

POWER FLYING CONTROLS1. Introduction

This section is concerned with the control and operation of the following flying control services:-

- (a) Power flying controls.
- (b) Normal and Emergency trim.
- (c) Artificial feel.

2. Power Flying Controls

Owing to the high aerodynamic loading on the flying control surfaces a considerable physical effect would be required to move them in order to effect control during flight. For this reason a system is employed whereby the control surfaces are moved by means of hydraulic pressure, which is obtained from pumps driven by electric motors. Movement of the pilots controls operates a system of valves, which in turn direct the pressure to be applied to one side or the other of a two way jack connected to the control surfaces.

3. Control Surfaces

The conventional ailerons and elevators are combined to form a system of control surfaces, referred to as ELEVONS. These are split into eight independently operated surfaces and are fitted four to each wing. Thus failure of one or more surfaces is adequately catered for. The surfaces are numbered 1 to 8 from the port side.

Operation of the pilot's controls to effect climb or descent will cause all eight surfaces to move up or down in unison. Operation of the controls to effect bank will cause movement of the four port surfaces in unison but in opposition to the movement of the four starboard surfaces.

A single surface is provided to effect rudder control, duplication of control being provided in this case by two independent flying control units. Normally, although both units are running, only the main unit operates the rudder surface, the auxiliary unit remaining in an 'idling' condition.

When the main unit fails the auxiliary unit automatically takes over the working effort.

4. Flying Control Motors

The motors are 200V 3 phase 400 cycles induction motors. The motors are integral with the P.F.C. units and are supplied with 200V A.C. obtained direct from the main alternator distribution panels 58P, 59P, 60P, 61P, via 3 phase latched type contactors.

5. Power Factor Correctors

Since the power factor of an induction motor is inherently low each motor is provided with two power factor corrector units consisting essentially of capacitors connected between the input lines to their associated motor. Each capacitor is fused, all fuses being contained in the corrector unit itself. The corrector unit is a sealed item and each unit carries the following warning:- "Important. Do not short circuit this condenser. Discharge through resistance of not less than 5000 ohms."

## 6. P.F.C. Motor Contactors

These are heavy duty 3 phase latched type contactors. Each contactor is equipped with two operating coils, one for closing the contactor and completing the mechanical latch and the other coil for tripping the contactor by breaking the mechanical latch.

## 7. Control Switches

Three push switches control the starting of each P.F.C. group. The switches located on panel 6P are labelled P.F.C. START and designated A-R-E. One half of each switch controls via a time switch the starting of a group of P.F.C. motors:-

- A - eleven units, Nos. 1, 2, 7 and 8
- E - eleven units, Nos. 3, 4, 5 and 6
- R - rudder units, Main and auxiliary

The other half of each switch controls the artificial feel engage thus:-

- A - aileron sense control
- E - elevator sense control
- R - rudder sense control

The three start pushes may be operated simultaneously only when all four alternators are operating. At all other times they are to be operated in rotation allowing each P.F.C. group to be completely started before depressing the next push. The P.F.C.s are also started and artificial feel engaged during engine starting using the RAPID START system.

Ten illuminated spring return push switches are fitted to 6P and are labelled P.F.C. MOTORS. The individual switches are further designated according to the P.F.C. motor they control. The switches when pushed stop their associated motor by tripping its contactor. The lamp in the head of the switch registers failure of its particular motor.

## 8. Time Delay Switches

Three time delay switches are employed to effect the sequential starting of the P.F.C. units. Those for the A and R circuits are fitted to 4OP and that for E on 4IP. The time delay switches operated by the A-R-E pushes connect 28V D.C. to close the 3 phase contactors of their respective P.F.C. motors.

## 9. Main Warning System

A main warning system is employed consisting of two amber lamps mounted at opposite ends of an array of magnetic indicators on 1P. The two amber lamps are labelled MAIN WARNING. The system is, should a failure occur in any one of the P.F.C. units, the amber lamps will illuminate, thus giving the pilot's immediate indication of P.F.C. failure and thereby drawing the 1st pilot's attention to the P.F.C. panel lamps on 6P. The failed unit's lamp push on being depressed will put out the amber main warning lamps and cause a magnetic indicator labelled P.F.C. UNITS to present a WHITE indication thus providing a reminder for the Pilot that P.F.C. unit has failed. The main warning system also provides warning for the following systems - Artificial Feel and Autostabilization.

## 10. P.F.C. Motor Operation

The following description applies to the 'A' group of P.F.C.s only but is descriptive of all groups with the exception of the rudder P.F.C. failure.

When 28V is connected to the aircraft system it is applied via fuse 603, to illuminate the No. 1 eleven stop switch lamp via the lock micro switch and via this micro switch and the contacts of the No. 1 indicator relay (281) to illuminate both main warning lamps on 1P. The other contacts of the indicator relay convey the supply from fuse 603 to contacts of the remaining nine P.F.C. indicator relays to energise the single P.F.C. reminder magnetic indicator on 1P to present 'BLACK.'

11. Starting P.F.C.s(a) NORMAL.

Depressing the 'A' start push will convey 28V D.C. to wind up the 'A' time switch via terminals M. After a delay of 1 second the time switch contacts will operate, which will result in 28V being fed from fuse 478 to be applied to the 'CLOSE' coil of the No. 1 elevon motor 3 phase contactor. The No. 1 elevon motor will commence to run and drive its associated P.F.C. pump.

The resultant build up in pressure will now change the contacts of the lock micro switch over and thus put out the No. 1 elevon stop switch lamp.

NOTE: It should be appreciated that although the supply from fuse 603 has now been withdrawn from the No. 1 elevon indicator relay contacts supplying the main warning lamps, and they will not be put out until the tenth P.F.C. motor has started.

The time switch continuing its cycle will, with 2 second intervals, start up the remaining elevon P.F.C.s in the "A" group i.e. No. 2, No. 7 and No. resulting in similar circuit operations as previously described.

