System

Fig 55

The position in the cockpit of the manual feather lever is shown in the Fig. 56 (a small turbo prop), on some aircraft the manual feathering is actuated through a gate on the RPM lever.



Manual Feather Lever

Fig 56

Also a full auto feather system without the pilot having to pull the manual feathering lever can also be found on some turbo props, an example of which is shown later in the paragraph covering double acting systems.

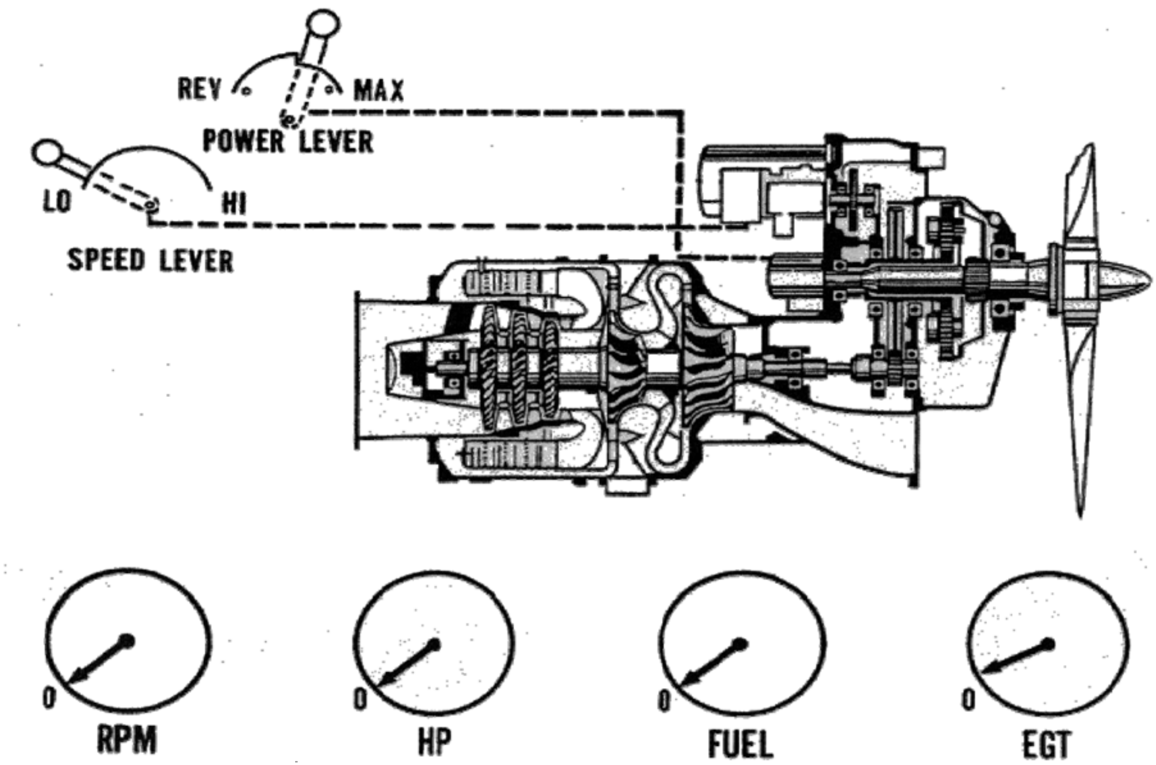
Because the electric starter motor does not have the capacity to motor the engine for air starts. With the propeller feathered the high torsional loads will result in possible overheating and failure of the start motor. The unfeathering pump is used to move the propeller blades out of the feathered position and the propeller then causes the engine to spool up. An air start is accomplished by placing the power lever and RPM lever to their air start positions and placing the air start / ground start switch to air start.

The start switch is actuated causing the unfeather pump to operate and send oil to the propeller piston. The oil pressure moves the propeller out of the feather position. The propeller begins to windmill, RPM increases to 10 percent, fuel and spark are introduced into the engine. Combustion occurs and the engine accelerates to the preselected RPM and power settings. Since the propeller is driving the engine, the negative torque system will modulate the propeller blade angle to properly control engine acceleration during air starts.

3.2.2 SINGLE ACTING TURBO PROP OPERATION (CONSOLIDATION)

Before moving on to double acting propellers the following diagram and explanations will help the student consolidate the information listed in the notes thus far and hopefully help towards the understanding of the operational sequence and control of a small turboprop aircraft.

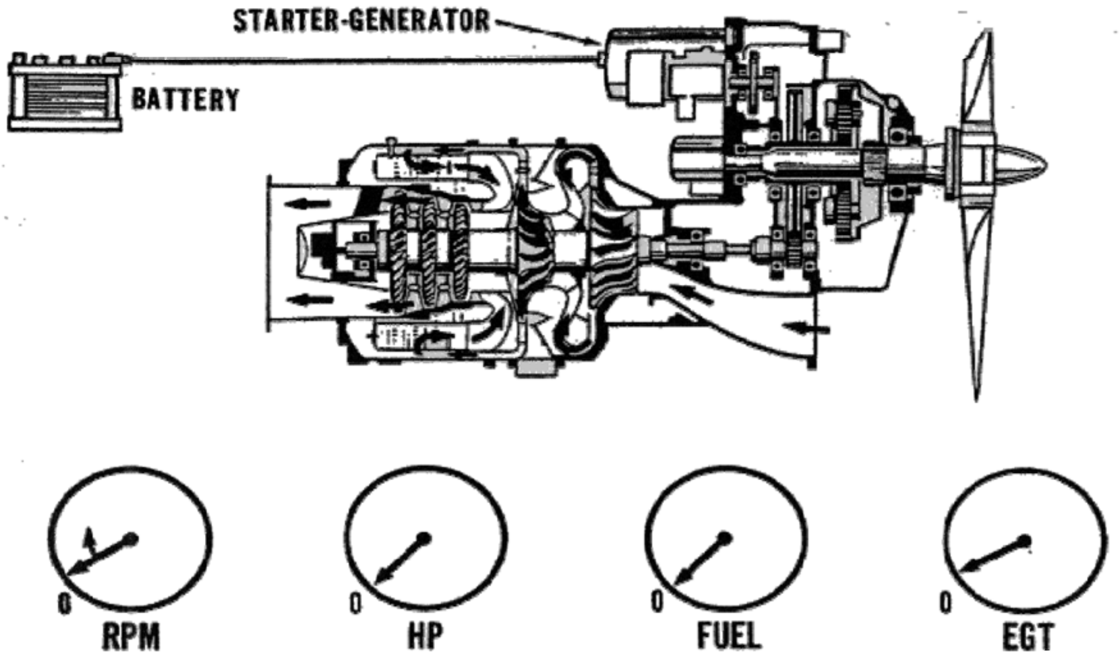
Several things should be checked prior to starting the engine. Ensure the propeller is 'on the locks'. Pull the propeller through, listening for unusual noises. Check for control lever freedom of travel and position the speed lever to the low or taxi position. Place the power lever ahead of ground idle. The preferable position is in flight idle.



Pre-Start Condition

Fig 57

Actuate the start switch. Note the increase of RPM on the cockpit indicator as well as propeller rotation.

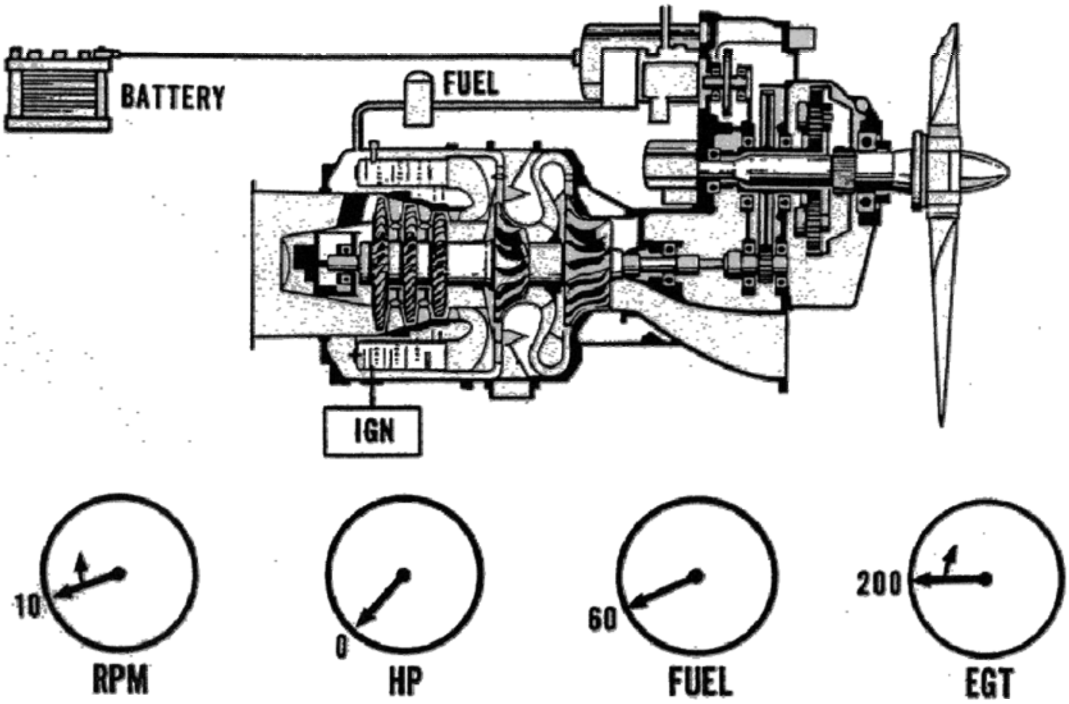


Engine Cranking

Fig. 58

The engine will accelerate to 10 percent RPM (Fig. 59). The EGT rise is the true indication of lightoff. If lightoff does not occur within 10 seconds after 10 percent, the start be aborted.

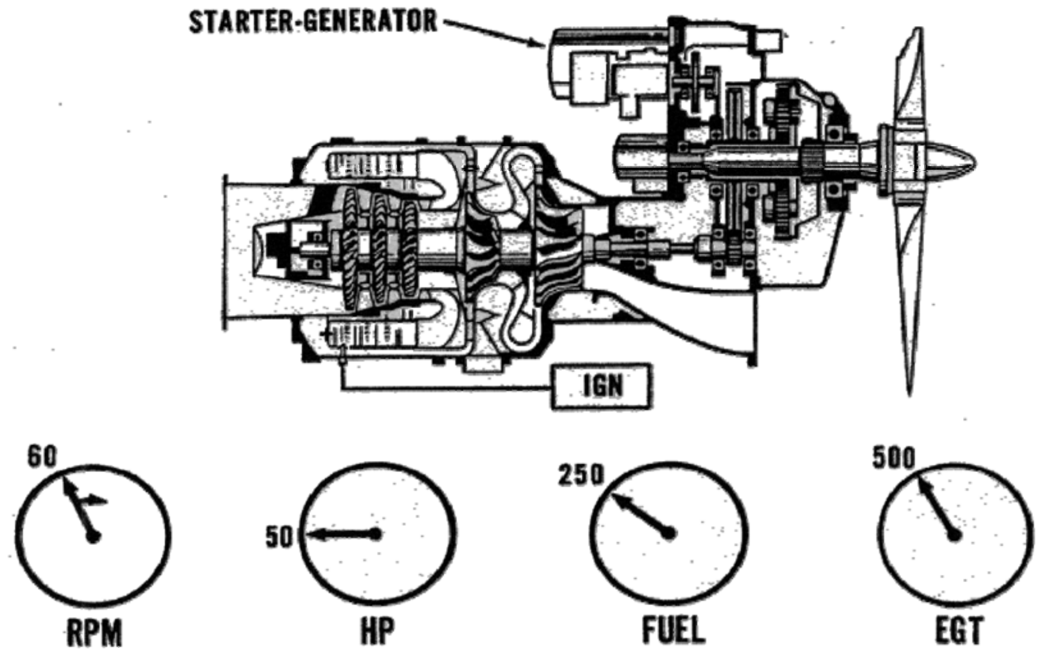
RPM will continue to increase, fuel and temperature will increase with temperature stabilising at the starting value. Horsepower or torque will also begin to indicate.



Engine Ignition at 10%

Fig.59

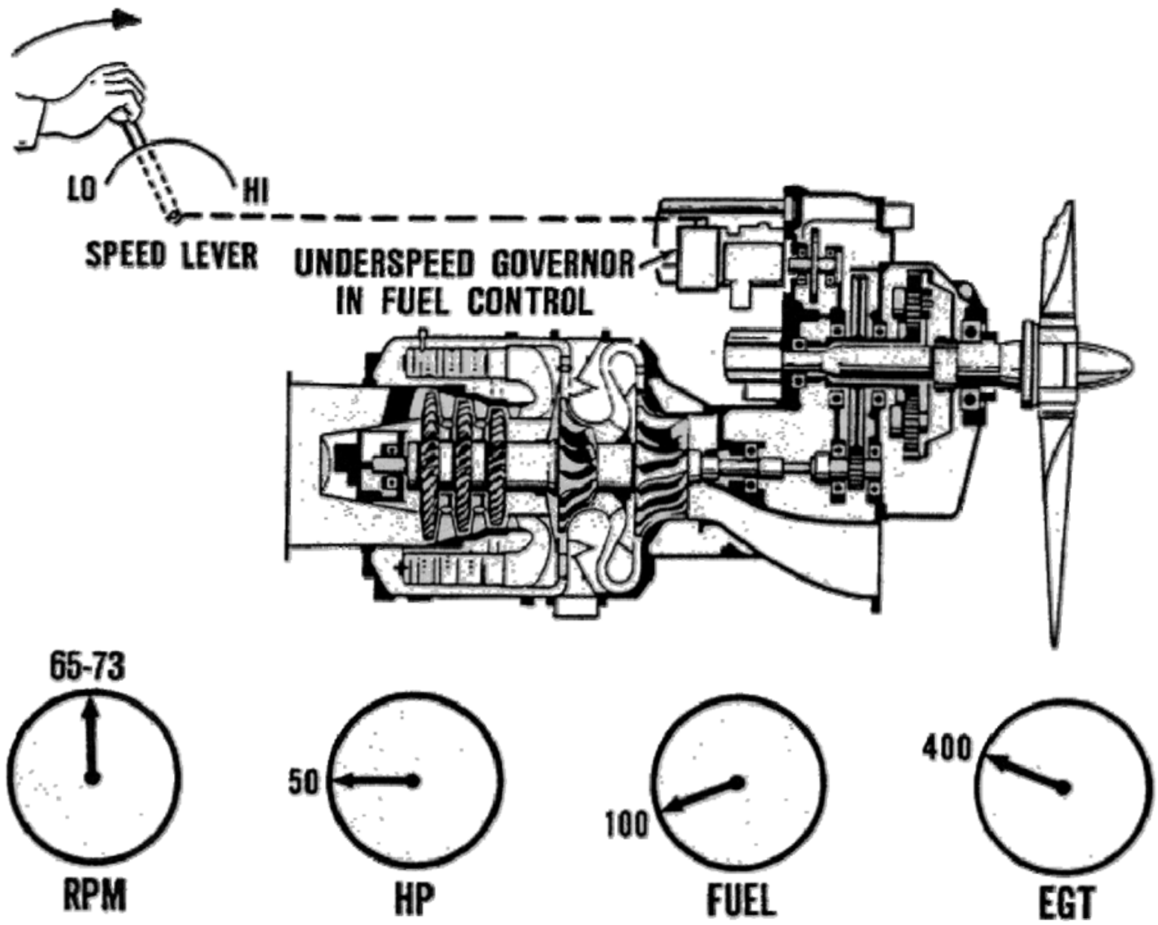
As engine speed reaches 60 percent (Fig 60), the speed switch will send a signal to de-energise the ignition system. Horsepower has stabilised due to the fixed prop load, fuel will remain the same while temperature has decreases due to the increased air flow. The engine is now considered self-sustaining.



60% RPM

Fig. 60

The engine will continue to accelerate on its own until it reaches its onspeed condition (Fig 61). RPM will stabilise at 65 percent. Fuel flow and temperature will have reduced and stabilised. RPM is now a function of the underspeed governor.



On-Speed

Fig. 61

The chart at Fig 62, illustrates the action of the underspeed governor and the reason for the reduction in fuel and temperature. Notice that the fuel required for acceleration is greater than that required at a stabilised onspeed condition, or 'required to run'. Acceleration fuel starts at 10 percent RPM when the fuel valve opens. From that point the acceleration schedule is a function of increasing P3 air. Increasing P3 air is indicative of engine rotational speed increasing. As the engine approaches its low speed setting, the underspeed governor begins to meter fuel to the engine. It will continue to cut back on fuel flow until the stabilised RPM is achieved or when power equals propeller load.

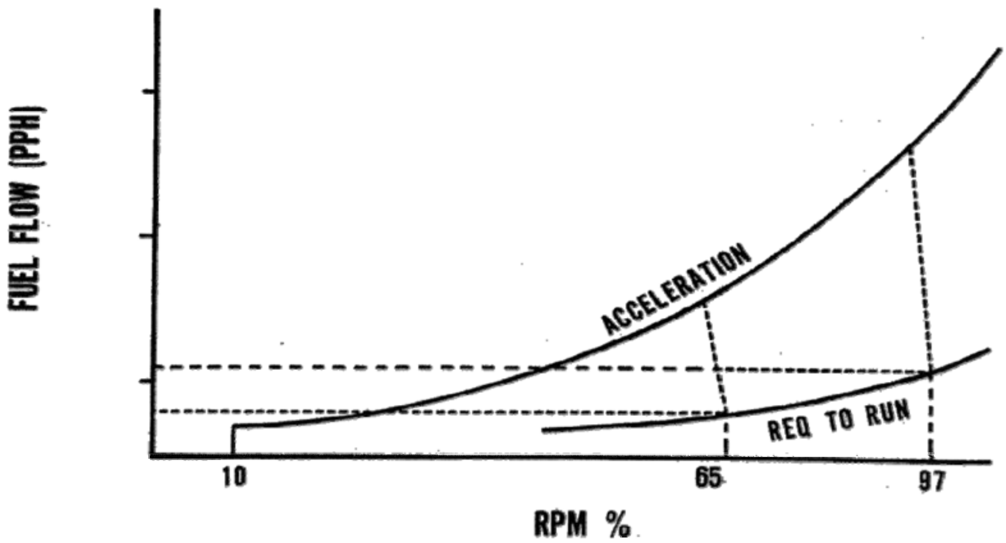
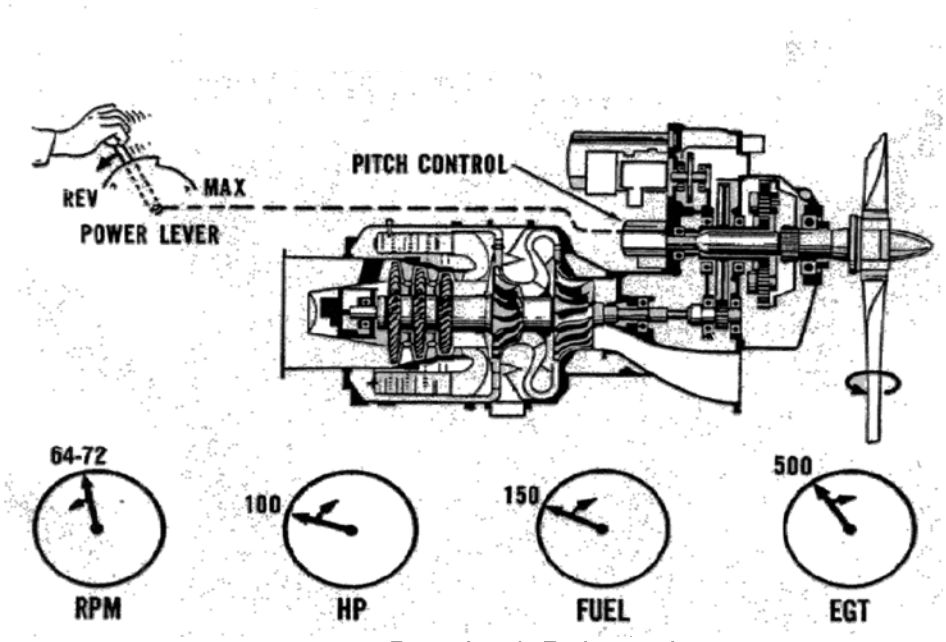


Chart of Fuel Flow v RPM

Fig 62

When the engine has stabilised and all parameters are check, the propeller can be removed from the locks (Fig 63). This is necessary to allow the propeller to produce thrust which would otherwise be extremely difficult with the propeller fixed at a low blade angle. To accomplish this, the power lever is moved toward reverse. By being in beta mode, blade angle is controlled by the propeller pitch control through the power lever. This will cause the propeller to move toward a reverse blade angle. This reverse blade angle is a greater load than the starting blade angle, so the operator will notice an increase in torque, fuel flow and temperature.

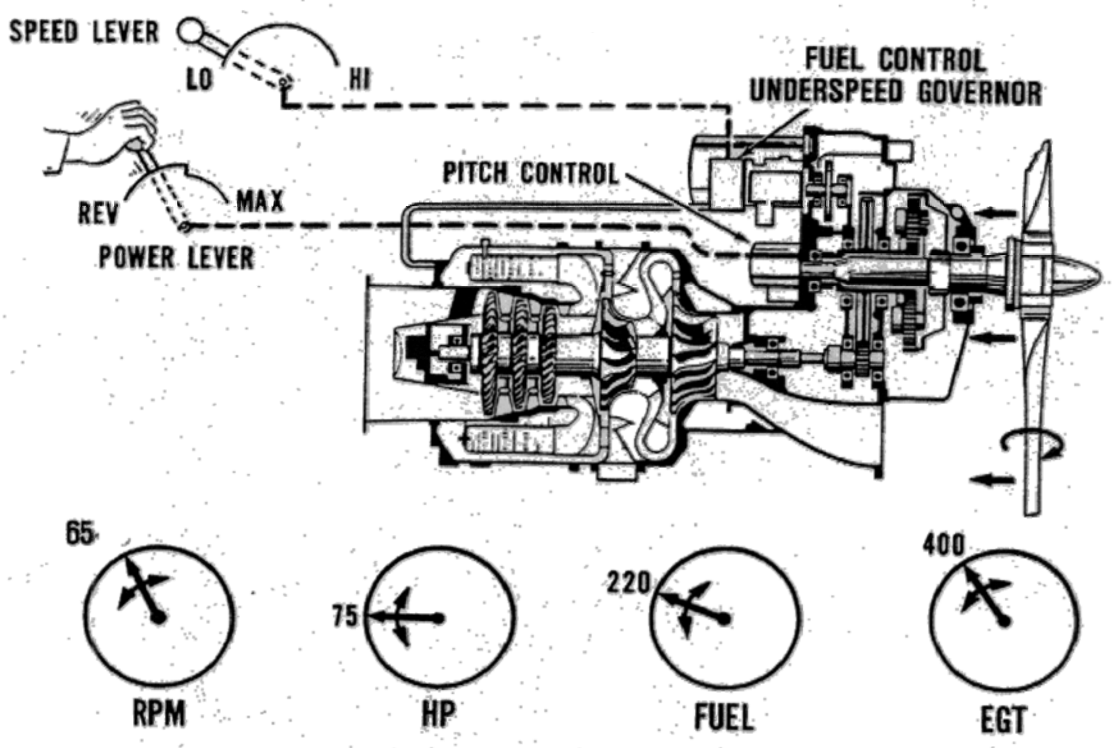


Prop Lock Released

Fig 63

A slight decrease in RPM will be noted because of the load increase. **Do not bog the engine down**. It is not necessary to use full reverse to remove the propeller from the locks. On some aircraft this practice may result in setting the aircraft on its tail. Experience with the aircraft will show the amount of reverse required to bring the propeller off the locks.

When the propeller is off the locks and all pre-taxi checks are complete, taxiing becomes a matter of moving the power lever to produce the required thrust (Fig 64). Fluctuating indications will be normal because of the changing load. The amount of power lever movement required to taxi will depend upon aircraft weight, wind and ramp conditions. For noise considerations, the speed lever is left in the low position. The lower engine RPM provides a lower propeller speed, hence less noise.

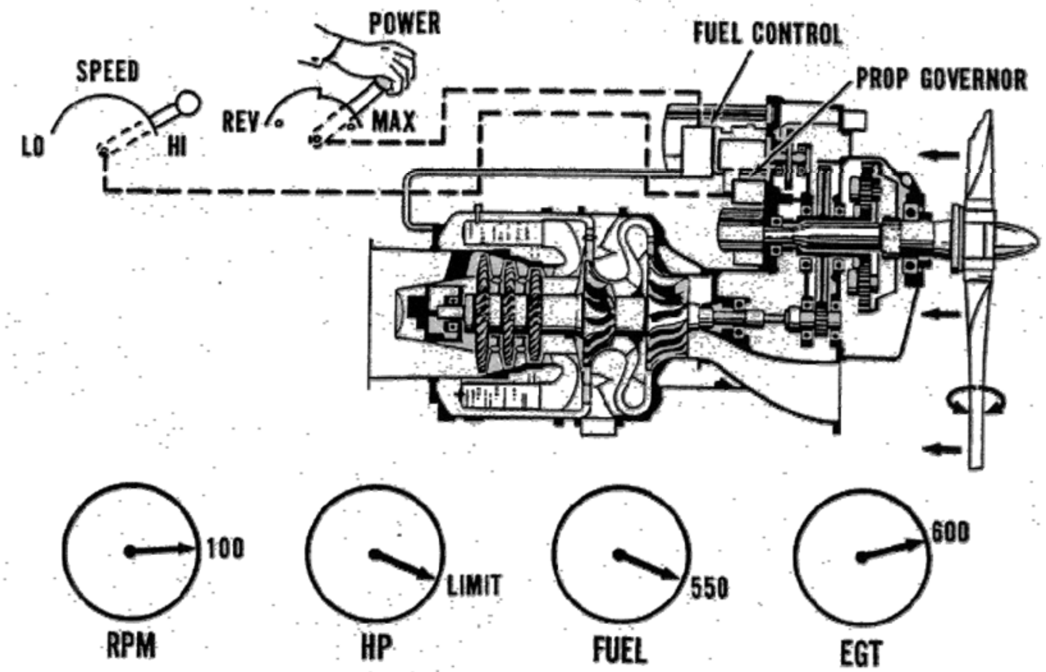


Taxi – Low Speed

Fig 64

For takeoff (Fig 65), the speed lever is advanced to the high / takeoff position. The engine will accelerate to 97 percent RPM. Fuel, temperature and horsepower will all increase.

