Appendix 1

FORCE/DEFLECTION PLOTTER TEST SET

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Introduction

1. This appendix deals with the calibration of the flying control systems using the force/deflection plotter test set as an alternative to the spring-balance and inclinometer method detailed in Chapter 4. Using the test set, the control and rudder pedal forces are plotted in graphical form relative to control surface movement throughout the airspeed range. By comparing the resultant graphs with master traces, the following control system characteristics can be determined:-

Break out and self-centring
Force/deflection characteristics
Aileron stop range of movement

FORCE/DEFLECTION PLOTTER TEST SET

2. The test set comprises a box of equipment 26DC/95403 and a box of carriers and linkages 26DC/95401. The equipment consists of a monitor unit, recorder unit, three control force transmitters, five electrical connecting cables and a set of master traces. Three carrier assemblies and linkage mechanisms are provided to connect the recorder unit to the aileron, elevator and rudder control surfaces respectively.

3. The equipment is arranged in the aircraft as in fig.1. The aircraft controls are functioned through the force transmitters, and control surface movement is transmitted to a magazine within the recorder unit by the linkage mechanism which is clamped to the control surface

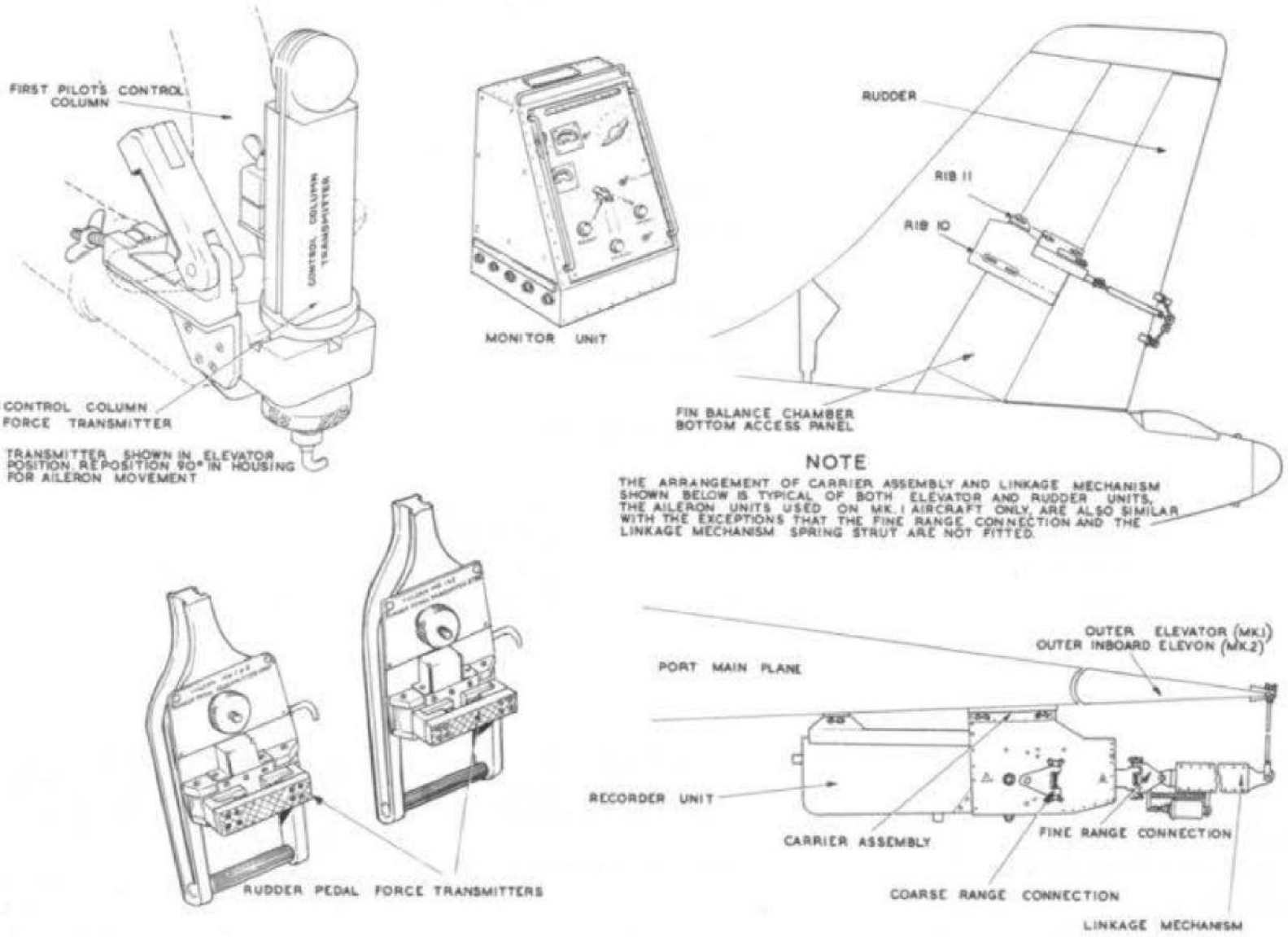


Fig.1. Arrangement of test equipment

trailing edge. The graph is made on sensitised recording paper contained in the magazine. The paper moves in conjunction with the control surface and is exposed to a light beam reflected by a galvanometer which deflects in proportion to the force applied to the transmitter. To check calibration of the aileron stops and also provide a means of identifying the individual graphs, a second galvanometer is arranged to deflect, in small steps, across the paper by operation of the airspeed selector switch. Similar galvanometers in the monitor unit operate in parallel to provide the force and airspeed light spots which are displayed on the monitor scale to give visual indication of system functioning.