(b) RAPID

During engine rapid start, the P.F.C.'s are started by feeding 28V from fuse 674 via the engine rapid start push to wind up the rudder time switch. When the time switch runs, contacts 1 and 2 close to start the main and auxiliary rudder P.F.C. as for normal start, but after 5 seconds contacts 3 and 4 close to feed 28V from fuse 674 to wind up the 'A' and 'E' time switches which will then operate as for a normal start and start the elevon units.

12. Failure(a) Elevons

In the event of the P.F.C. motor failing or some internal P.F.C. failure, the effect will be of removing pressure from the plunger operating the lock micro switch, the micro switch will revert back to its unoperated position and cause the lamp in the head of the stop switch and the two main warning lamps to illuminate.

Depressing the stop switch will trip out the affected motor contactor and also energise the failed units' P.F.C. indicator relay. The relay in energising will remove the supply from the main warning warning lamps and withdraw the supply from fuse 603 to the reminder indicator on LP which will now present "WHITE". The contacts of the indicator relay in changing over lock out the relay itself and thus can only be de-energised by (a) removing fuse 603 (in the case of No. 1 elevon) or (b) removing the 28V D.C. from the essential bus bar.

(b) Rudder

Due to the rudder arrangement a lock valve micro switch is fitted to only the auxiliary rudder P.F.C. because of this each P.F.C. is fitted with a pressure switch. Also fitted to each unit is a servo valve trip mechanism which includes a servo valve trip micro switch.

In the event of either the pressure or servo trip micro switches on the main unit or pressure, servo trip or lock valve micro switches on the auxiliary unit operating, they will cause the main warning lamps and the stop push lamp to illuminate.

Depressing the stop push results in action similar to the elevons.

### 13. Auxiliary Rudder Load Shedding.

The auxiliary rudder P.F.C. is part of the load shedding when the R.A.T. lowered. With the R.A.T. lowered the non-essential 28V bus bar is shed which causes relay 559 to de-energise thus feeding 28V from fuse 846 via relay 559, relay 152 to energise relay 151. Relay 151 in energising feeds 28V from fuse 607 to trip the auxiliary rudder contactor to stop the P.F.C. The pressure switch will change over to give indication, but only on the P.F.C. stop push, as the feed to the main warning lamps is broken by relay 151.

If, however, during the operation of the R.A.T. the main rudder was failed it would not be necessary to trip the auxiliary rudder. With the main unit failed relay 152 will be energised from the micro switch circuit of the main unit. Relay 152 prevents relay 151 from energising and thus the auxiliary rudder unit is not tripped.

### 14. Normal and Emergency Trim (Introduction)

Aircraft trim adjustment is effected by electric actuators coupled in the control rod systems of the three control surfaces i.e. aileron sense, elevator sense and rudder. Extension or retraction of the actuator jacks causes movement of the control rod system, thus adjusting the control and surface neutral positions to any required angle within the range of the actuator travel.

### 15. Normal Trim Switches

#### (a) Elevator and Aileron Trim

The head of each pilots control column is equipped with a trim control switch shaped like a 'Chinaman's hat.' This switch controls the trim actuators in the aileron and elevator sense and consists of two single pole four way switches. The forward switch marked 'A' on routing charts control the supply to the normal trim actuators, and the aft switch marked 'B' controls the earth making relay for the normal trim actuator.

#### (b) Rudder Trim

Control of the normal rudder trim actuator is effected by two single pole switches mounted together on the fuel contents panel 2P. The switches are 'finger coupled' and are spring returned to the 'OFF' position, and again one pole controls the supply to the trim actuator and the other pole controls the RUDDER TRIM, PORT - STARBOARD.

### 16. Emergency Trim Switch

Control of the emergency trim actuators is effected by a switch Type 101 which is fitted to the forward end of 5P. The switch provides six positions in three axes i.e.:-

- (i) Elevator sense - push knob forward or aft.
- (ii) Aileron sense - rock knob from side to side.
- (iii) Rudder - rotate knob clockwise or anticlockwise.

A push switch in the centre of the control knob labelled 'PRESS FOR EMERGENCY TRIM' has to be depressed throughout all emergency trim operations.

17. Trim Actuators

Three twin motor linear actuators are employed one in each flying control rod. One motor of the twin actuator serves as the normal trim actuator whilst the other serves as the emergency trim actuator. The motors drive a common shaft through a differential gearbox. The actuators of the elevator and rudder sense trim systems are fitted in the control rod runs, adjacent to the respective feel unit. The trim actuator for the aileron sense is integral with the aileron feel unit.

18. Trim Operation (Normal)

The following description is for a trim selection in the elevator sense 'NOSE DOWN' - the circuit operation for aileron is similar. Rudder trim is described separately.

Operation of the 1st Pilot's trim switch to the 'NOSE DOWN' sense will result in the 'A' switch conveying 28V D.C. from fuse 929 to energise relay 147 which causes 28V D.C. from fuse 928 to be applied to the 'NOSE DOWN' field of the elevator normal trim actuator. Switch 'B' will apply 28V D.C. from fuse 929 to energise relay 174 which in closing will complete the earth for the trim actuator which will commence to run. Releasing the trim switch will result in relays 147 and 174 de-energising, thus stopping the trim actuator.

Normal rudder trim is controlled in the following manner. The 'finger coupled' control switch on 2P is selected to say 'PORT' which will convey via one switch 28V D.C. from fuse 930 to the 'PORT' field of the normal trim actuator and the other switch completes the earth to the actuator which commences to run. Releasing the trim switch stops the actuator running.

19. Trim Operation (Emergency)

The following description is for emergency trim 'NOSE DOWN'. The other sense being similar in operation.

When the trim switch on 5P is in the unoperated position, both fields of all emergency trim actuators are inhibited through the de-energised contacts of the following relays, i.e.:-

- (a) Aileron actuator - Relay 360.
- (b) Elevator Actuator - Relay 362.
- (c) Rudder Actuator - Relay 361.

