

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. 10 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) Post-Mod. 2789, if the aircraft is to be abandoned using the ejection seats, 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 as 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. Pre-Mod. 2789 the red handle on each pilot's console must be operated to retract the control column.

(ii) 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 wheelbraking.

(b) Rudder pedal adjustment is achieved by rotating the crank handle beneath each control column tube.

4 Powered flying control units (PFCU)

(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 inter-connects 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 (Mod. 828)

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 pressure is 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 force transmitted to the pilot is approximately proportioned 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 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.

7 Auto-mach trim system

(a) The purpose of the system is to counteract the nose-down trim changes 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 2nd 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 and above 20,000 feet, the servo begins to operate at approximately 0.85M. 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.

(c) G cut-outs prevent servo movement if the normal acceleration of the aircraft exceeds 1.8 G or is less than 0.6 G.

(d) AC supply is obtained from No. 2 Type 350 inverter and DC supply from No. 2 LV bus-bar.

Controls and Indicators

8 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.

(b) Ten lights below the switches come on if their associated sub-units suffer hydraulic pressure failure.

(c) On the AEO's panel BC are twenty magnetic indicators, two for each sub-unit. If overheating of the hydraulic fluid in a sub-unit occurs the appropriate indicator in the upper row will show white. Warning of hydraulic pressure failure will be given by the appropriate sub-unit indicator in the lower row showing white.

9 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 AE.

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

(c) Power supplies to the normal yaw damper are from No. 2 Type 350 inverter and No. 2 LV bus-bar.

(d) Power supplies, AC and DC, to the standby yaw damper are from the flight instrument supplies.

10 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.

11 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

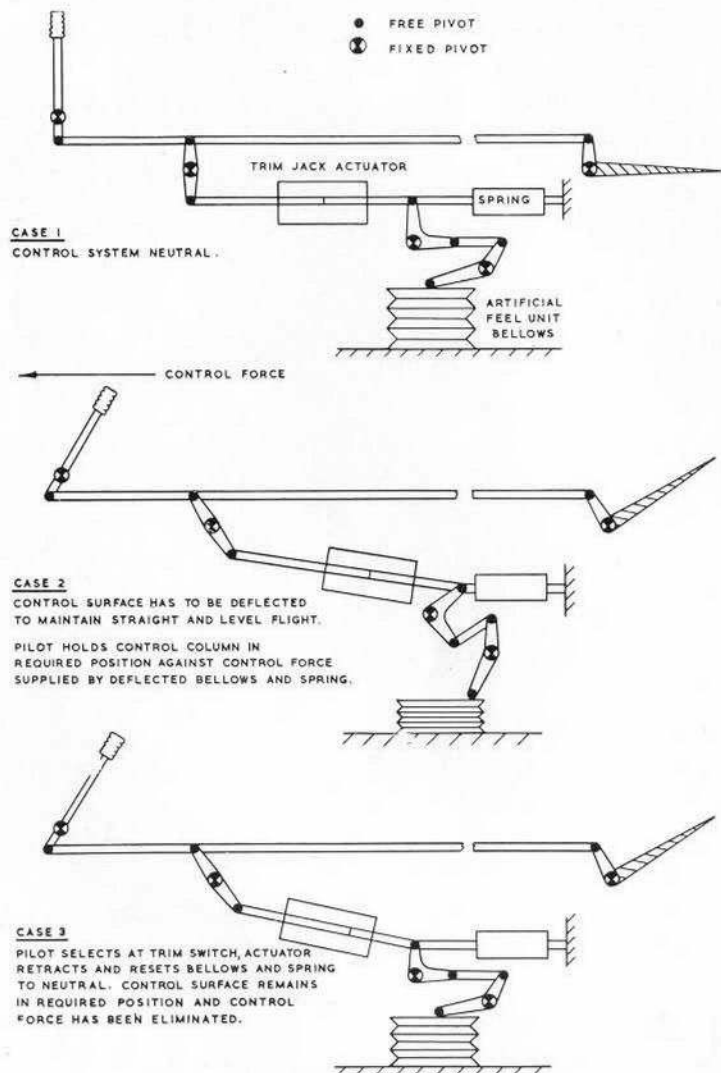


Fig. 1 Artificial feel and trim system

switch can be operated a central push-button 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 reset 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.

Management of the Powered Controls and Trimmers

12 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 112 volt external supply must be available. 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 over the full range of movement.

(i) Console trim controls

Without pressing the pushbutton, move the console trim 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 to neutral.

