Part I

Chapter 5—Powered Flying Controls and Trimmers

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Description

1 General

(*a*) Dual controls are fitted for side-by-side seated pilots. Electro-hydraulic power units are provided to operate the ailerons, rudder and elevators. There is no manual reversion.

(*b*) Provision is made for a Mk. 10B electrically-operated auto-pilot.

2 Control columns

(*a*) The control columns are of the horizontal sliding type and are free both to rotate and slide. Each control column incorporates an elevator trim switch and an auto-pilot instinctive cut-out switch, on the inboard handgrip. The control columns operate push-pull rods to the powered flying controls units.

(*b*) (i) To prevent injury during ejection both control columns are disconnected from the elevator control and moved forward to

clear the pilots' knees. This is achieved automatically when the escape hatches are jettisoned when the ejection seat firing handle is pulled. If only one hatch is jettisoned its associated handwheel will be disconnected, but the other will remain effective until the second hatch is jettisoned.

(ii) Control column retraction is achieved by gases from a cartridge fired by the action of pulling the face screen handle. A safety-pin, for the firing unit sear, must be removed before flight.

(iii) If either escape hatch is jettisoned by means of the ditching handle, the associated control column does not slide forward.

3 Rudder pedals

(*a*) In addition to normal fore-and-aft pedal movement for rudder control each pair of rudder pedals is used for wheelbrakes application. Depressing the pedals by toe action actuates the brake cylinders, the amount of toe movement controlling the pressure and differential wheel braking.

(*b*) Rudder pedal adjustment is achieved by rotating the crank handle beneath each control column tube. During flight it is possible that the handle may rotate, thus altering the adjustment.

4 Power control units

(*a*) The power unit for the rudder, each elevator and each aileron consists of two self-contained sub-units. Each sub-unit comprises an electric motor driving an hydraulic pump, a reversible hydraulic motor, a self-contained hydraulic fluid supply and a valve gear. The hydraulic motors of both sub-units drive a single screw jack which transmits control column input to the associated control surface by means of skew levers.

(*b*) When the valve gear is moved by the control column in either direction hydraulic fluid is passed to the hydraulic motor to drive the screw jack, and thus the control surface. When control column movement ceases the screw jack continues to move until the valve is reset to the neutral position by means of a reset lever which interconnects the screw jack with the valve gear. When the valve reaches a neutral position, hydraulic flow is cut off and control surface movement ceases until the control column is again displaced.

(*c*) Two sub-units are incorporated in each power unit so that if failure of one sub-unit occurs control movement can still be achieved. With one sub-unit out of action the maximum rate at which the control can be operated remains the same but for a given rate the hinge moment against which the control surface can be moved is reduced.

(*d*) *Pressure-off brakes*

Each PFCU is fitted with a pressure-off brake designed to prevent the flying control surfaces from tramping under gusting wind loads when the aircraft is parked. Two brake shoes, spring-loaded to the " brake-on " position, apply a load to the output drive of the PFCU when the complete unit is switched off. As each sub-unit is switched on, its associated brake shoe is lifted from the output drive by hydraulic pressure. To gain complete freedom from brake effect both sub-units must be switched on and operating correctly. If sub-unit failure occurs the attendant brake-shoe will be applied.

5 " Q " feel units

(*a*) Since there is no feed back of control surface hinge moments to the pilots' controls, synthetic feel, which varies with airspeed and control displacement, is given in the controls signalling systems by " Q " feel units. Each unit is connected in parallel with its associated controls system and embodies a duplicated motor actuator for trim control.

(*b*) In "Q" feel units pitot and static pressures are fed to the inside and outside respectively of a bellows so that the difference in pressure, i.e. dynamic pressure, is measured. Movement of the pilot's control compresses the bellows by means of a toggle mechanism so that the forces transmitted to the pilot is approximately proportional to the dynamic pressure and the displacement of the control. Each feel unit contains in addition a double-acting centralising spring unit which in addition to giving a force proportional to control displacement also assists in returning the feel unit to neutral when the controls are centralised.

6 Roll damper system

(*a*) This is fitted to correct disturbances about the longitudinal axis by automatically applying aileron. A gyro senses any disturbance and via an amplification system signals two electric actuators in the aileron system. These actuators extend and retract in response to the signals and operate the PFCU reset levers to bring about the necessary aileron deflection.

(*b*) An altitude control is fitted which progressively increases the strength of the gyro signal with increasing altitude.

7 Yaw damper system

(*a*) This is fitted to correct disturbances about the normal axis by automatically applying rudder. Two yaw dampers are fitted, the normal and the standby and each functions in a similar manner. A gyro senses and signals any disturbance to an electric actuator in the rudder system. This actuator extends and retracts to operate the PFCU reset lever.

