PART 1 : SECTION 2

CHAPTER 6

PROPELLERS

Introduction

1. This chapter is concerned with the mechanism and handling of the propellers fitted to piston engines. There are two principal types of propellers, fixed pitch and variable pitch ; the fixed pitch type, which has no working parts, is used only on low-powered engines. The pitch setting cannot therefore be changed and is at the angle calculated to obtain the best all-round performance from the particular type of aircraft.

2. Variable pitch propellers are used in conjunction with an engine-driven constant speed unit (C.S.U.) and are known, more correctly, as constant speed propellers. The pitch is automatically adjusted to variations of power and speed, thus allowing the propeller to operate more efficiently at any selected combination of r.p.m., boost, and airspeed.

3. Constant speed propellers may be electrically or hydraulically operated and may be of the feathering or non-feathering type ; included in these variations are counter-rotating and braking types.

Constant Speed Unit

4. Fig. 1 shows a typical C.S.U. The rotating, engine-driven, governor weights can be set by the propeller control lever to secure a desired r.p.m. Any variation in the engine speed causes a change in the speed and equilibrium position of the governor weights ; movement of the weights then adjusts the position of a valve which, with hydraulically-operated propellers, controls the flow of oil to and from the pitch-changing mechanism which in turn increases (coarsens) or decreases (fines) the pitch until equilibrium is restored. A study of the three examples of Fig. 1 will show the function of the C.S.U.

5. Each setting of the r.p.m. control lever will maintain a definite engine speed during flight. Similarly, on engines fitted with automatic boost control, each setting of the throttle will, within limits, maintain a definite boost pressure. Operation of these two controls will provide the required combination of boost and r.p.m. and the constant speed unit will enable the selected r.p.m. to be maintained under all normal flight conditions without further adjustment by the pilot.

6. The C.S.U. governs over a certain range of r.p.m. The upper limit is the fine pitch setting for the maximum r.p.m. permitted for the engine, and the lower limit should give a sufficiently coarse pitch to ensure that overspeeding does not occur at the maximum diving speed.

Constant Speed Propellers

7. All types of constant speed propellers operate on the same principle, although constructional details may vary. In early types, the pitch is coarsened by the action of centrifugal force on weights mounted on the blade roots, while finer pitches are obtained by oil pressure working on a single-acting piston in opposition to the coarsening tendency of the weights. Later propellers dispense with the weights and employ double-acting pistons, one to decrease and one to increase the pitch. On electrically-operated propellers, the C.S.U. makes and breaks to operate an electric motor which changes the pitch.

8. On some engine installations the r.p.m. control lever and boost control are interconnected. With the r.p.m. control lever at AUTO, the r.p.m. appropriate to the selected boost is selected automatically by the setting of the throttle lever.

Feathering Propellers

9. Feathering is the procedure by which the propeller blades can be turned until, with the blade chord-lines almost parallel to the airflow, there are no rotating forces acting on the propeller as a whole. This action stops the engine and reduces the drag of the stationary propeller to a minimum. The constant-speed range of these propellers is the same as that of non-feathering types but the angular movement of the blades is increased to permit feathering.

10. On hydraulic propellers, feathering is carried out by an electrically-driven high-pressure oil pump. This pump is independent of the engine and can be used whether the engine is running