At this time, the power lever is advanced ahead of flight idle. The manual fuel valve and propeller pitch control cams react and RPM increases to 100 percent. The power lever is advanced until the torque or temperature limit is reached. Temperature limits for takeoff (depending on type of engine) to be observed. As the power lever is being advanced to its limit, the propeller governor continue to ass blade angle and the aircraft accelerates down the runway.

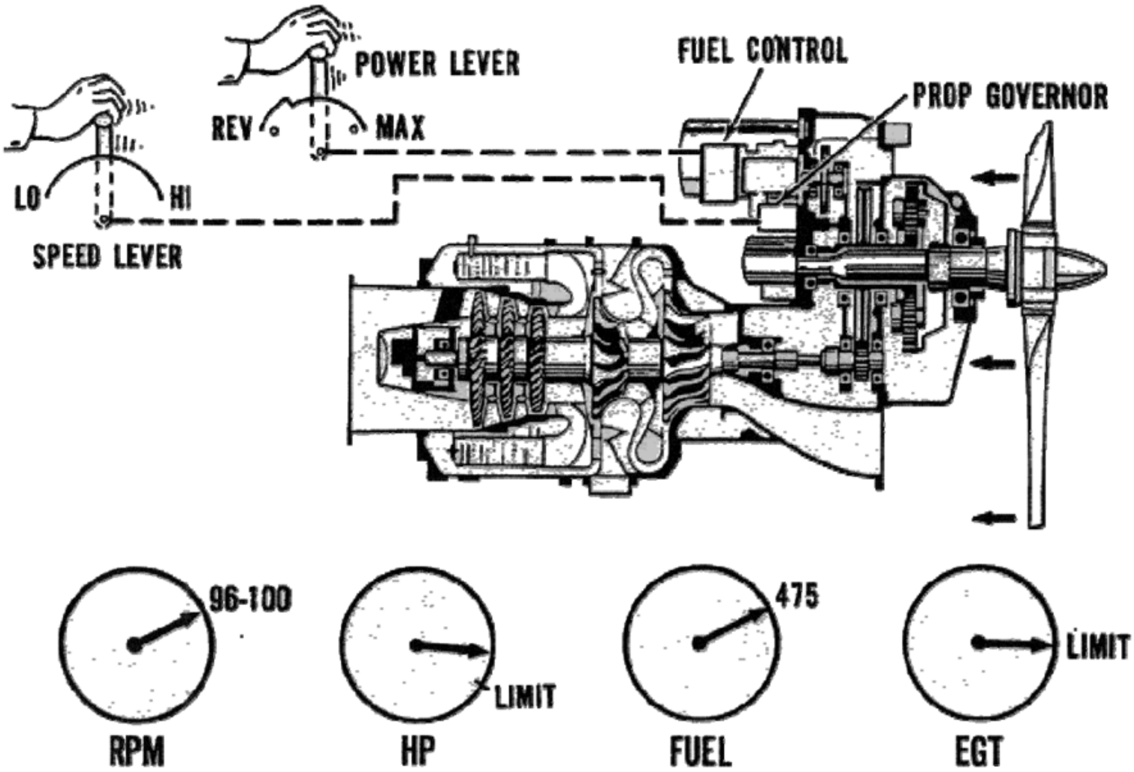


Take-Off

Fig 65

During climb the operator will notice a steady increase in temperature and a decrease in torque. This is due to the change of air density as altitude increases. This action may require the operator to continually retard the power lever to stay within temperature limits.

Having reached the desired altitude, the operator may wish to reduce the engine to a lower cruise RPM (Fig 66). This is done primarily as a noise reduction measure, with a secondary benefit of some fuel economy. Normal cruise RPM is from 96 to 100 percent. This small range allows for noise reduction while keeping the engine operating near its maximum limits for efficiency. To bring the engine into cruise first reduce fuel with the power lever. This will reduce the temperature. Move the speed lever from high / takeoff to the cruise position. Temperature will rise, as well as torque. Do not allow the

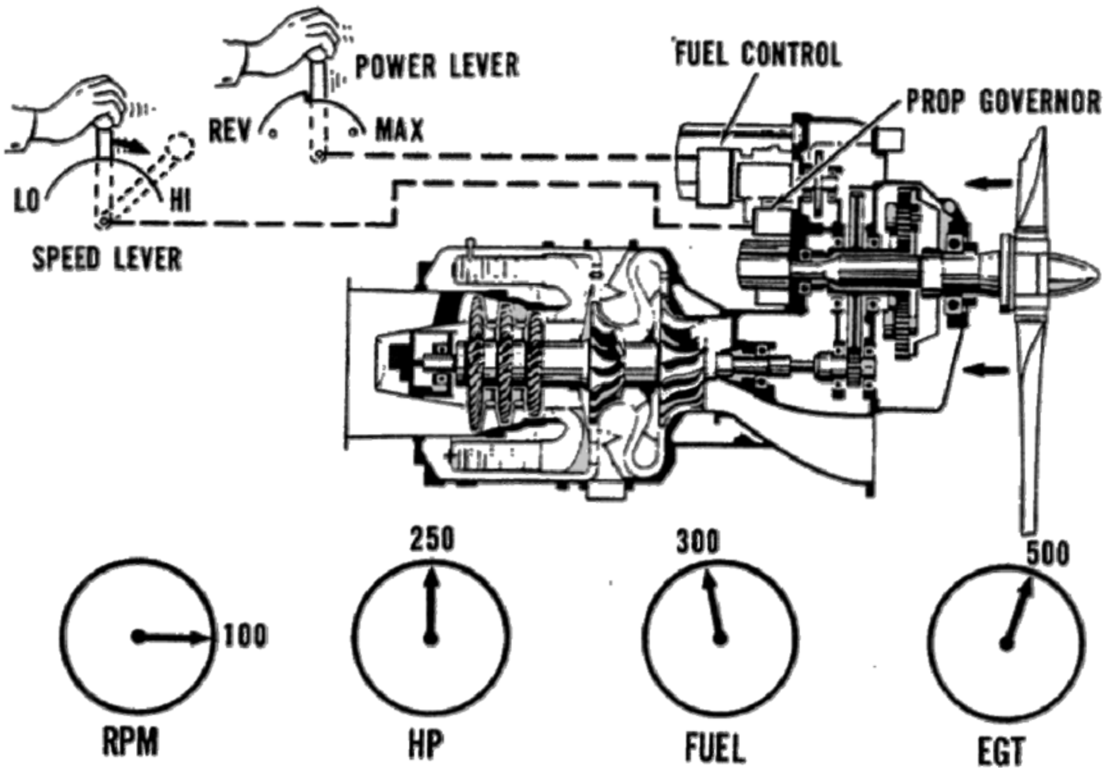


Cruise

Fig. 66

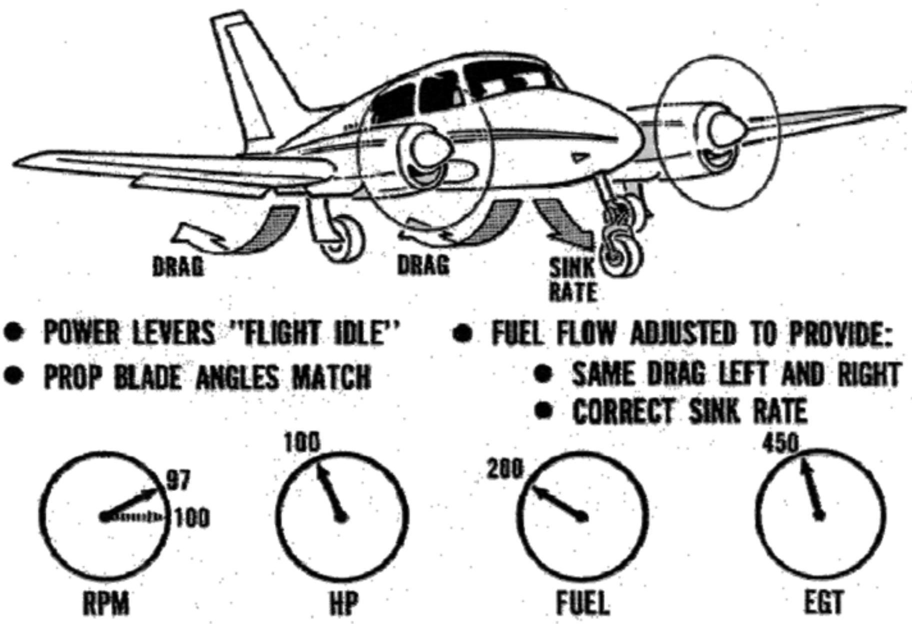
temperature to exceed limits. If further reduced to allow cruise RPM to be reached.

When the operator desires to prepare for approach (Fig 67) to his destination, the speed lever is moved to the high position. RPM will increase to 100 percent, temperature and torque will decrease slightly. Bringing the speed lever back to high on approach is to ensure the operator has full power available should he need it. After the speed lever is advanced, the power lever is then retarded toward flight idle. Aircraft weight will determine the amount of power required for proper descent rate. Fuel flow, temperature and torque all will decrease.



Approach

Fig 67

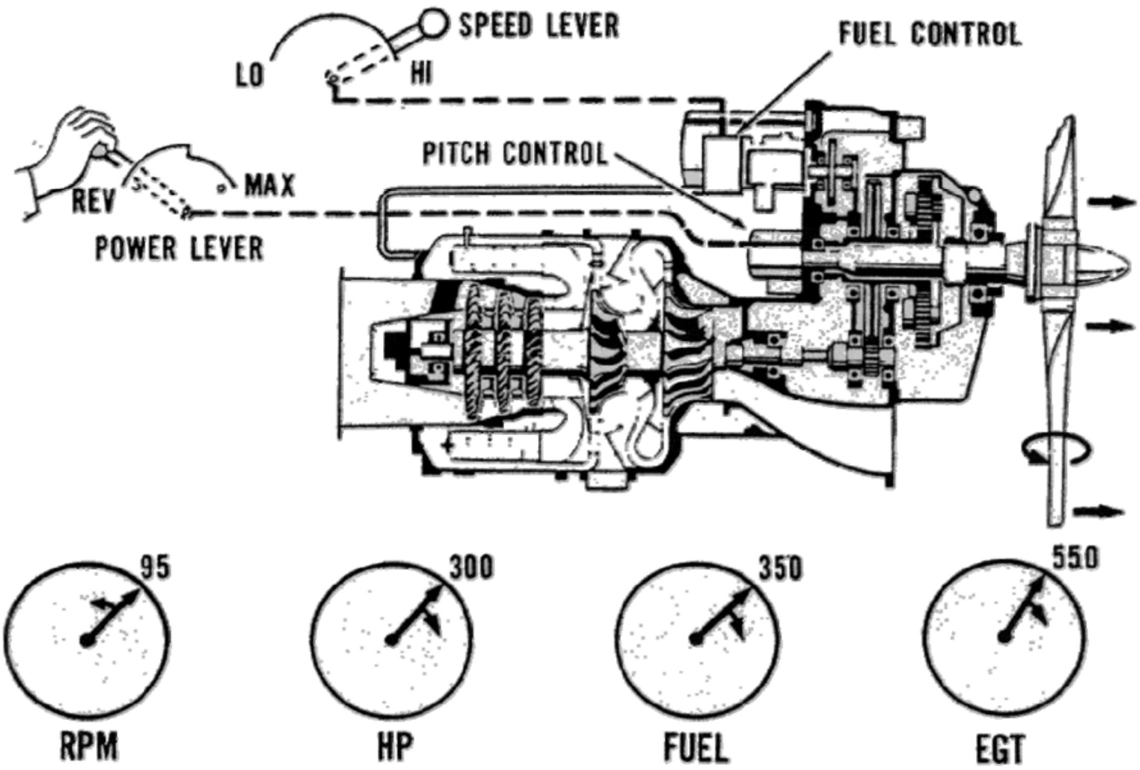


Flare-out on Landing

Fig 68

As the aircraft approaches the threshold (Fig 68), the power levers are moved to flight idle. Upon touchdown and rollout, as forward speed decreases, loading of the propeller by relative wind increases. RPM will fall below the setting of the propeller governor by this loading as well as the low demand for fuel. As 97 percent RPM, the underspeed governor takes control of fuel and maintains RPM. The 'beta lights' will come on indicating that manual pitch control for braking is now possible.

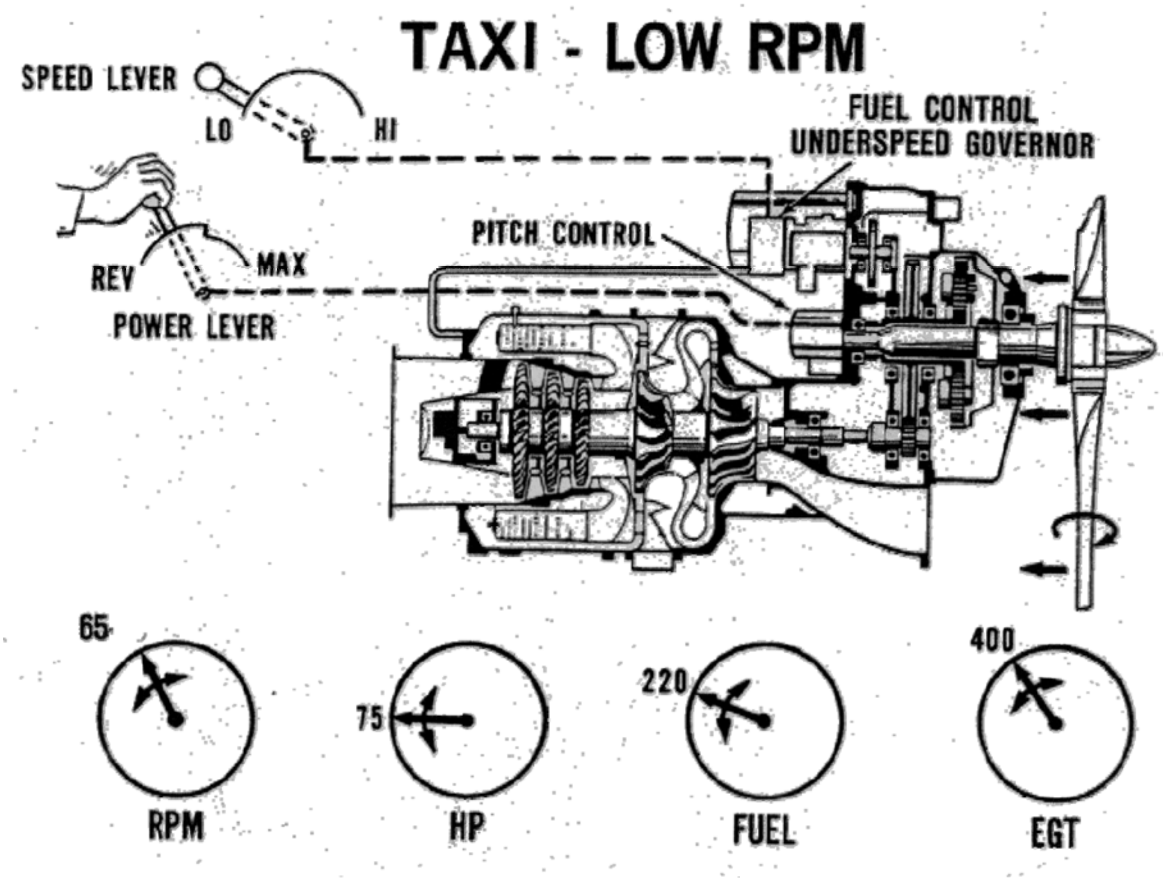
Braking of the aircraft is accomplished by moving the power lever behind flight idle forward reverse (Fig 69). Runway length should determine the amount of reverse to use. Ground idle is effectively 0 degrees pitch, and is highly effective in bringing the aircraft to a halt. Using full reverse is not recommended unless in an emergency. Full reverse tends to increase the amount of material the engine ingests from the runway.



Braking on Landing

Fig. 69

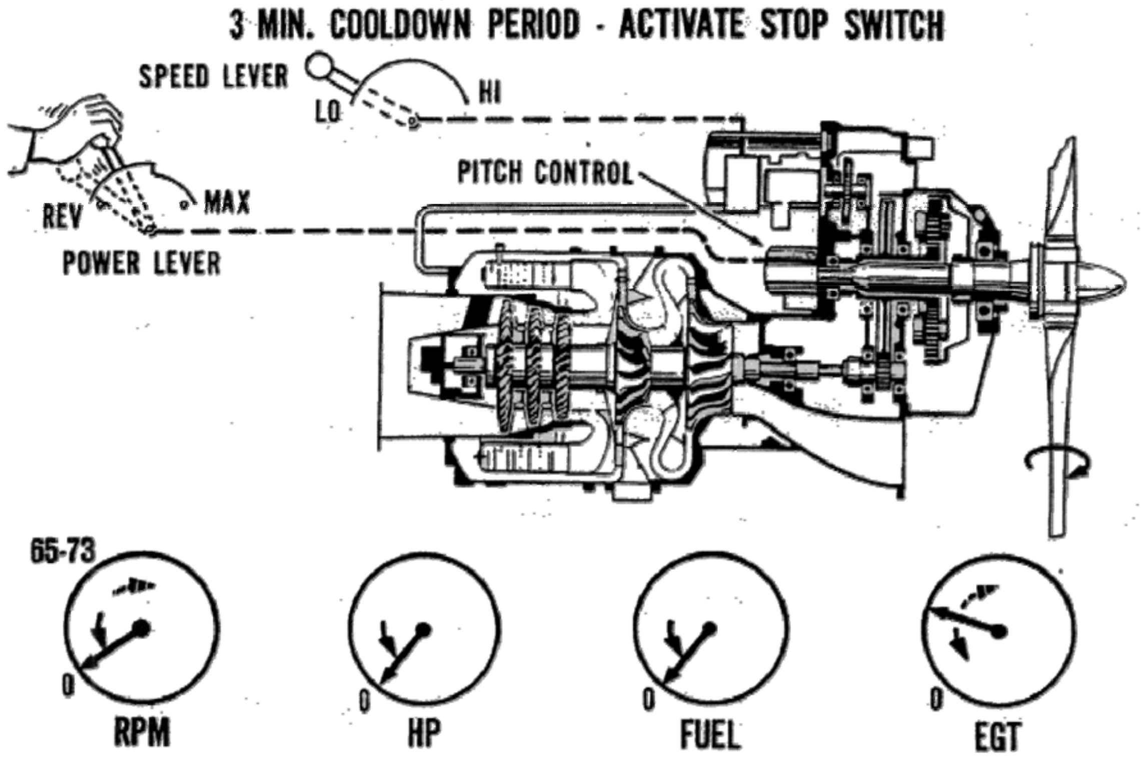
Once off the runway, the speed lever may be moved to the low position and taxiing is again accomplished by use of the power lever.



Low Power Taxi

Fig.70

With the aircraft parked, the engine may be shutdown. Actuating the stop switch closes the fuel shutoff valve. Fuel flow decreases to 0. At approximately 50 percent RPM brings the power levers back to full reverse and hold them to put the propeller back on the locks. The power lever may be held in this position until RPM is less than 10 percent. This applies to both Hartzell and Dowty propellers. When less than 10 percent RPM, the power levers may be returned to flight idle.

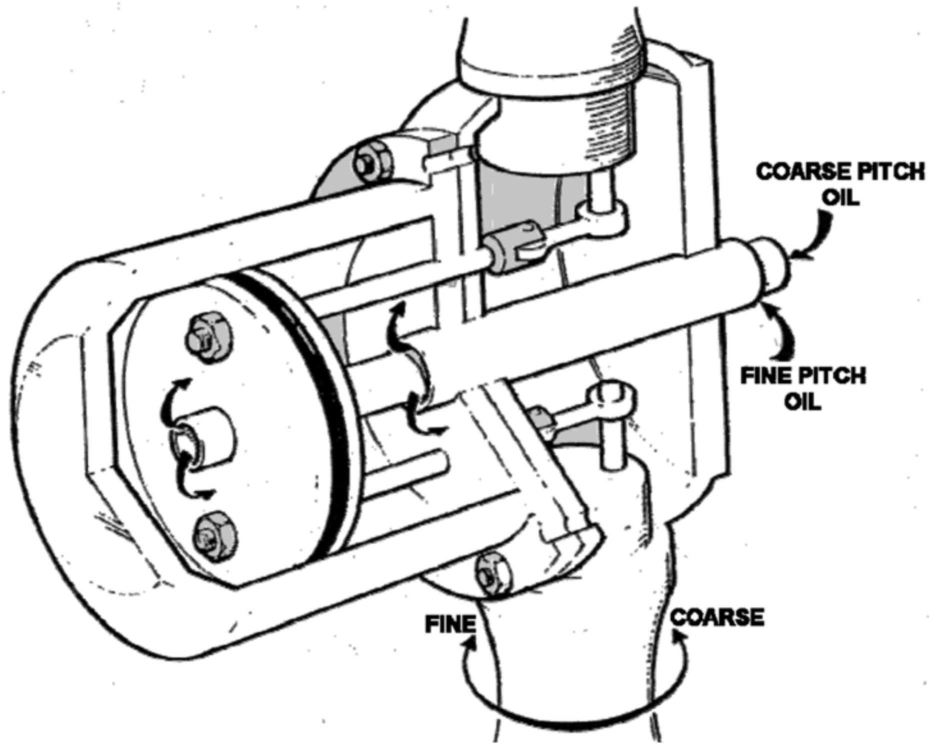


Engine Shut Down

Fig.71

3.2.3 DOUBLE ACTING PROPELLERS

This type of propeller is normally fitted to larger engine and, because of engine requirements, is more complicated than the propellers fitted to smaller engines. Construction is similar to that of the single acting propeller, the hub supporting the blades, and the cylinder housing the operation piston. In this case, however, the cylinder is closed at both ends, and the piston is moved in both direction by oil pressure. In one type of mechanism links from the annular piston pass through seals in the rear end of the cylinder, and are connected to a pin at the base of each blade. In another type of mechanism, the piston is connected by means of pins and rollers to a cam track and bevel gear, the bevel gear matching with a bevel gear segment at the base of each blade; axial movement of the piston causes rotation of the bevel gear, and alteration of the blade piston causes rotation of the bevel gear, and alteration of the blade angle. Operating oil is conveyed to the propeller mechanism through concentric tubes in the bore of the engine reduction gear shaft. And another type Fig 72, has the

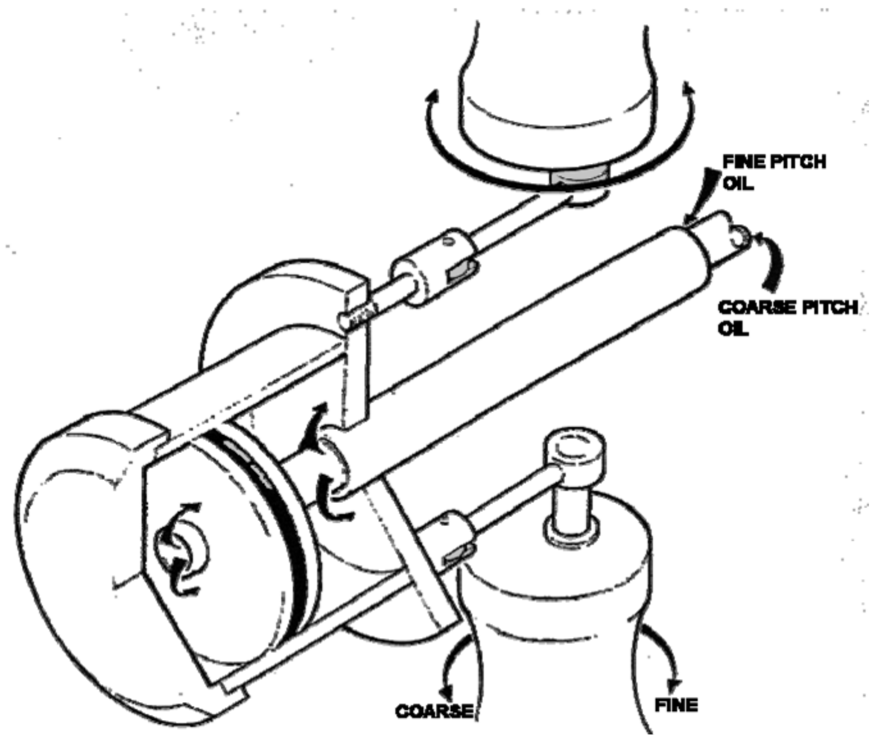


Moving Piston with Blade Links

Fig. 72

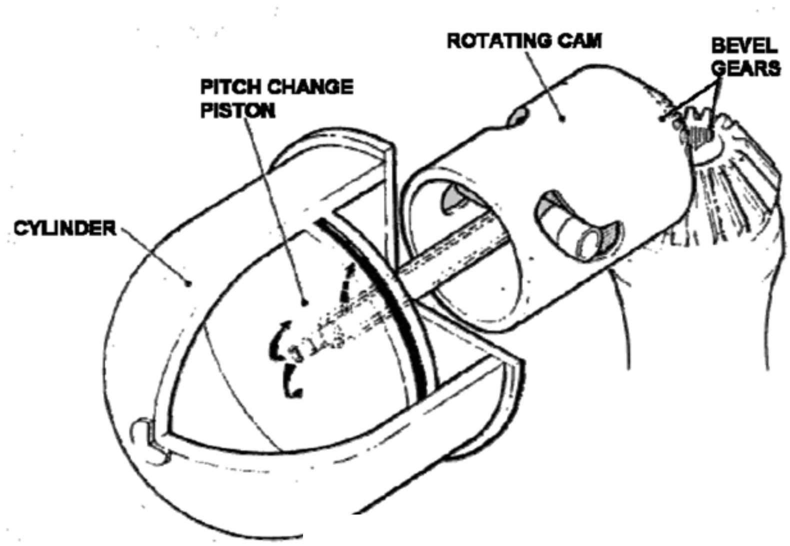
blades connected by links to the cylinder which moves with the piston held stationary.