(*b*) An airspeed unit is fitted which progressively decreases the gyro signals with increasing airspeed.

8 Auto-mach trim system

(*a*) The purpose of the system is to counteract the nose-down trim change encountered at high mach number. This is achieved by introducing a servo jack into the elevator PFCU signalling system between the "Q" feel unit and the PFCU. The operation of the servo jack is controlled by the second pilot's machmeter, the output signals of which are amplified to operate a relay unit to supply power to the servo jack which moves in proportion to the output signal. The effective length of the particular portion of the signalling system is then altered.

(*b*) When switched ON, the servo begins to operate at approximately 0·80M. A further increase in mach number results in upward movement of the elevator without altering the stick position, the amount increasing with increase of mach number. At approximately 0·95M and above the servo jack is fully extended.

NOTE: A mach switch, set to operate at 0·79M, prevents inadvertent or runaway operation of the system at mach numbers below 0·79M.

(*c*) G cut-outs prevent servo movement if the normal acceleration of of the aircraft exceeds 1·8G or is less than 0·6G.

(*d*) AC supply is obtained from No. 4 200 volt 3-phase bus-bar and DC supply from No. 2 LV bus-bar.

Controls and Indicators

9 Power controls switches and indicators

(*a*) An individual ON—OFF control switch for each sub-unit, i.e. 10 in all, is on panel AZ in the pilots' cockpit. These control, via change-over contactors, the 200 volt AC supplies to the respective sub-unit motors.

(*b*) Ten lights below the switches (duplicated at the AEO's station) come on if their associated sub-units suffer hydraulic pressure failure.

(*c*) A further ten lights at the AEO's station provide overheat warnings of the return fluid in the sub-units. The indication implies that the affected sub-unit must be switched OFF.

10 Roll damper control

(*a*) The roll damper ON/STANDBY/OFF switch is on the pilots' panel AZ.

(*b*) When STANDBY is selected from OFF any aileron deflection which may have remained is automatically cancelled.

(*c*) The roll damper must never be selected to ON if the PFCU sub-units are not running.

(*d*) Power supplies are from No. 4, 200 volt bus-bar and No. 2 LV bus-bar.

11 Yaw damper controls

(*a*) Two ON/STANDBY/OFF switches are fitted for the yaw dampers, that for the normal damper being on panel AZ and for the standby damper on panel AC.

(*b*) Only one yaw damper should be ON in flight, the other being selected to STANDBY. Neither should be selected ON if the PFCU sub-units are not running.

(*c*) Power supplies to the normal yaw damper are from No. 4, 200 volt bus-bar and No. 2 LV bus-bar.

(*d*) Power supplies to the standby yaw damper are from No. 2 transformer and No. 1 LV bus-bar. Thus if a main generating failure occurs these supplies will be available from the port RAT and the standby damper will be operative.

12 Auto-mach trimmer control and indicator

(*a*) An ON/OFF/RESET switch is on panel AZ with an adjacent magnetic indicator.

(*b*) When RESET is applied the electric actuator retracts fully and thus removes any applied auto-mach trim.

(*c*) The indicator shows black (IN) with the actuator fully retracted, and white (OUT) with the actuator anywhere but fully retracted.