4. The controls and indicators for functioning the test set are mounted on the front panel of the monitor unit as in fig.3. The magazine rewind control is mounted on the side of the recorder unit and has direction and position markings. By turning the control one revolution, the recording paper will be advanced the amount required for each individual graph. A full description of the test set will be found in A.P.1275E, Vol.1, Sect.7.

INSTALLATION OF TEST EQUIPMENT

5. Prior to installation in the aircraft, the test equipment must be checked for satisfactory functioning and, sufficient recording paper must be available for the calibration. This check-out of equipment will normally have been made prior to issue from the Instrument servicing bay, in accordance with the procedure contained in A.P.1275E, Vol.1, Sect.7.

Control force transmitters

6. The control column and rudder pedal force transmitters are mounted on the respective controls at the first pilot's station, as shown in fig.1, and are to be secured in position using the clamps provided. The port and starboard pedal transmitters are not interchangeable. The control column transmitter is used for elevon operation in both the elevator and aileron sense. For elevator movement the strain gauge blade must be located in a transverse position in the transmitter, and in the fore-and-aft position for aileron movement.

Monitor unit

7. The monitor unit should be positioned in the 2nd pilot's seat within convenient reach of the cabin operator.

Carrier assemblies and linkage mechanisms

8. The elevator and aileron carrier assemblies are mounted to the port wing undersurface at the elevator power unit access door and the aileron bottom access panel positions respectively. The rudder carrier assembly is mounted on the port side of the fin at the balance chamber bottom access panel. To mount the carrier assemblies, remove the five securing screws from the respective access doors, at the positions shown in fig.2, and secure each assembly using the bolts provided.

9. To couple the carrier assemblies to their respective control surfaces:-

(1) Set the control surface in the neutral position.

(2) Support the link mechanism in approximate alignment with the carrier assembly gearbox and clamp the peg fittings to the control surface trailing edge.

(3) Move the gearbox driving lever, against the spring action, to the mid-position, and engage the link mechanism fork end in the gearbox connecting lever. Tighten the wing nuts to secure the connection.

NOTE...
On elevator and rudder assembly gearboxes two connecting levers are provided. Initial connection should be made to the FINE range lever which extends through the rear end of the gearbox casing. The alternative COARSE range lever is mounted on the side of the gearbox.

Recorder unit

10. To fit the recorder unit in the carrier assemblies:-

(1) Remove the knurled locating pin from the carrier gearbox.

(2) Slacken off the knurled nut on the recorder transmission arm connecting pin and set the transmission arm in the mid-position.

(3) Slide the recorder unit into the carrier mounting rails from the rear end, and move into position so that the gearbox driven lever engages the transmission arm connecting pin, and the locating pin can be refitted to enter the transmission arm shaft.

(4) Tighten the locating pin and the connecting pin knurled nut.

Electrical connections

11. Connect the five electrical cables, supplied with the test set, to the monitor unit in accordance with the cable idents. Make the connections to the control column and rudder pedal force transmitters. Run out the recorder unit cable through the cabin entrance door and connect to the recorder unit. Connect the supply cable to the aircraft 28 volt d.c. supply through the lamp housing under the navigator's table; it is important that the connection is made in the correct polarity.