The piston may move in the cylinder or the cylinder may move over the piston (Fig 73) , the linear movement being transmitted to the blades by various linkages to convert it to rotary motion.



Moving Cylinder System

Fig 73



Geared Hydromech System

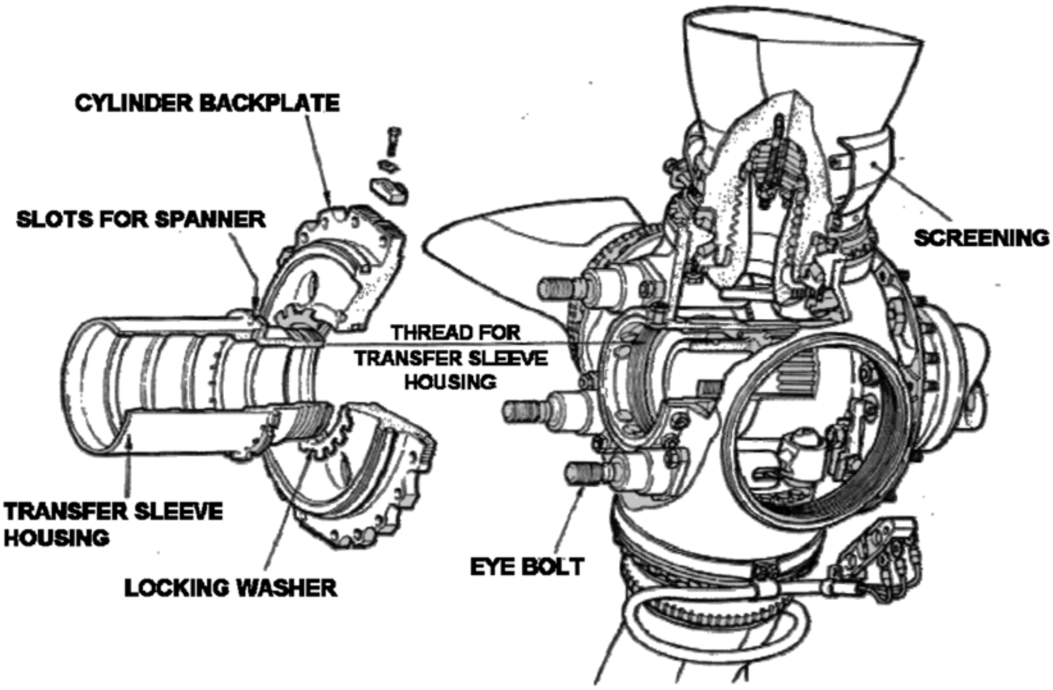
Fig 74

The geared, or hydromatic (Fig 74), pitch change mechanism utilises a piston inside a stationary cylinder. The piston is 'U' shaped to contain a pair of co-axial cylindrical cams. The outer cam is fixed and the inner is free to turn. This carriers a bevel gear which meshes with bevel gear segments on the blade roots.

3.3 THE PITCH CHANGE MECHANISM (MOVING PISTON)

The pitch change mechanism for this type of propeller consists of:

- A cylinder backplanes and transfer sleeve housing.
- A fixed cylinder enclosing a piston and pitch stops.
- Pitch lock and oil sleeves.
- Blade operating link assembly.



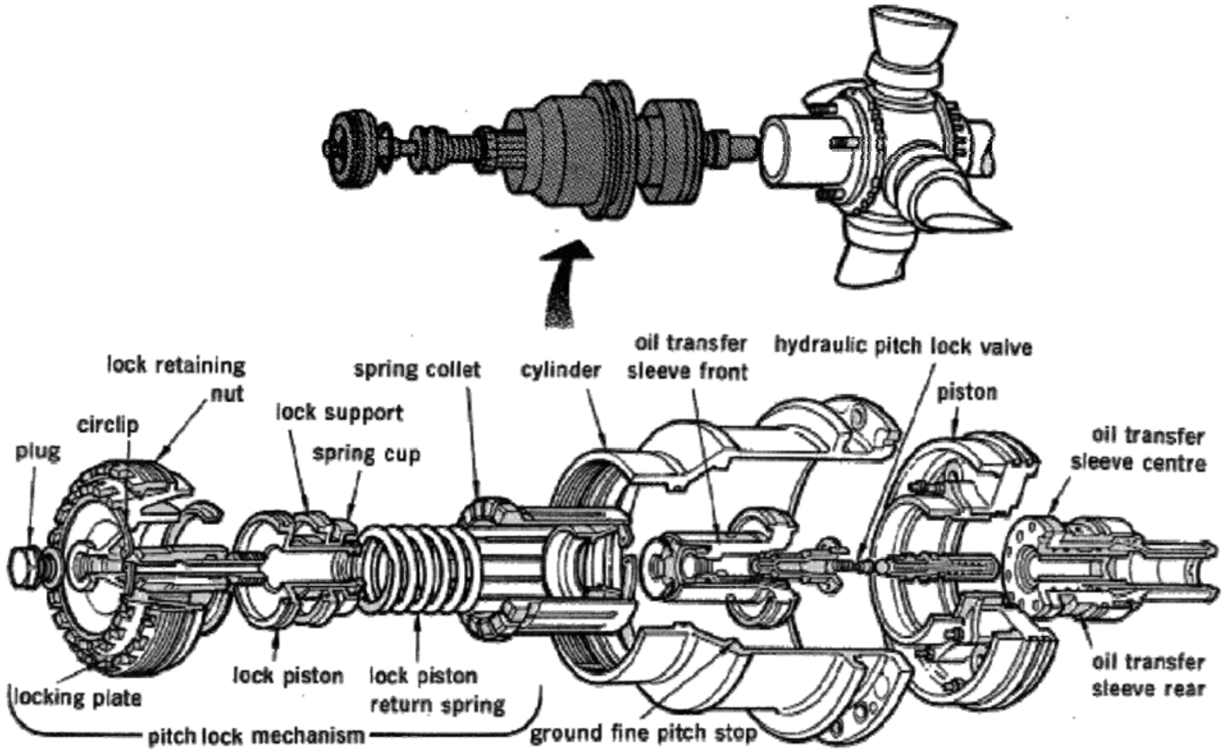
Cylinder Backplate Location and Attachment

Fig. 75

The cylinder backplanes. The disc shaped backplate (Fig 75) provides a mounting for the pitch change cylinder. This backplate fits in front of the propeller hub and it has four clearance holes to permit movement of the operating link assembly for the blades. It is secured to the hub by the transfer sleeve housing which screws into the hub and is locked by the washer as shown below.

Transfer sleeve housing (Fig 75). One end of the sleeve is screwed into the hub so that the sleeve surrounds the front end of the oil tubes. The sleeve flange which secures the cylinder backplate against the front of the hub, has slots to accept the spanner used for fitting or removing the sleeve housing. A ring of holes is drilled through the wall of the sleeve, just in front of the external flange. These holes transfer governor pressure oil to the rear side of the pitch change piston which slides upon the outer surface of the sleeve.

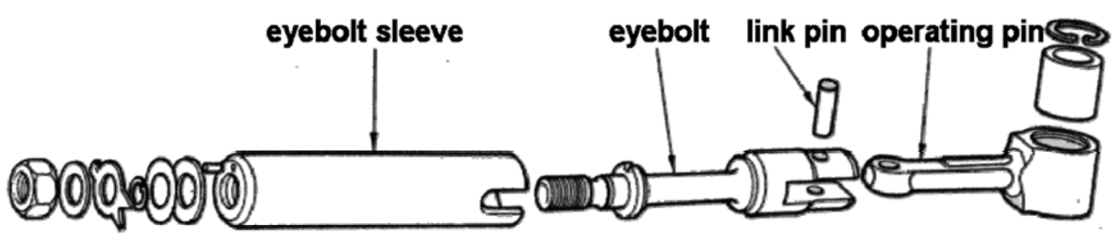
The cylinder (Fig 75). The shaped cylinder is flanged and drilled at the rear for mating with, and bolting to, the cylinder backplate. The cylinder provides a working surface for the pitch change piston and a shoulder towards the front forms one part of the ground fine pitch stop. The front of the cylinder is bored to obtained access to the propeller retaining nut and to permit fitting of the pitch lock mechanism. The mouth of the bore screw threaded internally to match the lock retaining nut and the pitch change cylinder is sealed by the pitch lock cylinder cover which beds onto a seal and is secured in position by a ring nut, locking plate and circlip. Finally, a screwed plug is fitted to the hole in the centre of the pitch lock cylinder cover.



Propeller Pitch Change Mechanism

Fig. 76

Blade operating link assembly. The operating link assembly provides the means of converting the axial movement of the piston into rotary movement to turn each blade around its axis so that the blade angle is changed by pitch change piston movement. The assembly consists of an eyebolt sleeve, eyebolt and an operating link. Each eyebolt fits inside an eyebolt sleeve which provides a working surface in the bushed hub shell. The front end of each eyebolt is secured to the pitch change piston and its rear end is attached to the front of an operating link by a pivot or link pin. The bushed rear end of each operating link fits snuggly over a pin attached to the root end face of a propeller blade. Slots in the rear of each eyebolt and sleeve allow for articulation of the operating link caused by the radial movement of the blades as the pitch change piston moves forward and backwards in its cylinder.



Blade Operating Link Assembly

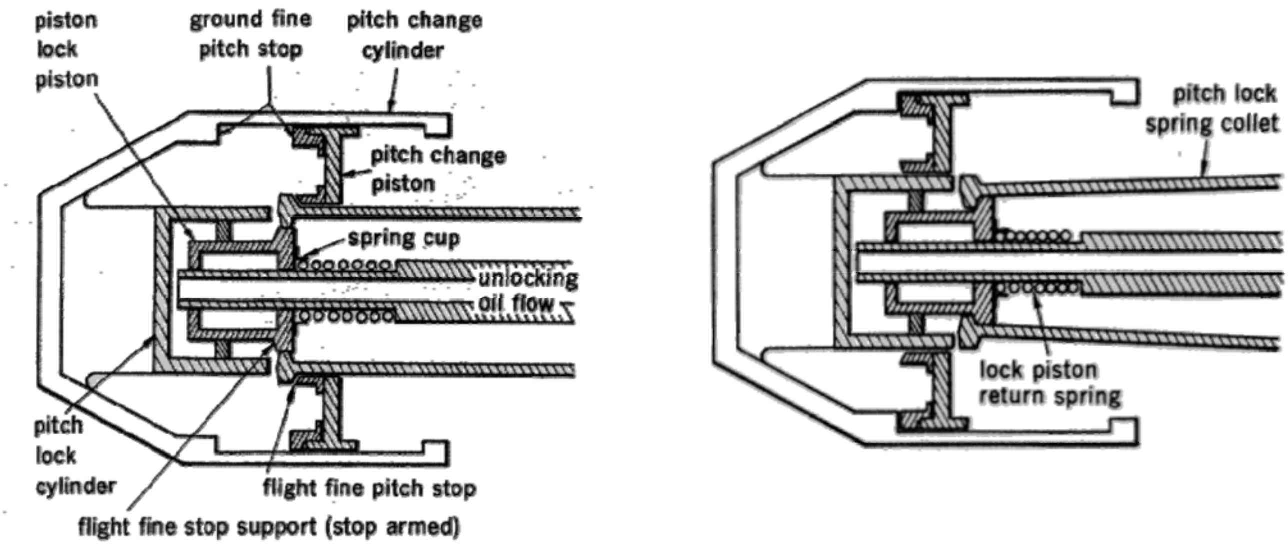
Fig 77

3.3.1 PITCH LOCK MECHANISM

The pitch lock mechanism (Fig. 78) is necessary to cater for the two fine pitch position of 'flight fine pitch' and 'ground fine pitch'. It acts as a safety device designed to prevent the propeller from inadvertently over-running the flight fine pitch position to the detriment of flight safety.

3.3.2 PRINCIPLE OF OPERATION

The pitch change piston is fitted with two pitch stops - the flight fine pitch stop and the ground fine pitch stop. The flight fine pitch stop provides a normal fine pitch angle, whereas the ground fine pitch stop does not arrest the piston movement until the propeller blades turn into the plane of rotation to attain zero pitch angle. To obtain a zero blade angle it follows that the pitch change piston must move beyond the flight fine pitch position and, to achieve this, the flight fine pitch stop must be withdrawn or rendered ineffective whenever ground fine pitch is required. Therefore, the flight fine pitch stop is a flexible arrangement which requires a support to maintain it in the flight fine pitch stop position. When the support shown is withdrawn, the flight fine pitch stop can move down flush with the level of the pitch lock cylinder and the oil pressure acting upon the pitch change piston can now move it forward into the ground fine position. The pitch lock assembly fits inside the pitch change cylinder and the transfer sleeve



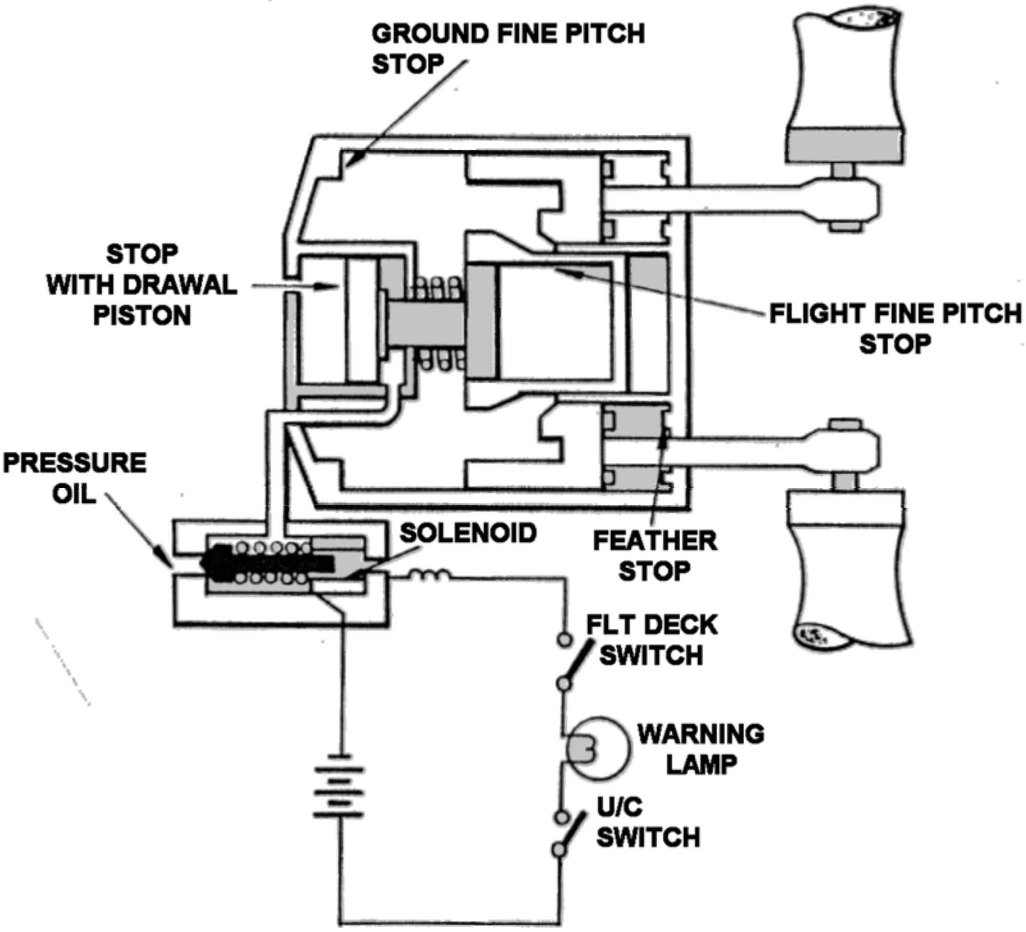
Principles of the Pitch Lock Mechanism

Fig 78

housing where it connects with the oil tubes to complete the oilways to the PCM.

When the aircraft is on the ground the undercarriage switch is closed, the flight deck switch completes the circuit to energise the solenoid valve.

The open solenoid valve directs oil pressure to the stop withdrawal piston allowing the spring collect to spring inwards to remove the Flight Fine Pitch Stop (Fig 79).



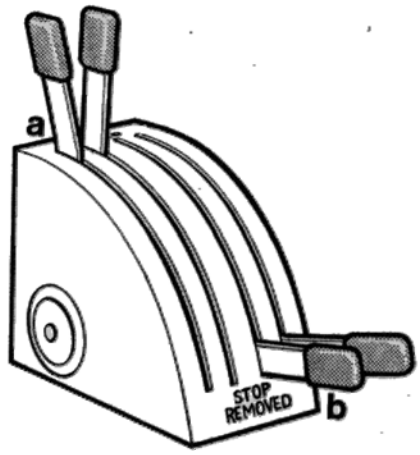
Flight Fine Pitch Stop

Fig. 79

To enable either flight fine pitch or ground fine pitch to be selected, pitch selection levers are provides. These levers (one for each propeller) are fitted to the main control pedestal in the aircraft cockpit. They are called 'fine pitch stop levers' (Fig. 80) and they provide the two stop positions required for flight fine or ground fine. The lever positions are:

- **Stop armed** - This is the flight fine position and the stop lever is at the front of the quadrant.
- **Stop removed** - This is the ground fine position and the stop lever is at the rear of the quadrant.

To prevent inadvertent loss of propulsive thrust, the pitch stop levers are mechanically inter-connected with the throttle lever so that when all throttle levers are advanced towards open (for max or cruise power) the pitch stop levers must move into the stop armed position. Thus always when the aircraft is flying the flight fine pitch stop is armed.



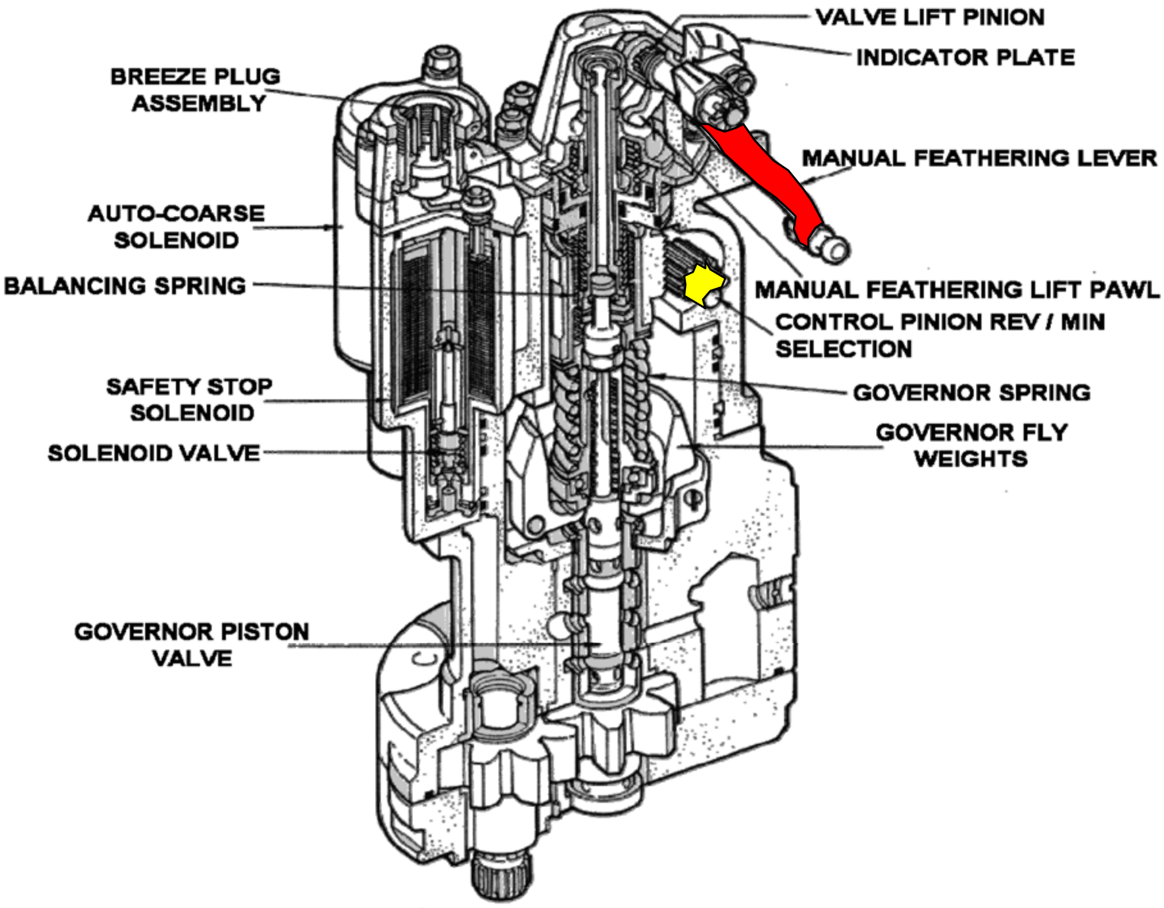
Pitch Selection Levers

Fig.80

3.3.2.1 Propeller Control

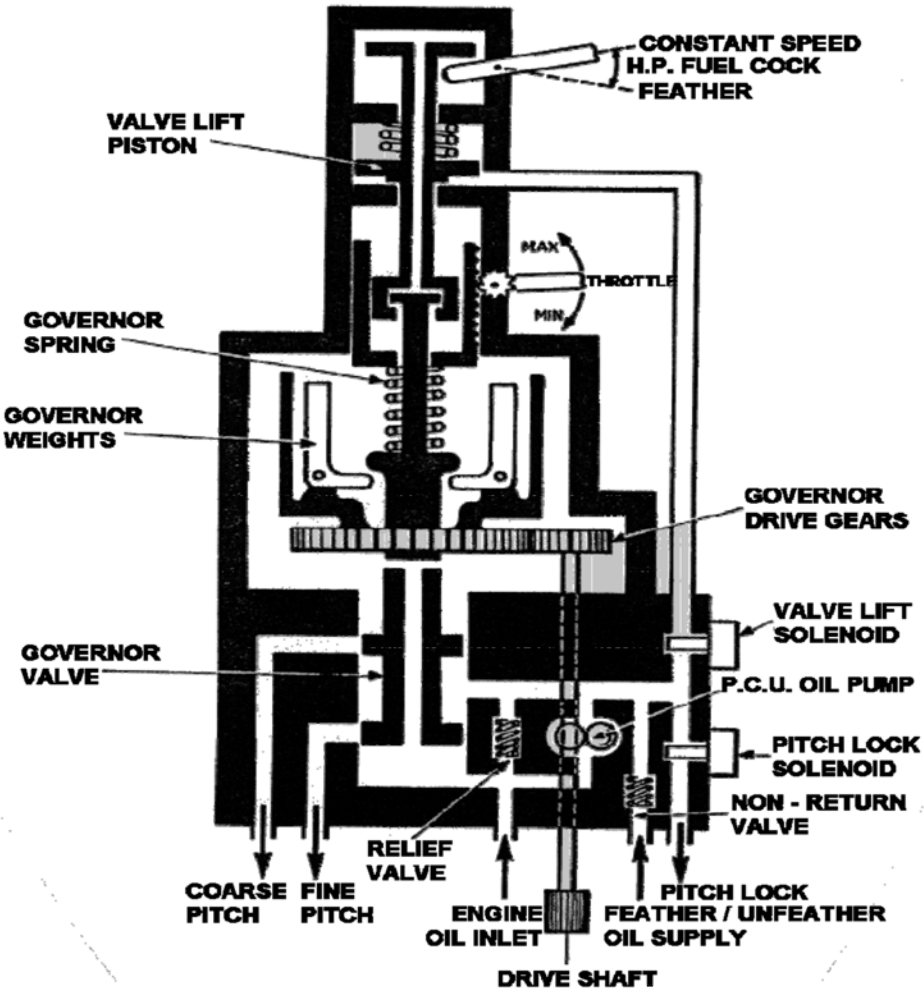
There is no separate propeller control selector for this engine / propeller combination. Instead of a separate propeller control lever, the governor is designed to operate from engine control inter-connections (Fig 81 & Fig 82). At the top of the governor is a lever and mechanism for selecting either constant speed operation or feather, whilst below this there is a normal rack and pinion rev / min selector which varies the value of the governor spring. The levers at these control points are linked into the engine control system as follows:

- **Constant Speed or Feather** - The lever at the top of the governor unit is called the manual feathering lever (Fig 81& Fig 82). It is inter-connected with the high pressure shut-off cock (HP cock) control so that when the HP cock is at the run or 'shut-off' position, the governor is set for constant speeding. When the high pressure fuel cock control lever is moved beyond fuel shut-off to the feather position the manual feathering lever pawl mechanically lifts the governor piston valve to direct pressure oil to the coarse pitch side on the pitch change piston.