On depressing the button in the head of the emergency trim switch all three relays are energised, thus removing the inhibiting earth. Pushing the trim knob forward in the 'NOSE DOWN' sense results in 28V D.C. from fuse 521 being applied to the elevator emergency trim actuator 'NOSE DOWN' field via the energised contacts of relay 362. The actuator commences to run. If the trim knob is released the actuator will stop.

20. Artificial Feel

The artificial feel system is employed to simulate aero-dynamic loading at the pilots controls. This is effected by three artificial feel units, one for each control axis, which provide a restriction to control rod movement with a corresponding increase in airspeed and a relaxation to control rod movement with a corresponding decrease in airspeed.

Adjustment of the units, according to airspeed variation is effected by electrically controlled actuators. To obtain the necessary change in feel with change in airspeed, a control system is employed consisting of two potentiometers connected in parallel (Wheatstone bridge principle).

One potentiometer is effected by airspeed and is fitted in the pilot static system, the other potentiometer is fitted to the feel unit and is operated by the feel unit mechanism. The wiper of each potentiometer is bridged by the coil of moving coil relay, the contacts of which will operate the feel unit actuator when the relay operates.

The artificial feel is engaged when the appropriate P.F.C. start push or Engine Rapid Start push is operated.

#### 21. Operation Rudder

Depressing the Rudder P.F.C. start push or Engine Rapid Start push will energise Relay 132 which in energising takes a hold in from fuse 507. The other contacts of relay 132 feed 28V from fuse 507 to ensure the relief actuator of the feel unit is extended to its correct operating position.

With the relief actuator extended 28V from fuse 487 is fed via the internal micro switch operated by the relief actuator, onto the Wheatstone bridge formed by the airspeed potentiometer and the follow up potentiometer and also to energise relay 431 which is part of the indication circuit.

Variation of airspeed will unbalance the bridge causing current to flow in the moving coil relay which at 90 micro amps will close its contacts. 28V from fuse 487 is now fed to energise relay 430 (increase airspeed) or relay 442 (reduced airspeed). These in turn cause the Main Feel actuator to either Retract or Extend until the follow up potentiometer balances the airspeed potentiometer which causes the moving coil relay to de-energise, thus stopping the Feel actuator in a position of feel relative to the airspeed.

#### 22. Failure Indication

A second Wheatstone bridge formed by a second airspeed potentiometer and the follow up potentiometer provides a means of failure indication. 28V is fed onto this bridge at the same time as it is fed to the first.

Variations of the airspeed also unbalances this bridge but to close the contacts of the moving coil relay requires a larger airspeed displacement and under normal conditions this value is not reached. If a fault in the system develops which causes 90 micro amps to flow, then the moving coil relay will operate, 28V from fuse 487 is fed to energise relay 436 which causes relay 431 to de-energise. With relay 431 de-energised 28V from fuse 454 is fed via the contacts of the rudder warning push on 6P to illuminate the Main warning lamps and the lamp in the head of the push. The other contacts of relay 431 de-energise a magnetic indicator. Depressing the push extinguishes the main warning lamp but maintains the push lamp illuminated.

#### 23. Feel Relief

After a failure the feel unit has to be reduced to minimum. As this may be impossible under normal control, minimum feel is achieved by the relief actuator. Operation of the feel relief push on 2P de-energises relay 132 which removes the hold in supply and also feeds 28V from fuse 507 to the retract field of the relief actuator via the internal stop micro switch. If the unit is not in minimum then this micro switch will be closed to allow the relief actuator to retract. In retracting the main actuator is moved across bringing the feel down to minimum. When at minimum the micro switch is operated to stop the travel of the relief actuator.

24. Operation Elevator - Aileron

The operation of the Elevator and Aileron feel system is similar to the rudder except that the feel forces are also altered by the engaging of auto-pilot and auto-approach.

When auto-pilot is engaged relay 703 is energised which in turn energises relay 704. With relay 703 energised the 28V to the aileron follow up potentiometer is removed causing an unbalance in the bridge which causes the feel unit to run to maximum feel. The other contacts of relay 703 place 28V onto the second moving coil relay causing the contacts to close to provide a hold in circuit for relay 704. The contacts of relay 704 prevent an indication of aileron failure and the other contacts break the supply of the magnetic indicator thus causing it to go 'WHITE'.

With auto pilot selected and then selecting auto-approach, relay 702 is energised. With relay 702 energised 28V is reconnected to the aileron feel unit follow up potentiometer but reduced by the series resistors. This will allow the moving coil relay to energise at speeds below 150 kts. This will cause the feel unit to reduce feel until a balance exists between follow up and air-speed potentiometers.

Relay 702 also inserts No. 1 and No. 2 potentiometers into the control and indication bridges of the elevator feel unit thus causing an unbalance to reduce feel forces.

To prevent warning indication during the rebalancing of the feel unit a 2 second time delay unit is introduced which holds off the indication circuit.

25. Failure Indication and Feel Relief

Indication of failure is similar to that for the rudder circuit. Relief is also similar and is controlled by the feel relief pushes on the 1st and 2nd pilots control handles. Operation of either push relieves both systems which means the re-engagement of the non faulty system if required.