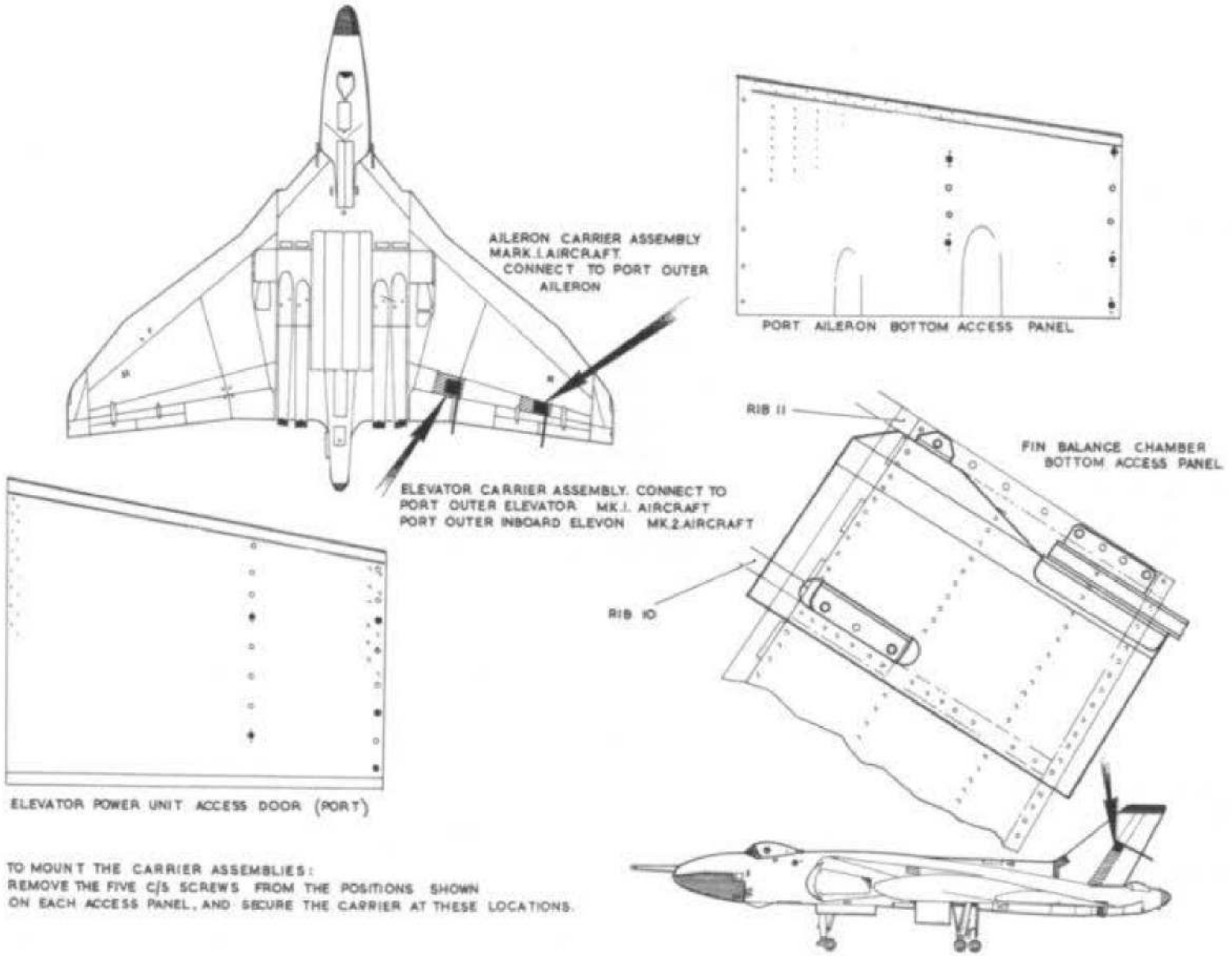


Fig.2. Location of carrier assemblies

CALIBRATION

Calibration procedure

12. For this method of calibration three men are required. The test procedure is controlled by one operator stationed in the cabin who moves the aircraft controls and also makes the necessary selections on the monitor control panel. A second operator makes the required adjustments at the recorder unit, and a third applies varying airspeeds to the artificial feel units in the bomb compartment. A pitot test set is required to simulate airspeed at the feel unit, and electrical supplies of 28 volt d.c. and 112 volt d.c. must be available in the aircraft to operate the test equipment and to function the power units.

Precautions

13. During calibration the following points must be observed:-

(1) All connections must be made between the monitor unit and the test equipment before switching on the 28 volt supply - a warning to this effect is displayed on the monitor panel.

(2) Movement of the aircraft controls must be smooth and progressive. The applied forces must be such that tracer light movement across the monitor scale never exceeds 2.5 inches either side of zero. This is particularly important when operating on the FINE range setting. At increased airspeed settings, full deflection of the tracer light cannot be obtained, and sufficient control movement will have been made when forces of approximately:-

25 lb.	- Aileron
80 - 100 lb.	- Elevator
120 - 150 lb.	- Rudder

have been applied. The controls should be allowed to return to the self-centring position by slowly removing the applied force.

(3) Airspeed must always be applied to the elevator and rudder feel units in a rising direction, and to the aileron artificial feel unit in the direction of airspeed switch sequence.

(4) All P.F.C. motors, appropriate to the system being operated, must be running during calibration. If a single motor in the system fails to run, the results will be effected.

(5) The record switch must only be set to RECORD for the minimum periods necessary to complete individual tests. At each selection to RECORD, ensure that the filament lamp in the recorder unit is illuminated by noting that the milliameter registers between 200-300 mA.

Test system checks

14. With the test equipment installed and connected, check the test system as follows:-

(1) Set the 28 volt supply switch to ON and check that the power ON warning lamp illuminates.

(2) Set the indicated voltage to 6 volts.

(3) Set the channel selector switch to P. RUDDER.

(4) Centralize the force trace light on the monitor scale using the appropriate balance control.

NOTE...
Two light spots will be apparent on the monitor scale. The airspeed trace light can be identified by operating the airspeed selector switch.