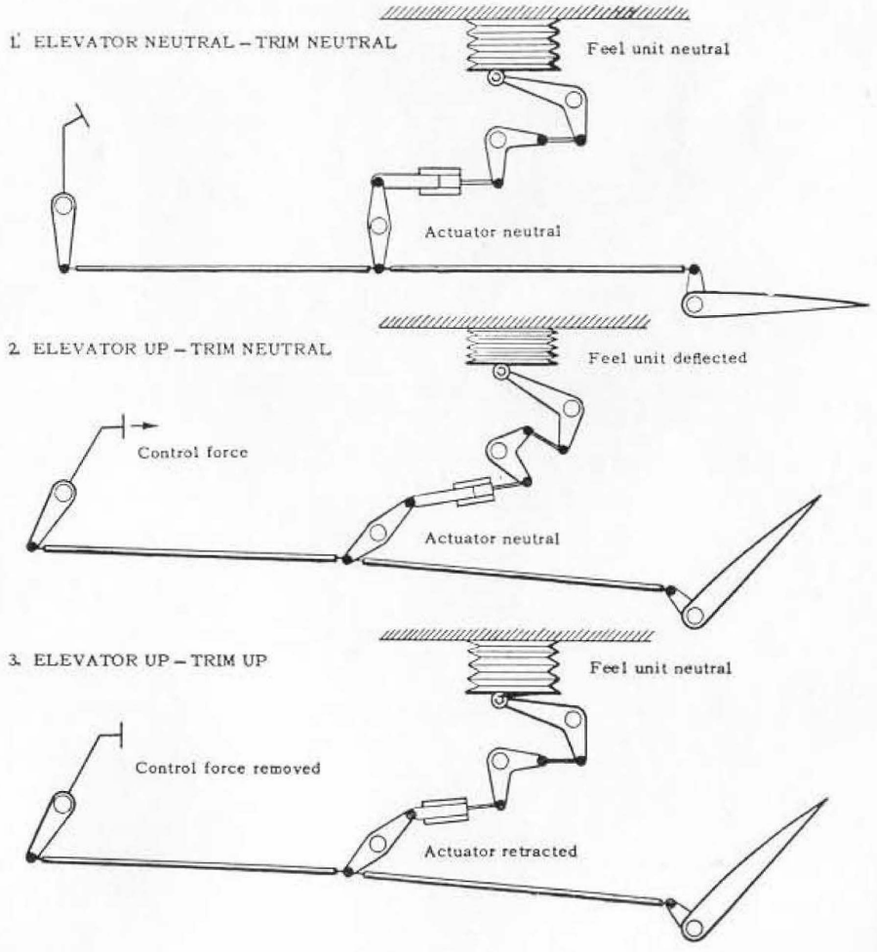

Fig. 1 Artificial feel and trim operation

13 Trimmer controls

A standard trim switch, for the ailerons elevators and rudder is located on each pilot's console, AE and AF: before either trim switch can be operated a central pushbutton must first be depressed.

An alternative trim switch for the elevators is situated on the inboard handgrip of each pilot's control column, beneath a protective guard. When either guard is lowered its associated trim switch circuit is " dead ". No trim tabs are fitted to the control surfaces; the trim system operates the main controls signalling systems through electric actuators and will trim the stick forces out while keeping the pilots' control columns stationary. Operation of the trim switch for any of the controls extends or retracts an actuator to rest the feel simulator. Each actuator is driven by one of two electric motors through a differential gear box. The 1st pilot's controls operate one motor and the 2nd pilot's controls operate the other. In the case of the elevator trim circuit, the 1st pilot's control column alternative switch operates the motor normally controlled by the 2nd pilot's console switch and *vice versa.*

Normal Management of the Powered Controls and Trimmers

14 Ground checks and starting

(*a*) *General*

The powered flying controls and the control trimmers must be checked before starting the engines. A 28 volt DC supply and a 200 volt 3-phase 400 cycles AC supply must be available, either from an external supply source or from the AAPP. Before starting any of the PFCU's check with the crew chief that all ground personnel are clear of the control surfaces.

(*b*) *Testing trimmer controls*

The trimming controls of both pilots must be tested in each direction and at least one set of controls must be tested over the full range of movement.

(i) *Console trim controls*

Without pressing the pushbutton, move the console trim control in each direction to check functioning of the cut-out. (If the trims move, the system is unserviceable). Then depress the button and move the trimmer control in each direction to check the correct movement of the aileron, rudder and elevator controls. Watch the trim indicators for smooth travel over the whole range of movement. At full travel the indicators will normally move beyond the extreme marks on the indicator face. The control column and rudder pedals will normally move some distance in the direction of applied trim. When elevator trim is applied, the elevator trim-load indicator on each pilot's instrument panel will move in the appropriate direction but its rate of movement is not directly proportional to the trim movement applied. Repeat the checks on the other pilot's console trimmer control and return the trims to neutral.

(ii) *Control column trim controls*

Operate the control column trimmer control switch through the hole in the flap and check that the elevator trim does not move. (If the trim moves, the system is unserviceable). Then raise the flap and operate the trimmer over its full range of movement in each direction. Repeat the checks on the other pilot's trim controls and return the trim to neutral.

(*c*) *Starting and testing* PFCU's

Check that all the red power failure warning lights on the pilot's coaming panel (AZ) and at the AEO's station are illuminated. Start the No. 1 set (odd) by selecting the number 1, 3, 5, 7 and 9 switches (coloured red) to ON (up). Check that the appropriate red warning lights on the pilot's coaming and the AEO's station go out. Switch the main roll and yaw dampers to STANDBY. Test the controls for free, smooth and correct movement over their full travel (by ground crew observation). Jerky control surface movements or vibration may indicate unserviceability. Switch OFF the No. 1 (odd) set of controls (check that the red warning lights come on) and repeat the checks for the No. 2 (even) set of controls switches numbered 2, 4, 6, 8 and 10 (coloured green). On completion of checks switch OFF all PFCU's until ready for take-off. Before take-off, switch on all PFCU's, check that all warning lights go out, and check the controls for freedom of movement over their full travel.