CONTROLLER UNIT

Rev / min Selector - The engine throttle control is linked to a normal rack and pinion control in the governor unit (Fig. 81 & Fig. 82) so that movement of the throttle control acts through inter-connecting linkage to vary the load imposed upon the governor spring to act as a rev / min selector.



Pitch Control Unit

Fig 82

3.4 PITCH CONTROL UNIT (PCU) OPERATION

.The action of the Governor bob weights, due to the varying RPM of the engine, is to raise or lower an internal piston to cover or open fluid pressure channels to move the propeller blades to the appropriate positions. There are three main conditions, ‘On Speed’, ‘Under Speed’, and ‘Over Speed’.

3.4.1 'ON SPEED' CONDITION

The speeder spring setting balances the centrifugal force acting through the governor weights.

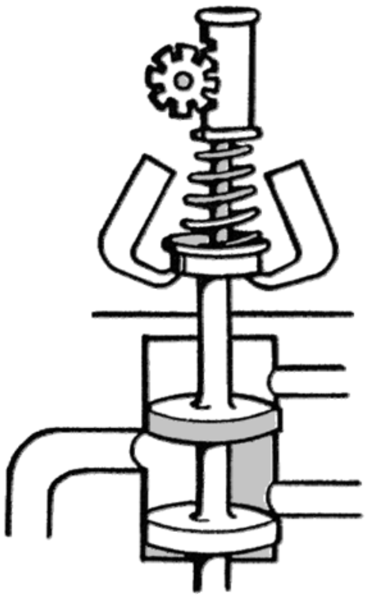
The engine RPM is equal to that selected by the power lever.

The control valve is in a neutral position hydraulically locking the pitch change piston.

3.4.2 UNDER SPEED

Speeder spring load (Fig. 83) is greater than the force of the governor weights the valve is pushed down.

Propeller blades move to a **finer pitch** to increase RPM.



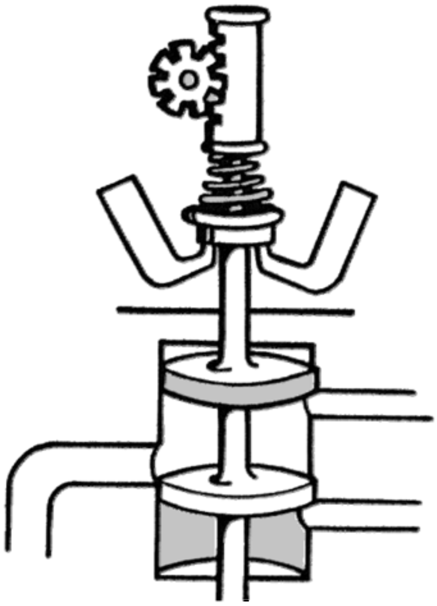
Under Speed Condition in PCU

Fig.83

3.4.3 OVER SPEED

Centrifugal force of the governor weights overcomes the speeder spring load, the control valve moves up (Fig. 84).

Propeller blades move to a **coarser pitch** to decrease RPM.



Overspeed Condition

Fig.84

3.4.4 RPM INCREASE SELECTED

Using the diagram at Fig 85 opposite follow the sequence of events outlined below.

Power lever moved.

Speeder spring load increased.

Control valve moves down.

Pressure oil directed to fine pitch line.

Return oil from coarse pitch line goes to pump inlet.

Blade angle changes to a finer pitch.

RPM increases as the load on the propeller reduces.

Governor weights fly outwards to lift the control valve as the RPM increases due to pitch change and increased power.

Control valve is moved to the 'on speed' position when speeder spring and governor weight forces balance.

The throttle / power lever is connected to the fuel control unit and the propeller control unit as shown in the diagram, increase the throttle, movement and you will increase the fuel flow. From the graph you will see this as a straight line linear increase, but the RPM and blade angle increases are not proportional.

To understand this we must first understand the anomalies of the Gas Turbine at low RPM's (GI). As there is very little power available to drive the propeller any increase in propeller load (blade angle) will result in a resistance to rotation (torque), engine RPM will reduce and so will mass airflow.

The fuel control system is scheduling the fuel flow for normal ground idle (GI), which is no longer being obtained. This represents an over-fuelling condition and serious over-heating will occur. This problem exists anywhere over the idling RPM range, ground idle (GI) to flight idle (FI).

To overcome this, propeller control unit (PCU's) are designed with 'dead movement' see P.C.U. diagram. With reference to this diagram and the graph at Fig 86 the following paragraphs explain the power (throttle) lever movements.

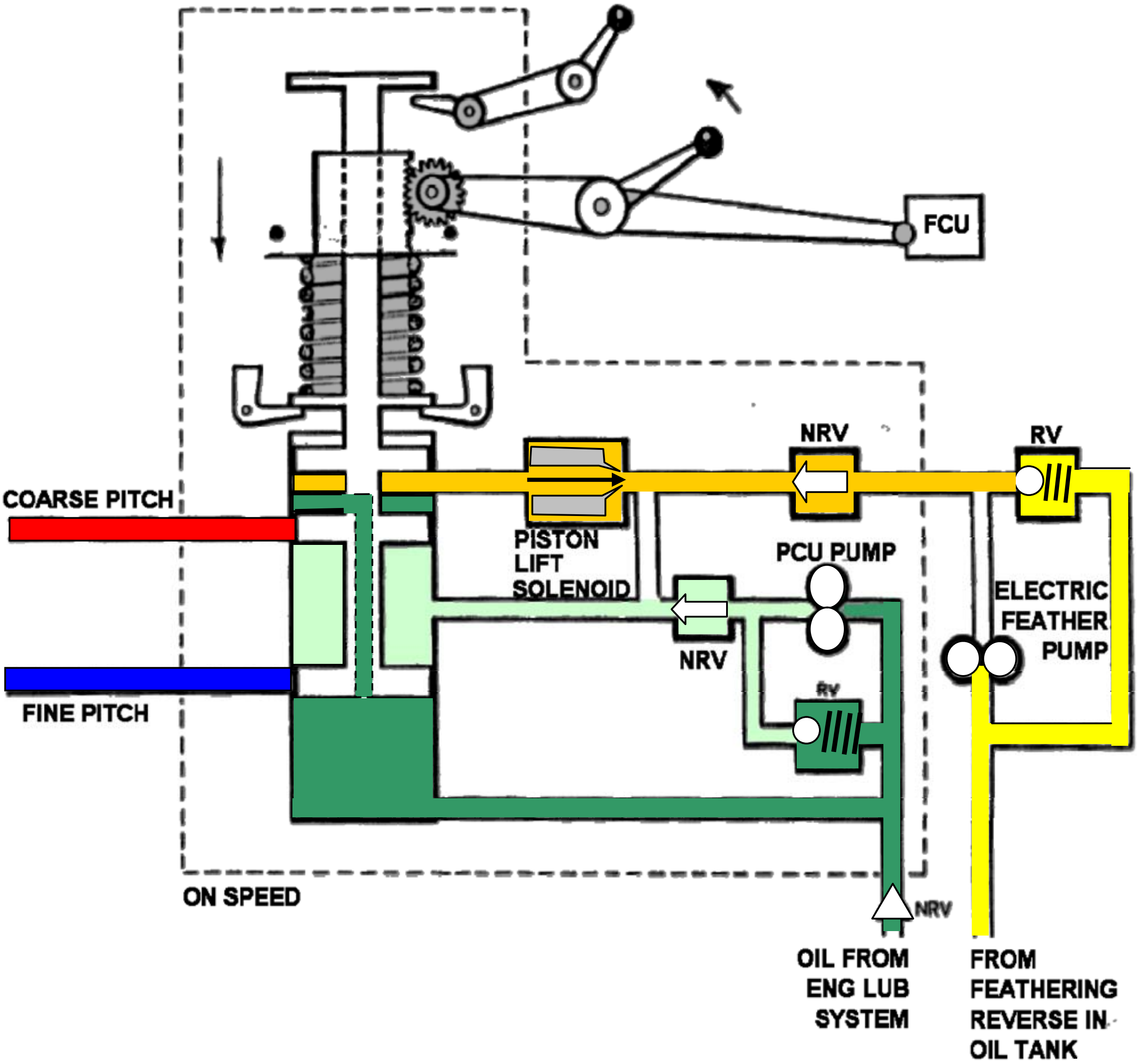


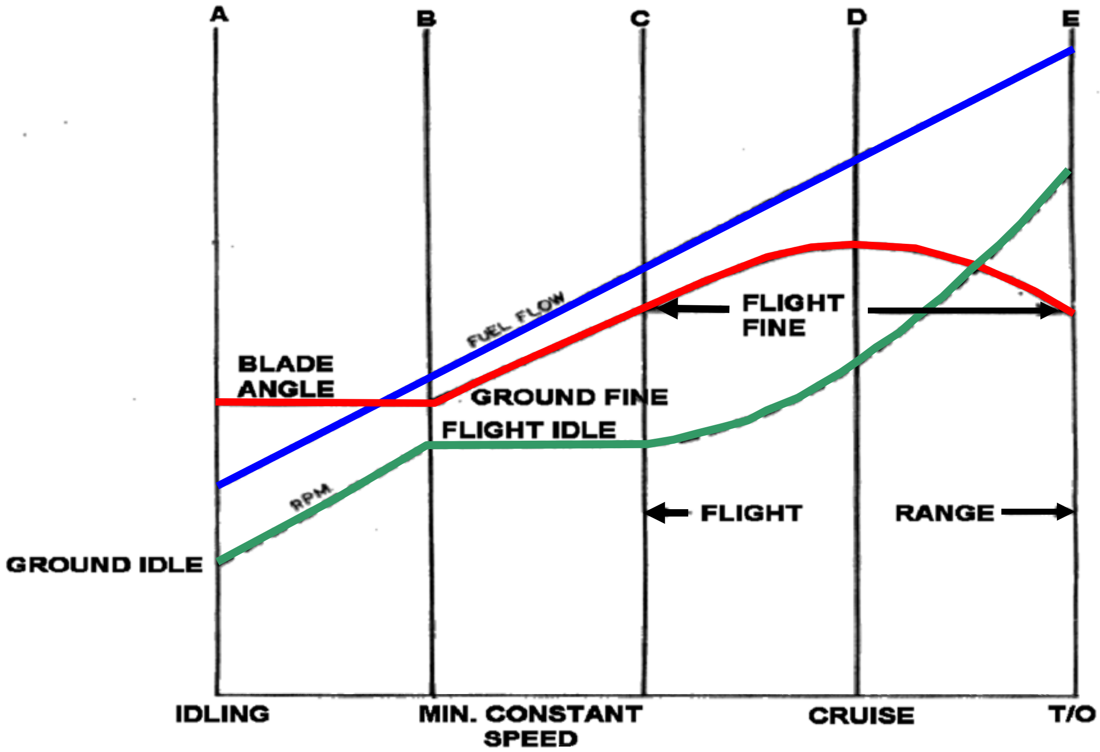
Diagram For Use With Power (Throttle) Lever Movements

Fig 85

3.4.5 POWER LEVER MOVEMENTS

3.4.5.1 Moving from A to B (Fig.86)

For the whole of this range the propeller is held at zero pitch (ground fine), the centrifugal weights in the P.C.U. do not have enough centrifugal energy to close off the fine pitch oil supply, thus the propeller is offering resistance of rotation. Consequently, as the throttle / power lever is opened, the RPM increase is due to increasing fuel flow, this is mechanically achieved in the P.C.U. by having 'Dead movement' built into the throttle rack movement and ensuring that when the speeder ring is on the minimum control speed stops the pre load on the spring, is sufficient to hold the centrifugal weights in the fine pitch oil supply position but RPM will increase to flight idle (FI).



Graph Illustrating Blade Angle, Fuel Flow and RPM Through Engine Range

Fig 86

3.4.5.2 Moving from B to C (Fig.86)

As the throttle / power lever is moved from B to C (towards the flight range) the power available from the engine of the propeller is increased. The propeller blades move from the ground fine position towards the flight fine position, blade angle will increase because the centrifugal weights will have more energy to overcome the valve port oil supply from the P.C.U. pump to the coarse pitch supply line. While this action is taking place the R.P.M. will remain constant, this range is known as the **Minimum Constant Speed Range**.

3.4.5.3 Moving from C to D to E (Fig.86)

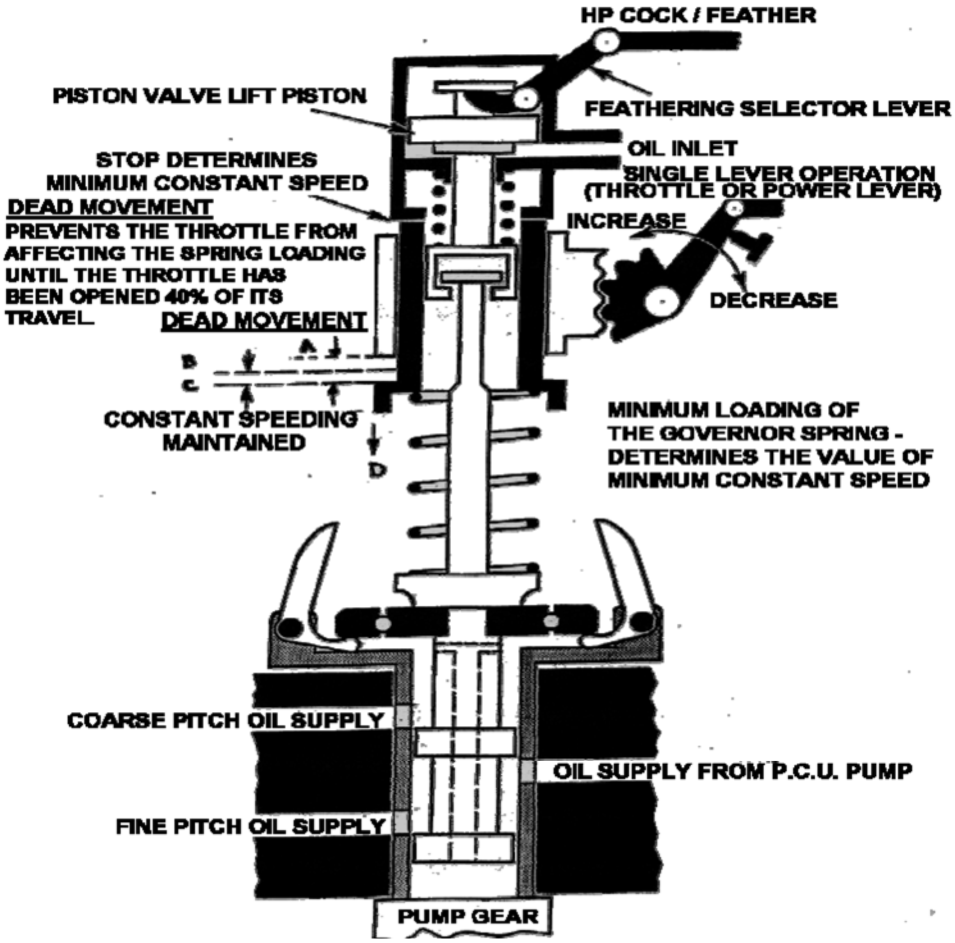
Further movement of the throttle lever will take the engine into the normal flight range of control. As the throttle lever is moved towards the take-off power setting, higher RPM and fuel flows are selected, and the propeller blade angle will increase to absorb the higher power. A greater RPM increase is required for take off the governor speeder spring is compressed by the throttle rack, restricts the increase in blade angle whilst allowing the RPM to increase.

3.5 DOUBLE ACTING FEATHERING SYSTEM

To prevent excessive drag in the event of a propeller on engine failure, the double acting propeller as with the single acting propeller requires a feathering system (Fig 87).

3.5.1 DESCRIPTION

The system has mechanical and electro hydraulic means of lifting the PCU control valve. An electrically driven pump supplies the feathering oil pressure. Oil is supplied from a 'Feathering' Reserve in the main engine oil tank.



PCU & Feathering Unit

Fig. 87

3.5.2 OPERATION

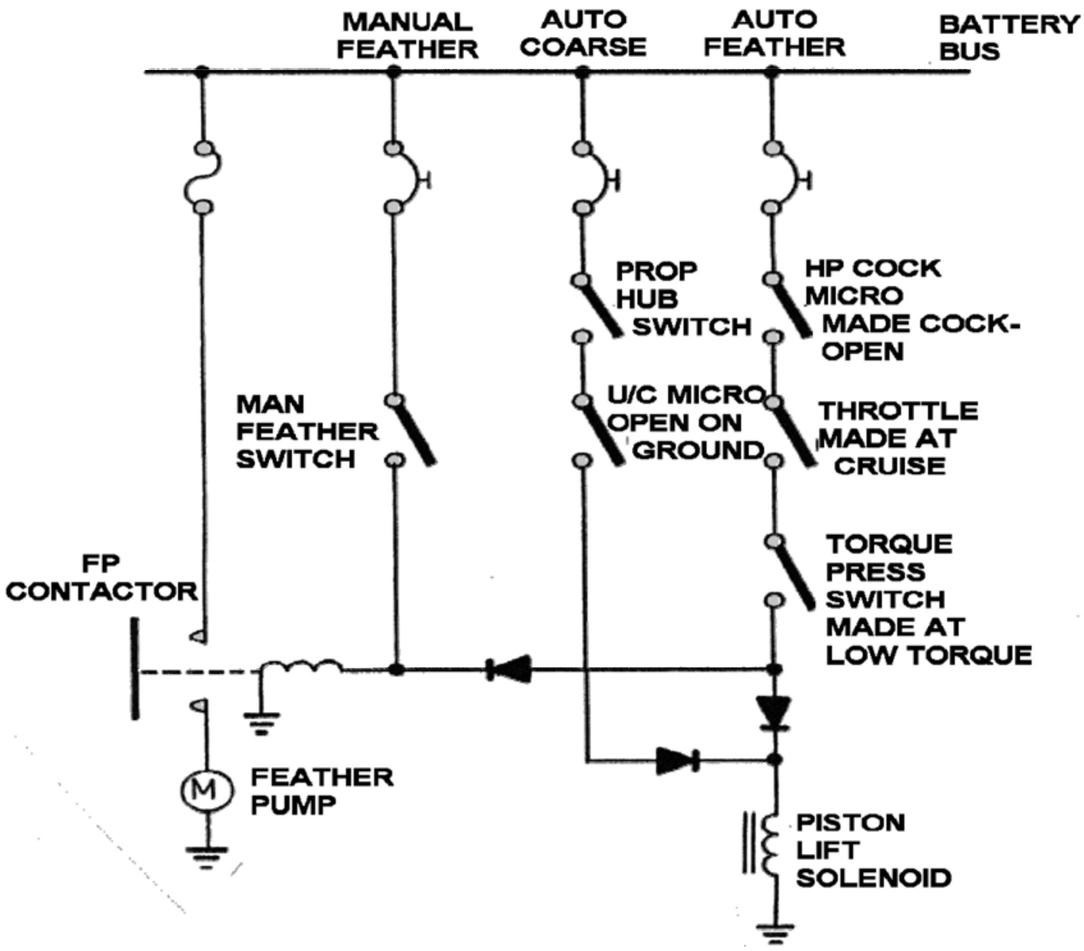
The control valve is lifted by moving the HP fuel cock lever to 'Feather' or by the piston lift solenoid valve opening and hydraulic pressure acts on the valve lift piston.

Oil pressure from the feathering pump is directed to the coarse pitch line to feather the blades. When the feathering is complete a pressure operated switch de-energises the pump-solenoid to stop the pump.

To unfeather the HP lever is opened and the feathering pump switched on for a few seconds.

3.5.3 MANUAL FEATHERING

HP fuel cock lever moved to 'feather'. Feathering pump started by Manual Feather Switch (Fig 88). Some systems have the feathering pump switch incorporated in the Engine Fire Handle.



Electrical Circuit Showing Feather and Auto-Feather Systems

Fig. 88

3.5.4 AUTOMATIC FEATHERING

This uses the torque indicating system to sense engine failure.

When torque drops to a certain valve a **low torque pressure switch** (Fig 88) completes a circuit to operate the **piston lift solenoid** and start the **feathering pump**.

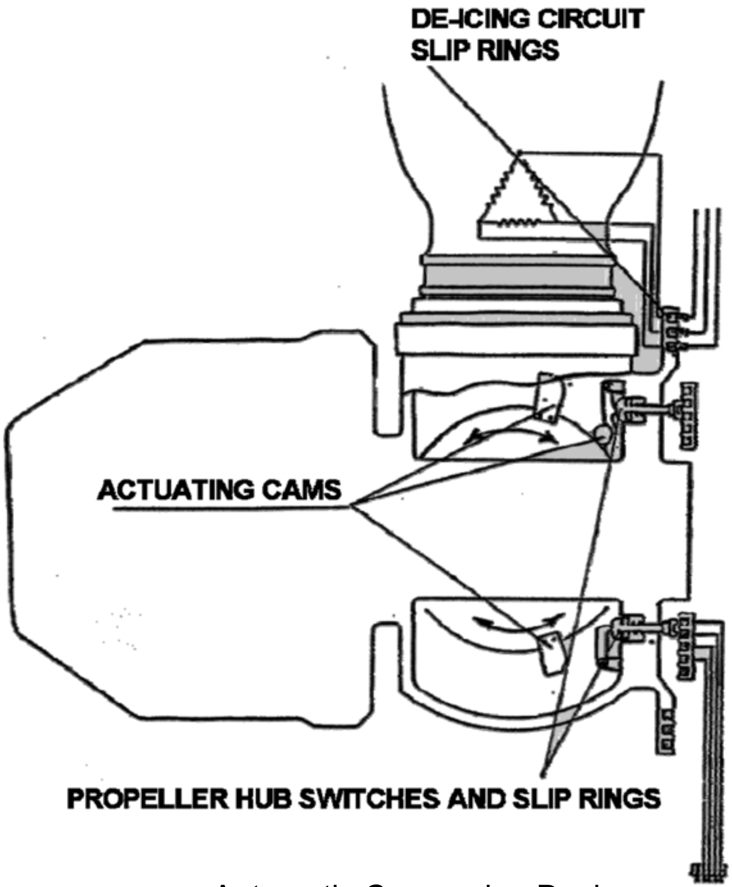
3.6 PROTECTION DEVICES

Defacts or faults such as flight fine pitch stop failure, ruptured oil pipe, governor failure all have to be catered for, the following are some examples of how these failures are contained.

3.6.1 FLIGHT FINE PITCH STOP FAILURE (OVERSPEED)

An overspeed is prevented by an automatic coarsening device.

A switch mounted on the Hub closes when the blade angle is below Flight Fine Pitch. With the circuit complete the Piston Lift Solenoid is energised and the propeller coarsens off. (Feathering circuit diagrams).