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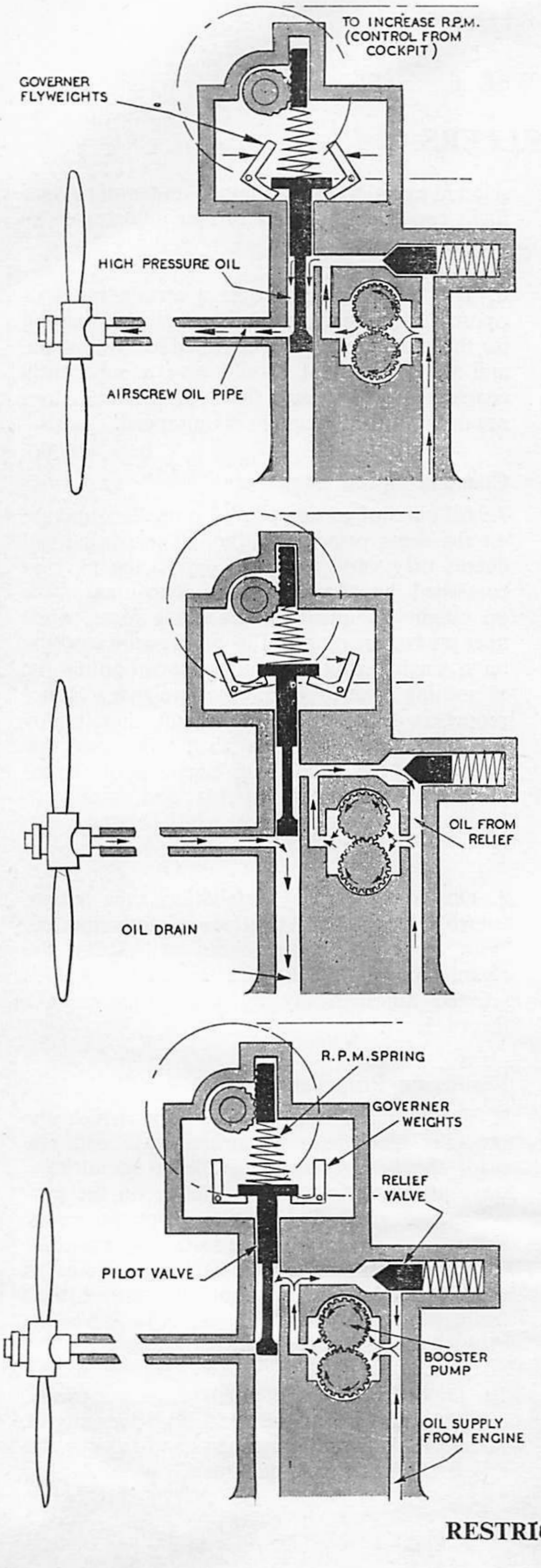
Fig. 1.
Principle of a Simple Constant Speed Unit.



(*a*) Underspeeding.
High-pressure oil enters airscrew cylinder to decrease pitch.

(*b*) Overspeeding.
Oil drains from airscrew cylinder to increase pitch.

(*c*) Constant r.p.m.
Pilot valve closes airscrew oil duct to maintain pitch.

or not. The pump is operated by pressing a push button in the cockpit. On electrically-operated propellers the feathering motor is actuated by a feathering switch.

Feathering

11. All feathering mechanisms obtain their motive power for feathering from the electrical services of the aircraft. The propeller blades are moved through a large angle at a much greater rate than in normal constant-speed operation. The process of feathering and unfeathering imposes a severe drain on aircraft batteries unless the generators are charging satisfactorily.

12. The feathering drill is :—

(*a*) Close the throttle of the engine concerned.

(*b*) Operate the appropriate feathering mechanism as indicated in Pilots' Notes for the type.

(*c*) Turn off the fuel supply to that engine and switch off the booster pump concerned.

(*d*) If engine failure is accompanied by fire, operate the correct fire extinguisher only when the propeller has stopped rotating.

(*e*) Switch off the ignition of the dead engine.

13. This feathering drill is standard for all types of piston engine propellers, but the feathering operation (see para. 12(*b*)) will vary according to the type of propeller fitted to the aircraft. The most important differences are :—

(*a*) With some types the propeller is feathered by operating the push button only, while with others it is necessary to move the r.p.m. control lever through a feathering gate to the feathering position before the push button is pressed.

(*b*) Some push buttons must be held in manually during the feathering operation ; others are solenoid operated and, after pressure is released, they will remain in until feathering is completed. The pilot should always ensure that the push button springs out when feathering is complete ; if it does not, it must be pulled out by hand.

(*c*) Electric propellers feather at a slower rate than hydraulic propellers when the switch is moved to the feathering position. When the blades reach the feathered position, the current to the propeller motor is automatically switched off.

14. The above differences should be sufficient to emphasize the necessity of knowing the correct operation given in Pilots' Notes. Feathering is an emergency action and, as such, should be practised until it is instinctive and automatic.

Unfeathering

15. Apart from practice and test feathering, a propeller is feathered after engine failure or as a safeguard when low oil pressure or excessive temperatures have indicated the development of a possible defect. In these circumstances an engine should not normally be restarted. When unfeathering for practice or if, having regard to the reasons for which the propeller was feathered, the pilot considers that the circumstances nevertheless justify restarting the dead engine, this should be done at a safe speed and/or height. Otherwise difficulty may be experienced owing to the increased critical speed resulting from the additional drag of the windmilling propeller while under conditions of asymmetric power.