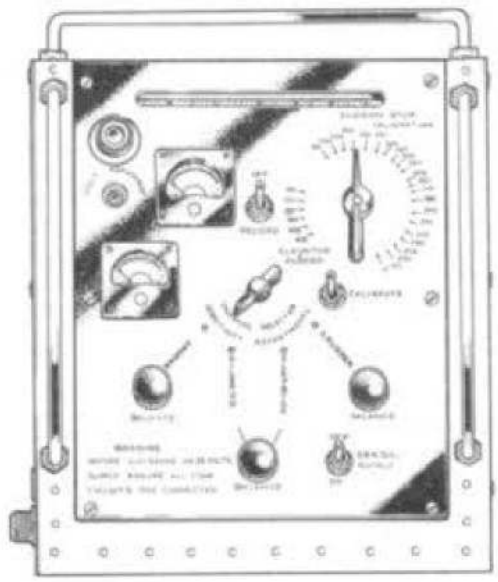


Fig.3. Monitor unit control panel

(5) Press the calibrate switch and check that the force trace light deflects 2.5 main divisions across the monitor scale. Adjust the appropriate sensitivity trimmer if necessary.

(6) Set the channel selector switch to AILERON, ELEVATOR and S. RUDDER in turn, and repeat operations (4) and (5) at each setting.

(7) Switch OFF the 28 volt supply at the monitor unit.

CALIBRATION CHECKS

15. Before commencing these checks the ranges of movement and friction of the aircraft control circuits, and the cut-in and cut-out speeds must have been proved satisfactory as described in Chapter 4.

16. The checks necessary for each control circuit are contained in the following paragraphs. The graphs which will result, are listed in sequence in Table 1, together with the master traces against which they are to be compared and the system characteristics which are to be determined.

Elevator controls

17. To check the elevator controls:-

(1) Connect the pitot test set to the elevator artificial feel unit.

(2) Fit the recorder unit in the elevator carrier.

(3) Check that the linkage mechanism is connected to the gearbox FINE range setting.

(4) Set the control column force transmitter for elevator movement (see fig.1).

(5) Start the four elevator P.F.C. motors. Ensure that the controls are in the neutral position.

(6) Switch on the 28 volt supply switch.

(7) Set the channel selector to the ELEVATOR position.

(8) Set the airspeed selector switch to 100 knots on the elevator/rudder scale.

(9) Apply 100 knots to the feel unit.

(10) Set the record switch to RECORD. Using the *pilot's control handle* move the control column forward then allow to centralize. Switch OFF the record switch.

NOTE...
The purpose of operation (10) is to obtain a zero force reference on the plot, and only slight movement of the controls is necessary.

(11) Set the record switch to RECORD. Using the *force transmitter* move the control column forward then allow the controls to centralize. Move the control column aft then allow the controls to centralize. Switch OFF the record switch.

(12) Rotate the frame rewind control one turn.

(13) Set the airspeed selector to 150, 200, 300, 400 and 450 knots in turn on the elevator/rudder scale, and with an equivalent airspeed applied to the feel unit, repeat operations (10), (11) and (12) at each setting.

(14) Reduce airspeed at the feel unit to 100 knots.

(15) Set the airspeed selector switch to 100 knots on the elevator/rudder scale.

(16) Disconnect the link mechanism lever and reconnect to the gearbox COARSE range connection.

(17) Repeat operations (10), (11) and (12) at the 100, 150, 200 and 300 knots airspeed settings.

(18) Reduce airspeed at the feel unit and airspeed selector switch to ZERO.

(19) Stop the P.F.C. motors.

Aileron controls

18. To check the aileron controls:-

(1) Connect the airspeed simulator to the aileron artificial feel unit.

(2) Fit the recorder unit to the aileron carrier, and connect the extension cable loom.

(3) Set the control column force transmitter for aileron movement (see fig.1).

(4) Start the four aileron P.F.C. motors. Ensure that the controls are in the neutral position.

(5) Switch ON the 28 volt supply switch.

(6) Set the channel selector to the AILERON position.

(7) With zero airspeed at the feel unit, set the airspeed selector switch to zero on the aileron stop calibration scale.

(8) Set the record switch to RECORD. Using the *pilot's control handle* move the control column to port then allow to centralize. Switch OFF the record switch.

NOTE...
The purpose of operation (8) is to obtain a zero force reference on the plot, and only slight movement of the controls is necessary.

(9) Set the record switch to RECORD. Using the *force transmitter* move the control column fully to port then allow the controls to centralize. Move the control column fully to starboard then allow the controls to centralize. Switch OFF the record switch.

(10) Rotate the frame rewind control one turn.

(11) Set the airspeed selector switch to 300 knots on the aileron stop calibration scale.

(12) Apply 300 knots to the feel unit.

(13) Set the record switch to RECORD. Using the *pilot's control handle* move the control column fully to port then allow the controls to centralize. Move the control column fully to starboard then allow the controls to centralize. Switch OFF the record switch. DO NOT MOVE THE FRAME REWIND CONTROL.