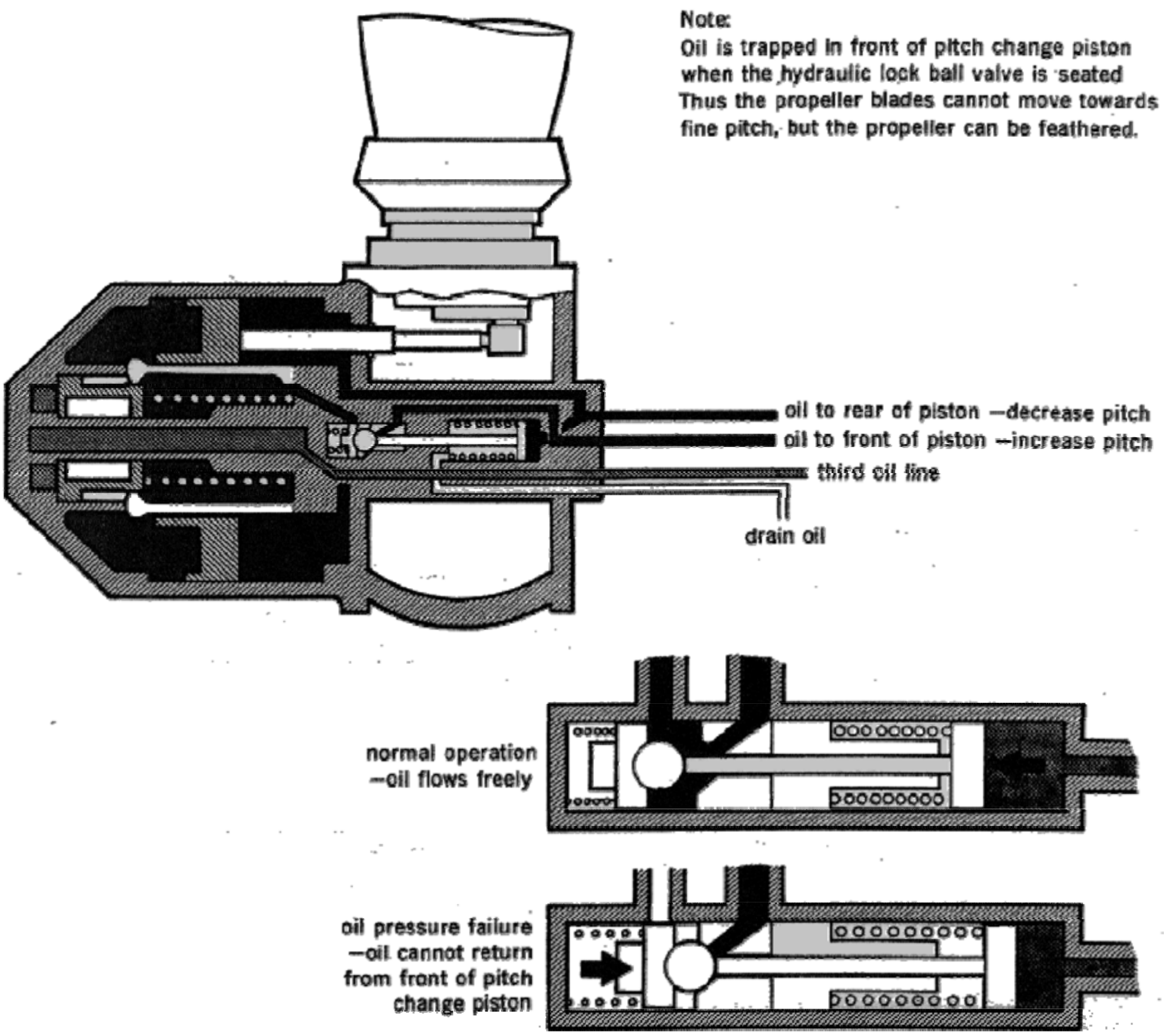
Automatic Coarsening Device

Fig 89

3.6.2 OIL SUPPLY FAILURE (OVERSPEED)

To prevent an overspeed caused by an oil supply failure, one of two methods may be employed:

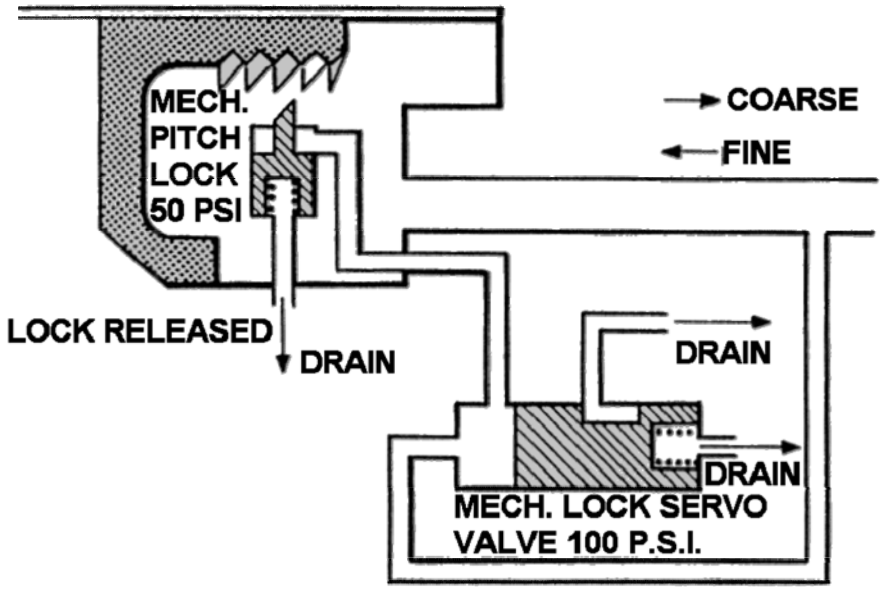
- **Hydraulic lock valve** (Fig 90) The pitch lock mechanism houses a valve called the 'hydraulic lock valve'. This is a spring loaded ball valve opened by fine pitch oil pressure and closed by a spring. In the event of an oil supply failure the hydraulic lock valve closes and acts like a non-return valve to trap coarse pitch oil in the pitch change cylinder. The oil trapped in the cylinder prevents centrifugal twisting movement (CTM) from turning the propeller blades towards fine pitch without affecting the feathering ability if the propeller.



Hydraulic Lock Valve

Fig. 90

- **Mechanical locking device** (Fig 91). A rachet mechanism allows the propeller to move to coarse pitch and to be feathered. The Pawl has to be withdrawn by P.C.U. action before the blades can move to a finer pitch.

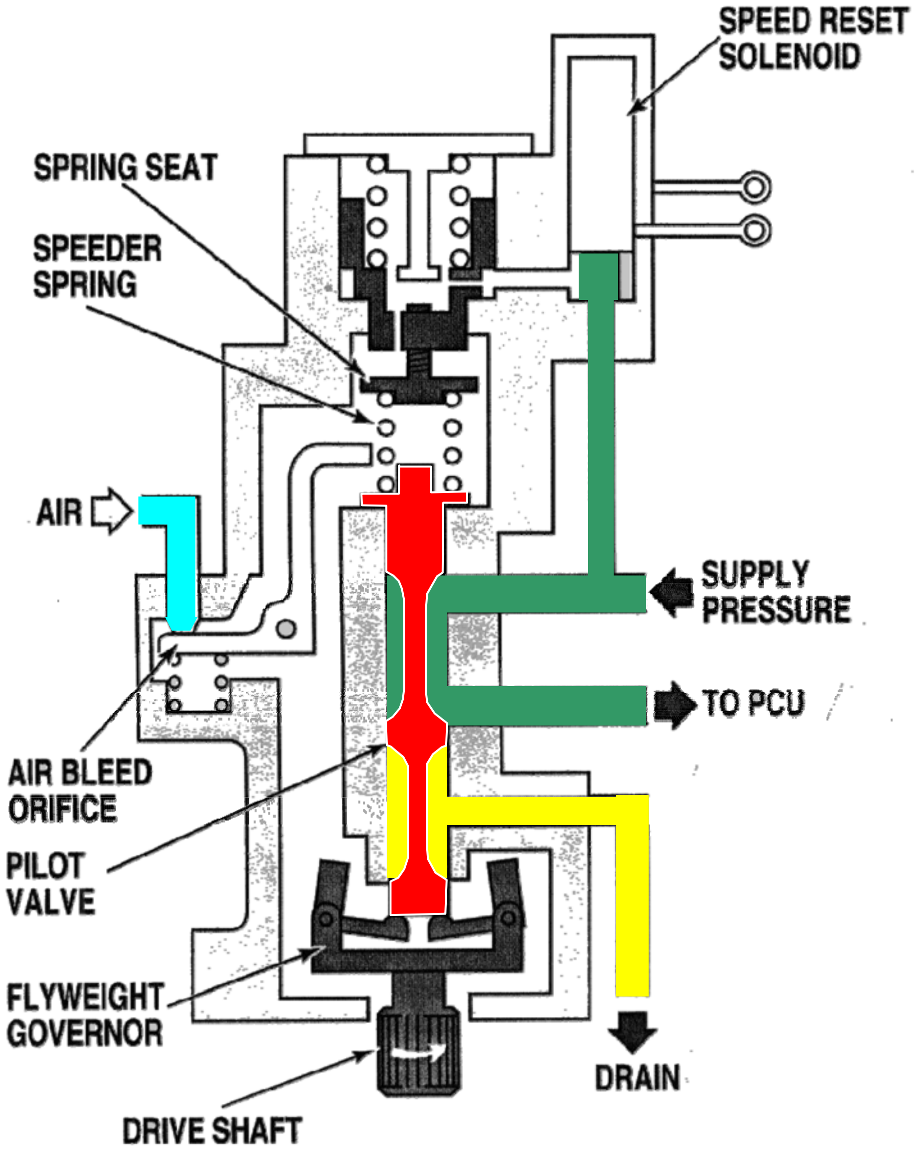


Mechanical Locking Device

Fig. 91

3.6.3 PROPELLER OVERSPEED GOVERNORS

These devices protect against overspeed, they are separate governors to the P.C.U. and direct oil during an overspeed situation to coarsen the blade. Built into the device is an air bled (Fig.92) which at max. RPM will back off the fuel flow from the fuel control unit.



Automatic Overspeed Protection Devices – Air Bleed

Fig. 92

The governor is equipped with a solenoid valve (Fig. 92) to enable its operation to be tested. When energised, the valve opens, allowing pressure oil to alter the position of the speed reset adjuster. Speeder spring compression is reduced by the upward movement of the adjuster and integral spring seat, which acts against the speed reset spring. Reduced spring force allows the flyweights to move out at a lower speed to simulate an overspeed condition. When the solenoid is de-energised, the oil supply to the adjuster bore is cut off, allowing the governor to function normally.

4 SYNCHRONISING

All multi engined propeller driven aircraft suffer from propeller beat noise which induces vibration in the airframe and causes fatigue and discomfort in the passengers and crew. This noise is produced by the propellers rotating at different speeds when each propeller produces its own frequency which beats with the frequencies of the other propeller. The noise and vibration levels are a function of the differences between the propeller speeds.

Modern aircraft use automatic systems to synchronise the propeller speeds. One engine is selected as the master and the other engines are slaved to the master engine's selected speed.

The simplest way to accomplish this would be to adjust the throttle and speed control of each engine until the relevant tachometers indicate the same reading at the instrument. Unfortunately the tolerances of each indicator are too great for accurate synchronisation to be achieved which in turn would lead to the engines being run at different speeds. In addition the alternative of synchronising the engines by throttle alone is also very difficult as the sensitivity of the throttles is much less than the indicators. To overcome these problems the synchroscope is fitted.

The synchroscope provides a good indication of the differences between two or more engine rotation speeds. The instrument is designed to operate from an alternating current supply generated by the Tachometer generator. The principle of operation is that of a frequency comparator unit comparing the frequency of Tachometer generator No. 1 with that of Tachometer generator No. 2 usually referred to as the 'Master' and 'Slave'. By using a technique of setting the 'on' speed conditions on the master engine, the indicator gives a clear indication of whether the slave engine is running faster or slower than the master.

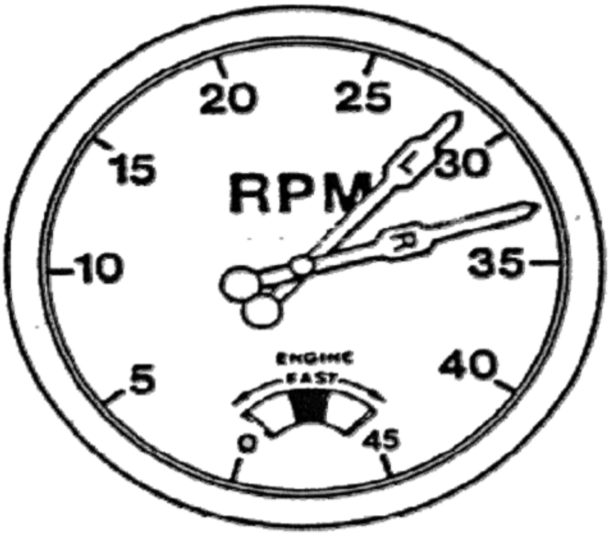
4.1 INDICATOR PRESENTATIONS

Fig 103 shows a typical two-engines synchroscope which includes a single unit with a single central pointer. Dial markings indicate the direction of pointer rotation which in turn denotes the increase or decrease in speed of the slave engine in relation to the master.

Two Engine Synchroscope

Fig.103

A combined RPM gauge / synchroscope indication (Fig.104) may also be used on a twin engined installation.



Combined Engine/Synchroscope

Fig 104

Four Engined Synhcroscope

Fig. 105

Fig.105 shows a typical four engined synchroscope which thus includes three units arranged symmetrically about the axis of the instrument. Dial markings indicate the associated engine numbers and the directions of pointer rotation which denotes whether an engine is rotated more slowly or faster than the master.

The tacho generators that supply the synchroscopes also supply the engines automatic synchronisation system.

4.2 SYNCHROSCOPE INDICATOR INTERPRETATION

The interpretation of the synchroscope pointer indicated faults are as follows:

Irregular or Oscillating movement;	Difference in speed beyond the indicating limits of the instrument.
Regular counter-clockwise rotation;	Engine slower than the master if error indicating.
Regular clockwise rotation;	Engine faster than the master if error indicating.
Pointer stationary;	Engines synchronised. Or one engine stopped.

The dial presentation of the synchroscope can be utilised in one of two ways.

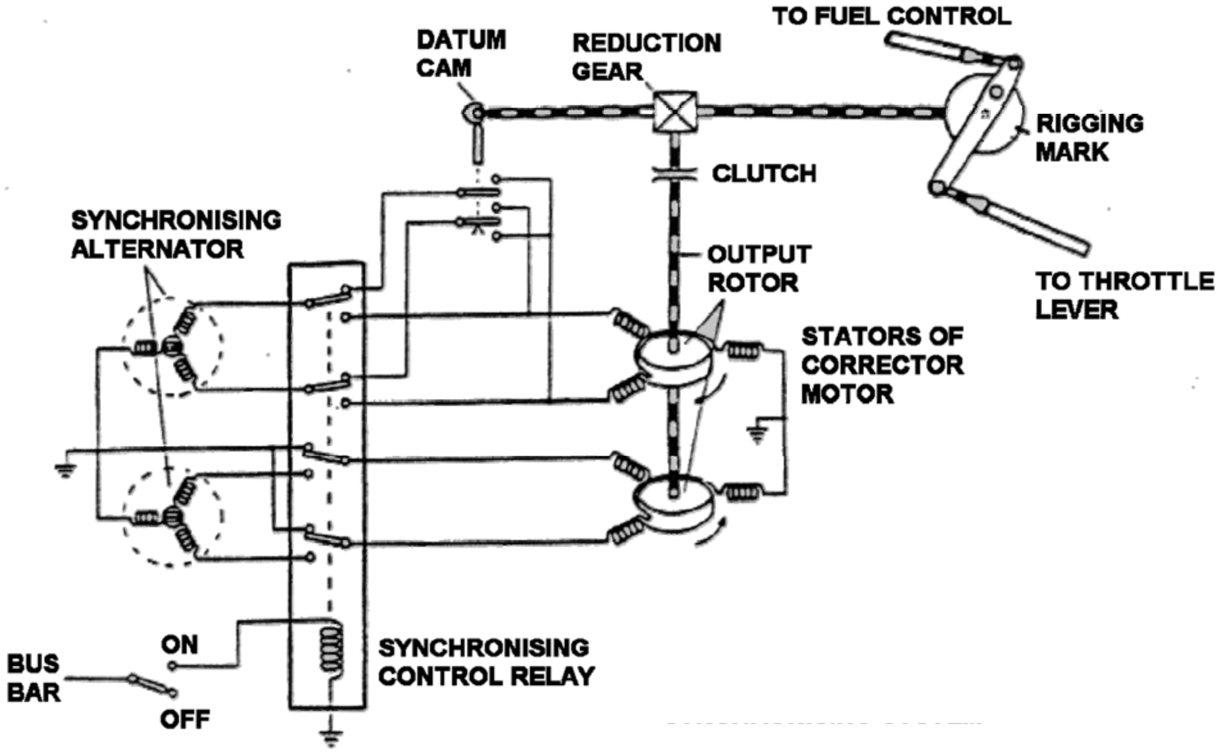
- One is to indicate an error i.e. the pointer indicating 'Slow' means that engine's speed is slower than the master.
- The other is as a correction demand indication i.e. the pointer indicator 'Slow' means that engine's speed must be reduced to gain synchronisation.

The same instrument can be wired to be used in either way and this is decided by the phase sequence of the aircraft wiring as in the wiring diagram manual.

When undertaking a functional check, following a unit replacement, it is essential to move the throttles and check that the sense of indication is correct for the type of aircraft.

4.3 AUTOMATIC SYNCHRONISING

Automatic Synchronisation uses engine driven synchronising alternators to detect electrically any increase or decrease in a slave engine's speed (Fig.106). Each alternator's output voltage is directly proportional to its engine speed and this voltage is sent to the corrector motor on the slave engine to modify its RPM if a difference in output exists by comparison with the master engine.



Synchronising System

Fig.106

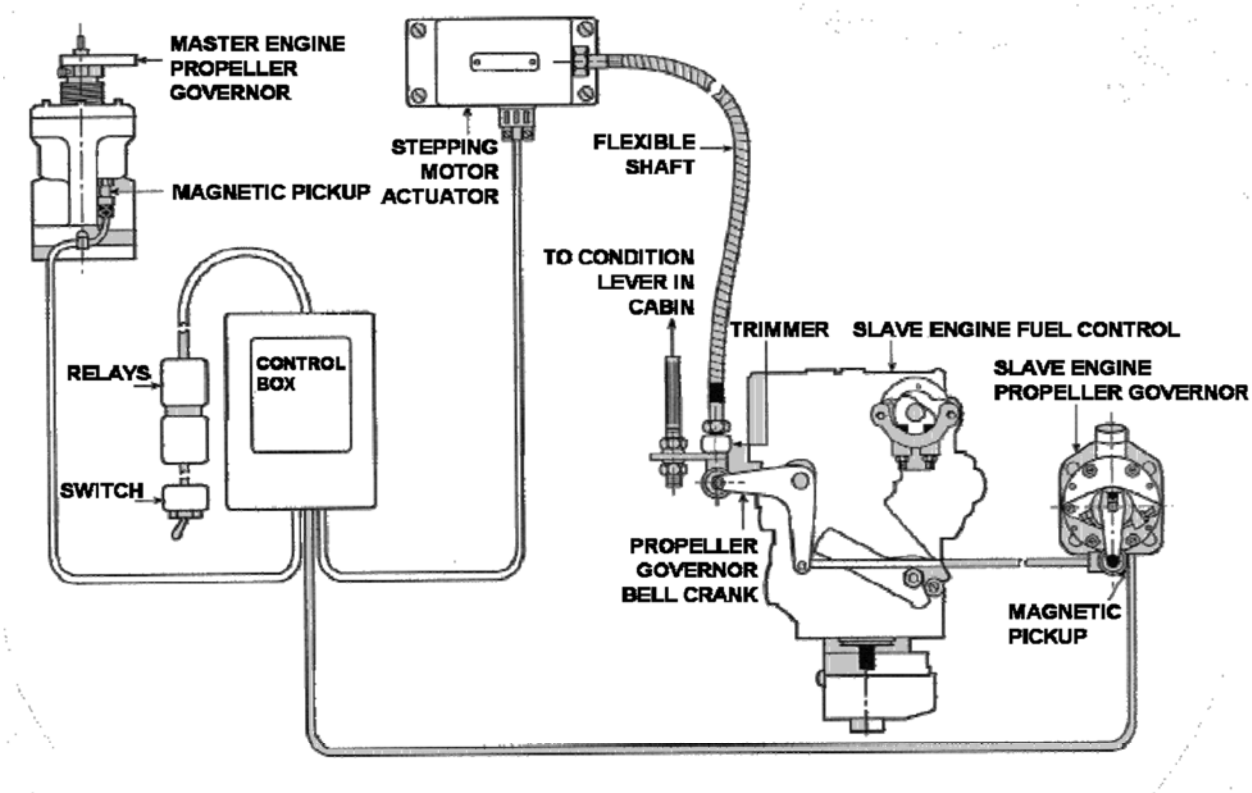
The corrector motor assembly consists of two stators mounted on a common rotor. One stator is fed from the master engine alternator and the other stator is fed from the slaw alternator. The wiring from the alternators is in such a way that the magnetic fields produced in the stators are in opposition. The output from the common shaft is through a clutch assembly and reduction gear to the slave engine throttle controls.

Rotation of the shaft imparts a small linear movement to the control lever and operates the input rods to the fuel and propeller control units. The operation of the PCU will, depending on the direction of correction, increase or decrease the blade pitch which with the fuel control unit will cause the slave engine's RPM to rise or fall until it equals the speed of the master engine.

The range of the synchronising system is restricted, so that a master engine failure, or for that matter an overspeed, only affects the slave engine to a limited extent. On the output shaft is a datum cam which causes the corrector motor to return to the mid point of the operating range when the system is switch off.

The opposition windings of the stators in the correction motor are wired so that the slave motor will influence the rotor in the decrease RPM direction and the master stator will influence it in the increase RPM direction.

A further method of propeller synchronising is the use of magnetic pick ups and stepper motor (Fig.107).



Propeller Synchroniser System for a Twin Engine Turboprop Aircraft

Fig.107

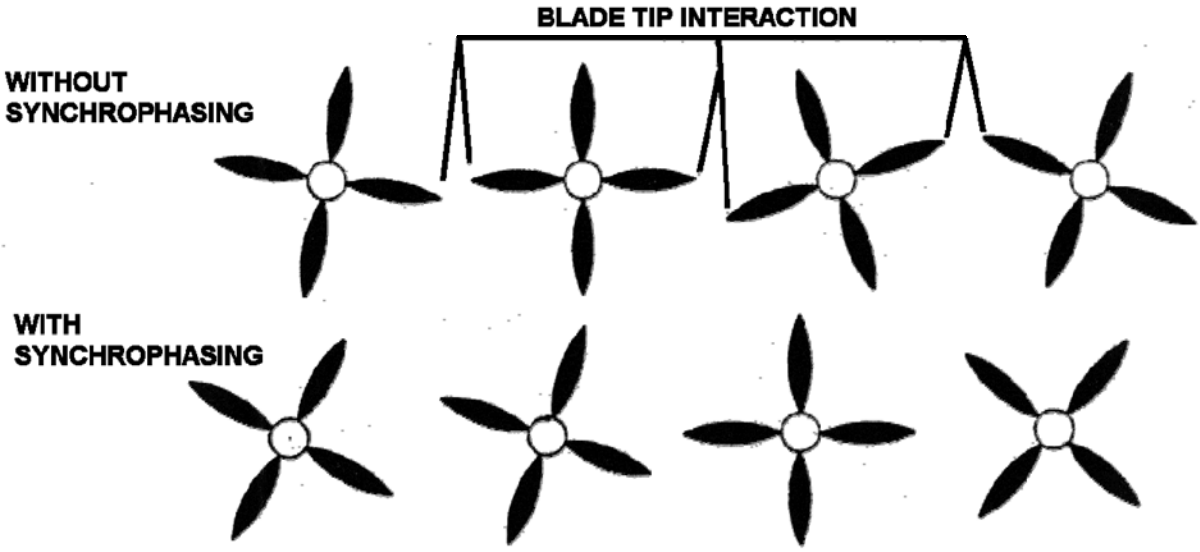
One engine is designated as the 'Master Engine'. When the RPM of this engine is adjusted by the pilot and the synchroniser system is **on**, the RPM of the slave engine will automatically adjust to the same RPM.

Each propeller governor contains a rotating magnet and a magnetic pickup which produces alternating current as the governor rotates. The frequency of this AC is proportional to the speed of the governor. The outputs from the two governors are compared in the synchroniser control box, and an output signal is sent to the DC stepping motor actuator. A flexible steel shaft connects the actuator to the propeller governor bell crank on the fuel control of the slave engine. If the slave engine is slower than the master engine, the control box will drive the actuator motor in a direction that will move the bell crank and connection arm on the slave motor fuel control and the propeller governor, in the correct direction to increase its RPM.

The operation of the synchroniser system is simple. It is left **off** during takeoff and landing. When the aircraft is trimmed for cruise flight, the condition levers of the engines are manually adjusted to bring their RPM close enough to the same speed that the engines will be within the synchronising range. Then the synchroniser is turned **on**. Any difference in RPM is sensed, and the slave engine fuel control and propeller governor are adjusted so the slave engine RPM matches that of the master engine.

When making power changes in flight, adjust both condition levers together to keep the RPM within synchronising range. If the engines get out of synchronisation beyond the limits of the system, the actuator will be driven to the limit of its travel. Turn the system **off** and the actuator will return to its centre position. Manually synchronise the engines and turn the system **on**. It will fine tune the synchronisation and hole the engines together.

4.4 SYNCHROPHASING



Synchrophasing Blade Relation

Fig.108

Although much of the audible beat frequency is eliminated by synchronising the propellers, the noise and vibration may still be quite high. The noise is produced by the interaction between the air and the blade tips as the blade tips of adjacent propellers pass close to each other (Fig.108). The position of the propeller relative to each other, (the phase difference between adjacent propellers) can be adjusted to an optimum combination which will reduce the interference to a minimum.

Synchrophasing is performed by each propeller driving a pulse generator. Each generator produces one pulse per propeller revolution. Synchrophasing is only available in the flight range. When in this range a master engine is selected and its signals are electronically compared with the slave engine signals. The discrepancy or phase difference between the engines is analysed, and by adjusting the propeller control units, the speed and correct phase relationship can be established with the master engine.

5 ICE PROTECTION

Propellers and spinners are exposed to an environment that under certain climatic conditions can lead to ice on the surface rapidly decreases its efficiency, leading to a loss of lift or thrust, and increasing its weight. Another problem with ice formation on a rotating mass such as a propeller is that if unevenly distributed, it can lead to imbalance which will cause excessive vibration. Ice build up on a propeller can also be the cause of another problem called ice throws, where the chunks of ice are thrown off the propeller at high speed due to the centrifugal force. These lumps of ice can cause considerable damage to any structure that is in their path.

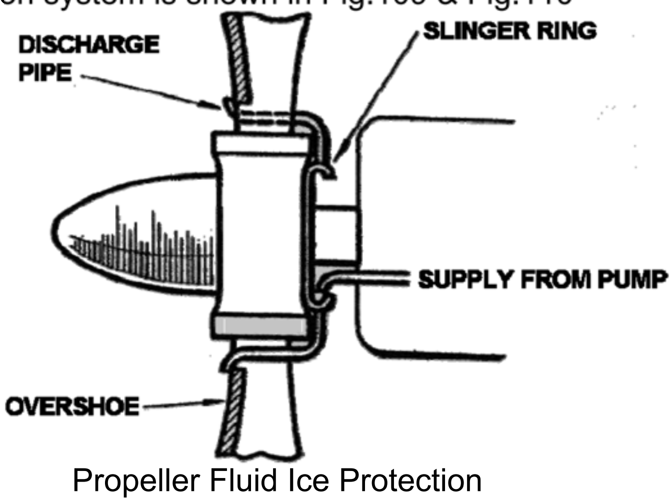
5.1 ICE PROTECTION SYSTEMS

Ice protection systems fall into two major categories depending upon the purpose for which the ice protection system is used. They are:

- **Anti-Icing** - This is a term used to describe the continuous heating or protection of a component to prevent the formation of ice occurring on it.
- **De-Icing** - This is used where components are cleared of ice formation after the ice has been allowed to build up. The method of de-icing is usually cyclic and this intermittent heating and cooling permits ice to form during the heat off period. A thin layer of ice is allowed to build up and acts as an insulator so that the temperature rise is more rapid during the time the heat is on, and thus the ice that has adhered to the surface is more easily melted.