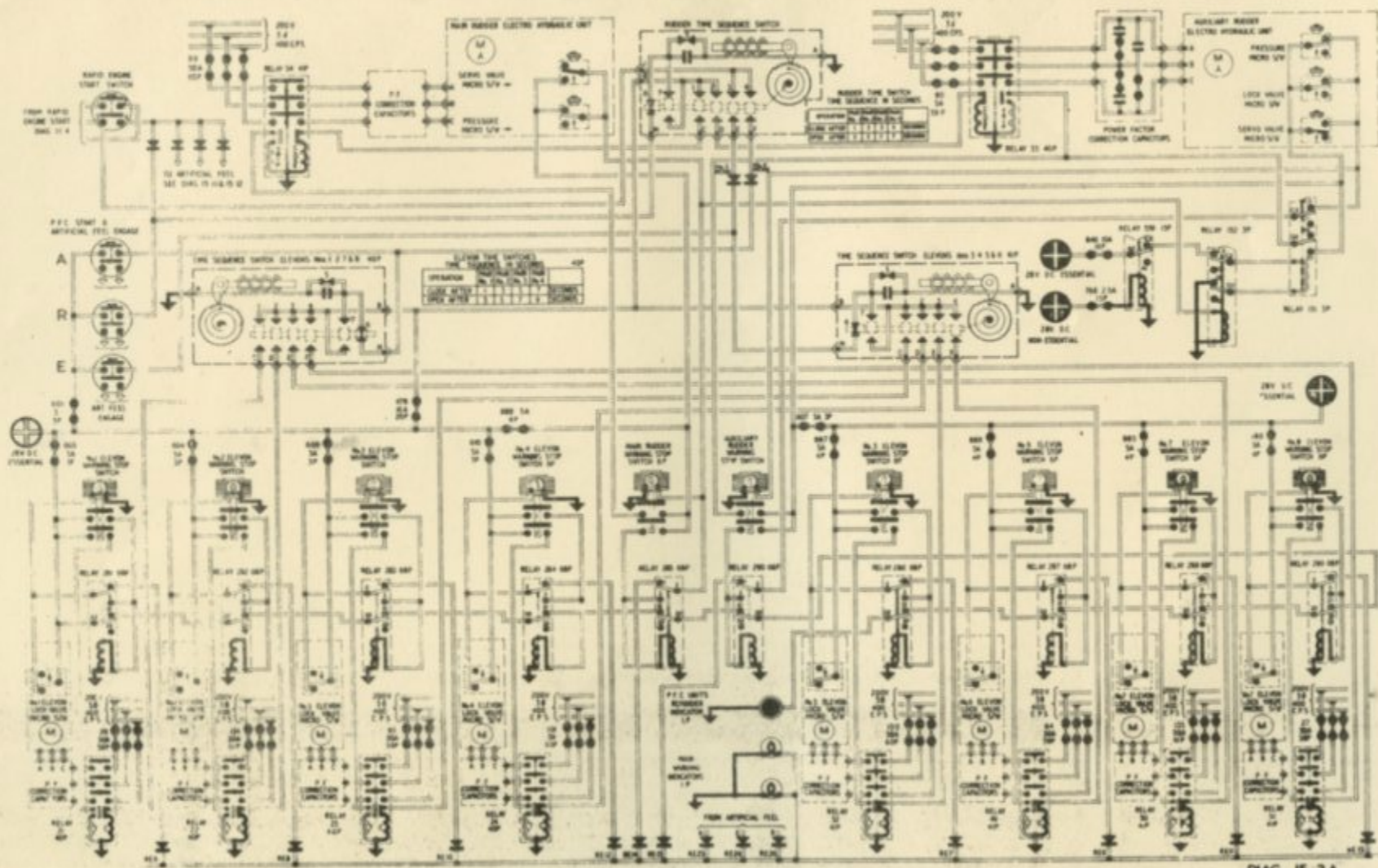
26. Testing the Warning System

Three test pushes on 66P when operated insert further resistors into the warning bridge of each system so unbalancing the bridge to give warning indication.

27. Circuit Components

<u>Component</u>	<u>No.</u>	<u>Location</u>
Elevcon	8	Adjacent to their respective control surface
Rudder P.F.C. Motor	2	Rear of rudder hinge
P.F.C. Contactor	10	40P and 41P
Power Factor Correctors	20	Adjacent to P.F.C.s
Time Delay Switches	3	Power compartment 40P & 41P
P.F.C. motor stop switch	10	6P
P.F.C. Group start switch	3	6P
Trim Actuator Aileron	1	Aileron feel unit starboard bomb bay

<u>Circuit Components</u>	<u>No.</u>	<u>Location</u>
Trim Actuators, Elevator, Rudder	2	One each near associated feel unit bomb bay
Emerg. trim switch type 101	1	5P
Indicator relays	10	68P
Blocking rectifiers	10	68P
Aileron Feel Unit	1	Starboard side bomb bay
Elevator and Rudder feel unit	2	Port side of bomb bay
Artificial feel control system	3	Near associated feel unit
Artificial feel warning system	3	66P starboard side bomb bay



DIAG. 15 3A

P.F.C. START & INDICATION.