(14) Progressively move the airspeed selector switch to 320, 340, 360, 380, 400, 420, 450, 420, 400, 380, 360, 340, 320, 300 knots on the aileron stop calibration scale, and with an equivalent airspeed applied to the feel unit, repeat operation (13) at each setting.

(15) Rotate the frame rewind control one turn.

(16) Reduce airspeed at the feel unit and the airspeed selector switch to zero.

(17) Switch OFF the 28 volt supply at the monitor unit.

(18) Stop the P.F.C. motors.

Rudder controls

19. To check the rudder controls:-

(1) Connect the pitot test set to the rudder artificial feel unit.

(2) Fit the recorder unit to the rudder carrier and connect the extension cable loom.

(3) Check that the link mechanism is connected to the gearbox FINE range setting.

(4) Start the rudder P.F.C. motors. Ensure controls are in the neutral position.

(5) Switch ON the 28 volt supply switch.

(6) Set the airspeed selector switch to 100 knots on the elevator/rudder scale. Apply 100 knots to the feel unit.

(7) Set the record switch to RECORD. Using the *pilot's rudder pedals* move the rudder bar, then allow to centralize. Switch OFF the record switch.

NOTE ...
The purpose of operation (7) is to obtain a zero force reference on the plot, and only slight movement of the controls is necessary.

(8) Set channel selector switch to P. RUDDER. Set the record switch to RECORD. Using the *force transmitter* move the port rudder pedal forward then allow to centralize. Switch OFF the record switch. Set the channel selector to S. RUDDER. Set the record switch to RECORD. Using the *force transmitter* move the starboard rudder pedal forward then allow to centralize. Switch OFF the record switch.

(9) Rotate the frame rewind control one turn.

(10) Set the airspeed selector switch to 150, 200, 300, 400 and 450 knots in turn on the elevator/rudder scale, and with an equivalent airspeed applied to the feel unit, repeat operations (7), (8) and (9) at each setting.

(11) Reduce airspeed at the feel unit to 100 knots.

(12) Set the airspeed selector switch to 100 knots on the elevator/rudder scale.

(13) Disconnect the link mechanism and reconnect to the gearbox COARSE range connection.

(14) Repeat operations (7), (8) and (9) at the 100, 150 and 200 knots airspeed settings.

(15) Reduce airspeed at the feel unit and airspeed selector switch to zero.

(16) Switch OFF the 28 volt supply at the monitor unit.

(17) Stop the P.F.C. motors.

Assessment of results

20. On completion of checks, remove the recorder unit, by reversing the procedure detailed in para.10, and return to the instrument bay for film processing.

21. The graphs should be in the form of continuous curves of reasonably smooth contour. Elevator and rudder system graphs will include a zero force trace to provide a reference for aligning the master trace horizontal axis, and an airspeed identification trace. The position of the identification trace varies with the air-speed setting, and will appear near to the top edge of the frame at 450 knots and move progressively inwards with decreasing airspeeds.

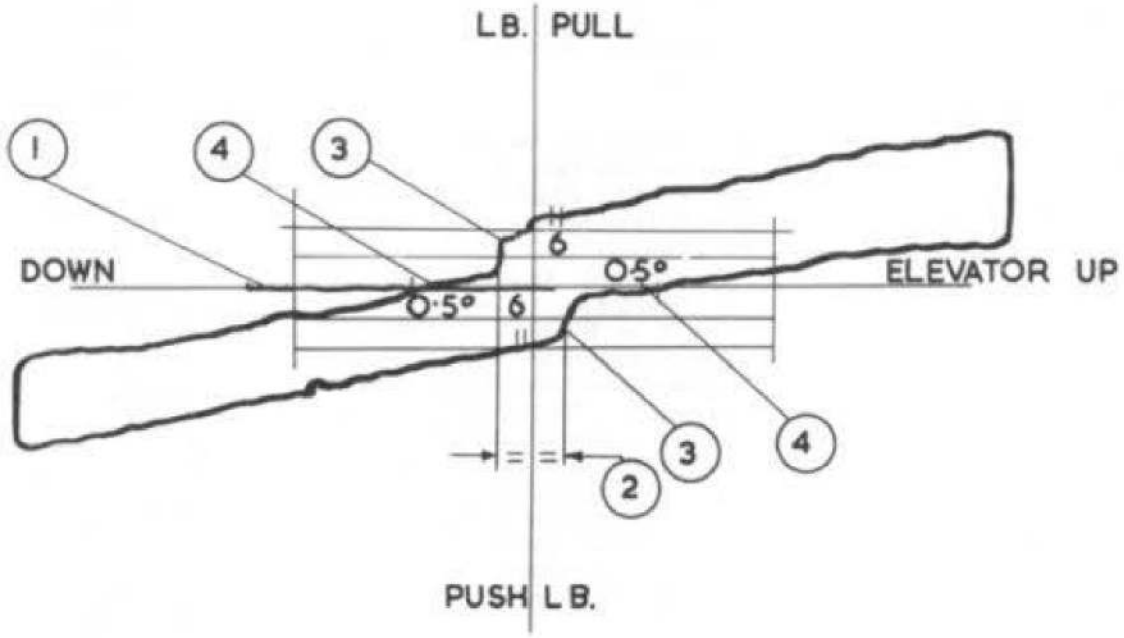
22. To interpret the results, select the master trace appropriate to the graphs as listed in Table 1. With the trace in position on the graph check the respective circuit characteristics as follows:-

Break-out and self-centring

A typical graph and the method of determining break-out and self-centring is shown in fig.4.