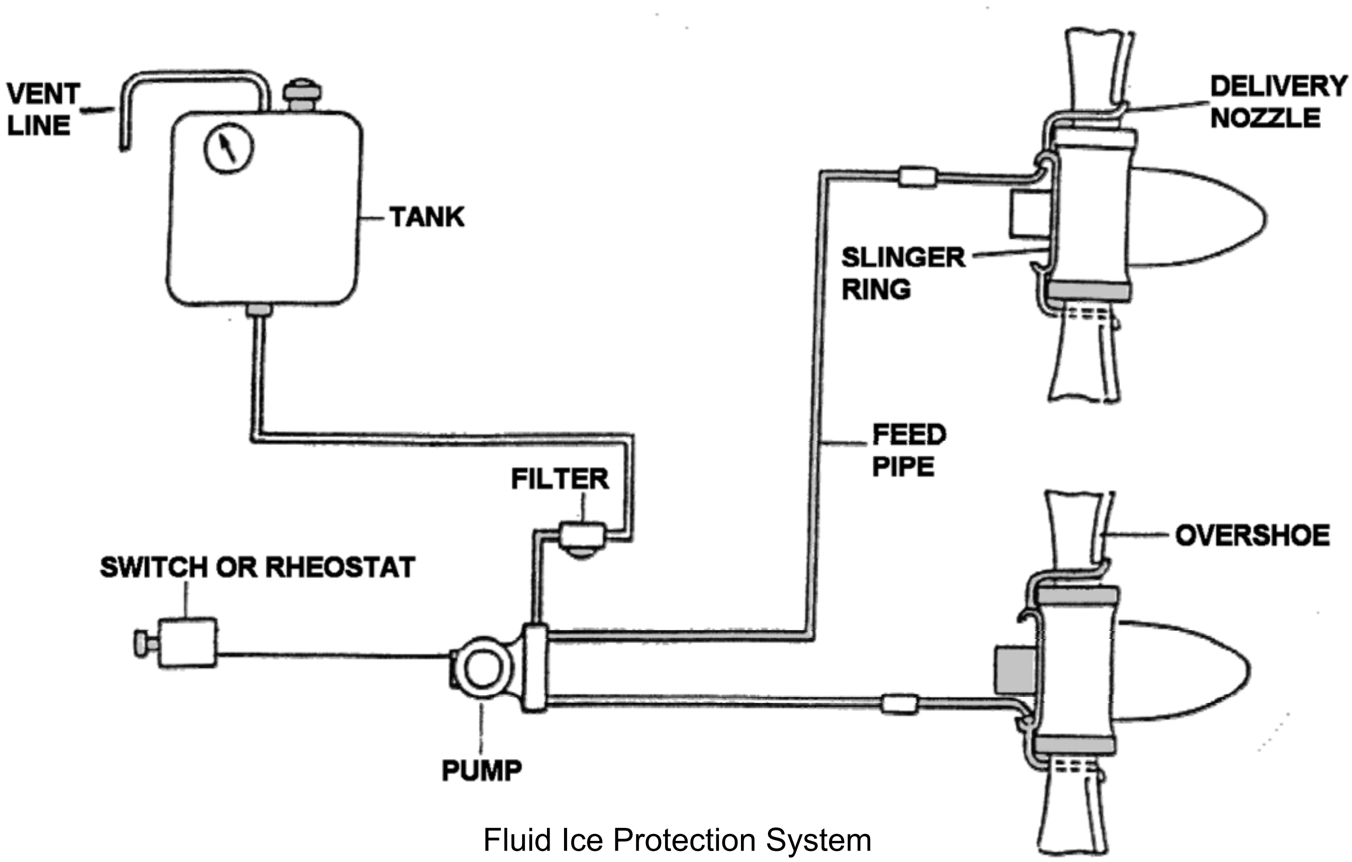
5.1.1 FLUID (LIQUID) ICE PROTECTION SYSTEMS

Liquid ice protection systems can be used as either anti-ice or de-ice systems. The system is designed to project a film or fluid over the surface of the blade which when mixed with water will reduce its freezing point. If ice is already present the fluid will penetrate below the ice layer and reduce its surface tension sufficiently to enable it to be thrown off by centrifugal force. A typical fluid ice protection system is shown in Fig.109 & Fig.110



Propeller Fluid Ice Protection

Fig.109



Fluid Ice Protection System

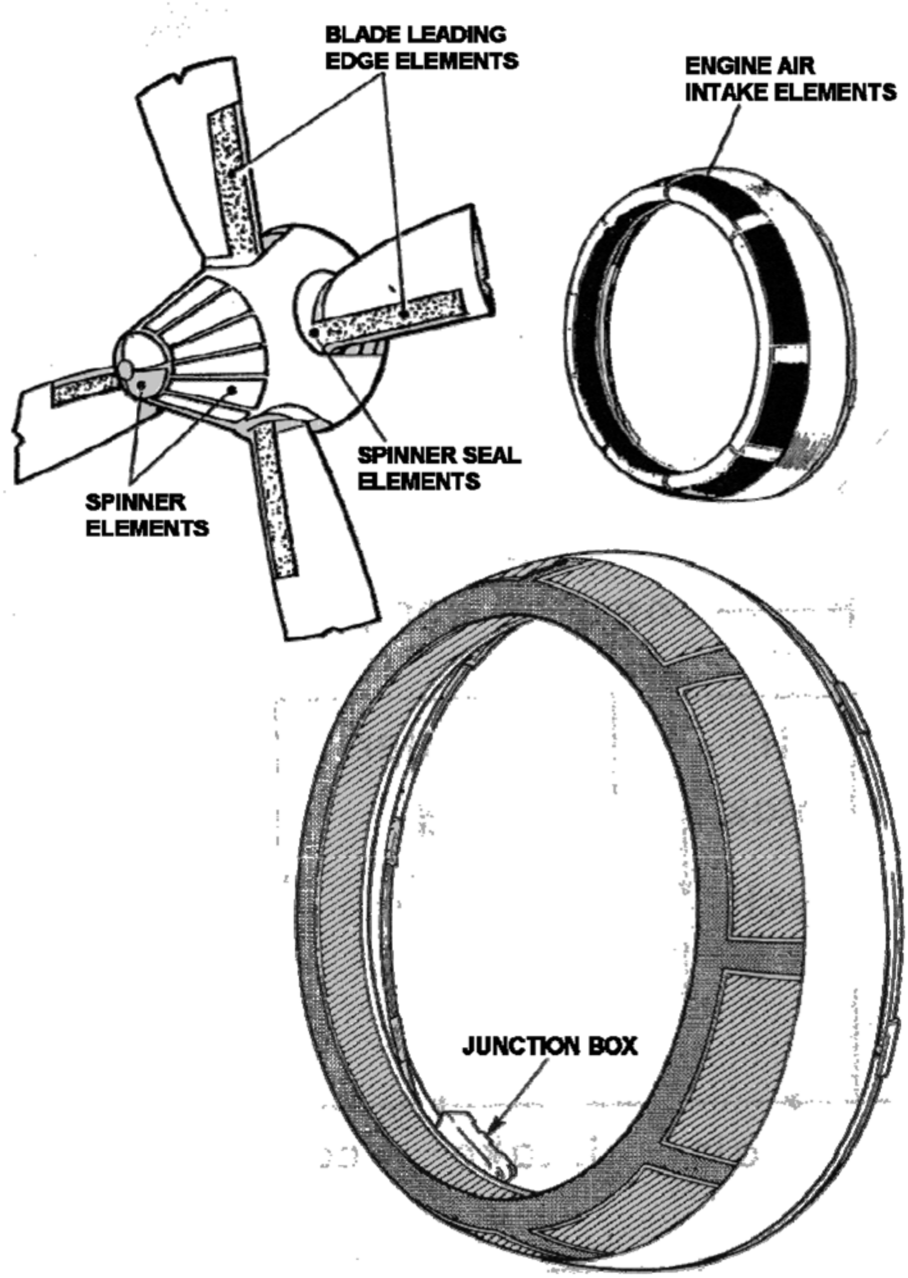
Fig.110

The fluid is stored in a tank and passes via a filter to an electric supply pump. The pump is controlled by a switch on the instrument panel. In some installations the speed of the pump and thus the quantity of fluid supplied to the propeller can be varied by the use of a rheostat. The output fluid from the pump goes through pipelines which terminate at the rear of the propeller hub. Attached to the propeller hub is a 'U' shaped channel called a slinger ring and from points around the slingers ring delivery nozzles are arranged to apply the fluid along the leading edge root section of each blade. Centrifugal force will then disperse the fluid along the blades' leading edge and the airflow over the blades will allow a film of fluid to be deposited on the face and camber sides of the blades.

The airflow around the blade root however is fairly disturbed and does not always disperse the fluid where it is more required, that is where ice build up is greatest. Propellers with this type of ice protection system usually have boots or feed shoes installed along their leading edges. An overshoe consists of a strip of rubber or plastic material set into the leading edge of the blade, from the delivery nozzle at the root end along the blade's length. The shoe extends about 2/3rds of the length of the blade, and has several open parallel channels in which the fluid can flow under the influence of centrifugal force. The overflow of the channels along the length of the overshoe will evenly disperse the fluid over the blade.

5.1.2 ELECTRICAL ICE PROTECTION SYSTEMS

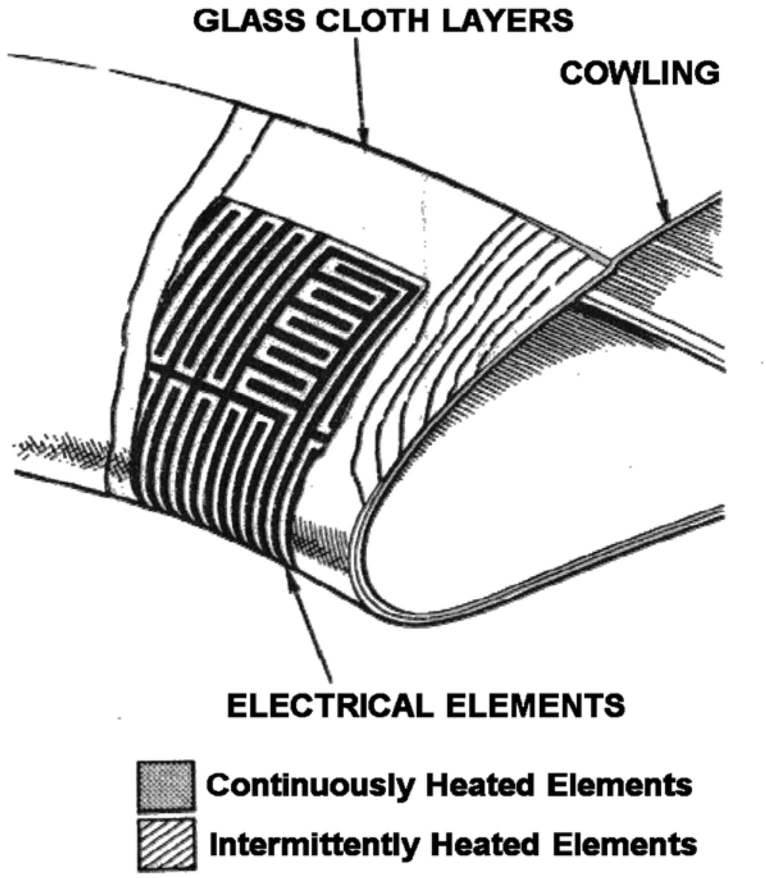
Electrical ice protection systems are used on most turbo-props (Fig.111). Resistance wire heater elements are embedded in rubber and cemented from the root to about 2/3rds of the blade's length along the leading edge. The rubber is usually protected by a wire gauze to withstand light stone damage and erosion. Often the aerodynamic spinner and engine intake lip are also protected from ice formation using this method.



Electrical Ice Protection on Turbo-Prop

Fig.111

This type of ice protection system works on the cyclic principle. The current is fed to the propeller blades, spinner, and the engine intake lip by an automatic time switch. Part of the intake lip (Fig.112) is continuously heated. This method ensures that the areas that have de-iced do not turn to water and then flow backwards to freeze again on the unheated trailing edge. The cyclic method also conserves electrical power so a smaller alternator can be installed.



Electrical Ice Protection Element at Intake Lip

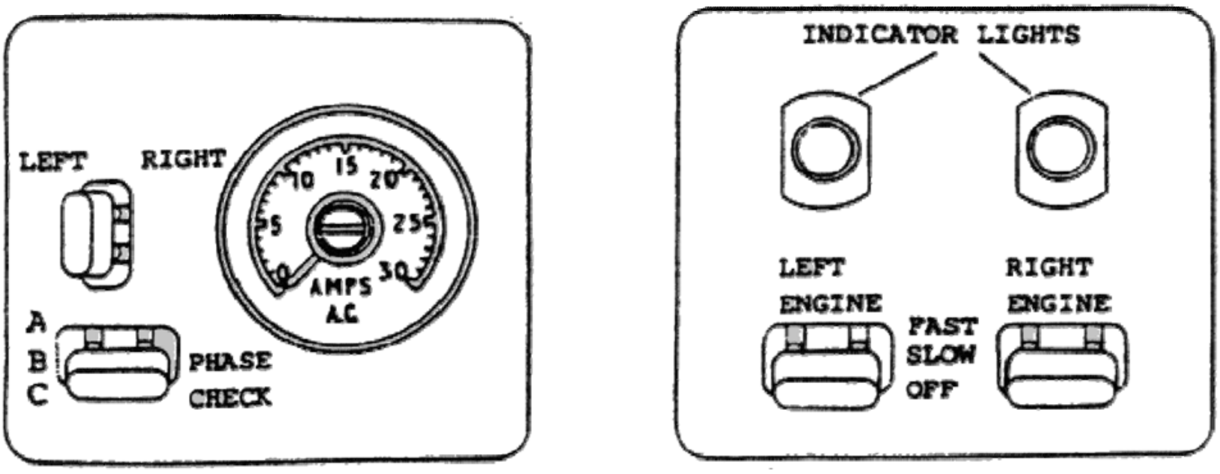
Fig.112

The cyclic timers have two speeds to use under differing ambient temperature conditions.

Fast is used at temperatures from -6°C to +10°C when icing conditions are prevalent, e.g. in rain or clouds.

Slow is used at temperatures of -6°C and below.

The operation of the cyclic de-icing system is usually indicated by flashing lights (usually green or blue) or an ammeter (Fig.113) showing the current consumed by the elements. Some aircraft have a phase test switch which enables the operator to check the current drawn from each phase of the a.c. supply. A typical control and test panel is shown in Fig.113.



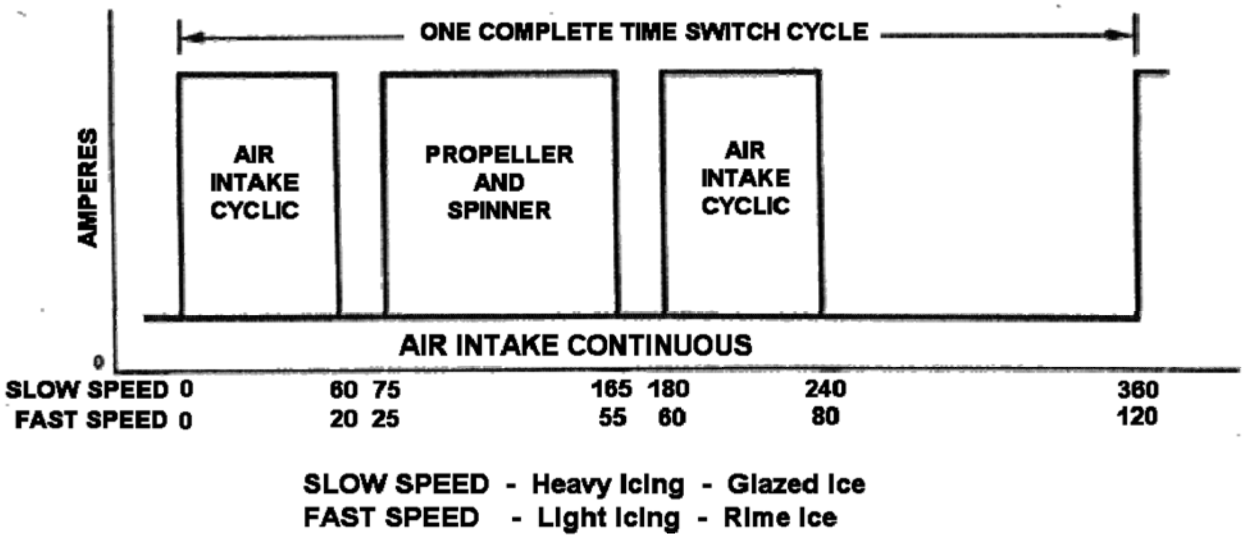
De-Icing Control and Test Panel

Fig.113

5.2 SYSTEM OPERATION

During each cycle rapid heating and cooling takes place. A thin layer of ice is allowed to form on the leading edges of the propeller blades. This thin layer of ice acts as an insulator so that when the current is switched on by the cyclic timer the temperature rises more rapidly than it would on an unprotected surface.

The ice layer next to the heating element melts and the thin layer of ice is easily dispersed by centrifugal and aerodynamic forces. The cyclic timer now transfers the power from the blade to the engine intake, and the leading edge of the blade rapidly cools allowing another thin layer of ice to form and the cycle is repeated.



De-Icing Switch Cylcle

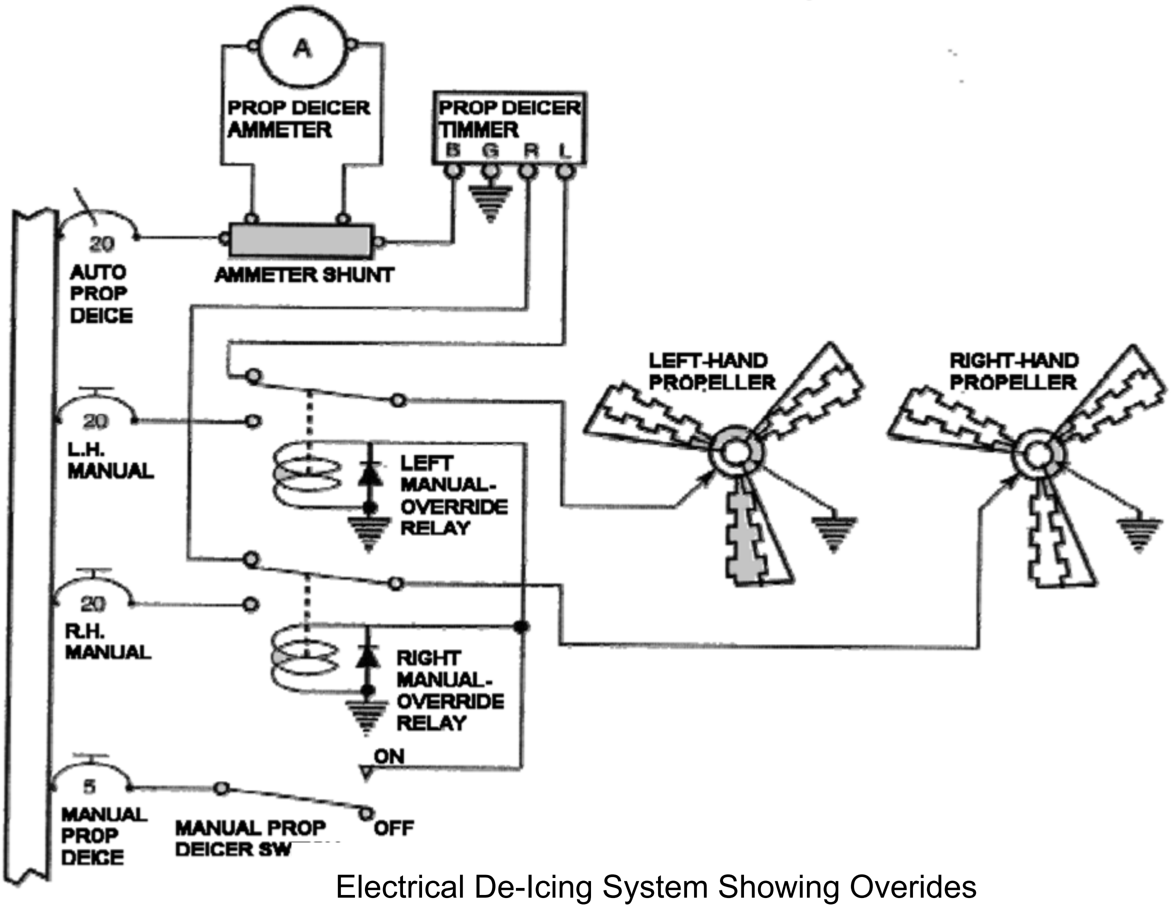
Fig.114

Electrical power carried to the propeller blades and spinner by a brush box, which contains several carbon brushes which are spring loading to contact slip rings on the rear plate of the propeller's hub. The current is then carried to the blades by cables to the blade roots. A de-icing time switch cycle is illustrated at Fig.114.

5.3 MANUAL OVERRIDE RELAYS

When the manual-override relays (Fig.115) are not energised, this current flows through brushes riding on slip rings mounted on the propeller spinner bulkhead and into the heating elements bonded to the propeller blades. The slip rings are connected to the heater elements through flexible conductors that allow the blades to change their pitch angle.

The timer sends current through the right propeller for about 90 seconds, then switches over and sends current through the left propeller for 90 seconds.



Electrical De-Icing System Showing Overides

Fig.115

Some propeller de-icing systems have two separate heating elements on each blade. Current flows through the right propeller outboard element for about 30 seconds, then through the right propeller inboard element for the same length of time. After the right propeller is de-iced, the timer shifts over and sends current through the left propeller outboard elements and then the left propeller inboard elements.

Current cycles of the two propellers are controlled by the timer as long as the propeller Auto Prop De-ice switch is **on**. When the Manual Prop De-icer switch is held in its momentary **on** position, the two manual-override relays are energised, and current flows directly from the bus to the blades without going through the timer.

The pilot can easily tell whether or not the de-icing system is operating correctly in the **Automatic** mode by watching the propeller ammeter. It will indicate a flow of current each time one of the heater elements draws current.

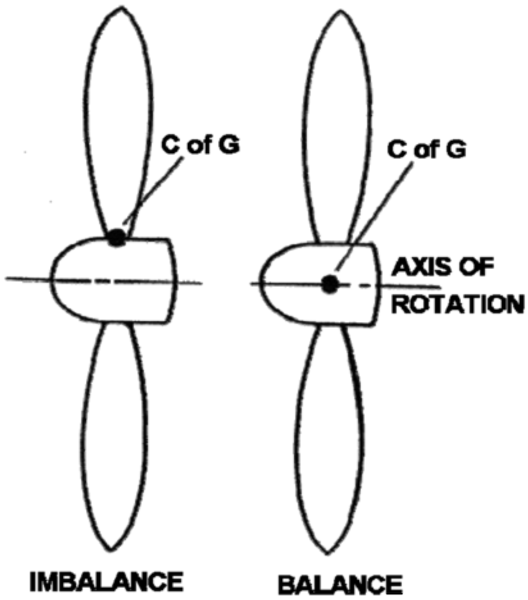
6 PROPELLER MAINTENANCE

6.1 STATIC & DYNAMIC BALANCING

6.1.1 STATIC BALANCE

When the weight distribution about the propeller axis is equal, with the propeller in any position, it is said to have static balance.

On fixed pitch propellers an unbalanced condition (Fig. 93) can be rectified by the removal of material from heavy blades or by the addition of extra coats of paint on the lighter blades. Some propellers have weights attached to the propeller boss.



Propellers in Un-Balanced & Balanced States

Fig.93

On variable pitch propellers, balance is corrected by the addition of weights at the hub, or by the installation of lead wool or washers in the hollow blade roots.

Static: Balanced when the centre of gravity acts through the Axis or Centre of Rotation.

6.1.2 DYNAMIC BALANCE

A propeller possessing static balance may cause vibration due to the non symmetrical disposition of the mass within the propeller (Fig. 94). Unequal weight distribution about the propeller axis can only be corrected by repeated ground runs following the addition of weights to the propeller.

Dynamic: Balanced when the blades' centres of gravity are in the Plane of Rotation.