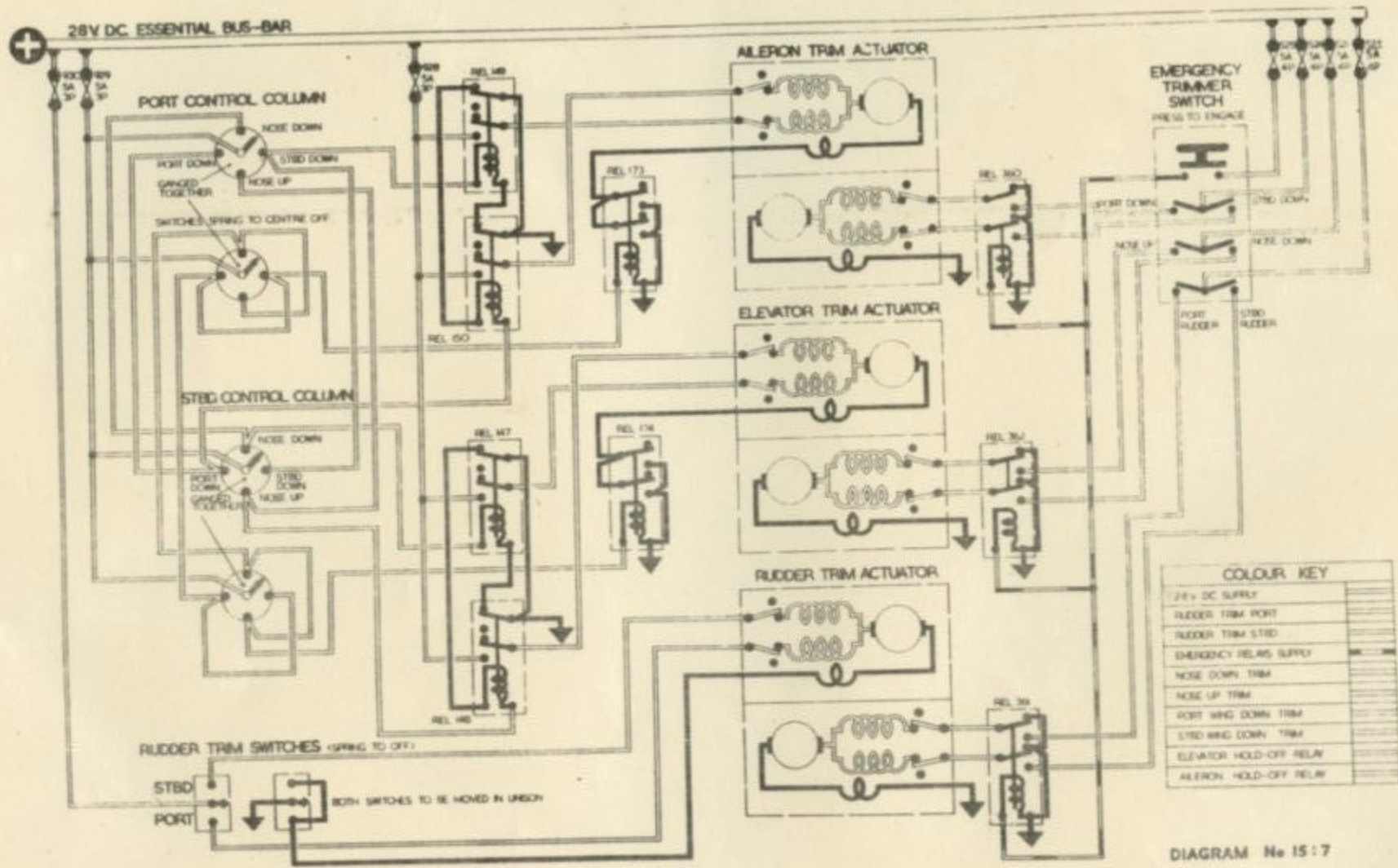
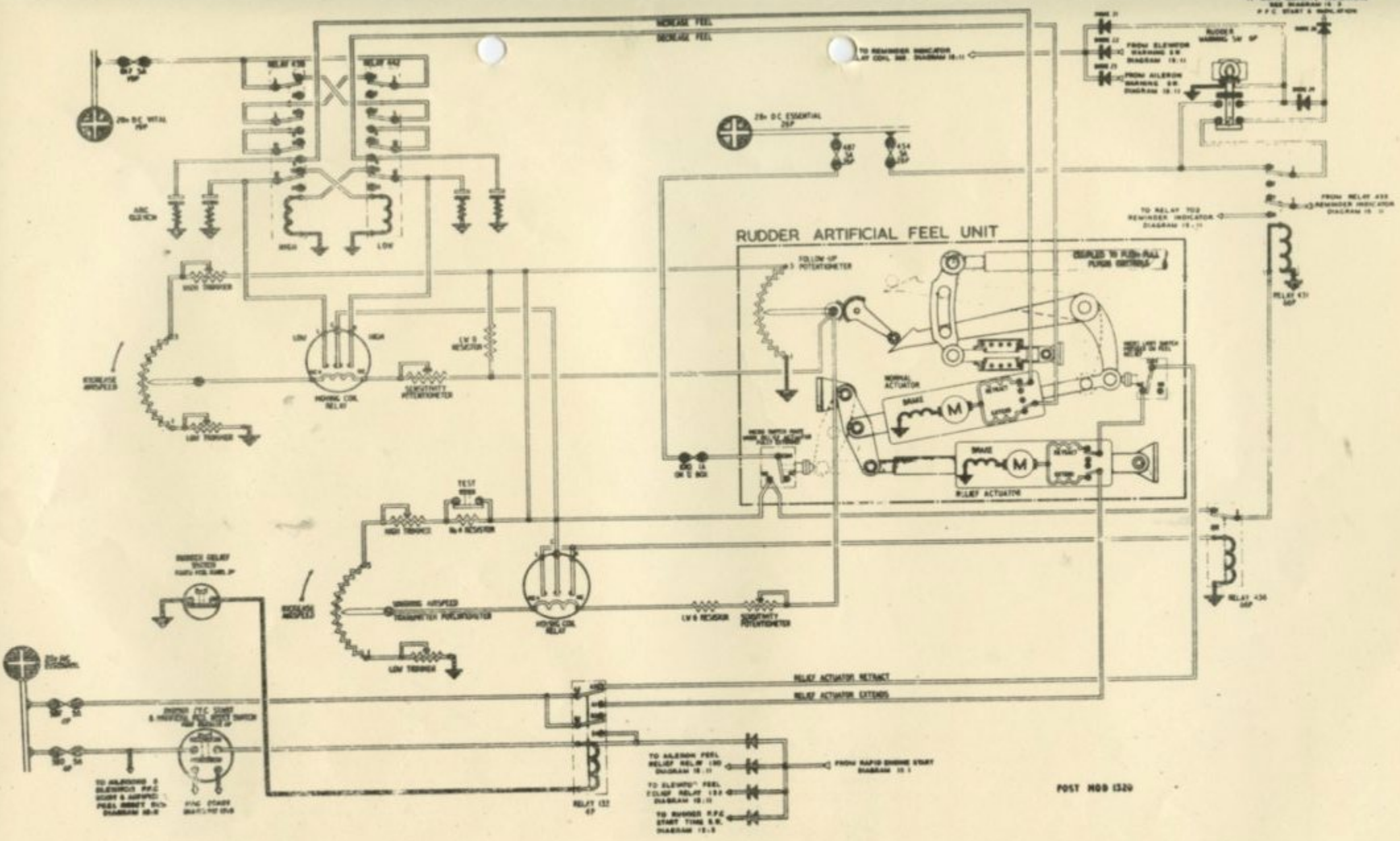