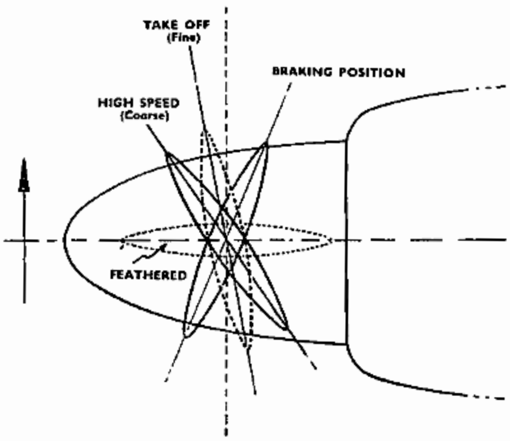


Fig. 2.

Typical Blade Settings, Showing the Large Range of Pitch Movement Required for High-Performance Engines.

Unfeathering in Flight

16. The unfeathering drill in flight is as follows:—

(*a*) Set the throttle fully closed, unless any other position is recommended in Pilots' Notes for the type. When the closed position is specified, the throttle must not be opened until the windmilling r.p.m. have reached their peak, since a fire may result from a blow-back through the carburettor.

(*b*) Set the r.p.m. control lever just forward of the minimum r.p.m. position, or just out of the feathering gate.

(*c*) Switch on the ignition.

(*d*) Operate the feathering push button or switch, as directed in Pilots' Notes for the type. When the correct r.p.m. have been reached, the pilot should check that the feathering push button is fully out ; it must be pulled out by hand if it has not come out automatically.

(*e*) Turn on the fuel supply and switch on the appropriate booster pump, if fitted.

(*f*) Warm up the engine (see para. 21) and then return to normal constant-speed conditions.

Unfeathering on the Ground

17. The procedure outlined below is preferred by both the propeller and engine manufacturers when unfeathering after a practice feathered landing :—

(*a*) The stopped engine should be restarted with its propeller still in the feathered position. This avoids discharging oil from the unfeathering propeller into the engine sump while the scavenge pump is not working.

(*b*) The controls should be set and the engine started in the normal manner. When the engine is running steadily, and if the propeller has not started to unfeather, the feathering push button should be pressed in. When the propeller has moved from its feathered position, the push button should be released, if applicable.

18. In many cases the propeller will start to unfeather without the push button being pressed, but when this occurs on some installations pressing the push button will first cause the propeller to refeather before it finally unfeathers.

19. If difficulty is found in starting certain engines owing to the high drag of the fully feathered propeller, it may be partially unfeathered first. This should not be done if there is any evidence (such as loss of oil through the breathers after starting) that flooding of the crank case results. With radial engines there is a danger of hydraulic locking when starting in this manner and these engines should be started as soon as the propeller has been partially unfeathered. If for any reason an immediate attempt to start cannot be made, or if an attempt is made and the engine fails to turn over through at least one complete revolution of the propeller when the starter is operated, no further attempt to start should be made until a check for hydraulic locking, by hand turning, has been carried out.

20. Engines must never be run at more than 1,000 r.p.m. with their propellers feathered. During both restarting and unfeathering the throttle of the live engine driving the generator should be set to give more than 1,500 r.p.m., thus ensuring that the batteries are being supported while bearing the starting and unfeathering loads.

Warming Up in Flight After Unfeathering

21. Engines may be warmed up in flight at as much as 2,000 r.p.m. at small throttle openings, provided that the oil inlet temperature has not fallen below +5°C.

Practice and Test Feathering

22. Feathering should not be practised or tested if the air temperature is below −15°C. Most aircraft are limited to twelve complete feathering and unfeathering operations during the course of a single flight, owing to the drain on the aircraft batteries. On some American aircraft, however, the limit is considerably less than twelve operations ; therefore reference should be made to Pilots' Notes for individual aircraft to ascertain the limiting figure. The electrical load can be reduced by exercising the constant speed unit to ensure an adequate circulation of warm oil before feathering.

23. On twin-engined aircraft equipped with a single generator it is important to minimize the number of feathering and unfeathering operations on the engine with the generator, and to ensure that the propeller of this engine remains feathered for short periods only. On all aircraft it is advisable to switch off non-essential services to reduce the load on the batteries as far as possible.

24. On a four-engined aircraft, if two propellers are in the feathered position the propeller of the engine which drives a generator should be unfeathered first so that the generator can supply current for the second unfeathering. A pause of some minutes between opening up the first engine and unfeathering the second propeller will allow the battery to be partly recharged.