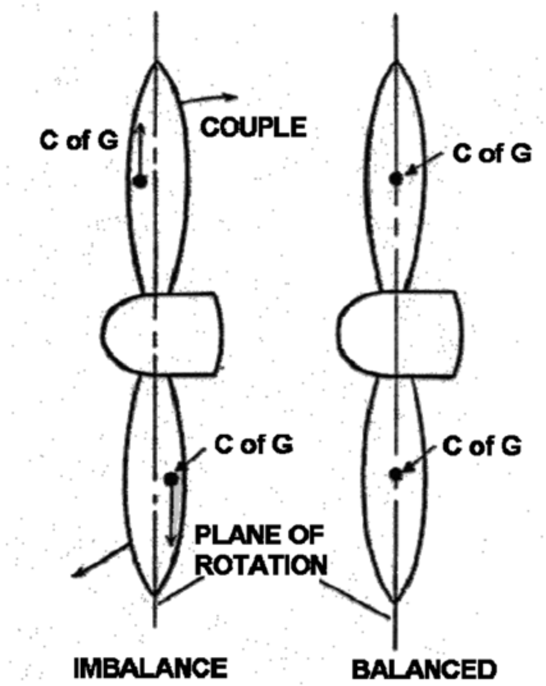


Illustration of Dynamic Imbalance and Balance

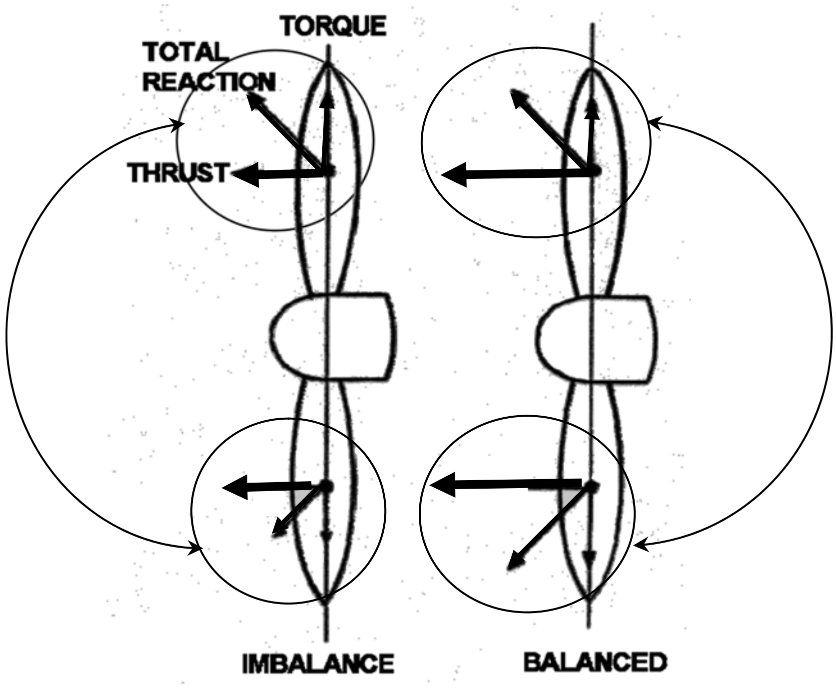
Fig.94

6.1.3 AERODYNAMIC BALANCE

When all the blades of a propeller are producing equal thrust, it is said to posses aerodynamic balance (Fig. 95). To achieve this it is necessary to adjust the blade angles relative to one another, by a few minutes of a degree when setting the initial blade angles on assembly.

Note: Balancing can only be carried out by approved propeller repair organisations using approved balancing test apparatus.

Aerodynamic: Balanced when the aerodynamic forces on all the blades are equal.



Aerodynamic Balance

Fig. 95

6.2 BLADE INDEXING

Slight differences in blade shapes produce unequal aerodynamic forces on the propeller.

These inequalities can be corrected for by slight adjustments to the individual blade angles to produce a specific thrust.

The adjustment or index is termed the Aerodynamic Corrected Factor (A.C.F.) and is usually painted on the blade root.

The ACF is the amount to be added or subtracted from the basic setting when assembling the propeller.
The process is sometimes referred to as 'Indexing' and an Index is shown in Table 1.

Table 1

BLADE NO.	**A.C.F.**	**PROTRACTOR SETTING**
1	Normal	27°
2	Set 0°5' Coarse	27° 5'
3	Set 0°9' Fine	26° 51'
4	Normal	27°

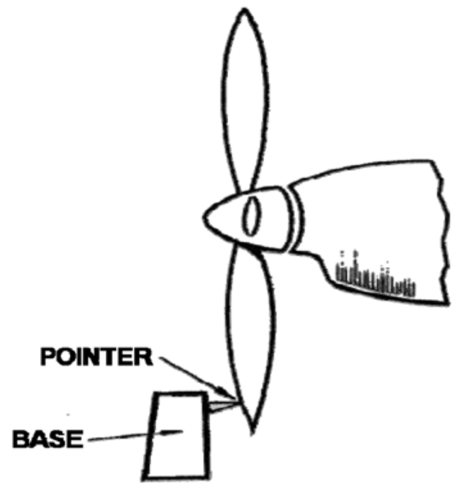
.

6.3 PROPELLER TRACK

An out of track propeller will suffer an imbalance caused by the Dynamic and Aerodynamic being out of balance.

Propeller track is the path followed by a blade segment in one rotation. If one blade does not follow in the same track as the others, its angle of attack and thus the thrust it produces, is different to the remaining blades, and vibration will result.

A simple blade tracking check would entail, chocking the wheels to prevent the aircraft from moving. Place a board under the propeller (Fig. 96) so the blade tip ‘nearly’ touches it. Mark the board at the tip of the propeller, and then rotate the propeller until the next blade approaches the board…mark the second blade position. Repeat for all blades. It can be observed from the marks generated, the extent of tracking deviation between blades. The amount that blades can be out of track is specified in the relevant Aircraft Maintenance Manual (AMM).

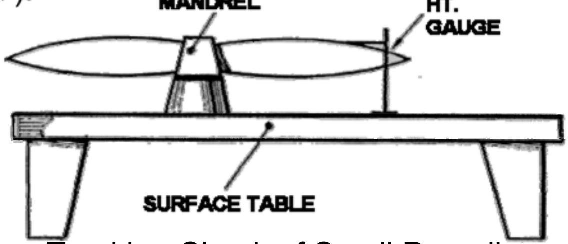


Blade Tracking Check

Fig.96

For information only, an average ‘maximum’ permitted deviation in track is 0·25 inches. Wherever possible the pointer should be attached to the aircraft structure to avoid the possibility of aircraft movement during the check.

Small propellers may be checked using a special mandrel, a surface table and a height gauge (Fig 97).



Tracking Check of Small Propeller

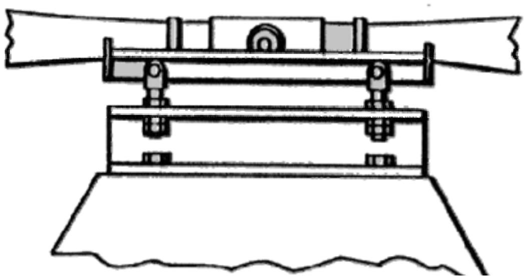
Fig. 97

6.4 PROPELLER BALANCE

There are two types of balance of importance when working with propellers:

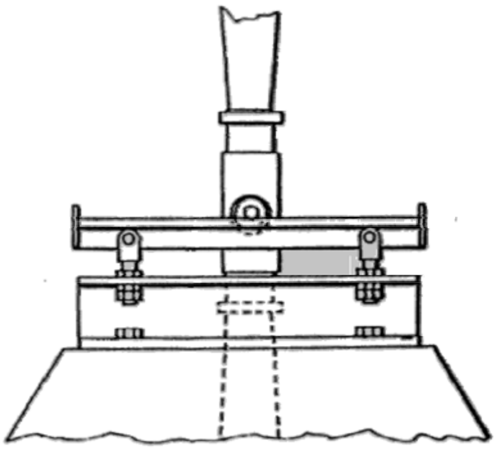
- Static Balance
- Dynamic Balance

Static balance is checked and corrected at a propeller repair shop. The propeller is mounted on a mandrel and placed across perfectly level knife edges. The balance is check in two planes, one with the blades horizontal (Fig 98) and one with them vertical (Fig 99).



Balancing in the Horizontal Plane

Fig. 98



Balancing in the Vertical Plane

Fig. 99

Fixed-pitch metal propellers are balanced in a propeller repair station by removing some of the metal from the heavy side and then refinishing the propeller.

Constant-speed propellers are balanced by placing a lead washer on a balancing stud inside the hollow blade shank. Small amounts of unbalance are corrected by packing lead wool in the hollow shanks on the bolts that fasten the halves of the propeller barrels together. This type of balancing can only be done by a certificated propeller repair station.

6.4.1 DYNAMIC BALANCE

Dynamic balance is the most effective type of balancing as it take all of the factors into consideration. It is done with the propeller installed on the engine in the airplane.

There are several aircraft balancers / analysers on the market that are essential for helicopter maintenance and extremely valuable for propeller balancing. The use of a microprocessor-controlled instrument that measures the amount of vibration and shows the position and amount of weight needed on the propeller spinner bulkhead to correct the out0of-balance condition is used through out the industry.

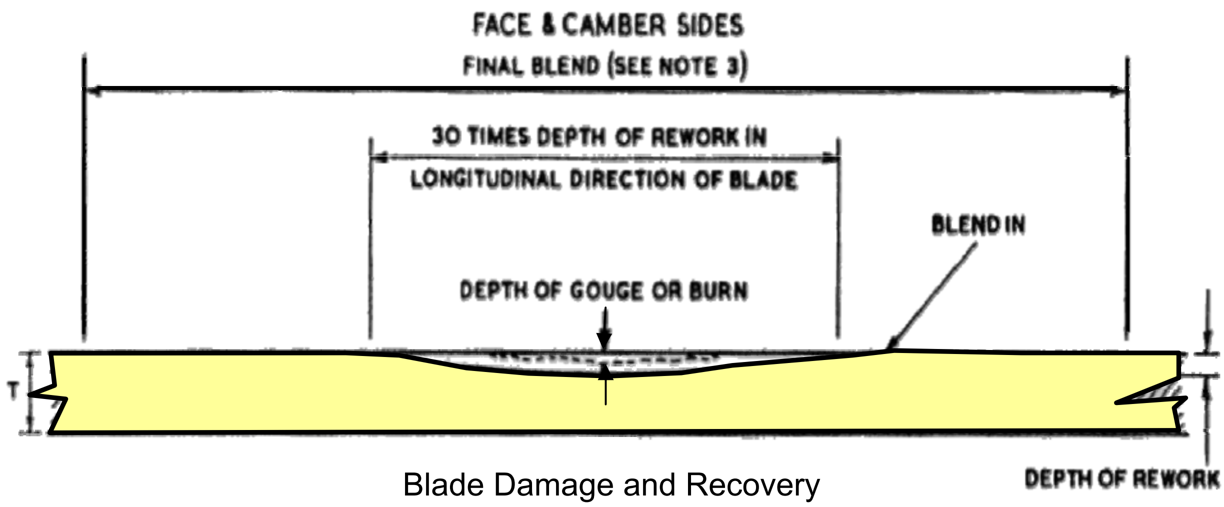
The equipment offers an option to split weights. If the location for mounting the permanent weights or the weight allowed per location is limited, enter the angles that are available and the unit will give a weight correction for each new location.

Install the permanent weights, and make a final engine run to ensure that they have the same balancing effect as the test weights.

6.5 ASSESSMENT OF BLADE DAMAGE

The most frequent major damage to a propeller is bent blades. No straightening is allows by anyone other than the propeller manufacturer or an approved repair station that must be approved for the particular operation. It is, however, the responsibility of the licensed technician to know the repairable limits of a propeller, so that a decision can be made to either remove/replace the propeller or to send it to a repair station.

Blades which are bent, twisted or cracked, or have severe surface damage, are to be considered unserviceable, and the propeller must be removed and returned to the manufacturer or an approved overhaul organisation. Minor surface damage may be blended out in the same way as for fixed pitch metal propellers, and within the limitations laid out in the relevant AMM.



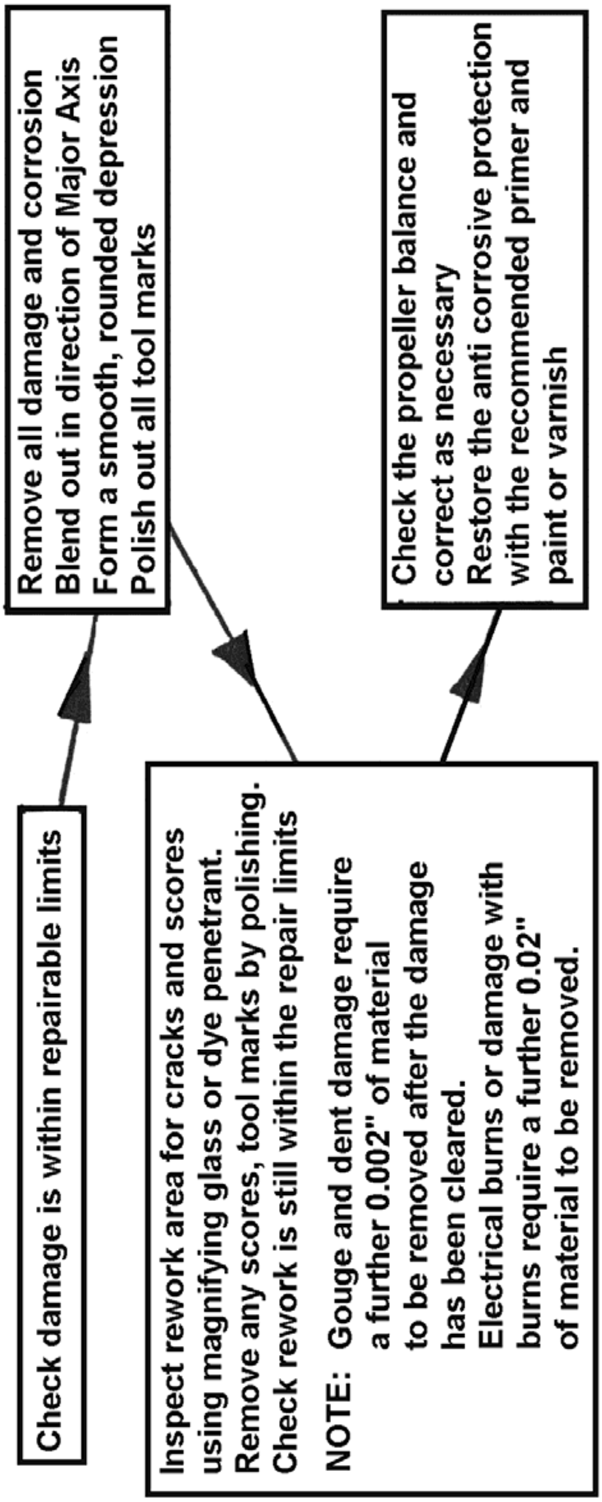
Blade Damage and Recovery

Fig. 100

As a general rule only:

1. Rework depth, face or camber sides must not exceed 060".
2. Reduction of section thickness must not exceed 25% of 'T' in area of rework.
3. Final blend area must not extend over more than 25% of chord, or 4" whichever is less.
4. After removing visible damage, remove further 002" for gouge rework, or 020" for burn rework with polished finish.
5. Length of any one (combined) blending shall not exceed 7".

A Simple flow chart showing the step by step process of recovering a damaged blade is shown in Fig 101. Note that the AMM procedures and limitations are always to be refered to, do not use these notes or rely on memory when carrying out assessments.



Simple Flow Chart on Blade Damage Recovery

Fig. 101

6.5.1 REMOVING DAMAGE

Blending out damage and correction using;

- Riffler files
- Scraper
- Small power grinder (with suitable butts or grinding discs)
- Fine abrasive or powder.

The rework must be carried out in the direction of the major axis of the blade, forming a smooth rounded depression in the blade surface. The junction between edges of the depression and surrounding blade surface must be faired out with a smooth blend. All traces of file or grinding marks must be removed using abrasive cloth and then the worked area finally polished.

The rework area should now be inspected for cracks, indentations and tool marks using a magnifying glass. A crack will cause rejection of the blade. Any further marks should be polished out and the inspection repeated. Check that the rework length / depth proportions are within limits. For gouge and dent damage a further ·002" of material should be removed, beyond that required damage. Electrical damage or damage with burrs a further 0·20" of material should be removed. It is essential that as soon as a repair has been carried out, the blade is reprotected.

6.5.2 COLD STRAIGHTENING

Cold straightening of the blade is allowed within the limits prescribed in the relevant AMM, provided the blade has not been subjected to impact damage. Impact damage is defined as damage, visible or not, from a blade striking, or being struck while rotating or when stationary. If a blade has suffered impact damage (although it may be within the cold straightening limits of the AMM) the damage details must be recorded and communicated to the manufacturer before any cold straightening procedure is undertaken.

The term 'cold straightening' has become accepted, by common usage, to mean blades that can be straightened or twisted without prior annealing. Blades damaged beyond the limits of cold straightening will require heat treatment prior to bending or twisting operations and must therefore be returned to the manufacturer for repair.

A blade may be subjected to cold bending or twisting within the prescribed limits on two successive occasions only. Where correction is required for a third time the blade must be returned to the manufacturer for heat treatment.

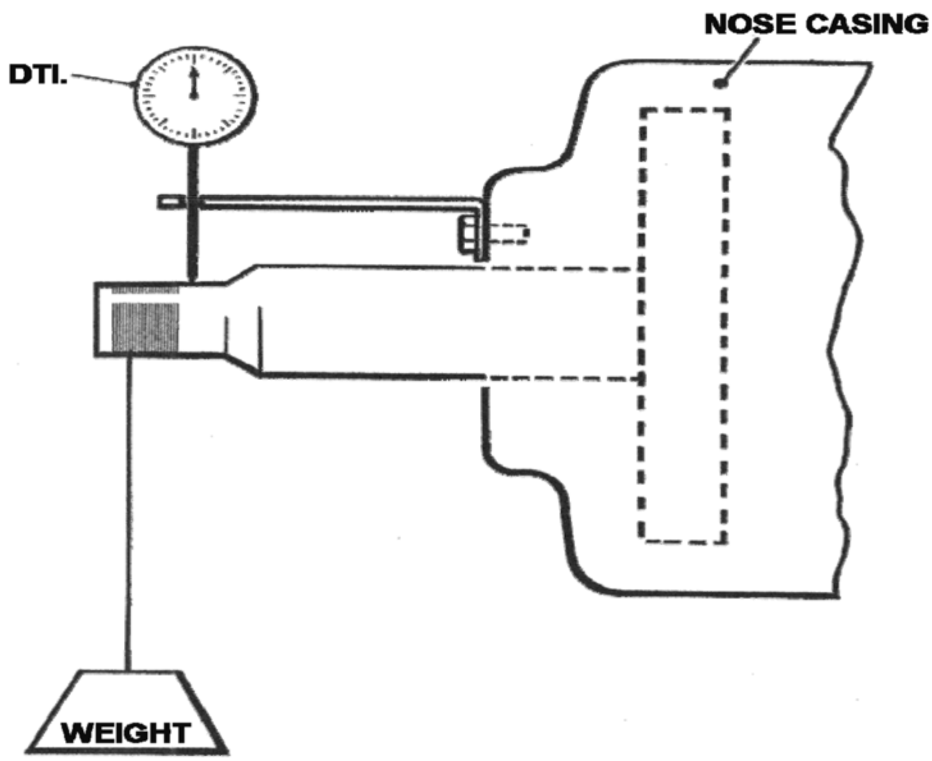
6.5.3 TIP CROPPING

The tip of the blade can be cropped with the limits specified in the AMM. A template should be made to the new tip dimensions and the template placed against the face side of the blade. Using a sharp pencil, mark the new tip arc. The portion of the blade outboard of the marking is removed by hacksaw or coarse grinding disc depending on the amount of material to be removed. All file and grinding marks must be removed and the work area polished using fine emery cloth. The blade should then be inspected to determine that the blade length is within permitted limits.

The amount of tip cropping must be recorded on the blade butt face in code form (e.g. T.C ¼).

6.5.4 SHOCK LOAD CHECK

When an engine has been subjected to a shock load, for example, during a heavy landing, or if the propeller is struck by a Foreign Object (FOD), the propeller shaft is to be checked for concentricity by attaching a D.T.I. to a bar that is bolted to the engine casing (Fig.102). With a weight attached to the end of the shaft and a D.T.I. in contact with the front parallel portion set to zero, the shaft is rotated through 360° and the indicator movement is observed. The maximum permissible accentricity will be stated in the appropriate maintenance



Propeller Shaft Concentricity Check

Fig.102

manual.

6.5.5 LIGHTENING DAMAGE

If a metal propeller is struck by lightening, burn damage to the blades is likely to occur. In removing this damage the normal repair limits apply, but after cleaning out all physical damage, a further specified thickness of metal must be removed, and the depression blended to a smooth contour. The damage area should then be chemically etched, and inspected with a magnifying glass to ensure that there are no signs of material abnormalities. Any electrical circuits in the propeller should be checked for continuity and insulation resistance.

6.5.6 OVERSPEEDING

Propellers may occasionally exceed their normal maximum rotational speed, and be subjected to centrifugal forces in excess of those for which they were designed. With variable-pitch propellers, overspeeding will normally only occur following failure of the control system, but with fixed-pitch propellers the maximum engine speed may easily be exceeded during manoeuvres if the engine speed indicator is not carefully monitored. The extent of the checks which must be carried out following overspeeding, will depend on the margin by which the normal maximum rev / min have been exceeded, and on any particular instructions contained in the approved Maintenance Manual. The figures quoted here are typical values.

No special checks are normally required following overspeeding up to 115% of normal maximum rev /min, but it may be recommended that the track of the propeller is checked.

If the propeller has been overspeeding between 115% and 130% of normal maximum rev / min, for a period in excess of any specified time limit, it should be removed for inspection. All blades should be carefully inspected for material failure, using a penetrant dye process. Blade bearings should be cracked tested, and the rolling elements and raceways should be inspected for brinelling (i.e. indentation). The hub and counter-weights should be inspected for cracks and distortion, and particular attention should be paid to the blade mounting threads and spigots.

If the overspeeding has been in excess of 130% of normal maximum rev / min, the propeller should be returned to the manufacturer for investigation.

6.6 SPECIAL INSTRUCTIONS

Manufacturers of propellers may issue, from time to time, instructions dealing with the detection and rectification of faults which are known to exist on particular types of propellers. These instructions are often issued in the form of Service Bulletins, and engineers should be acquainted with such advice, and should take action accordingly.

6.6.1 STORAGE - INSTALLED PROPELLERS

Propellers installed on an engine which may be out of use for a period of up to three months should be kept clean, and should be inspected regularly for corrosion. The internal parts of a variable-pitch propeller will be protected by exercising the propeller during weekly engine runs where these are possible, but, if the engine cannot be run, the propeller should be feathered and unfeathered using the feathering pump. If the engine is likely to be out of use for more than three months, the propeller mechanism should be flushed with inhibiting oil, and all external parts of the propeller should be treated with lanolin or an approved rust preventative. The propeller operating mechanism should be covered with waxed paper, and all visible parts should be regularly inspected for corrosion.

6.6.2 STORAGE - UNINSTALLED PROPELLERS

Uninstalled propellers should be stored in conditions which are clean, dry, warm and free from corrosive fumes. Two-bladed propellers are usually stored in racks to permit free circulation of air, but propellers with more than two blades may be stored vertically, on stands, to minimise the amount of floor space they occupy. Propellers should be retained in the manufacturer's packaging whenever possible, or wrapped in mouldable wrap and waxed paper. The external parts of metal propellers should be coated with lanolin or an approved alternative. The pitch change mechanism of a hydraulically operated propeller should be inhibited with approved oil, and all loose parts, such as oil tubes and mounting cones, should be coated with lanolin and waxed paper.

When a variable-pitch propeller is disassembled for storage, individual mechanical parts should be immersed in inhibiting oil, and then allowed to drain, bearings should be coated with mineral jelly, and electrical connections should be smeared with petroleum jelly. All electrical equipment, such as motors and slip rings, should be thoroughly cleaned, the connections smeared with petroleum jelly, external surfaces should be treated with a rust preventative, and each part sealed in a moisture vapour proof bag. All parts of the propeller should be wrapped in waxed paper and, if possible, packed in a suitable carton or crate.

When assembled propellers or pre-loaded blade assemblies are held in storage, the bearings must be exercised after six months and nine months. At the end of twelve months in storage the bearings must be removed and examined for brinelling and corrosion, and, if they are found to be satisfactory, they should be cleaned, greased, and re-assembled on the blade. They will then be satisfactory for a further six months storage.

6.6.3 INSTALLATION OFCSU/ PCU

Installation of the CSU / PCU is normally straight-forward. A new gasket should be fitted to the mounting flange, and the unit should be installed carefully, ensuring that the driven gear meshes with the driving gear or quill shaft, and that any dowels are correctly located. Mechanical linkage on a piston engine should be adjusted, so that the CSU control is on the maximum rev / min stop when there is a slight clearance between the pilot's control lever and the forward end of the gate in which it operates. The controls to the PCU of the turbine engine are interconnected with the high pressure fuel cock, and with one or more of the electrical contacts associated with the operation of the various propeller functions; they may also be electrically or mechanically connected to the controls on the flight deck. Mechanical linkage is normally adjusted by locking the pulleys and levers in set positions, using rigging pins or similar equipment as necessary, and adjusting the connecting rods or cables to suit. Details of the procedure for setting up the propeller controls on any particular aircraft must be obtained from the appropriate Maintenance Manual.

6.6.4 INSTALLATION OF PROPELLER

The method of installation will depend on the type of propeller, and all instructions detailed in the appropriate AMM should be carefully followed; these will include any special checks to be carried out, and details concerning lubrication, torque loading and locking or retaining parts. The following procedures are applicable to most propellers:

- Remove all protective covers and plugs, and clean parts which have been treated with a protective coating. Lubricate specified parts with the recommended grease or oil before installation.
- Fit the electrical brush gear housing to the engine reduction gear casing, and check that it is square with the engine shaft, using a dial test indicator clamped to the shaft.
- Fit the sling to the propeller, lightly smear the front and rear cone seatings with engineers' blue, and temporarily fit the propeller to check the contact area of the cones. Tighten the hub retaining nut by hand, rotate the propeller at least one revolution, then remove the propeller and check the extent of blueing of the cones. If the contact area is less than 80%, high stops may be removed by light stoning, or where permitted, by lapping on a suitable mandrel. Clean the cones and cone settings.
- With hydraulically-operated propellers, fit and lock the oil tubes in the engine shaft.
- Refit the propeller, lightly lubricate the splines, cone bore and threads with specified lubricants. Cone faces should not normally be lubricated, as this may result in looseness of the propeller when the oil film is lost. Lubricating the propeller bore, rather than the shaft will prevent any lubricant from being displaced on to the cone face when the propeller is installed.
- Turn the blades to the feathered angle, and fit the pitch-change mechanism.
- Install the brush gear, and check for correct contact between the brushes and the slip rings.