(ii) *Control column trim control*

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 the ten red power failure warning lights on the pilot's coaming panel (AZ) are on, and that the ten power failure magnetic indicators are white and the ten overheat magnetic indicators at the AEO's station are black. Start the No. 1 set by selecting the number 1, 3, 5, 7 & 9 switches to ON (up). Check that the appropriate red warning lights on the pilot's coaming go out and the indicators at the AEO's station are black. Test the controls for free, smooth and correct movement over their full travel (by ground crew observation). Jerky control movements or vibration may indicate unserviceability. Switch OFF the No. 1 set of controls (check that the red warning lights come on) and repeat the checks for the No. 2 set of controls switches numbered 2, 4, 6, 8 and 10. 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

magnetic indicators are black. 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.

13 Auto-stabilisers and auto-mach trimmer

(a) *Auto-stabiliser*

The yaw dampers should never be switched to STANDBY or ON unless the appropriate PFCU's are running. Before take-off, and after starting the PFCU's select the normal and standby yaw dampers to STANDBY. ▶ ◀ 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. The auto-mach trim should be selected to OFF for take-off.

14 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 power failure warning lights should remain out and the overheat magnetic indicators should remain black.

◀ (ii) Throughout flight the hydraulic yaw damper should be selected ON and the standby yaw damper should be selected to STANDBY.

(iii) Once above 20,000 feet if the mach trimmer is required it should be switched ON between 0.84 and 0.85M before speed is increased further. If, when the mach strut is selected on, its ▶

- ◀ magnetic indicator has not turned white by the time 0·87M is reached the speed should be reduced to 0·84M and the mach trimmer switched off. If during normal use the magnetic indicator remains white after the speed has decreased below 0·84M then the reset switch should be used until the magnetic indicator reverts to black. As speed is increased above $0·85M \pm 0·01M$ the auto-mach trimmer should provide a progressive nose-up trim force. The indicator should indicate white (OUT).
- (c) (i) Depending on orders in force, 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

15 "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 occurs, the control forces will be light and overstressing of the aircraft by over-application of elevator or rudder could easily result. At the higher speeds and mach numbers the aileron jacks will stall and so limit the amount of aileron that can be applied irrespective of the movement of the handwheel. The controls must be used with care above 180 knots, and large deflections must be avoided at any speed. The elevator must be moved slowly and cautiously with frequent reference to the accelerometer to avoid exceeding the G limitations.

16 PFCU failures

(a) If a sub-unit failure warning light on panel AZ comes on and/or the associated magnetic indicator at the AEO's station shows white, the associated switch should be put off.

(b) If a sub-unit failure is caused by a valve jamming, the first subsequent movement of the control will require the application of more force than usual. The additional force applied will operate a "break-link" to isolate the jammed valve and thereafter the control forces required will be normal.

(c) Pre-Mod. 828 (PFCU's fitted with pressure-off brakes) no significant effects will be noticed on the handling characteristics at any speed within the limitations if a sub-unit fails. On aircraft fitted with pressure-off brakes, rudder or elevator sub-unit failure will have no noticeable effect on the handling of the aircraft, but in the case of aileron sub-unit failure the aileron angle which can be applied will be progressively reduced as mach number increases. At the maximum permitted mach number, 0·95M, only very small aileron angles will be achieved, and above this limit, the ailerons will be virtually immovable. Additional aileron control can be obtained by compressing an over-travel spring link, but the forces involved are extremely high and if the wing with the inoperative sub-unit is allowed to drop, it may require the maximum combined effort of both pilots to raise it. Control at high airspeed (low mach number) and on the circuit and landing is normal. Handling characteristics with two aileron sub-units inoperative are similar. If an aileron sub-unit fails, therefore, speed must be reduced to below 0·9M.

(d) Complete aileron or elevator power unit failure

(i) If a complete aileron or elevator power unit fails, adequate control remains for gentle manoeuvres, approach and landing. Control forces are higher than normal and it is advisable to have both hands on the control column for approach and landing.

(ii) If an aileron unit has failed, the landing may be made using normal technique provided that due caution is exercised and that conditions are favourable, but some increase in approach speed is advisable if appreciable turbulence or crosswind exists.

(iii) If an elevator unit has failed only gentle manoeuvres should be performed. The landing should be made using take-off flap and the normal threshold speed for the AUW should be increased by 20 knots.

17 Overheating of a PFCU

If an overheat magnetic indicator goes white during flight, switch OFF the affected PFCU. When the indicator goes black, wait approximately 5 minutes and re-select the PFCU to ON. If the indicator again goes white, switch OFF and leave OFF.

18 Failure of a control trimmer

If a trimmer fails to respond to a trim selection, make no further selections of that control, until the appropriate circuit breakers have been checked. The alternative elevator trim actuator may be used if necessary, i.e. if the 1st pilot's control column trim control or the 2nd pilot's console trim control has failed, use the 1st pilot's console trim control or the 2nd pilot's control column trim control, and vice-versa.

19 Yaw damper failure

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.

20 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 force to a nose-down trim force 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 0.85M 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 0.85M.

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