25. The oil inlet temperature on a dead engine should be watched to ensure that it does not drop excessively before unfeathering.

26. Feathering checks on the ground should be done using an external battery as the electrical power source.

Counter-Rotating Propellers

27. The counter-rotating propeller enables the output of high-powered engines to be more efficiently transformed into useful thrust; this is effected by having two separate propellers mounted in line on two shafts, one inside the other, which run in opposite directions. The two propellers therefore rotate in opposite directions, so cancelling the individual torque reaction and improving some of the handling characteristics of the aircraft; a further improvement is obtained because the slipstream is straighter than that behind a single propeller. The front propeller includes the pitch change mechanism and alterations of pitch are transmitted to the rear propeller by a translation unit.

28. The propeller has a normal constant-speed operation and is handled similarly to other single propellers. Operating instructions for a particular installation are given in Pilots' Notes for the type.

Braking Propellers

29. Braking propellers, in addition to their constant-speed and feathering actions also incorporate reversible pitch. The propeller pitch can be reversed quickly through zero pitch, so enabling the propeller to exert a braking effect. These propellers are used to produce reverse thrust after touch-down and as an aid to ground manœuvring and water handling. Full throttle can be applied when the angle of the blade is in reverse pitch, allowing maximum power to be available for braking purposes; the C.S.U. is inoperative when reverse pitch is engaged and the r.p.m. therefore vary with throttle movement.

Fine Pitch Latches

30. When an engine fails in flight, the C.S.U. automatically puts the pitch of the propeller to fully fine in an attempt to maintain the r.p.m. Viewed from head-on, the propeller blades are then presenting a large area to the airflow and so cause a high drag. If this occurs immediately after take-off while the speed is low, the asymmetric handling qualities of the aircraft are seriously impaired until the pilot is able to feather.

31. To reduce the windmilling drag following engine failure, certain propellers are fitted *with* a latch which restricts the normal fine pitch angle of the blades to an angle coarser than fully fine. To permit the propeller blades to override this latch, and so move to the fully fine pitch setting needed during the initial stages of the take-off, the mechanism can be temporarily unlatched by operating a switch. On releasing the switch the latch is automatically reset so that during take-off, once the blade pitch has automatically coarsened with increase of speed, subsequent engine failure will mean that the blades can fine off only as far as the fine pitch latch setting, thus minimizing the drag. When propellers are exercised during the pre-flight checks, they must be unlatched after finally returning the r.p.m. control lever to the maximum r.p.m. position; this must be done at about warm-up r.p.m. to ensure that the propellers will fine off past the stops before the switch is released.

Failure of Constant Speed Unit

32. If the C.S.U. fails, the pitch may lock at the setting which was being maintained at the time of failure. If failure occurs during a climb, the r.p.m. may be high, but should not be too high for continuous flight. The r.p.m. should be kept as low as possible by restricting the throttle openings and by flying at a suitably low airspeed.

33. **Failure in Level Flight.** If the failure occurs during cruising flight, the r.p.m. will usually be low and the pitch at a fairly coarse setting. These conditions will be suitable for level flight, but a baulked landing, or any manœuvre requiring the use of high power, should be avoided.

34. **Failure at High Speed.** If the propeller is one of large pitch range, 35° or more, and failure occurs at high speed, the pitch may be too coarse to maintain level flight on single-engined aircraft.

35. **Probable Causes of Failure.** Foreign matter in the C.S.U. is the most likely cause of failure. At the first sign of trouble, therefore, the immediate action should be to exercise the C.S.U. in an attempt to allow the circulating oil to move the foreign matter. Complete failure may be due to a fractured pipe and can lead to loss of oil pressure, and subsequently to complete loss of engine oil. In these circumstances the propeller should, when possible, be feathered immediately.

36. **Flying at Low Temperatures.** When flying in very cold conditions, frequent exercising of the C.S.U. may be necessary to prevent the oil in it congealing and so causing sluggish operation.

37. **Electric Propellers.** Electric propellers have an alternative control should the C.S.U. fail, since the pitch can be set to any position by holding the selector switch to "increase" or "decrease" r.p.m. and then returning it to "fixed".

Overspeeding

38. Overspeeding may be caused by complete loss of oil pressure or failure of the C.S.U. In either case the following actions should be carried out immediately to prevent serious damage to the engine :—

(*a*) Reduce the airspeed.

(*b*) Close the throttle.

(*c*) If the propeller cannot be restored to constant speed conditions, attempt to feather.