NOTE: Rapid control movement may cause flickering of the power failure warning lights. This should cease when control movement ceases.

15 Dampers and auto-mach trimmer

(*a*) *Dampers*

The roll and yaw dampers should never be switched ON unless the appropriate PFCU's are running. Before take-off, and after starting the PFCU's, select the control switches of the roll damper, and the normal and standby yaw dampers to STANDBY. After a short pause select the roll damper and the normal yaw damper switches to ON. There is no indicator to show that the units are operating.

NOTE: Only one yaw damper should be selected to ON. The other should be selected to STANDBY.

(*b*) *Auto-mach trimmer*

The auto-mach trim indicator should be IN and black when the aircraft is on the ground. If the indicator shows white (OUT), after starting the elevator PFCU's select the control switch to RESET and check that the indicator changes to black (IN). If it fails to do so, the aircraft must not be flown.

16 In-flight management of the powered controls

(*a*) If any component of the flying control system is found to be faulty before take-off, the aircraft must not be flown.

(*b*) (i) Throughout flight the red warning lights indicating power failure or overheating of the PFCU's should remain out.

(ii) The roll damper should be ON throughout flight. The main yaw damper should be selected on, and the standby yaw damper selected to STANDBY. Before engaging the auto-pilot select both yaw dampers to STANDBY.

(iii) Before reaching an altitude of 20,000 ft. or a speed of 0·79M, the auto-mach trimmer should be selected ON. As speed is increased above 0·80M + 0·01M the auto-mach trimmer should provide a progressive nose-up trim force. The indicator may not indicate white (OUT) until 0·82—0·84M is reached. The auto-mach trimmer must be selected OFF before engaging the auto-pilot.

(*c*) (i) Up to five PFCU's may be selected OFF during flight for training purposes only. It is recommended that only one PFCU to each control surface is switched OFF at any time.

(ii) The auto-mach trim may be switched off for training purposes but speed should not exceed 0·90M whilst it is selected to OFF.

Malfunctioning of the Powered Controls and Trimmers

17 "Q" feel unit failure

Feel failure warning is not incorporated since the system is mechanical and it is unlikely that failure will occur. If failure does occur the control forces will be light and all controls must be used with care to avoid over controlling. In the case of the ailerons, power units cannot apply enough deflection to cause over stressing as the hinge moments are too great. Over stressing could however result from over application of elevator or rudder at the higher speeds. The elevator must be moved slowly and cautiously with frequent reference to the accelerometer to avoid exceeding the G limitations. The rudder may be used as required in correcting a swing due to engine failure at low speed, or in a cross-wind landing, but must be moved slowly and cautiously at speeds over 200 knots.

18 Failure of a PFCU

If a power failure warning light for any PFCU illuminates during flight, its control switch should be selected to OFF. Selection to OFF will not cancel the warning.

19 Failure of 5 PFCU's

If the power failure warning lights of 5 PFCU's supplied from one synchronising bus-bar illuminate in flight, it is an indication of electrical failure of two alternators on one side. The RAT turbine alternator is not designed to cope with this type of failure and no PFCU selection will enable it to take over their supply. For restoration of electrical supplies see Part I, Chapter 1.

20 Overheating of a PFCU

If an overheat warning light illuminates during flight, switch OFF the affected PFCU. When the warning light goes out, wait approximately 5 minutes and re-select the PFCU to ON. If the warning light re-appears, switch OFF and leave OFF.

21 Failure of a control trimmer

If a control trimmer fails to respond to a trim selection, make no further selections of that control. Malfunction of individual switches or actuators still permits full trim travel using the alternative trim controller. If double failure of a control trim system (aileron, elevator or rudder) occurs leading to total loss of that system, it is still possible to fly the aircraft. However, in this case curtail the sortie because of the considerable pilot effort which may be required over a long period.

22 Damper failures

(*a*) Failure of the roll damper may be indicated by rolling oscillations, or by a wing low trim force. Switch OFF the roll damper and trim as necessary.

(*b*) Failure of a yaw damper may be indicated by yawing oscillations or by a yawing trim force. Switch OFF the yaw damper, trim as required and switch ON the standby yaw damper.

23 Auto-mach trim failure

The auto-mach trimmer may fail by sticking in one position of actuator extension, or by the actuator moving to its full travel of extension or retraction. The first failure will be indicated by a gradual change from a nose-up trim change to a nose-down trim change as speed is increased in the operative speed range. The second failure will be indicated by a sudden nose-up or nose-down trim change. Reduce speed to 0·90M or below, and if necessary retract the actuator in small increments by selecting the control switch to RESET in short "blips". If the mach trim indicator remains black (IN) when flying in the operative speed range, do not increase speed above 0·90M and switch off.