- Fit the spinner, and turn the blades through their full pitch range, to check for fouling.

6.6.5 TESTING AFTER INSTALLATION

After installation of a propeller, the engine must be ground run in order to check the propeller for correct function and operation. Aircraft propeller installations vary considerably, and no set testing procedure would be satisfactory for all aircraft. It is imperative, therefore, that any particular installation should be tested in accordance with the approved AMM procedure, which will normally include the following general requirements:

- The engine should normally be fully cowled, and the aircraft should be facing into wind before starting an engine run. It is sometimes recommended that the pitch change cylinder should be primed with oil before starting, by operation of the feathering pump.
- The safety precautions appropriate to engine ground running should be taken, the controls should be set as required, and the engine should be started.
- As soon as the engine is operating satisfactorily, and before using high power, the propeller should be exercised in the manner specified in the Maintenance Manual, to establish that the pitch change mechanism is operating.
- The checks specified in the Maintenance Manual to confirm satisfactory operation of the propeller system, including constant speed operation, feathering, operation of the propeller pitch change throughout its range, synchronisation with other propellers on the aircraft, and operation of associated warning and indicating systems, should be carried out.
- Engine running time should be kept to a minimum consistent with satisfactory completion of the checks, and a careful watch should be kept on engine temperatures to avoid overheating. With turbine engines, changes to operating conditions should be carried out slowly, to avoid rapid engine temperature changes, and to conserve engine life.
- When all checks have been successfully carried out, the engine should be stopped, and a thorough inspection of all propeller system components should be carried out, checking for security, chafing of pipes and cables, and signs of oil leaks.
- Don’t forget to complete all paperwork related to the maintenance activity, including Duplicate Inspections.

Note: If vibration was experienced during the engine run, the hub retaining nut should be re-tightened after the engine shaft has cooled down.

6.6.6 SERVICING OF CHEMICAL DE-ICING SYSTEMS

It is essential for the correct operation of the ice protection system that servicing is carried out on a regular basis. The fluids used in these systems are based on:

- Isopropyl alcohol
- Phosphate compounds

Isopropyl alcohol is flammable and must therefore be treated with great care. Both the fluid types are prone to solidifying in to a jelly type substance if left on the blades the resulting deposits will build up and eventually obstruct the distribution nozzles and the overshoe grooves. This will lead to uneven distribution, or no distribution at all, of the de-icing fluids.

The commonly accepted method of keeping the de-icing pipes clear is to flush the system using methylated spirit and distilled water as follows. This is a general procedure and not specific to any aircraft type. Always refer to the aircraft AMM for the correct procedures.

- Fill the tank with the above mixture.
- Operate the pump observing any time limitation on the motor.
- Turn the propeller by hand until the fluid is seen to emerge from the delivery nozzles.
- Empty the tank through the nozzles to ensure sufficient cleaning fluid has passed through the system.
- Clean the blades with methylated spirit or warm soapy water, paying particular attention to the grooves in the overshoes.
- If the system is to be left empty it should be inhibited according to the manufacturer's instructions.

6.6.7 FUNCTIONAL CHECKS OF CHEMICAL DE-ICING SYSTEMS

Once the correct flow rate of the fluid supply has been established the distribution of the fluid flow over the blades should be checked. This check is carried out with the engine(s) running and all the necessary safety precautions must to be observed. The following operations are carried out prior to the ground run:

- The overshoe grooves are checked to ensure that there is no build up of gummy deposits obstructing the flow of fluid (cleaning will be discussed later in this booklet).
- The blades should be pained with a disclosing fluid or whitewash, as directed by the propeller manufacturer.
- A dye should be added to the contents of the de-icing tank.
- The engine is then run at the RPM laid down in the manual.
- For a specified period the system is turned on, and at the correct rate if a rheostat is fitted.

- The fluid with added dye will stain the disclosing fluid and when the engine has stopped the blades van be examined for even distribution.

6.6.7.1 Inspection

The ice protection system should be inspected at regular intervals to ensure its effective and efficient operation. The following details should be observed / examined:

- If uneven distribution is apparent the positioning of the feed pipe and slinger ring should be examined as very little clearance is permitted. It is essential for the correct operation of the system that the rotating slinger ring does not contact the feed pipe.
- The delivery nozzle position should be checked in relation to the overshoe grooves and it should be clear of any obstructions.
- The overshoe grooves must be straight and free from deformations or damage.
- Adherence of the overshoe to the blade must be tested for loss of adhesion.
- Feed pipes must be correctly and adequately clamped to prevent movement due to vibration.

6.6.8 ELECTRICAL DE-ICING SYSTEM MAINTENANCE

Tests of the system must be carried out when the servicing schedule required it or when a component has been replaced. Typical tests are outlined below.

- Continuity and resistance checks should be carried out before the installation of a propeller or when the efficiency of an overshoe's heating surface is suspect. The values of resistance that the elements should have are laid down in the Maintenance Manual.
- Insulation checks are required to ensure that there is no breakdown of the element's insulation from the propeller blades or other metallic objects.
- Voltage proof checks are used to ensure that no insulation breakdown exists between the blade and heater element. They involve applying a high voltage between the blade and element and ensuring that no leakage exists. These checks are normally carried out after repairs to the overshoe.
- Functional tests of the ice protection system chan be carried out noting the current displayed for each of the phases of a.c. power on the flight deck ammeter. To prevent overheating of the elements the engine must maintain a minimum speed while the heating is on, as this allows a flow of air over the blades and engine intake. Some types of aircraft reduce the voltage of the system when the air / ground sense is in the ground mode and this lower voltage must be taken into account when monitoring the ammeter.

6.6.9 INSPECTIONS & SERVICING

Apart from frequency inspections of the overshoes for damage very little inspection is required on this type of ice protection system. The brush gear must be checked at frequency intervals and the brushes should be replaced when their length is below the minimum specified by the manufacturer. The brushes are fragile and should be handled carefully. They should be free to slide in their holder. Brushes wear more quickly in wet and dusty conditions so more frequent monitoring is required where these climatic conditions exist. The slip rings should be clean and free from carbon build up. They can be cleaned using white spirit and dried using lint free cloth. When new brushes are fitted a contact check should be carried out to ensure an 80% minimum area is touching the slip ring. Some brush box assemblies are balanced so care must be taken to ensure that the assembly's parts are kept together. On replacement of the brush gear the engine should be run to bed in the brushes, after which a de-icing system test should be carried out.

6.6.10 OVERSHOE INSPECTIONS

The overshoes are prone to suffer damage due to their position on the leading edges of the blades. The following inspections should be carried out frequently to detect any damage and rectify it before more serious damage occurs.

- Check for adhesion failures particularly at the tips and edges.
- Look for blisters in the rubber.
- Look for erosion of the rubber that expose the protective gauze or heater element.
- Ensure the rubber has not turned spongy by being allowed to come into contact with solvents.
- If a lightning strike is suspected look carefully for burnt out heater elements.

EXAMS

1. Thrust and camber faces of a propeller should be blended out to

a) 5 times the depth of damage

b)10 times to the depth of damage

c) 30 times to the depth of damage

Answer:c

2. Leading edges should be blended out to

a) 5 times the depth of damage

b)10 times the depth of damage

c) 30 times the depth of damage

Answer:b

3. The shank of the propeller is permitted to have

a) minor repairs

b)no repairs

c) no decals fitted

Answer:b

4. Wooden propellers are permitted

a) no repairs

b)repairs using sawdust and aeroglue

c) repairs that do not affect weight and balance

Answer:b

5. Composite propellers may have minor repairs carried outby

a) the operator

b)any approved 3rd party maintenance organization

c) any approved composite repair facility

Answer:c

6. Details of propeller overhaul may be found in

a) Airworthiness Notice 75

b)the AMM

c) Airworthiness Notice 55

Answer:a

7. The tip clearance of a single engine tail wheel aircraft is measured

with the aircraft

a) tail wheel on the ground

b)tail wheel in the take off position

c) in the rigging position

Answer:b

8. The tip clearance of a multi engine aircraft

a) is taken between the engines with the props aligned.

b)is taken between the prop and the fuselage

c) is taken from the ground

Answer:b

9. The tip clearance of a sea plane is

a) 9 inches

b)1 inch

c) 18 inches

Answer:c

10. Cropping is permitted to a maximum of

a) ½ inch on one blade only

b)½ inch on all blades

c) 1 inch on all blades

Answer:c

Exam-2

1. Dynamic balance is confirmed by use of

a) knife edges and mandrel

b)a tracking check

c) a vibration analyser

Answer:c

2. Synchrophasing reduces vibration by the use of

a) pulse probes and a single synchrophase unit

b)tachometers and correction motors

c) coordinating the rpm of each engine

Answer:a

3. A metal propeller may be statically balanced by

a) removing metal from the opposite blade

b)adding varnish to the lighter blade

c) adding or removing lead wool to the hollow blade roots

Answer:c

4. When in the windmill position ATM

a) assists CTM

b)opposes CTM

c) is not related to CTM

Answer:a

5. A hydraulic pitch lock is utilised in a hydromatic propeller to

a) lock out the course pitch oil line in the event of underspeeding

b)prevent the propeller overspeeding in the event of oil supply failure

c) lock out the fine pitch oil line in the event of overspeeding

Answer:c

6. Electronic torque measuring systems utilise

a) stress gauges in the reduction gear

b)pressure transducers in the reduction gear

c) strain gauges in the reduction gear

Answer:c

7. A conventional turboprop torque meter uses

a) engine oil as the pressure medium

b)hydraulic oil as the pressure medium

c) coiled spring levers as the pressure medium

Answer:a

8. When in the beta range the propeller pitch is controlled

a) directly from the pitch change mechanism to the PCU

b)indirectly from the power lever

c) directly from the power lever

Answer:c

9. The advantage of the beta range is it allows

a) low fine pitch settings with high power

b)low power settings with higher than normal pitch setting for ground

manoeuvres

c) high power settings with higher than normal pitch settings when in

flight

Answer:b

10. Electrically de-iced propeller slip rings have regular resistance

checks for

a) open circuit heating elements

b)wear between brushes and slip ring

c) oxidisation due to altitude

Answer:a

This is exam number 3.

1. The optimum angle for a fixed pitch propeller is

a) 2 - 4 degrees

b)6 - 10 degrees

c) 15 degrees

Answer:a

2. A left handed propeller is one that

a) rotates clockwise when viewed from the front

b)rotates clockwise when viewed from the rear

c) is fitted to an engine on the left side of the aircraft

Answer:a

3. If the speeder spring pressure of a CSU is increased the blade will

a) fine off

b)coarsen off

c) will not move

Answer:a

4. Mechanical vibration relating to propellers in a piston powered

aircraft

a) is due to the lead lag of the propeller compared to the engine b)is due to the power stroke of the engine and may have a more detrimental effect than aerodynamic vibration

c) is due to the crankshaft at intermittent power settings

Answer:b

5. Prop anti-icing may be achieved by

a) a using hot air from the compressor

b)using commercial de-icing fluid sprayed on the pro

c) using iso-propyl alcohol de-icing fluid sprayed on the blade

Answer:c

6. De-icing of the propeller can be monitored by

a) viewing the blade and observing ice falling off the blade

b)an ammeter in the flight deck

c) viewing the deicing fluid level sight glass

Answer:b

7. Metal at the tip and along the leading edge of a wooden propeller is

a) for protection

b)for Anti-icing

c) for balancing

Answer:a

8. Insulation testing of electrical de-icing systems should be periodically carried out because of

a) oxidation due to atmospheric conditions

b)wear on the slip rings

c) an open circuit in one of the blades

Answer:c

9. Synchronising can only be achieved if the slave propeller is

a) a within 20 rpm of the master

b)within 100 rpm of the master

c) the same speed as the master

Answer:b

10. Synchronising is carried out to

a) match engine rpm

b)match prop tip speed

c) match blade phase angle difference

Answer:a

This is exam number 4.

1. Forces acting on a propeller are

a) centrifugal, twisting, and bending

b)torsion, tension and thrust

c) torque Thrust and Centrifugal

Answer:a

2. Aerodynamic Correction Factor (ACF)

a) is indicated in the form of degrees and minutes of pitch

b)corrects for dynamic balance

c) corrects for static balance

Answer:a

3. The blade angle at the root is

a) greater than the tip

b)less than the tip

c) same from tip to root

Answer:a

4. A propeller with an adjustable blade can be adjusted

a) in flight

b)on the ground with the engine running

c) on the ground with the engine stationary

Answer:c

5. What force on a propeller blade turns the blades to a fine pitch?

a) Torque

b)ATM

c) CTM

Answer:c

6. When on the ground with the engine idling the prop control should be

a) fully forward with the mixture at idle

b)fully aft with the mixture at idle

c) fully aft with the mixture at rich

Answer:c

7. Operation with the engine at maximum boost should be limited to

a) prop at fine to prevent overstressing the engine

b)prop at course to prevent overstressing the engine

c) prop at windmill to prevent overstressing the engine

Answer:b

8. On an underspeed condition the blades are turned to

a) feather

b)coarse

c) fine

Answer:c

9. The synchronisation governor monitors

a) prop tip speeds

b)thrust tip speeds

c) RPM

Answer:c

10. The purpose of prop twist is

a) to maintain Angle of Attack at the same value along the blade.

b)to maintain Blade Angle along the blade

c) coarsen the blade angle at the root

Answer:a

This is exam number 5.

1. Synchronisation is used to

a) preset the phase angle of propellers

b)reduce vibration and noise

c) reduce the pitch of the fastest running blade

Answer:b

2. In a hydromatic propeller with counterweights what is used to make

the propeller move to fine pitch

a) ATM

b)centrifugal force acting on the counterweight

c) engine oil

Answer:c

3. The forces acting on a propeller blade are

a) thrust and torque

b)bending twisting and centrifugal

c) thrust aerodynamic and tension

Answer:b

4. Damage to a leading edge can be blended in comparison to a blade

face

a) by maintaining a smooth depression

b)by not exceeding 25% of the chord

c) at a steeper angle

Answer:c

5. The longitudinal clearance between the nose wheel and the propeller on

a tricycle geared propeller is

a) 18 inches

b) 9 inches

c) 1/2 inch

Answer:c

6. Relaxing tension on the governor spring will result in the blade

coarsening and

a) RPM increasing manifold pressure increasing

b)manifold pressure constant, RPM decreasing

c) RPM decreasing , manifold pressure increasing

Answer:c

7. A tracking check compares

a) 2 Opposite blades

b) 2 Adjacent blades

c) any 2 blades

Answer:c

8. Blade cuffs are fitted to the root of the blades

a) to increase thrust

b)to increase the strength of the blade

c) to increase flow of cooling air into the engine nacelle.

Answer:c

9. The ground fine pitch stop is

a) removed on the ground

b)never removed

c) removed during flight

Answer:a

10. Low torque sensing is used to

a) increase power

b)increase pitch

c) initiate auto-feather

Answer:c

This is exam number 6.

1. A line of indentations at one blade section can be

a) declared unserviceable

b)left for up to 12 months

c) blended within limits

Answer:a

2. On an electrical de-icing system fast cycle is used

a) at Low Air Temperature

b)at High Air Temperature

c) on the Ground

Answer:b

3. Blade angle at the root is

a) low

b)high

c) master blade angle

Answer:b

4. If governor fly wheel overcomes the speeder spring, it indicates

a) overspeed

b)underspeed

c) onspeed

Answer:a

5. Blade angle is taken from the chord and

a) relative airflow

b)propeller shaft

c) plane of rotation

Answer:c

6. Synchronisation is used

a) in flight

b)in flight except landing and take off

c) on the ground

Answer:b

7. Pitch control using torque measuring is for

a) increasing drag

b)reducing drag in engine failure

c) reducing drag in binding

Answer:b

8. If force is applied to the speeder spring, what will happen?

a) Blade angle coarsen

b)Blade angle finer

c) Blade angle is frozen in last known position

Answer:b

9. Propeller vibration due to a problem with propeller installations

would have a vibrating frequency of

a) higher frequency than turbine vibration

b)the same frequency as turbine vibration

c) lower frequency than turbine vibration

Answer:c

10. Insulation checks on propeller electrical heating elements should be

carried out frequently due to

a) short/open circuits in the heating system wires along the propeller

blade

b)oxidation of slip ring and brush gear assembly

c) deposits formed due to the wear of slip ring and brush gear

assembly

Answer:c

This is exam number 7.

1. Preloading propeller blades before installation prevents

a) blade flutter

b)aerodynamic imbalance on the blades

c) blade distortion

Answer:a

2. When is superfine pitch used?

a) In cruise

b)Landing and takeoff

c) Engine starting to reduce propeller torque loading on starter

motor

Answer:c

3. When unfeathering a propeller, the blade should be put into what

position to stop propeller overspeed?

a) Coarse pitch

b)Fine pitch

c) Negative pitch

Answer:a

4. Blade angle is measured using a

a) bevel protractor

b)propeller protractor

c) clinometer

Answer:b

5. What forces act on a propeller blade?

a) Thrust and torque

b)Bending, centrifugal CTM and ATM

c) Bending, thrust, torque

Answer:b

6. When the fly weights fly outwards in a PCU, this is known as

a) on speed

b)under speed

c) overspeed

Answer:c

7. In an ‘on speed’ condition, oil in the tube

a) flows out of the tubes

b)flows in the tubes

c) remains constant

Answer:c

8. Where is the de-icing boot?

a) Root

b)Tip

c) Trailing edge

Answer:a

9. On a reversing prop moving to the max reversing angle, the prop goes

a) from fine pitch through plane of rotation, fine reverse then course

reverse

b)from fine pitch through plane of rotation, course reverse then fine

reverse

c) from course pitch through plane of rotation course,fine reverse

then course reverse

Answer:a

10. In the Beta range,angle of attack increases. The fuel flow

increases, and what else?

a) RPM and EGT

b)EPR and fuel temperature

c) Fuel temp

Answer:a

This is exam number 8.

1. CTM will

a) turn the blade about the lateral axis

b)try to bend the blade away from the engine

c) cause the tips to rotate at supersonic speeds

Answer:a

2. With a propeller defect, will the frequency be

a) higher than a turbine defect

b)higher than a auxiliary gearbox defect

c) lower than a turbine defect

Answer:c

3. Torque sensing is used to

a) reduce drag

b)reduce drag following engine shutdown

c) synchronise blade angles

Answer:b

4. If pressure is increased on the speeder spring, rpm increases. What

happens to the blade angle?

a) Increases

b)Decreases

c) Remains unchanged

Answer:b

5. From reverse pitch, to return to normal pitch it

a) passes through fine

b)passes through coarse

c) passes through coarse then fine

Answer:a

6. In a prop with counterweights, what is used to make it move to fine

pitch?

a) ATM

b)Centrifugal force acting on the counterweight

c) Governor oil pressure

Answer:c

7. If a propeller is in fine pitch and then moves to feather it will

pass through

a) reverse

b)flight fine only

c) coarse

Answer:c

8. When in reverse pitch, CTM will tend to move the propeller blades

towards

a) a negative pitch

b)a positive pitch

c) a position depending on rpm

Answer:b

9. If the blade angle is increased

a) the pitch becomes finer

b)the pitch becomes coarser

c) lateral stability decreases

Answer:b

10. A “double” acting propeller has

a) oil pressure on one side of piston

b)oil pressure on two sides of piston

c) nitrogen or air on one side of piston

Answer:b

This is exam number 9.

1. During normal propeller operation, oil pressure for the governor is

provided by

a) the engine driven pump

b)a variable volume pump

c) a pump in the governor

Answer:c

2. Oil for an ‘on-speed’ condition passes through

a) the coarse pitch line

b)the fine pitch line

c) neither of the lines

Answer:c

3. If the spur gear pump in a single acting propeller governor failed,

the

a) blades would turn to a coarse pitch

b)blades would rotate to a fine pitch

c) blades would move to the feather position

Answer:a

4. The hydromatic variable pitch propeller is operated on the principle

of

a) oil pressure moving a piston

b)an electrical motor moving a gear segment

c) a venturi or “u” tube with mercury

Answer:a

5. Blending of propeller blade defects refers to the

a) repainting of blade tips after cropping

b)matching of paint finishes for appearances

c) conversion of rough or sharp edges into smooth depres-sions

Answer:c

6. Removal of material from the propeller blade tips, resulting in a

reduction in propeller diameter is called

a) tipping

b)topping

c) cropping Answer:c

7. The minimum percentage seating on a propeller rear cone should be

a) 95%

b)90%

c) 70%

Answer:c

8. As a propeller blade moves through the air, forces are produced,

which are known as

a) lift and drag

b)lift and torque

c) thrust and torque

Answer:c

9. A rotating propeller imparts rearwards motion to a

a) small mass of air at high velocity

b)large mass of air at low velocity

c) small mass of air at low velocity

Answer:b

10. Propeller efficiency

a) the ratio of the useful work done by the propeller to work done by

the engine on the propeller

b)the ratio of the work applied to the geometric pitch to useful work on

the C.S.U.

c) ratio of output speed to input propeller speed

Answer:a

This is exam number 10. You've been here 1 times.

1. Geometric Pitch is the distance moved

a) in one revolution without slip

b)in one revolution when slip is maximum

c) in one revolution

Answer:a

2. As propeller rotation speed increases the centrifugal turning moment

on the blades will

a) remain constant through r.p.m. range

b)increase

c) decrease.

Answer:b

3. Propeller torque is the resistance offered by the propeller to

a) changing pitch

b)rotation

c) feathering

Answer:b

4. The angle between the resultant airflow direction and the propeller

blade plane of rotation is known as

a) angle of attack

b)helix angle or angle of advance

c) blade angle

Answer:b

5. Which type of turbo-propeller engine is practically free from surge

and requires low power for starting

a) directly coupled

b)one using a centrifugal compressor.

c) twin spool free turbine

Answer:c

6. The propeller is “feathered” when the blades are at

a) 90o to plane of rotation.

b)0o to plane of rotation

c) 20o to plane of rotation

Answer:a

7. The constant speed unit (C.S.U.) governor works on the principle of

a) manual selection through a gearbox.

b)centrifugal twisting moments.

c) spring pressure acting against centrifugal force.

Answer:c

8. At constant rpm, advance per revolution depends on

a) the angle of advance.

b)forward speed.

c) SHP

Answer:b

9. Aerodynamic Twisting Moment

a) turns the blades to high pitch

b)turns the blade to low pitch.

c) turns the blade to windmill

Answer:a

10. The thrust of a propeller is normally taken by the

a) propeller rear cone.

b)torque meter.

c) front bearing in the reduction gear

Answer:c

This is exam number 11.

1. Under normal operation the point of maximum stress on a propeller

blade is at the

a) root

b)tip

c) master station

Answer:a

2. On which type of turbo-propeller would you expect to find a parking

brake

a) compounded twin spool

b)free turbine

c) direct coupled twin spool

Answer:b

3. Propeller blade angle

a) increases from root to tip

b)decreases from root to tip

c) is constant along the blade length

Answer:b

4. The purpose of the pitch change cams is to

a) convert linear motion to rotary motion.

b)convert rotary motion to linear motion.

c) prevent windmilling

Answer:b

5. What does the torque meter reading indicate in a gas turbine engine?

a) Torque reaction at the reduction gear

b)Engine torque

c) The ratio between engine thrust and engine torque

Answer:a

6. The gear type pump in a C.S.U. or P.C.U

a) lubricates the entire propeller system

b)boosts engine oil system pressure

c) assist the governor valve to move

Answer:a

7. The gear segments on the blade roots of a hydromatic propeller mesh

with the

a) stationary cam

b)torque tubes and eye bolts

c) moving cam

Answer:b

8. Coarse pitch is used for

a) take off and climb

b)maximum economical cruise in level flight

c) landing and power checks

Answer:c

9. A propeller is centralised on the propeller shaft by

a) the front git seal

b)the rear pre-load shims

c) the front and rear cones

Answer:b

10. Reduction gearing allows the

a) blade tips to operate above the speed of sound

b)blade tips to rotate slower than the root of the propeller blade

c) blade tips to operate below the speed of sound

Answer:c

This is exam number 12.

1. Effective pitch is

a) geometric pitch plus slip

b)distance moved in one revolution

c) pitch measured at the master station

2. Prior to using the universal propeller protractor

a) check date stamp for serviceability

b)determine the reference blade station

c) ensure the propeller blade is at the horizontal

3. A windmilling Propeller has

a) a small positive blade angle

b)a small positive angle of attack

c) a small negative angle of attack

4. To fit a new front cone to a prop shaft firstly

a) coat in Engineers blue to ensure seating in the propeller front boss

b)etch the propeller serial number to the rear face

c) cut in half with a hacksaw and etch a unique serial number to both

halves

5. When fitting a propeller to a tapered shaft

a) locate the master spline

b)ensure fully seated

c) ensure the master spline and blade alignment are in accordance with

the MM

6. Blade tracking is adjusted by

a) reseating the propeller on the front and rear cones

b)adding lead wool tothe blade shank

c) by fitting shims to the propeller shaft hub

7. What are the purpose of small holes at the tip of wooden propellers?

a) Balancing

b)Pivot points used during manufacture

c) Drainage

8. The thrust face of a propeller blade is the

a) rear face or flat side

b)front face or curved side

c) root to which the gear segment is fitted

9. How is anti icing fluid fed to the individual blades?

a) Pump to each blade rubber feed boot

b)Pump to a slinger ring

c) Under gravity to the slinger ring then on to the blade

10. Ice is removed from blades by

a) inboard and outboard boot sections heated in sequence by action of

the timer

b)a continuously heated electrical boot

c) rubber boots inflated in sequence using compressor hot air