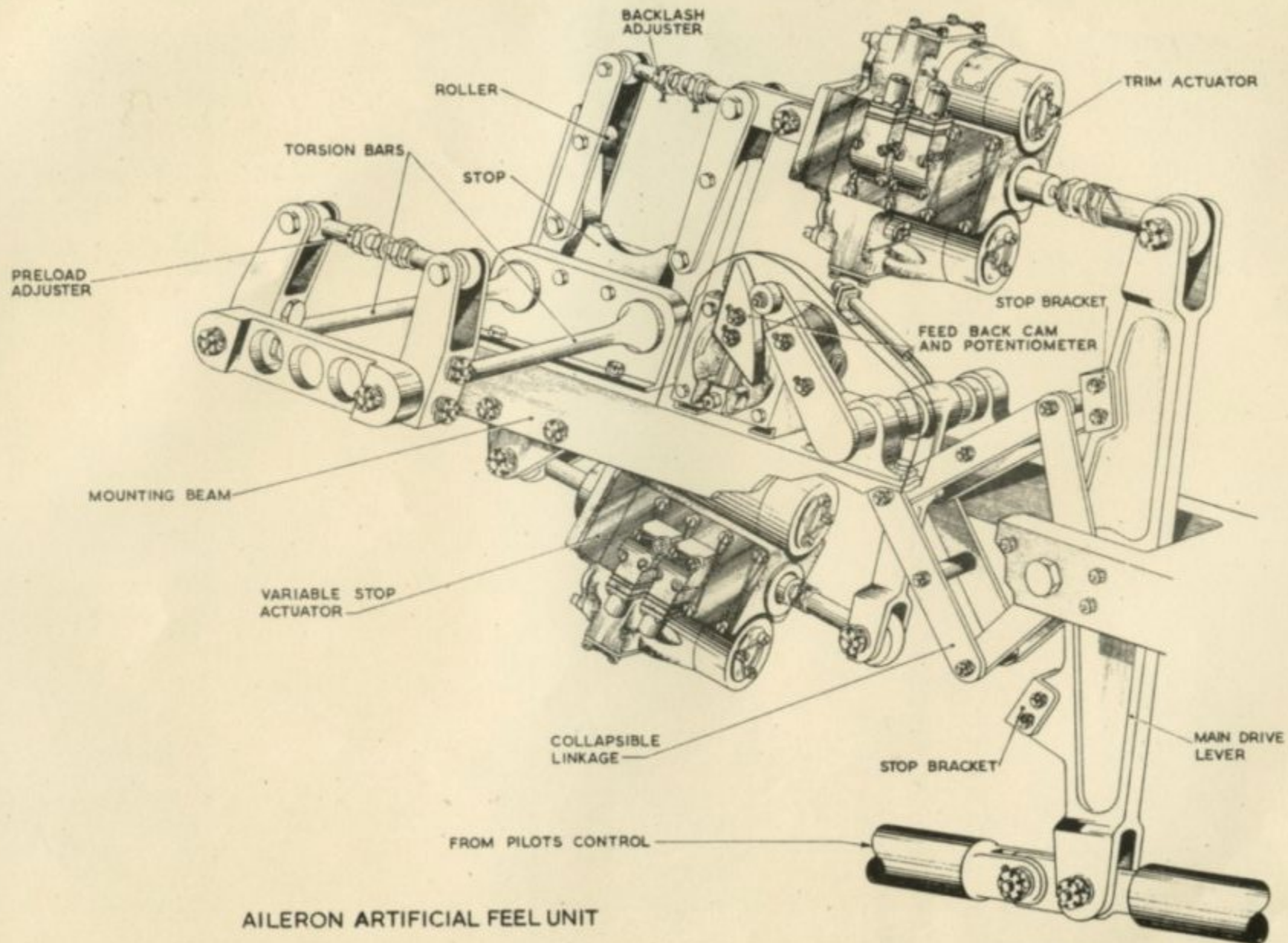