(E1) ELEVATOR FINE RANGE BREAK-OUT AND SELF-CENTRING

AIRSPEED IDENTIFICATION TRACE. 200 KNOTS.



To check break-out and self-centring (all systems):-

(1) Position Master trace on graph and set horizontal axis on zero force trace.

(2) Set vertical axis midway between break-out points.

(3) Break-out points must be within limits marked on Master trace.
i.e., For elevator as shown, between 6 and 11 lb.

(4) The self-centring position is the point at which the graph cuts the horizontal axis, and must be within the limits marked on the Master trace.
i.e., For elevator as shown, 0.5° or less from centre.

Fig.4. Break out and self-centring calibration

Force/deflection characteristics

A typical graph and the method of determining force/deflection characteristics is shown in fig.5 for rudder and elevator circuits, and in fig.6 for the aileron circuit.

Aileron stop calibration

A typical graph of aileron stop calibration is shown in fig.7.

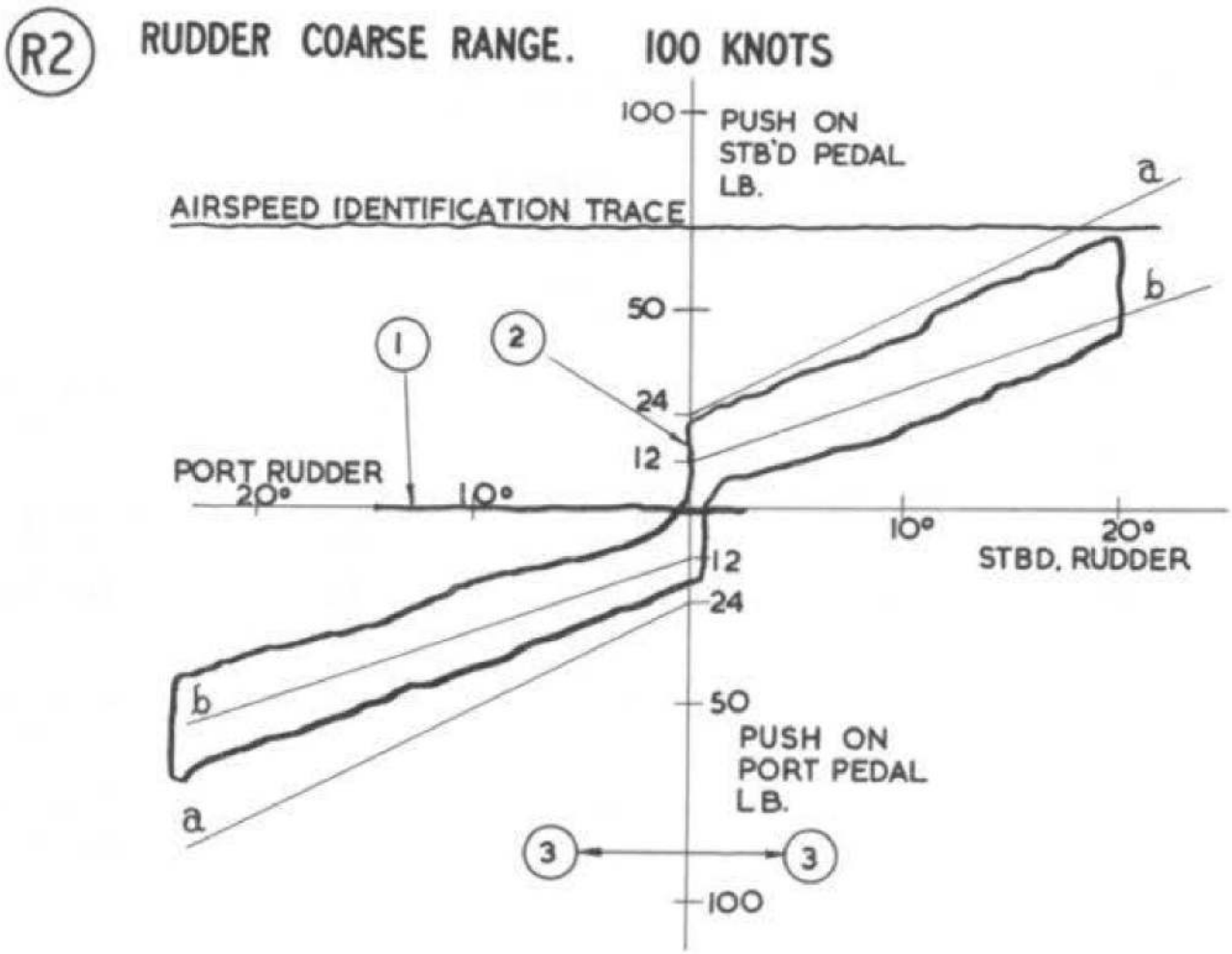
After test

23. Remove and stow the test equipment. Reconnect the artificial feel units to the aircraft pitot system and make independent checks on the system in accordance with current procedure.