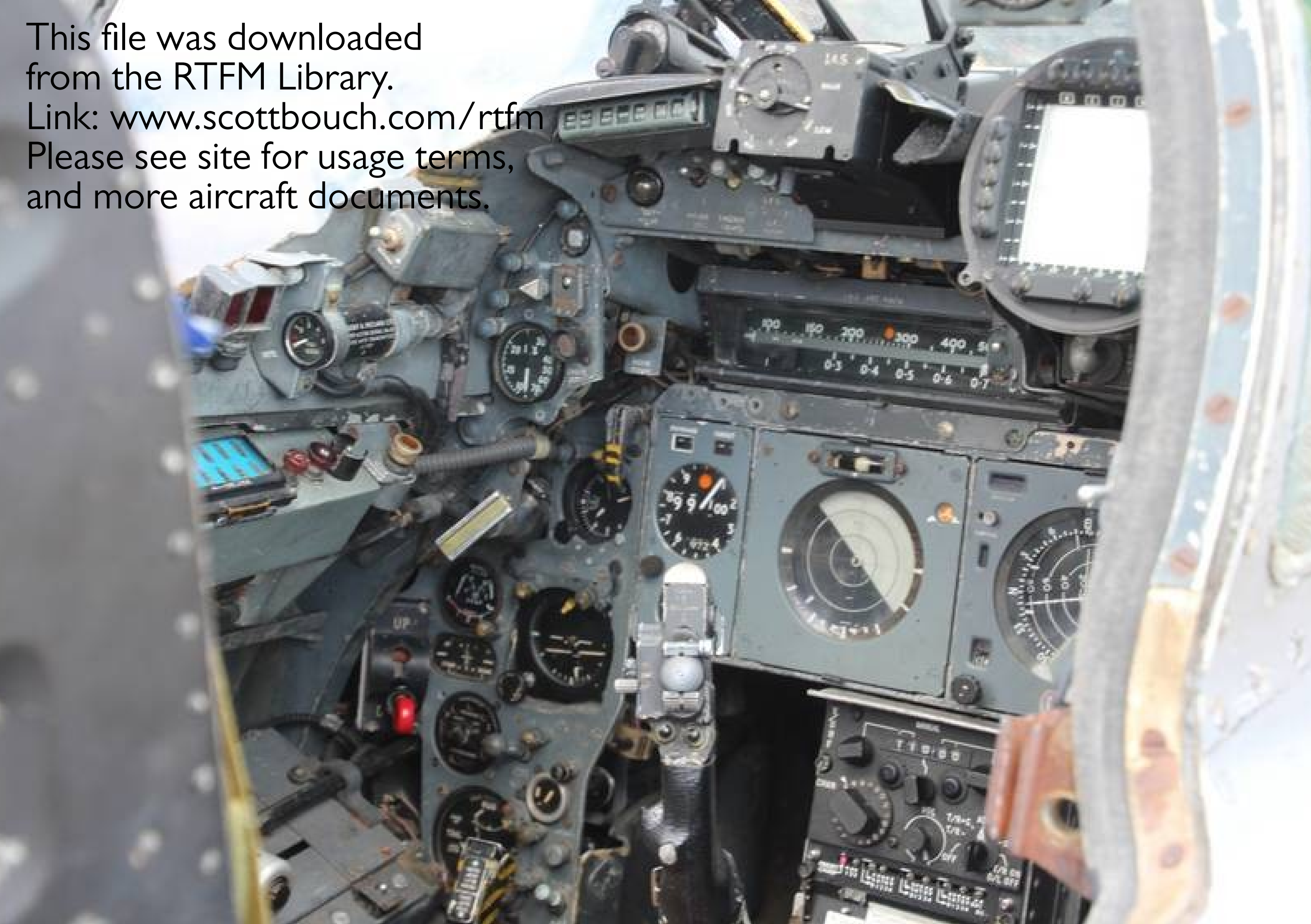
Failure to Feather

39. If the propeller fails to feather in response to the feathering drill, with electric and certain hydraulic types, an alternative method may be tried. This will cause the propeller to feather at a greatly reduced rate.

(*a*) With electric propeller, the switch should be held to the decrease r.p.m. position until the propeller stops.

(*b*) With hydraulic propellers on which the r.p.m. control lever has a feathering gate, the lever should be moved back through the gate.

40. It should be remembered that the drag from a windmilling propeller in fine pitch is much higher than when feathered. Flight on asymmetric power will be adversely affected and critical speeds will be higher.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