DIAGRAM No 15:7

TRIM CIRCUITS







AILERON ARTIFICIAL FEEL UNIT

DIAGRAM 15 : 5.

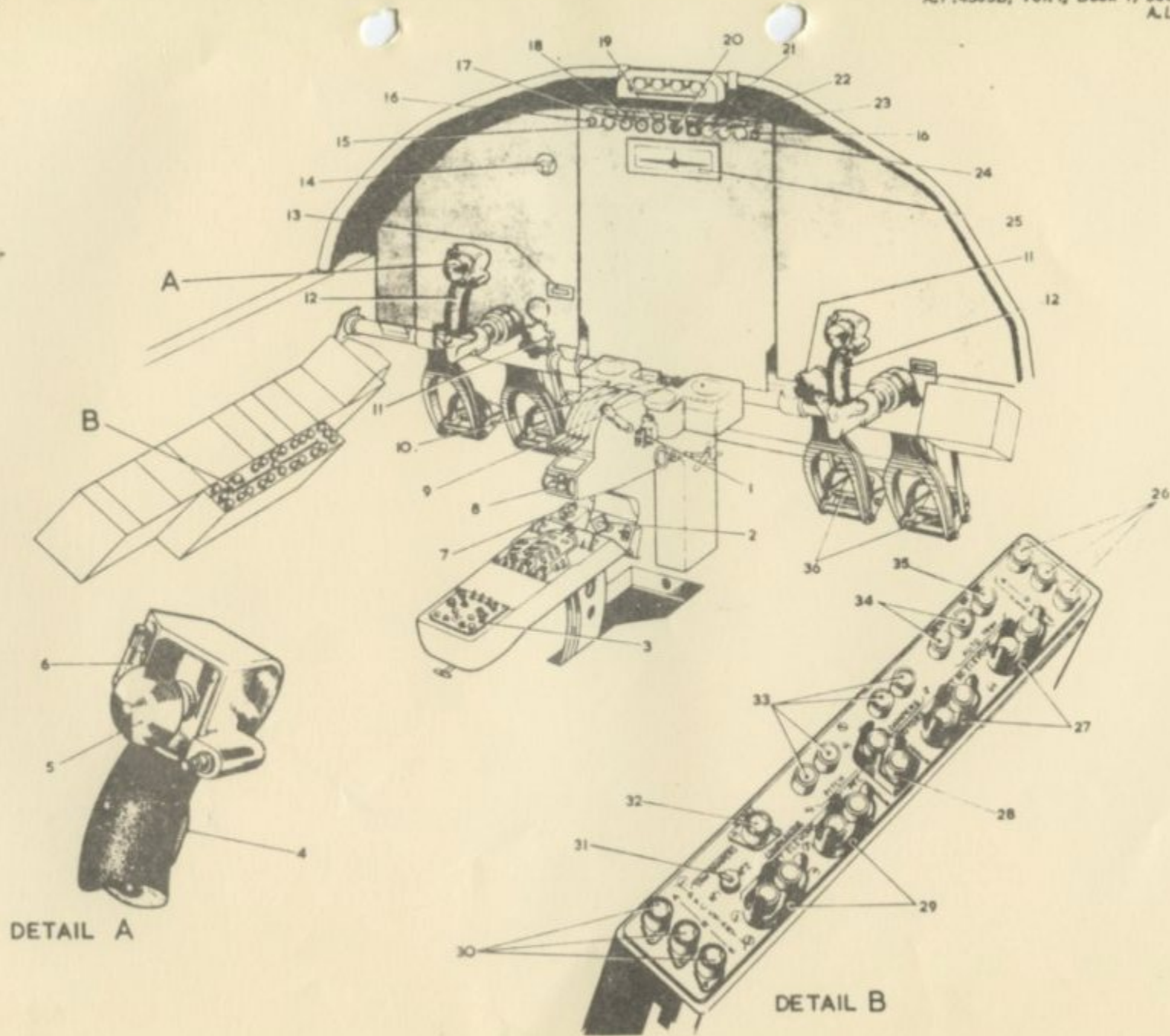


Fig. 1 Flying controls and indicators

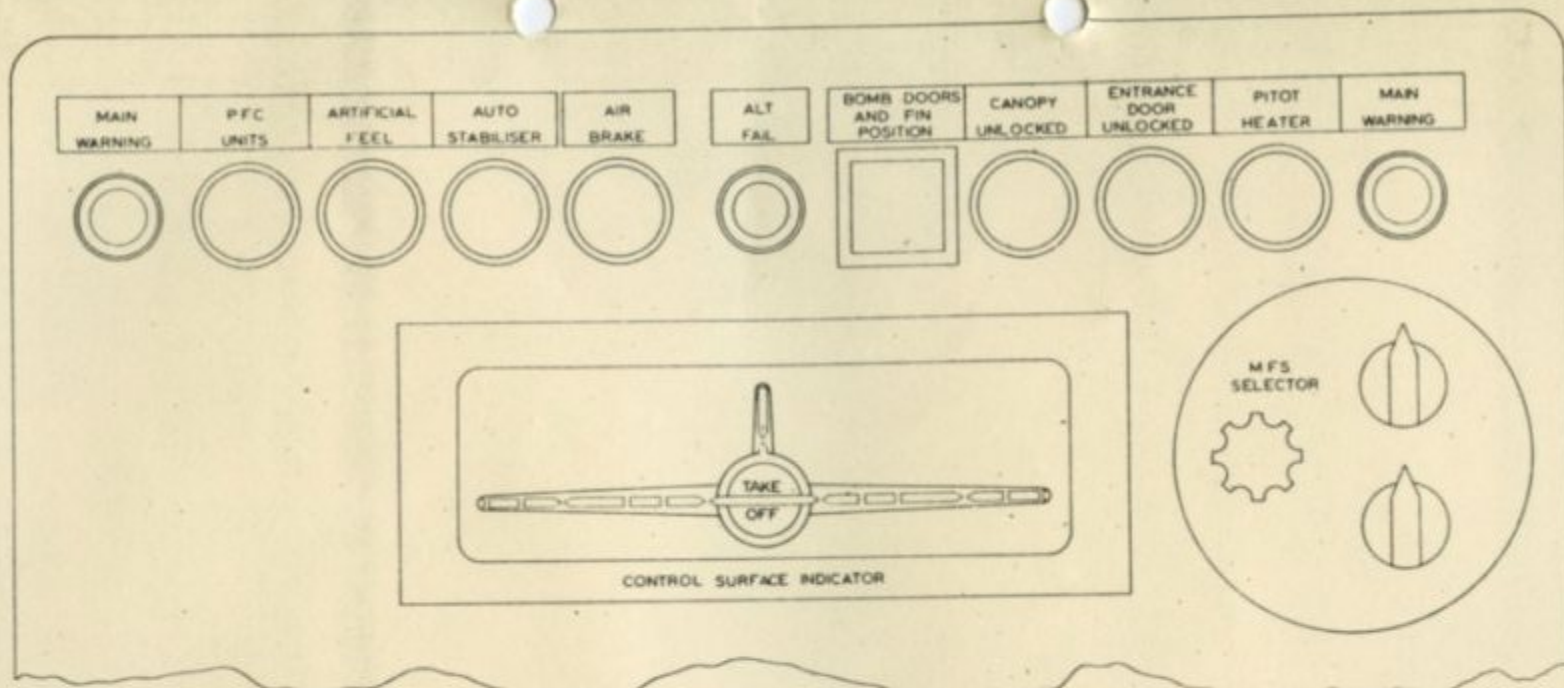
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## KEY TO FIG.1