TABLE 1

List of graphs and master traces

	Graph No.	Range	Airspeed	Master trace(s)	
Elevator	1	Fine	100	E1	(1) Check break-out and self-centring at 6 airspeeds (Graphs 1 to 6) using Master trace E1.
	2	Fine	150	E1	
	3	Fine	200	E1	
	4	Fine	300	E1	
	5	Fine	400	E1, E6	
	6	Fine	450	E1, E7	
	7	Coarse	100	E2	(2) Check force/deflection characteristics at 6 airspeeds (Graphs 5 to 10) using the individual Master traces specified.
	8	Coarse	150	E3	
	9	Coarse	200	E4	
	10	Coarse	300	E5	
Aileron	11	Coarse	Zero	A1, A2	(1) Check Graph 11 for break-out and self-centring using Master trace A1.
	12	Coarse	300/450	A3	(2) Check Graph 11 for force/deflection characteristics using Master trace A2.
					(3) Check Graph 12 for aileron stop calibration using Master trace A3.
Rudder	13	Fine	100	R1	(1) Check break-out and self-centring at 6 airspeeds (Graphs 13 to 18) using Master trace R1.
	14	Fine	150	R1	
	15	Fine	200	R1	
	16	Fine	300	R1, R5	
	17	Fine	400	R1, R6	(2) Check force/deflection characteristics at 6 airspeeds (Graphs 16 to 21) using the individual Master traces specified.
	18	Fine	450	R1, R7	
	19	Coarse	100	R2	
	20	Coarse	150	R3	
	21	Coarse	200	R4	



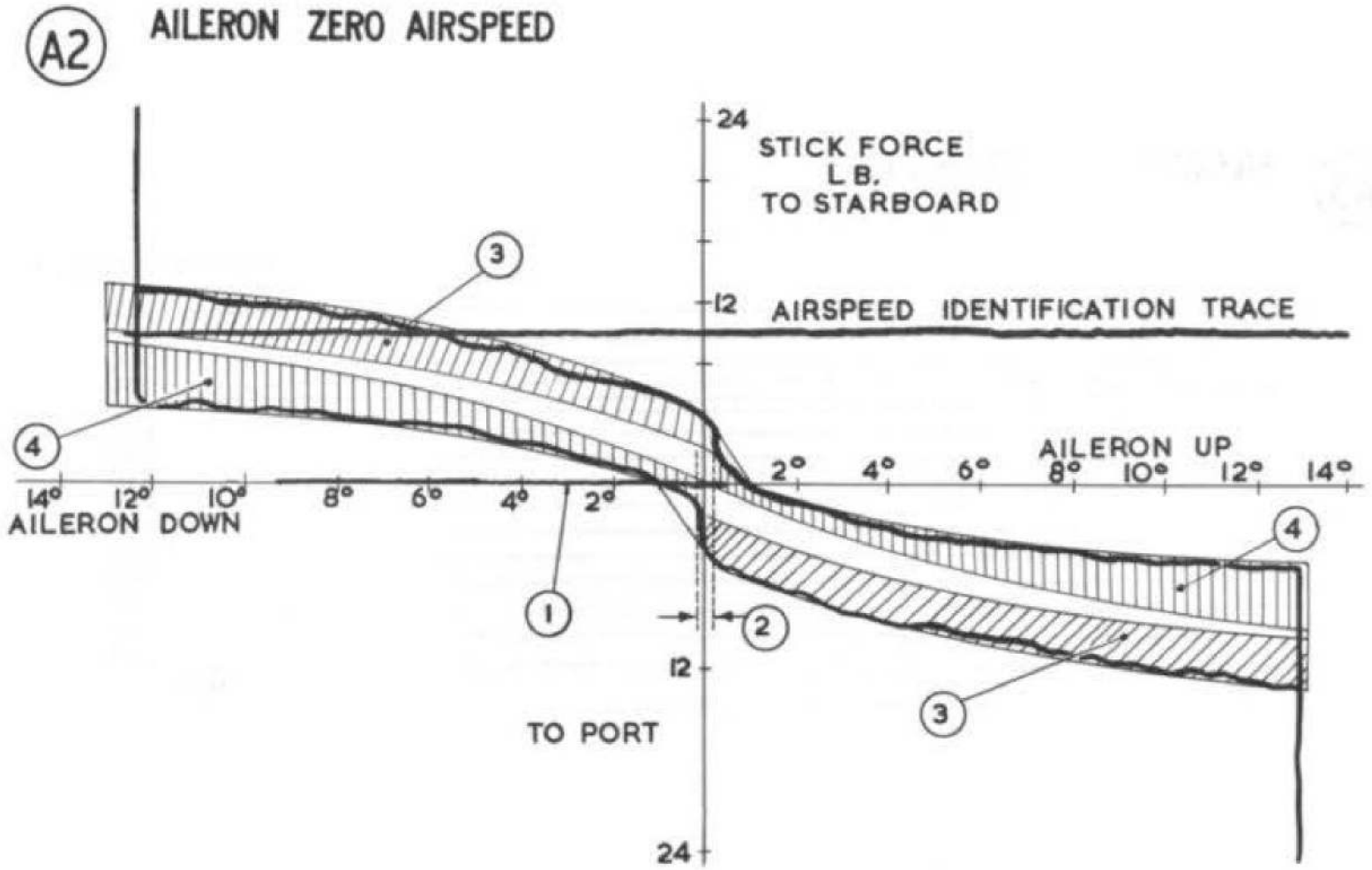
To check rudder and elevator force/deflection characteristics :-

(1) Position Master trace on graph and set horizontal axis on zero force trace.

(2) Align the vertical axis with each break-out point in turn and check that the traces of increasing force lie between the limit lines *a* and *b*.

(3) Move the Master laterally and check that the traces of increasing force each have a slope that is not more than that of *a* or less than that of *b*.

Fig.5. Force/deflection calibration - rudder and elevator



To check aileron force/deflection characteristics:-

(1) Position Master trace on graph and set horizontal axis on zero force trace.

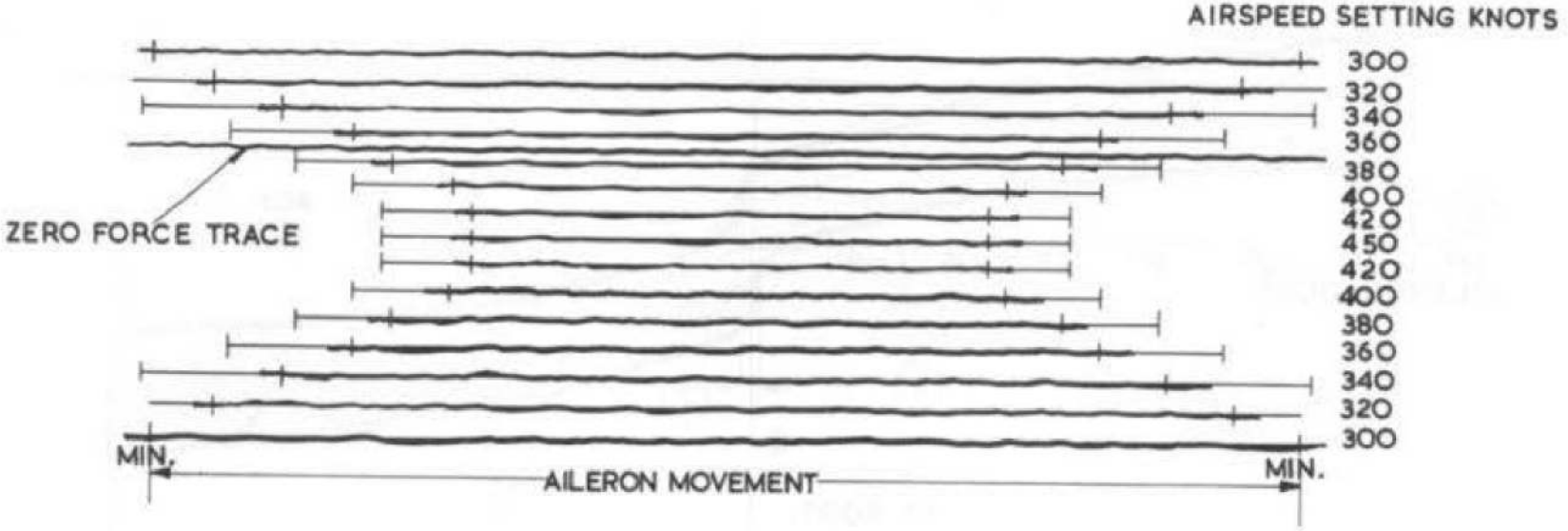
(2) Set vertical axis midway between the breakout points.

(3) Traces of increasing force must be within the areas marked thus ////////

(4) Traces of decreasing force must be within the areas marked thus |||||||

Fig.6. Force/deflection calibration - aileron

(A3) AILERON STOP CALIBRATION



To check aileron stop calibration:-
Position the Master trace on the aileron movement traces. At each airspeed the movement trace must extend between the limits appropriate to that speed.

NOTE...
The vertical spacing of the traces may not be perfectly regular and it is permissible to move the Master up or down to allow for this.

Fig.7. Aileron stop calibration