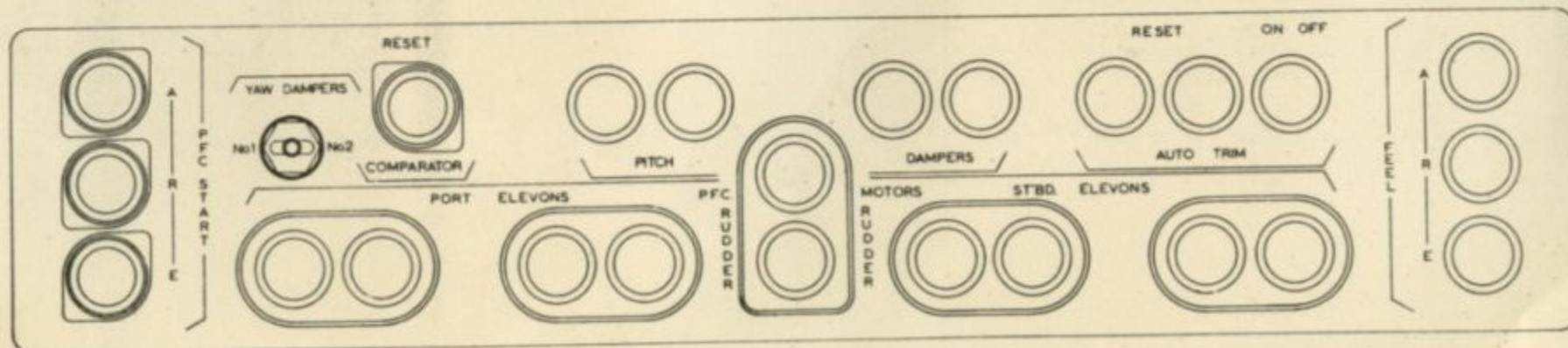
FLYING CONTROLS AND INSTRUMENTS  
IN COCKPIT

1. Air brakes emergency switch  
NORMAL - up  
EMERGENCY - down - energises standby motor to complete retraction if main motor fails.
2. Emergency trim control - used in natural sense.  
Centre button must be depressed whilst operating.
3. Autopilot control panel
4. Instructive auto-pilot cut-out - press to disengage.
5. Trim control switch - elevons - four-way switch used in natural sense.
6. Artificial feel relief switch, aileron and elevator sense -  
Press to operate.
7. Autopilot controller
8. Air brakes switches  
IN - air brakes closed  
MED. - DRAG - air brakes partly extended.  
HIGH - DRAG - air brakes fully out
9. Rudder trim control switch
10. Rudder artificial feel relief switch - press to operate
11. Rudder pedals adjuster
12. Pilot's control handle
13. Side slip indicator
14. Autopilot trim indicator
15. P.F.C. indicator - black when control units are running. White when any control unit is stopped
16. MAIN WARNING indicators - illuminate amber when failure occurs in the flying controls. Extinguished when faulty circuit is switched off.
17. ARTIFICIAL FEEL indicator - black when circuits are energised - white when any circuit fails.
18. AUTO-STABILISER indicator - black when circuits are energised - white when circuit is isolated.
19. AIR BRAKES indicator - black when air brakes are fully in - white when airbrakes are out
20. ALTERNATOR FAILURE indicator - amber warning light when single alternator failure occurs. Flashing amber light should more than one alternator fail. Extinguished when R.A.T. is lowered.
21. BOMB DOORS AND FIN POSITION indicator.
22. CANOPY UNLOCKED indicator. White when canopy is unlocked. Black when canopy is closed and locked.
23. ENTRANCE DOOR UNLOCKED indicator - white when entrance door is unlocked. Black when entrance door is closed and locked.
24. PITOT HEATER indicator - white when pitot heater is off. Black when pitot heater is ON.
25. CONTROL SURFACE INDICATOR
26. Artificial FEEL system failure indicator/push-pull switch.  
A - aileron sense  
R - rudder  
E - elevator sense  
Illuminate amber when failure of system occurs. Press to cancel main warning.
27. STARBOARD ELEVONS P.F.C. failure indicator/push switch - illuminate amber when P.F.C. failure occurs. Press to isolate failed P.F.C.
28. RUDDER P.F.C. failure indicator/push switch. Outboard switch, main P.F.C. - inboard switch, auxiliary. Illuminate amber when P.F.C. failure occurs. Press to stop failed P.F.C. ~~auxiliary will start.~~
29. PORT ELEVONS P.F.C. failure indicator/push switches - illuminate amber when P.F.C. failure occurs. Press to isolate failed P.F.C.
30. P.F.C. group START push switch.  
A - outboard elevons and artificial feel.  
R - rudder and artificial feel.  
E - inboard elevons and artificial feel.
31. YAW DAMPERS control switch  
No.1 - switch aft - No.1 system engaged.  
No.2 - switch forward - No.2 system engaged.
32. COMPARATOR RESET push switch  
Depress to reset
33. PITCH DAMPERS ~~push-pull switch.~~  
Illuminates ~~amber~~ failure.  
Depress switch to disengage
34. AUTO TRIM RESET indicator/push switch. Illuminates blue when auto-mach-trim is in. Depress both switches to retract servos.
35. AUTO TRIM start failure indicator/push pull switch.  
Illuminates amber to indicate failure.  
Depress switch to disengage.
36. Rudder pedals.

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CENTRE PANEL 1P



P.F.C. SWITCH PANEL 6P

DIAGRAM 15:2.

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